probably blocked the flow of nutrients to the embryo sac, and these nutrients were then used in cell proliferation in the vascular bundle. Seeds with necrotic spots were found in all subsequent fixations, i.e., through 8/11, at which time normal seeds were completely developed. In some seeds the necrosis was more advanced than indicated in Fig. 8, but in others it was less severe. In all seeds with necrosis the embryo sac sturctures had either been obliterated or only an under-developed embryo with little or no endosperm remained. Seeds with necrotic spots must have accounted for a fairly large proportion of the seedless fruits in that year and perhaps in other years in which the spots were noted. Tissue surrounding several brown spots was examined carefully to determine whether fungal hyphae or bacteria were present, but neither type of organism was seen. The cause of the brown spots might be a physiological disturbance. Their characteristic position suggests that the region affected was particularly vulnerable.

In collections in July and August, the embryos in some seeds without necrotic spots had failed to develop normally. The immediate cause seemed to be a deficiency in the quantity of endosperm, but the probable underlying cause in some cases was abnormal development of the nucellus. Instead of the nucellus gradually diminishing in quantity, as normally occurs, the cells became hypertrophied and crowded the endosperm and embryo (Fig. 9). In several embryo sacs, regions of enlarged nucellar cells were separated by regions of proliferating nucellar cells (Fig. 10). Such aberrations of nucellus and endosperm may account for the subnormal size of some seeds at maturity.

In 'Bronte' an unusual type of abnormality, which occurs in the later phases of seed development, may affect many seeds of a crop. Pressure against the integuments by the developing embryo and endosperm, particularly the latter, which appears sometimes to have developed at the expense of the embryo, causes the endostome to be greatly stretched. The inner integument or both integuments may rupture, allowing the endosperm or embryo, or both, to protrude (Figs. 11 and 12). Because of the excessive pressure on the embryo it is often malformed.

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Plant Population Studies with Pickling Cucumbers Grown for Once-over Harvest[1]

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Abstract. Cucumbers (*Cucumis sativus* L.), 'Bounty' and 'Premier', were grown at 8 population densities ranging from 50,000 plants per ha (46 x 46 cm spacing) to 850,000 plants per ha (10 x 10 cm spacing). Sections of the field were harvested once-over on 2 sampling dates. Yields as dollars per ha and as tons per ha increased with increasing plant population at densities of 50,000 to 100,000 and 250,000 to 500,000 plants per ha. Over the common commerical populations, 100,000, 150,000, 200,000 and 250,000 plants per ha, yields did not increase as population increased. Delay in harvest for 4 days did not affect dollars per ha yield but doubled the tons per ha produced. Fruit sizing was slower in higher plant populations (250,000 to 850,000 plants per ha) than in the lower plant densities (50,000 to 200,000 plants per ha). The number of fruit per plant decreased with increasing plant population. Length to diameter ratios of 'Premier' were lower at the lowest plant population, 50,000 plants per ha. L:D ratios of 'Bounty' were unaffected by plant population. Varying plant populations did not affect the percent off-shape fruit, or fruit color (green quality and uniformity) of either cultivar.

Fruits must develop uniformily for optimum yield and profit from size-graded fruit in a once-over harvested pickling cucumber crop. Plant population densities govern uniformity as well as the number of fruits produced per plant. Light, water, and nutrient availability affect yield, and all are affected by population density.

Much information has been reported on how various plant species respond to population pressure. Yields of snap bean (5), soybean (6), brussel sprouts (4), tomatoes (2, 3, 7, 9), and cucumbers (10) have been increased by planting more plants per unit area. Generally, per-plant yields decrease as plant population increases (2, 8).

Precise information regarding the response of pickling cucumbers harvested once-over to population pressure is not available. Our objective was to determine the effect of plant population on pickling cucumber yield and fruit quality.

Materials and Methods

Cucumbers (cv. Bounty and Premier) were seeded in a sandy loam soil with a Stanhay seeder. Population spacings were equidistant spacings "on the square" for all densities as outlined in Table 1. From 2–3 seeds per site were sown at each spacing then thinned to 1 plant after seedling emergence. Each plant spacing of each cultivar was replicated 5 times. Individual plots were 8 m long. Fertilizer was disked in before planting at a rate of 560 Kg/ha of 6-24-24 and 100 Kg/ha N as NH_4NO_3. Dyanap (dinoseb + naptalam) was applied immediately after seeding for weed control. Irrigation was used after the herbicide application and during fruit development to supplement rainfall. Recommended practices for disease and insect control were followed. One hive of bees per 50,000 plants was present.

Each sample plot was harvested twice by dividing the plots into 3-m sections, and allowing an additional 2 m of row for guard. The initial harvest was made 49 days after sowing when approximately 10–20% of the fruit were 4.1 cm or larger in size. The second harvest was made 4 days later. For each harvest all of the fruit was removed, graded,

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and weighed. The grades and dollar values were: 1) less than 1.9 cm fruit diameter ($253/metric ton); 2) 1.9 to 2.5 cm ($171/ton); 3) 2.5 to 3.2 cm ($149/ton); 4) 3.2 to 3.8 cm ($83/ton); 5) 3.8 to 4.1 cm ($61/ton); 6) 4.1 to 5.1 cm ($28/ton); and 7) over 5.1 cm ($22/ton). The percentage of offshapes (nubs and crooks) was determined from 25 fruits, randomly sampled from each replication. Length to diameter ratios were measured on 10 randomly sampled cucumbers in each of the 1.9 to 4.1-cm size grades from each replication. Green color quality and uniformity were also measured at this time. Data for number fruit per plant, percent off-shape, L:D ratio, and color were taken only on the first harvest date.

Results and Discussion

Yields in dollars/ha and in tons/ha of both cultivars usually increased as plant populations increased from 50,000 to 850,000 plants per ha for each harvest date (Tables 2 and 3). However, yields did not increase significantly over the plant density range of 100,000 to 250,000 plants per ha. At present these are the commercial plant populations used for once-over cucumber harvesting. They are approximately equivalent to 40, 60, 80, and 100 thousand plants per acre. Yields at the 500,000 plants per ha and higher population densities were significantly higher than those of the 5 lower densities. However, yield differences between the highest 3 populations usually were not statistically significant.

Table 1. Plant spacings that 'Bounty' and 'Premier' were sown in the experiment.

Spacing (cm)	Plant population/ha × 10^5	Rows/bed
10 × 10	850,000	8
13 × 13	650,000	8
15 × 15	500,000	8
19 × 19	250,000	8
23 × 23	200,000	8
25 × 25	150,000	8
31 × 31	100,000	7
46 × 46	50,000	4

Pickling cucumbers are priced according to size, with smaller diameter fruit worth more than larger diameter ones. For both cultivars, yields as dollars per ha were approximately the same for each plant population on both sampling dates. Tonnage, however, doubled from the July 26 harvest to the July 30 harvest. This meant that dollar values per ton on the second harvest date were about half those of the first. This was due to a shift in the amount of fruit in the smaller grade to larger grade sizes (Fig. 1). This shift was promoted further by plant population and earliness of the cultivar. Fruit sizing was slower in plant populations 250,000 to 850,000 plants per ha than in less dense populations. In the less dense populations (50,000 to 200,000 plants per ha) a delay in harvest of 4 days resulted in a shift in fruit sizes from approximately 6% of the fruit being over 5.1 cm (2 inches) on July 26 to over 45% on July 30. In the higher populations (250,000 to 850,000 plants per ha) this shift was not as large; 2% of the fruit over 5.1 cm on July 26 to about 20% on July 30. This increase in earliness as population decreased is opposite to observed responses of tomato yield to population pressure (2, 8). Tomatoes mature earlier under high population stress.

Although 'Premier' appeared to mature 1 or 2 days earlier than

Table 2. Effect of plant population on yield and fresh quality of 'Bounty' pickling cucumbers.

Plant population (plants/ha)	Yield					Quality		
	$/ha Harvest date		Tons (metric)/ha Harvest date		No. fruit/plant	L:D ratio	% Off-shape	Color[y]
	7/26	7/30	7/26	7/30				
850,000	4048d[z]	4557c	32.9b	75.3c	1.7a	3.0a	6.4ab	7.7a
650,000	4117d	4191c	30.7b	68.0c	2.0a	3.0a	9.6b	7.2a
500,000	3437cd	4159c	32.9b	69.5c	2.1a	3.0a	5.6ab	7.4a
250,000	2530bc	2456b	24.0ab	45.5ab	2.9ab	3.0a	4.8ab	7.4a
200,000	2192ab	2034b	20.3a	40.9ab	2.9ab	3.0a	6.4ab	7.2a
150,000	2229ab	2081b	23.5ab	47.4b	4.7b	3.0a	3.2ab	7.7a
100,000	1705ab	1658b	17.9a	38.5ab	5.5b	3.0a	2.4a	7.7a
50,000	1408a	1179a	19.1a	31.2a	8.5c	2.9a	7.2ab	7.8a

[z] Mean separation within columns by Duncan's multiple range test at the 5% level.
[y] Green color rated for quality and uniformity: 10 excellent, 0 poor.

Table 3. Effect of plant population on yield and fresh quality of 'Premier' pickling cucumbers.

Plant population (plants/ha)	Yield					Quality		
	$/ha Harvest date		Tons(metric)/ha Harvest date		No. fruit/plant	L:D ratio	% Off-shape	Color[y]
	7/26	7/30	7/26	7/30				
850,000	4697d[z]	5159e	52.3d	101.2e	1.3a	2.6b	1.6ab	7.2a
650,000	4534d	3986d	52.3d	88.3de	1.8a	2.6b	4.8bc	7.5a
500,000	3877c	3605d	43.3cd	77.2cd	2.0a	2.6b	5.6c	7.5a
250,000	2701b	2471c	34.4bc	53.5ab	2.8b	2.6b	2.4abc	7.0a
200,000	2560b	2179bc	33.2b	54.7ab	3.3b	2.7b	1.6ab	7.6a
150,000	2703b	2335bc	36.3bc	62.7b	5.1c	2.7b	2.4abc	7.4a
100,000	2162b	1952b	31.9b	55.2ab	5.5cd	2.5ab	1.6ab	7.6a
50,000	1275a	1102a	23.0a	47.9a	6.3d	2.3a	0.8a	7.0a

[z] Mean separation within columns by Duncan's multiple range test at the 5% level.
[y] Green color rated for quality and uniformity: 10 excellent, 0 poor.

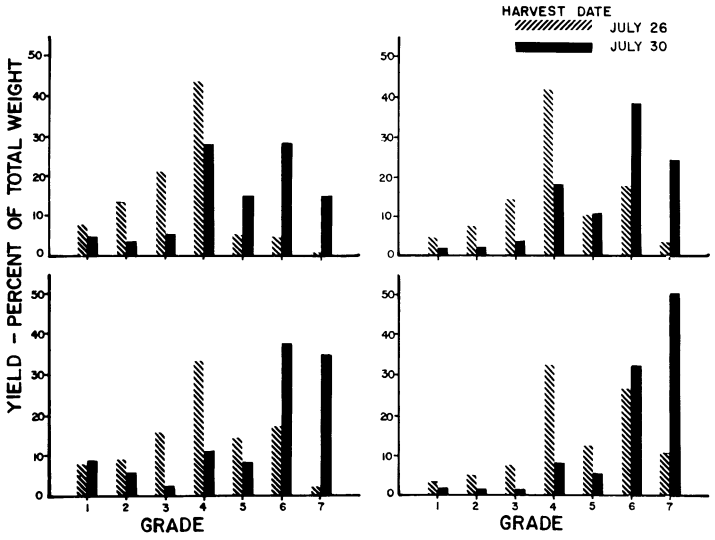

Fig. 1. Effect of population density and harvest date on yield of specific grade sizes. Data for combined populations of: A. 'Bounty' 250,000 to 850,000 plants per ha. B. 'Bounty' 50,000 to 200,000 plants per ha. C. 'Premier' 250,000 to 800,000 plants per ha. D. 'Premier' 50,000 to 200,000 plants per ha.

Table 4. Correlation coefficients between yield and plant population of pickling cucumbers harvested once in a destructive harvest.

Cultivar	Coef. of correl., r				No. fruit per plant
	$/ha		Tons/ha		
	July 26	July 30	July 26	July 30	
Bounty	0.952**	0.959**	0.917**	0.950**	−0.771**
Premier	0.951**	0.984**	0.937**	0.969**	−0.880**

** Significant *r* value at 1% level.

'Bounty', yield and quality were affected similarily in both cultivars by increasing plant densities. Correlations between increasing yield and increasing plant populations were highly significant for both cultivars on both sampling dates (Table 4). The number of fruit produced per plant decreased with increasing plant population (Tables 2 and 3). Negative correlations between fruit number and plant population for both cultivars were highly significant (Table 4). This is similar to the response of tomato to high population pressure (2, 7, 8).

'Bounty' length to diameter (L:D) ratios were unaffected by plant density while the L:D ratio of 'Premier' grown at 50,000 plants per ha was smaller than at higher populations. This was probably due to the tendency of 'Premier' to have relatively low L:D ratios and to the large increase in fruit per plant at this lower plant population.

Although the percent of off-shape fruit was different at some densities, this did not follow any trend in either cultivar and did not appear to be affected by plant density alone. Green color quality and uniformity was unaffected by plant density differences. White-spined 'Premier' maintained its green color longer and more uniformily than black-spined 'Bounty'. At higher plant densities even 'Bounty' did not yellow prematurally.

Present commercial pickling cucumber plant populations for once-over harvest average approximately 150,000 plants per ha. Pickling cucumber yields can be substantially increased by planting 500,000 plants per ha or more. The only additional costs to production would be the additional seed and bees required to grow this plant population. At present day prices, additional costs would come to approximately $325/ha. This extra production cost would have the potential to put almost $900/ha extra into net profit. This observation agrees with a report by Downes et al. (1) in which they estimated that 198,313 plants per acre (500,000 plants per ha) would yield the highest dollar return to growers.

Plant densities over 250,000 plants per ha (100,000 plants per acre) may exceed the limits of present day cultural practices and machinery. At higher plant populations, weed control is a problem because cultivation is difficult or impossible and the available cucumber herbicides do not give 100% full season weed control. Irrigation is needed for cucumbers planted at higher populations. Also, harvesting equipment may not be able to handle the heavy load of vines and fruit without modification. If these major problems can be overcome, then higher plant population may produce much higher yields of pickling cucumbers.

Proper scheduling of the time of harvest would be essential for maximum net returns. In the present experiment, dollar returns were not as much affected by delaying the harvest date as was the tonnage of fruit removed per ha. If harvest is delayed by 4 days, extra trucking costs for the additional tonnage should be considered. Also, most processors perfer smaller pickles and some even refuse to accept anything over 5.1 cm in diameter. Thus, for assurance of maximum dollar returns with a uniformily maturing pickle crop; the crop should be harvested as soon as 5.1-cm fruit are observed in the field.

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