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Plant Spacing and Variety Affect Pumpkin Yield and Fruit Size, but Supplemental Nitrogen Does Not

Stephen Reiners[1]
Department of Horticultural Sciences, New York State Agricultural Experiment Station, Cornell University, Geneva, NY 14456

Dale I.M. Riggs[2]
Cornell Cooperative Extension Capital District Vegetable Program, Albany Regional Office, 146 State Street, 4th Floor, Albany, NY 12207

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***Abstract.* Field studies were conducted at two locations in 1995 to determine the effect of spacing, nitrogen application, and variety on pumpkin (*Cucurbita pepo* L.) marketable yield. Pumpkin yield was unaffected by three rates of applied N (67, 112, or 157 kg N·ha^{-1}). Marketable fruit number per hectare increased with both 'Howden' and 'Wizard' pumpkins as in-row plant spacing decreased from 1.2 to 0.3 m. Average fruit size significantly decreased at the closer spacing, but the decline in mass was much greater in nonirrigated as compared to irrigated plots. This resulted in a significantly greater yield in the irrigated plots at the closer spacing, while there was no significant increase in yield without irrigation. The results demonstrate that growers may increase the number of fruit per unit area with closer spacing but optimal soil moisture may be a prerequisite for the increase.**

Acreage of pumpkins has grown considerably in the United States over the past 15 years. Although official statistics are not recorded, it is estimated that more than 2000 ha are grown in New York State alone, with a value exceeding $25 million annually. The majority of these pumpkins are grown solely for Halloween sales and are for decoration rather than for human consumption. With the increase in acreage, production practices have also changed. At one time, pesticide inputs were very limited. Recent studies, however, indicate that an effective disease control program may significantly increase the yield and quality of the crop (McClurg et al., 1992; Reiners, 1995). Weekly fungicide applications alone may cost more than $500 per hectare annually. Growers are exploring ways to increase yield per unit area in order to save on land, pesticide, fertilizer, labor, and machinery costs. Increasing the number of plants per hectare with careful attention to nitrogen nutrition and variety may accomplish this goal.

Increasing the rate of nitrogen fertilization has generally increased cucurbit yield. Yield of zucchini squash (*Cucurbita pepo* var. *melopepo* L.) increased as the N level rose from 67 to 202 kg·ha^{-1}, but decreased above this maximum (Dweikat and Kostewicz, 1989). Similarly high N levels significantly increased yields of watermelons [*Citrullus lanatus* (Thunb.) Matsum & Nakai] in Florida (Brinen et al., 1979). However, field observations indicate that super optimal levels of N may stimulate excessive vine growth, delay fruit set, and depress overall yield (Swaider, 1985). A study focusing on pumpkin N and K nutrition found that only excessively low rates of N and K (below 56 kg N·ha^{-1} and 112 kg K·ha^{-1}) negatively affected fruit set (Swaider et al., 1994), probably because of poor plant condition. Although vine dry matter and stem elongation increased at higher N levels, there was no indication of excessive vine growth. Highest marketable yields occurred with 112 kg N·ha^{-1}. The increase in yield with increasing N was due to a greater number of marketable fruit and not to larger fruit size. High N and K rates (greater than 168 and 224 kg·ha^{-1}, respectively) delayed fruit set and increased the number of green fruit at the time of harvest. Higher rates of N had a greater effect on yield when combined with irrigation (Swaider et al., 1988). Strong interactions between the level of N fertilization and irrigation have been demonstrated on yields of both cantaloupe (*Cucumis melo* L.) (Flocker et al., 1965) and summer squash (Smittle and Threadgill, 1982).

The relationship between plant population density and crop yield has been extensively studied for a number of horticultural crops. In general, increasing plant population increases yield per unit area until an upper limit is reached. At that point, competition between adjacent plants causes resources to become limited (Pant, 1979) and yield either levels off or declines (Weiner, 1990). In watermelon, two studies demonstrated that yield could be increased significantly using plant populations above the recommended spacings. NeSmith (1993) found that total yields increased in the high density planting because of a greater number of fruit per hectare, with only a slight decline in the average fruit mass. Brinen et al. (1979) reported reduced mass per fruit, an increase in fruit number, and an overall increase in total marketable yield per hectare as population density increased. The growth habit of the species may also play a role in determining the effect of spacing on yield. Generally, the recommended population density for semi-bush pumpkins is twice that for large vining types (Reiners and Garrison, 1994). These recommendations, however, were not based on field trials. Knavel (1991) found that closer spacings did not increase yield of short-internode (bushtype) muskmelons. Similar results have been found with cucumbers (*Cucumis sativus* L.) (Widders and Price, 1989). For pumpkins, there has been little work examining spacing, variety type, and the interaction of nitrogen.

Most northeastern pumpkin growers plant at a density of 3000 to 9000 plants per hectare, depending on variety, equipment, and available land (Reiners and Garrison, 1994). Recommended N ranges from 90 to 160 kg·ha^{-1}, depending on the soil type and the field's previous cropping history. The objective of our research was to determine the effect of spacing and N rate on the yield of two pumpkin varieties, one hybrid semi-bush type and the other an open pollinated, large vining type.

Materials and Methods

Experiments were conducted at two locations in 1995. The Geneva, N.Y., site was a Lima silt loam (fine-loamy, mixed, mesic, Glossoboric Hapludalf). The second site was approximately 300 km to the east at Livingston, N.Y. The soil type was a gravelly, sandy loam (loamy-skeletal mixed mesic Glossoboric Hapludalf). Soil tests indicated that nutrients were at the medium to high range (Table 1). Limestone was applied only at Livingston (4.48 t·ha^{-1}) and incorporated two weeks prior to planting. Both locations received banded applications of 44N–40P–74K kg·ha^{-1} (10N–8.7P–16.6K). Following banding, plots were hand seeded ≈5 cm to the side of the fertilizer band and 5 cm deep on 5 June and 9 June, at Livingston and Geneva, respectively. 'Howden' (open-pollinated, large vining type) and

Table 1. Soil analysis for test plots in Livingston and Geneva, N.Y., prior to the 1995 growing season.

	Mineral content (kg·ha^{-1})					Organic
Location	P	K	Mg	Ca	pH	matter (%)
Geneva	24	155	325	2688	6.5	2.0
Livingston	17	155	493	1142	6.0	2.2

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[1]Assistant Professor; to whom reprint requests should be addressed.

[2]Area Vegetable Specialist.

'Wizard' (hybrid, semi-bush type) pumpkins were planted at three plant spacings. Both experiments were designed as split-split plots with nitrogen the main plot, variety the subplot, and spacing the sub-subplot. All treatments were replicated three times. Rows were placed 1.8 m apart, and in-row spacings were 0.3, 0.6, or 1.2 m, resulting in plant populations of 18,520, 9,260, and 4,630 plants per hectare, respectively. Plots were three rows wide by 14 m long. All plantings were thinned to a single plant per hill. Approximately four weeks after planting, when vines began to run, an additional 22.5, 67, or 112 kg $N\cdot ha^{-1}$ (as ammonium nitrate) was sidedressed and shallowly incorporated. This resulted in a total N application of 67, 112, or 157 $kg\cdot ha^{-1}$, depending on the treatment. Weeds were controlled by using recommended herbicides, cultivation, and hand weeding. Insect and disease pressure was monitored and protective treatments applied when warranted (Reiners and Garrison, 1994). Overhead sprinkler irrigation was used to supplement rainfall in the Geneva plots only.

A one-time harvest was made on 21 Sept. at Livingston and 28 Sept. at Geneva. All pumpkins were harvested from the center rows of each plot, counted, and weighed. Only fruit that were orange, firm, and free from major blemishes or rot were considered marketable, while rotted and unripe fruit were considered unmarketable. Analysis of variance was used to determine main effects, subplot, and sub-subplot effects and interactions. For significant interactions, a protected LSD at the 5% level was used to separate means.

Results and Discussion

Nitrogen rate. Increasing N rates had no effect on yield at either site (Table 2). Previous work (Swaider et al., 1994) suggested that the optimum level of N for pumpkins was 112 $kg\cdot ha^{-1}$, with the effects of additional N being enhanced by irrigation (Swaider et al., 1988). The 1995 season was marked by extremely dry conditions in New York (Table 3). Only the Geneva plots received supplemental irrigation and there was a nonsignificant trend towards greater yield as the level of N increased. Optimizing soil moisture may be necessary to significantly increase yield with additional N inputs. Further studies are needed to develop the interaction between N and soil moisture. Contrary to previous studies (Swaider et al, 1994), the highest N levels did not result in significantly more unmarketable, green fruit at the time of harvest (data not shown). This indicates that fruit set was probably not delayed by the highest rates of N.

Variety. 'Wizard' produced significantly more $fruit\cdot ha^{-1}$ than did 'Howden' at Livingston, and fruit size was significantly larger for 'Howden' at Geneva. Of more importance than variety differences, however, are possible interactions between variety, spacing, and nitrogen. The lack of significant interaction between variety and nitrogen indicates that both varieties responded in similar fashion to increasing rates of N. The variety by spacing interaction was significant for fruit number at Geneva (Fig. 1). Although number per hectare increased for both varieties at the closer spacing, 'Wizard' numbers nearly tripled, while 'Howden' showed an approximate doubling. Being a semi-bush variety, 'Wizard' may simply be better able to exploit the limited resources of the closer spacing (Pant, 1979).

Spacing. The effect of in-row spacing was significant at both locations, with the exception of total fruit mass at Livingston. Fruit number for both varieties increased significantly with closer spacing, by 80% and 140% at Livingston and Geneva, respectively. These results agree with those of Dweikart and Kostewicz (1989), who found greater squash yields at higher plant densities. At Livingston, average fruit size declined 40% at the closer spacings, which essentially negated the effect of greater fruit numbers on yield. The same trend towards smaller fruit size with closer spacing was seen at Geneva as well, with a roughly 30% decline in average fruit weight. However, the greater fruit number per hectare at Geneva compensated for the effect on fruit size, resulting in a significant increase in yield.

The difference between the two locations may be due to the drier conditions experienced at Livingston (Table 3). Between 12 June and 25 July, only 3 cm of rain fell and no supplemental irrigation was applied. Additionally, the gravelly loam soil at Livingston had a low water holding capacity. Little available water was present at planting, so stress conditions persisted through much of the plant development stage. In contrast, rainfall was slightly more plentiful at Geneva, and irrigation was applied to maintain steady growth of the fruit. The positive effect of close spacing in increasing total yield appears to be constrained by the amount of water plants receive.

These results indicate that closer spacing will lead to a greater number of fruit per unit area for both semi-bush and vining varieties of pumpkin. The effect on total mass may be positive or at the very least stable. Moderate levels of N provided adequate nutrition and additional N was not warranted by either variety at the closer spacing. Although not specifically tested, adequate soil moisture may be necessary to fully benefit from closer spacing. The effect of irrigation on pumpkin yield needs to be more thoroughly examined. Higher plant densities may maximize pumpkin numbers per unit area, but growers must realize that greater fruit number will result in a smaller average fruit size. In addition, this study did not demonstrate the upper limit of pumpkin density at which yields may decline. Competition for light, nutrients, and water would be increased in high density plantings. In addition, closer spacings could increase leaf wetness and causing greater disease pressure. By maximizing production on a smaller acreage, growers may enhance profitability by decreasing fertilizer, pesticide, machinery, and labor costs.

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Table 2. Marketable fruit count, fruit weight, and average individual fruit weight of 'Wizard' and 'Howden' pumpkins grown at three plant spacings and three nitrogen levels during 1995.

	Livingston			Geneva		
Treatment	No. fruit/ha	Yield ($t\cdot ha^{-1}$)	Avg fruit mass (kg)	No. fruit/ha	Yield ($t\cdot ha^{-1}$)	Avg fruit mass (kg)
N/ha						
67	6647	20.09	3.02	5849	22.40	3.83
112	6891	23.14	3.36	6099	25.45	4.17
157	6820	22.53	3.30	6400	28.45	4.45
Significance	NS	NS	NS	NS	NS	NS
Variety						
Howden	5575	21.32	3.82	5642	27.82	4.93
Wizard	7999	22.56	2.82	6588	22.94	3.48
Significance	*	NS	NS	NS	NS	*
Spacing (m)						
0.3	8662	21.55	2.49	8810	31.32	3.55
0.6	6847	23.63	3.45	5849	26.79	4.58
1.2	4854	20.63	4.25	3684	18.19	4.94
Significance	L**	NS	L**	L**	L**	L**
Interactions						
N × V	NS	NS	NS	NS	NS	NS
N × S	NS	NS	NS	NS	NS	NS
V × S	NS	NS	NS	*	NS	NS
N × V × S	NS	NS	NS	NS	NS	NS

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

Table 3. Monthly rainfall and irrigation (cm) for Livingston and Geneva, N.Y., during the 1995 growing season.

	Location	
Month	Geneva	Livingston
June	5.0	1.5
July	10.4	8.9
August	7.8	3.6
September	6.5	3.9
Total	29.7	17.9

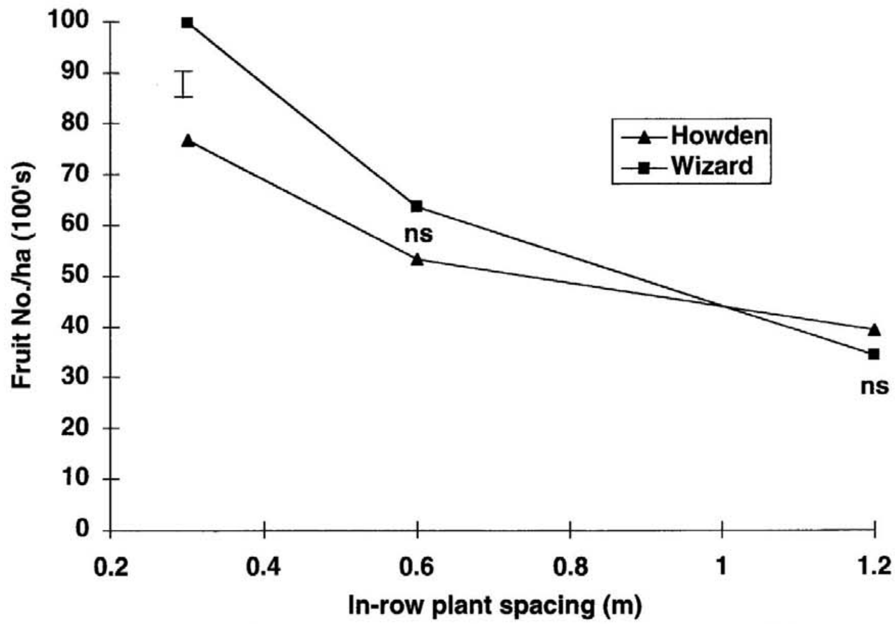

Fig. 1. Interaction of pumpkin variety and spacing on fruit number at Geneva, N.Y., in 1995. Vertical bar represents LSD at $P < 0.05$.

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