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Effect of end-border condition on small-plot yield of cucumber

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Summary

Twelve or 14 cultivars and breeding lines (collectively referred to as lines hereafter) of pickling and fresh-market cucumbers (*Cucumis sativus* L.) were evaluated in 1.5 m long plots. The plots were harvested once when the check lines reached the 10% oversized fruit stage, and total, marketable, and early (oversized) number of fruits per plot was counted. The plots were planted with or without 1.5 m long end-borders to determine whether end-borders can be eliminated in small-plot trials where seed numbers and field space are limiting. Yield in unbordered plots was inflated 5 to 21% over bordered plots, but there was generally no significant effect in the analysis of variance for line × end-border condition. Therefore, end-borders are not needed when comparing different lines.

Introduction

In breeding cucumber (*Cucumis sativus* L.) for improved yield, it is necessary to evaluate many progeny rows. That should be done in trials that use resources efficiently. Multiple-harvest trials with large plots and several locations and replications are useful in the final stages of testing, but they require considerable effort. Single-harvest trials are an efficient way to measure multiple-harvest yield in pickling (Wehner, 1986) and fresh-market (Wehner & Miller, 1984) cucumbers.

Guard rows are recommended around the perimeter of a trial but bordered plots (extra rows on either side of the center row or rows) are usually not necessary in cucumber trials (Wehner & Miller, 1986). However, the question arises as to whether end-borders are necessary in trials to provide more or less uniform growing conditions for the breeding lines or cultivars (collectively referred to as lines hereafter) being evaluated. That is especially true for small plots, since the space separating plots at each end (the alley) can be as large as the harvested area of the plot itself. In cucumber trials harvested once-over, the optimum plot size for single-row plots was determined to be approximately 1.5 m long × 1.5 m wide (Smith & Lower, 1978; Swallow & Wehner, 1986). In order to simplify the identification of the harvest area, we use 1.5 m alleys to separate the end of one plot from the beginning of the next in each row. Our observations indicate that the end plants of a plot have a higher yield than the center plants. That may result from a lack of competition on the alley side of the end plants.

Some cucumber researchers plant their trials without alleys separating the plots. However, it is especially difficult to obtain yield data after the vines have begun to overlap, since the fruits set on

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plants in one plot are often found in another plot. One researcher has used bush types of squash (*Cucurbita pepo* L.) at the ends of each plot to help identify individual plots that were planted without alleys (R.L. Lower, 1984, personal communication). In other crops such as soybean [*Glycine max* (L.) Merr.], there was significant interaction of line with end-border condition (Wilcox, 1970). That interaction was attributed to differences in earliness among lines.

It is important to know whether lines react the same to the reduced competition at the end of the plot, or whether there is an interaction for yield between line and end-border condition. Therefore, the objective of this study was to determine how yield was affected by adding end-borders to small plots of pickling and fresh-market cucumbers harvested once-over, and to measure the interaction of line and end-border condition over 3 different environments.

Materials and methods

Lines evaluated

In 1983, 6 pickling and 6 fresh-market cucumber lines were evaluated (Table 1). The lines were chosen to represent different cucumber types (resistant vs. susceptible to the local diseases, indeterminate vs. determinate, inbred vs. hybrid, new vs. old releases, monoecious vs. gynoecious sex expression, and developed for the northern vs. southern U.S.A.) so that the results would be applicable to a wide range of lines. The major disease which affected this experiment was anthracnose [*Colletotrichum orbiculare* (Berk. & Mont.) Arx].

In 1984, an additional line was added to the pickling ('SMR 58') and fresh-market ('Ashley') types to make 7 lines of each. Also, 'Dasher II' was substituted for 'Dasher', which had been discontinued that year. The originator and general characteristics of each line are given in Table 1.

Table 1. Seed source and general characteristics of the pickling and fresh-market cucumbers used in this study.[1]

Cultivar or line	Seed source	Anthracnose	Plant type	Line type	Sex expression
Pickling cucumbers					
Calypso	N.C. State Univ.	R	I	H	G
Castlepik	ARCO-Castle Seed	R	D	H	G
Clinton	N.C. State Univ.	R	I	I	M
M 21	N.C. State Univ.	R	D	I	M
Pikmaster	Northrup King	R	I	H	G
SMR 58	Asgrow Seed	S	I	I	M
Tamor	Asgrow Seed	R	I	H	G
Fresh-market cucumbers					
Ashley	Peto Seed	S	I	I	M
Bush Champion	Burpee Seed	S	D	I	M
Dasher	Peto Seed	R	I	H	G
Dasher II	Peto Seed	R	I	H	G
Early Triumph	Peto Seed	R	I	H	M
Poinsett 76	Asgrow Seed	R	I	I	M
Sprint 440	Asgrow Seed	R	I	H	G
Verino	Sluis & Groot	S	I	H	G

[1] Abbreviations are as follows: R = resistant, S = susceptible, I = indeterminate, D = determinate, H = Hybrid, I = inbred, G = gynoecious, M = monoecious.

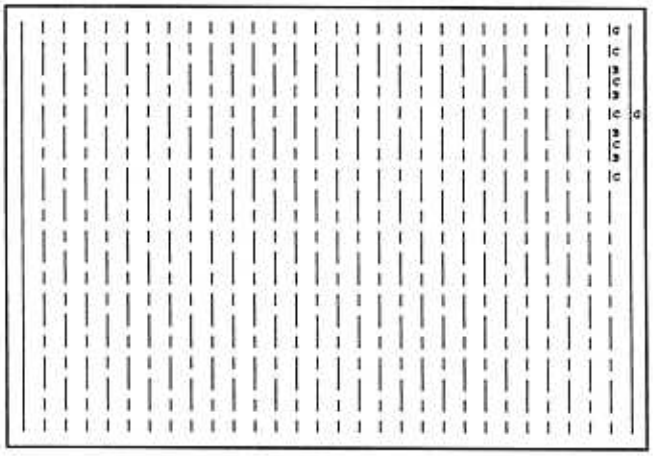

Fig. 1. Plot layout for the study of the effect of end-borders for once-over harvest trials used in measuring yield of cucumber lines. C = plot center (harvested area), B = plot border, G = guard rows surrounding the trial. Plots shown are either 1.5 m long (no end-borders) or 4.5 m long (1.5 m end-borders on each side of plot center).

Cultural practices

The research was conducted at the Horticultural Crops Research Station, Clinton, N.C. Lines were evaluated in 3 environments: spring 1983, spring 1984, and summer 1984. Plots were planted 29 April, 14 May and 5 July, respectively. Seeds were planted on raised beds, 0.5 m wide, using 25 seeds per plot in each 1.5 m section of the row. The plots were separated at the ends by 1.5 m long alleys. Rows were 1.5 m apart (center-to-center). Plots were thinned to 14, 15 or 20 plants (for the 3 environments, respectively) in the harvested section of the row at first leaf stage. Plot borders had the same plant density as the harvested area to simulate adjacent plots (i.e., no alleys separating plots).

Two plot types were used, bordered and unbordered. Unbordered plots were 1.5 m long. Bordered plots were 4.5 m long, with a 1.5 m harvest section in the center marked with flags. Bordered and unbordered plots alternated in each row, with each row beginning with a different type of plot (Fig. 1). Thus, 2 unbordered plots (separated by a 1.5 m alley, for a 4.5 m total length) were next to bordered plots (4.5 m long) in the 2 adjacent rows. End-borders 1.5 m long were used to make sure that competition was provided to the plot, and to simulate continuous 1.5 m long plots. (If end-borders were shown to be necessary, the next step would be to determine the minimum size of the end-border).

Standard cultural practices were used (Hughes et al., 1983). A tank mix of 2.2 kg/ha of naptalam and 4.4 kg/ha of bensulide was incorporated into the soil before planting to control weeds. Fertilizer was incorporated before planting at a rate of 90–39–74 kg/ha (N-P-K), with an additional 34 kg/ha applied at vine tip-over stage. Overhead irrigation was used to supplement rainfall for a minimum of 25 to 40 mm per week. Bees were present in large numbers, with several hives of honey bees placed near the field to supplement the wild bee population. Adequate pollination of the blossoms was observed in all plots.

Plots were harvested when the check plots ('Calypso' for the pickling types and 'Dasher' or 'Dasher II' for the fresh-market types) had approximately 10% oversized fruits as recommended by Miller & Hughes (1969) for optimum yield. Oversized fruits are those greater than 51 mm diameter for pickling or 60 mm diameter for fresh-market cucumbers. Harvest dates for the pickling cucumbers were 28 June, 5 July and 23 August for the spring 1983, spring 1984 and summer 1984 trials, respectively. For the fresh-market cucumbers, the harvest dates were 6 July, 12 July and 7 September,

respectively. Harvest was made when the check plots were at the correct stage (10% oversized fruits), rather than using a constant number of days from planting as the index.

Paraquat was used to defoliate the plots at harvest to make data collection more efficient (Wehner et al., 1984). At that time, the number of total and cull (crooks and nubs, but not oversized) fruits was counted, as well as the number of plants in the harvested area. Fruit number rather than fruit weight or value was used to estimate yield because of its greater stability and independence from maturity effects (Ells & McSay, 1981). Number of marketable fruits, percentage of culls ([total − marketable] × 100 / total) and number of fruits per plant were calculated from the data. In the 1984 trials, we also counted number of oversized fruits per plot as a measure of earliness.

Table 2. Fruit yield (in number of fruits per plot) of 12 cultivars and lines of pickling and fresh-market cucumbers in 1.5 m long plots harvested once-over, spring, 1983.[1]

Cultivar or line	Plot end treatment[2]	Yield		Culls (%)	Number of fruits per plant	Number of plants per plot
		Total	Marketable			
Pickling cucumbers						
Calypso	Ends	20	18	8	1.7	12
	None	25	24	4	1.9	13
Castlepik	Ends	24	22	10	1.7	14
	None	26	24	8	2.0	13
Clinton	Ends	18	18	0	1.5	12
	None	17	17	0	1.5	12
M 21	Ends	22	21	3	1.6	13
	None	24	22	5	1.7	14
Pikmaster	Ends	20	18	7	1.5	13
	None	25	24	6	1.8	14
Tamor	Ends	19	17	11	1.7	12
	None	23	21	8	1.8	13
Fresh-market cucumbers						
Bush Champion	Ends	16	13	20	1.3	12
	None	17	15	12	1.4	12
Dasher	Ends	19	17	10	1.4	14
	None	23	21	7	1.8	13
Early Triumph	Ends	20	19	8	1.5	14
	None	27	26	3	1.9	14
Poinsett 76	Ends	17	14	17	1.3	13
	None	18	17	8	1.4	13
Sprint 440	Ends	20	18	9	1.6	11
	None	22	20	12	1.8	11
Verino	Ends	22	19	10	1.8	12
	None	27	24	11	2.1	13
F ratio (Line × End-border)		1.1^{ns}	1.2^{ns}	1.5^{ns}	0.6^{ns}	–
F ratio (Ends vs. None)		28.2*	34.6*	8.4*	13.5*	–
Line means	Ends	20	18	9	1.6	–
	None	21	21	7	1.8	–

[1] Data are means over 6 replications. Due to missing data in certain treatment combinations, calculations from entries in other columns will not always produce the values shown. Means are rounded to the nearest significant digit as indicated by the size of the least significant difference.

[2] Plots had either a 1.5 m long border at each end or none.

*, ^{ns} Indicates significance at the 5% level, or not significant, respectively.

Table 3. Fruit yield (in number of fruits per plot) of 14 cultivars and breeding lines of pickling and fresh-market cucumbers in 1.5 m long plots harvested once-over, spring, 1984.[1]

Cultivar or line	Plot end treatment[2]	Yield			Culls (%)	Number of fruits per plant	Number of plants per plot
		Total	Marketable	Early[3]			
Pickling cucumbers							
Calypso	Ends	32	30	10	5	2.1	15
	None	42	42	9	1	2.8	15
Castlepik	Ends	30	29	7	3	2.0	15
	None	39	38	7	2	2.6	15
Clinton	Ends	24	24	3	0	1.6	15
	None	25	25	2	2	1.7	15
M 21	Ends	24	23	1	3	1.6	15
	None	25	24	2	1	1.6	15
Pikmaster	Ends	34	33	6	3	2.3	15
	None	40	38	7	4	2.6	15
SMR 58	Ends	22	20	5	10	1.5	15
	None	28	25	8	10	1.9	15
Tamor	Ends	34	33	7	3	2.2	15
	None	36	35	7	3	2.4	15
Fresh-market cucumbers							
Ashley	Ends	28	26	2	9	1.9	15
	None	28	26	0	6	1.9	15
Bush Champion	Ends	13	10	1	25	0.9	15
	None	25	20	0	21	1.7	15
Dasher II	Ends	34	31	3	10	2.3	15
	None	43	41	6	5	2.9	15
Early Triumph	Ends	29	27	1	6	1.9	15
	None	36	35	2	4	2.4	15
Poinsett 76	Ends	29	28	1	4	1.9	15
	None	38	37	1	2	2.5	15
Sprint 440	Ends	33	30	5	7	2.2	15
	None	41	39	7	5	2.7	15
Verino	Ends	30	27	1	12	2.0	15
	None	33	29	1	9	2.2	15
F ratio (Line × End-border)		1.7^{ns}	1.6^{ns}	1.2^{ns}	0.4^{ns}	1.7^{ns}	–
F ratio (Ends vs. none)		54.3*	55.2*	3.8^{ns}	5.7*	53.8*	–
Line means	Ends	28	26	4	7	1.9	–
	None	34	32	4	5	2.3	–

[1] Data are means over 6 replications. Due to missing data in certain treatment combinations, calculations from entries in other columns will not always produce the values shown. Means are rounded to the nearest significant digit as indicated by the size of the least significant difference.

[2] Plots had either a 1.5 m long border at each end or none.

[3] Early yield is the number of oversized fruits per plot at once-over harvest (made when the check plot had approximately 10% oversized fruits).

*, ^{ns} Indicates significance at the 5% level, or not significant, respectively.

Table 4. Fruit yield (in number of fruits per plot) of 14 cultivars and breeding lines of pickling and fresh-market cucumbers in 1.5 m long plots harvested once-over, summer 1984.[1]

Cultivar or line	Plot end treatment[2]	Yield			Culls (%)	Number of fruits per plant	Number of plants per plot
		Total	Marketable	Early[3]			
Pickling cucumbers							
Calypso	Ends	22	17	5	23	1.1	20
	None	26	23	9	13	1.3	20
Castlepik	Ends	21	13	4	39	1.0	20
	None	21	17	4	21	1.0	20
Clinton	Ends	17	15	2	12	0.8	20
	None	23	20	3	16	1.1	20
M 21	Ends	19	15	2	19	1.0	19
	None	17	13	2	20	0.9	18
Pikmaster	Ends	19	15	5	28	1.0	20
	None	23	18	5	26	1.2	20
SMR 58	Ends	13	8	4	49	0.7	20
	None	8	4	2	64	0.4	20
Tamor	Ends	20	18	7	13	1.0	20
	None	24	21	4	14	1.2	20
Fresh-market cucumbers							
Ashley	Ends	9	4	1	68	0.5	20
	None	13	4	1	68	0.6	20
Bush Champion	Ends	0	0	0	0	0.0	20
	None	1	0	0	100	0.1	20
Dasher II	Ends	20	15	5	28	1.0	20
	None	23	16	4	35	1.2	20
Early Triumph	Ends	25	19	4	26	1.2	20
	None	24	17	4	30	1.2	20
Poinsett 76	Ends	32	25	2	20	1.6	20
	None	30	25	4	18	1.5	20
Sprint 440	Ends	21	16	5	21	1.1	19
	None	27	21	9	22	1.3	20
Verino	Ends	15	9	1	51	0.8	20
	None	16	11	1	29	0.8	18
F ratio (Line × End-border)		1.5^{ns}	1.2^{ns}	1.8^{ns}	2.1^{*}	1.3^{ns}	–
F ratio (Ends vs. None)		4.6^{*}	4.7^{*}	0.8^{ns}	5.7^{*}	4.8^{*}	–
Line means	Ends	18	13	3	32	0.9	–
	None	20	15	4	30	1.0	–

[1] Data are means over 6 replications. Due to missing data in certain treatment combinations, calculations from entries in other columns will not always produce the values shown. Means are rounded to the nearest significant digit as indicated by the size of the least significant difference.

[2] Plots had either a 1.5 m long border at each end or none.

[3] Early yield is the number of oversized fruits per plot at once-over harvest (made when the check plot had approximately 10% oversized fruits).

$^{*, ns}$ Indicates significance at the 5% level, or not significant, respectively.

Experimental design

A split-plot treatment arrangement in a randomized complete block design with 6 replications was used in each of the 3 environments. Whole plots were the 12 or 14 lines, and subplots were the end-border treatments. Thus, each line in each replication in each environment was represented by paired plots 1.5 and 4.5 m long separated by 1.5 m alleys. Data were subjected to analysis of variance, the major items of interest being the main effect for presence or absence of end-borders and the interaction of line × end-border condition.

Results and discussion

Plant growth (vine size, vigor and freedom from disease) was best in spring 1984 (data not shown). That resulted in the highest total fruit yield and lowest percentage of cull fruits compared to the 2 other environments (Tables 2, 3, 4). Foliage disease (mainly anthracnose) was worst in the summer 1984 trial (data not shown), especially on the susceptible lines. The highest percentage cull fruits was observed in that trial. Extra culls were most likely due to the hotter, drier weather (which caused stress during fruit development) rather than to pollination problems (since bees were present in large numbers during flowering).

End-borders on plots caused 7 to 40% more culls over those without end-borders (Tables 2, 3, 4). Plots having end-borders may, therefore, be useful for evaluation of resistance to the production of culls in breeding lines. The lines with the highest percentage of culls were the ones that were susceptible to anthracnose (SMR 58, Ashley and Verino), or that were determinate (Castlepik and Bush Champion). The exception was M 21, a determinate line which never had more than 20% culls.

As expected, yield was inflated in all 3 environments in unbordered plots compared with the plots having end-borders (Tables 2, 3, and 4). The increase was 5 to 21% for total number of fruits per plot, 15 to 23% for number of marketable fruits, and 11 to 21% for number of fruits per plant. There was no interaction between line and end-border condition for any of the traits measured, except for percentage of culls in the summer 1984 trial (the most stressful environment for the plants because of the high temperatures experienced that season).

In conclusion, plot end-borders should be used in small plot trials if an accurate estimate of yield experienced by growers is needed (in which case, border rows and large plots should also be used, and yield should be measured as fruit weight or value instead of number). However, end-borders are not necessary in small plot trials where the objective is to compare lines for relative performance for yield.

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