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EFFECT OF INBREEDING ON HORTICULTURAL PERFORMANCE OF LINES DEVELOPED FROM AN OPEN-POLLINATED PICKLING CUCUMBER POPULATION

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SUMMARY

The effect of self-pollination of cucumber (*Cucumis sativus* L.) for 6 generations in lines developed from theNorth Carolina Medium Base Pickle population was determined by regression of trait expression for each generation on Wright's coefficient of inbreeding. Two yield traits (total and marketable), earliness and 3 fruit quality traits (shape, color and seedcell size) were evaluated in 2 environments (spring and summer, 1983). The regression did not result in significant negative slopes, indicating that inbreeding depression was not inmportant in the population for the traits studied. Midparent heterosis was found for most traits in many hybrids obtained from crossing S_6 lines with the gynoecious inbred line, Gy 14A.

INTRODUCTION

A reduction in vigor accompanying inbreeding has been found to occur in many cross-pollinated crop species (ALLARD, 1960). SHULL (1908) documented this phenomenon in maize (*Zea mays* L.) almost 80 years ago. However, species of the Cucurbitaceae, although predominantly cross-pollinating, have been reported to exhibit little inbreeding depression (ALLARD, 1960, p. 38).

Several workers have studied the effect of self-pollination on species of the Cucurbitaceae. JENKINS (1942) reported that several cucumber (*Cucumis sativus* L.) cultivars which were inbred for 5 generations were as vigorous as commercial open-pollinated stocks. SCOTT (1933) reported that a loss in vigor, as measured by fruit number and weight, did not always occur after inbreeding several cultivars of muskmelon (*Cucumis melo* L.) for 4 to 7 generations.

On the other hand, significant amounts of heterosis occur in cucumber (HAYES & JONES, 1916; HUTCHINS, 1938). GHADERI & LOWER (1979) reported that the degree of heterozygosity had a significant positive linear effect on yield in 5 of 6 cucumber families evaluated. They also suggested (GHADERI & LOWER, 1978) that, since hybrid vigor and inbreeding depression are both manifestations of the same phenomenon,

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inbreeding depression might be expected to occur in cucumber.

The objective of this study was to determine whether inbreeding depression occurs in lines derived by self-pollination of plants taken at random from an open-pollinated pickling cucumber population.

MATERIALS AND METHODS

The reference population for this study was the North Carolina Medium Base Pickle (NCMBP) population, which was formed by intercrossing several hundred pickling cucumber lines. The initial lines were crossed in various combinations for different experiments before combining the various sets of crosses and inbreds, and intercrossing in 1977, 1978, and 1980 to form the NCMBP population (WEHNER, 1984).

Fifty plants from the NCMBP population were selected randomly and self-pollinated for 6 generations to produce 24 complete sets of inbred lines. Remnant seeds from all 6 generations were planted at the Horticultural Crops Research Station at Clinton, N.C. in a split-plot in a randomized complete block design with 2 replications. Whole plots were the 24 sets, and subplots were the 6 generations (S_1 to S_6). F_1 seeds resulting from crosses of the S_6 generation of each set with the gynoecious inbred lines Gy 14A were also planted as a separate whole plot. A stand of 15 plants per 1.5 m plot (61750 plants/ha) was maintained with standard cultural practices. Plots were separated by 1.5 m alleys at each end. The experiment was planted on 11 may, 1983 and 13 July, 1983 for the spring and summer tests, respectively.

For the spring test, plots were evaluated 49 to 63 days after planting as each reached the stage where approximately 10% of the fruits were oversized (diameter > 51 mm). For the summer test, all plots were evaluated 48 days after planting when 'Calypso' check plots reached the stage where most of the fruits were oversized. MILLER & HUGHES (1969) recommended that plots be harvested at about 10% oversized fruits for maximum yield value, but we wanted to make sure that all plots had produced some fruits. In the summer test, plots were defoliated using Paraquat (1,1-dimethyl-4,4'-bipyridinium ion) as recommended by WEHNER et al. (1984) to make data collection at harvest stage more efficient. For each plot, total fruit number and marketable fruit number (= total fruit number – number of culls) were counted. Earliness was measured as the number of days from planting to harvest for the spring test, and as the number of oversized fruits per plot for the summer test. Since the NCMBP population was segregating for sex expression, the measurement of earliness may be somewhat biased due to the positive effect of gynoecy on earliness. However, since gynoecy is due to only a few gene loci (ROBINSON et al., 1976) it would disappear in the first few generations of inbreeding. Fruit shape, seedcell size, and color were rated on a scale of 1 to 9 with 1 = poor, 5 = average, and 9 = excellent.

Heterosis usually refers to traits that measure productivity such as yield and vine length, but we were interested to see whether fruit quality traits were affected by inbreeding. Thus, we used a subjected rating scale for quality to see whether it changed significantly with inbreeding.

Means over the 24 sets and 2 replications for the 6 generations of lines were calculated for each trait to determine whether inbreeding depression occurred. Regressions of trait expression on Wright's coefficient of inbreeding was used to measure the effect of the level of homozygosity on performance. In addition, midparent heterosis for the F_1 hybrids was calculated by comparing the hybrid with the mean of its parents (Gy 14A and each of the S_6 lines). Data for 2 S_6 lines in the spring test and 1 S_6 line in the summer test were missing due to problems with plant growth in the field.

RESULTS AND DISCUSSION

Inbreeding had no detrimental effect on the performance of lines for the traits studied. No significant trend for decrease was found for earliness, the 2 yield traits, or the 3 fruit quality traits after 6 generations of self-pollination (Table 1). If inbreeding depression were important for a trait, the regression of performance on Wright's coefficient of inbreeding (F) would result in a significant negative slope. None of the slopes were significantly negative (at the 5% level) for earliness, the 2 fruit yield traits, or the 3 fruit quality traits (Table 2). In fact, the slopes for total and marketable yield in the spring test were significantly positive (using a two-sided t test), indicating some

Table 1. Yield (= number of fruits per plot), earliness and fruit quality for 6 generations of selfing of lines derived from the NCMBP cucumber population evaluated for 2 seasons (spring and summer, 1983) in a once-over harvest system[1].

Number of generations of selfing	Wright's coefficient of inbreeding	Yield		Earliness[2]	Fruit quality[3]		
		total	marketable		shape	seed cell	color
Spring test							
0	0.00	28.1	26.7	53.0	5.0	4.7	4.9
1	0.50	28.2	26.0	56.6	5.3	5.1	5.9
2	0.75	33.9	30.8	57.9	5.4	5.5	5.5
3	0.88	40.9	38.3	56.3	5.5	5.1	5.8
4	0.94	35.2	31.4	57.2	5.8	5.2	5.7
5	0.97	36.8	32.6	57.4	5.4	5.5	6.2
6	0.98	38.7	34.7	56.9	5.2	5.2	5.9
Checks							
Calypso	0.00	22.4	21.6	50.1	6.7	6.0	5.7
Gy 14A	1.00	24.4	22.8	51.1	5.9	5.2	4.8
Summer test							
0	0.00	26.3	23.1	22.6	5.1	4.3	5.5
1	0.50	24.3	21.2	15.9	5.2	4.9	6.0
2	0.75	24.1	20.9	17.4	5.5	5.5	6.2
3	0.88	29.7	26.4	22.6	5.3	4.8	5.9
4	0.94	27.1	23.8	18.9	5.4	4.9	6.1
5	0.97	26.1	22.4	19.1	5.3	5.3	6.1
6	0.98	25.9	21.4	17.5	5.4	5.2	6.1
Checks							
Calypso	0.00	27.9	25.4	26.8	6.6	4.6	5.6
Gy 14A	1.00	27.9	24.9	26.5	5.1	3.1	3.4

[1] Data are means over 24 sets of lines and 2 replications.
[2] Earliness is the number of days from planting to harvest for the spring test, and number of oversized fruits (diameter > 51 mm) per plot at harvest for the summer test.
[3] Quality is scored 1 to 9 (1 = poor, 5 = average, 9 = excellent).

Table 2. Coefficients (b), obtained in 2 seasons (spring and summer, 1983), for the regressions of trait expression on the inbreeding coefficient. The data concern fruit yield (number of fruits per plot), earliness and fruit quality traits of lines developed from the NCMBP population[1].

Trait	b	
	spring test	summer test
Yield		
Total	19.68**	5.57
Marketable	16.03**	3.90
Earliness[2]	0.41	6.35
Quality[3]		
Shape	0.24	0.36
Seedcell	0.24	0.32
Color	0.35	0.08

[1] Regression coefficients were calculated using 24 sets of S_0 through S_6 lines in 2 replications per season.
[2] Earliness is the number of days from planting to harvest for the spring test, and number of oversized fruits (diameter > 51 mm) per plot at harvest for the summer test.
[3] Quality is scored 1 to 9 (1 = poor, 5 = average, 9 = excellent).
** b significant at the 1% level.

yield improvement during the inbreeding process. The yield improvement did not appear in the summer test where all plots were harvested at the same time, indicating that the effect may have been the result of slight, but nonsignificant trend for later maturity of the advanced inbreds. Thus, inbreeding depression was not important in affecting the performance of the lines for these traits in the spring and summer tests.

Midparent heterosis occurred for many of the crosses of S_6 lines with Gy 14A, a gynoecious inbred line (Table 3). High parent heterosis occurred for all traits in at least a few of the lines. We used the term heterosis to describe cases where there was improvement in fruit quality score, but that does not fit the normal definition of the term, which is usually applied only to biomass traits such as vine length and plant yield. However, we were interested to know whether there was heterosis for fruit quality. High parent heterosis for total fruit yield was not as pronounced in the spring test, where 4 of 22 F_1 exceeded the high parent, as in the summer test, where 13 of 23 F_1 exceeded the high parent. The number of hybrids exceeding the high parent for yield was greater when all of the entries in the test were harvested simultaneously as in the summer test, indicating the importance of gynoecious sex expression (which occurred in all of the F_1) in helping to increase early yield.

Although significant amounts of heterosis have been reported for cucumber (HAYES & JONES, 1916; HUTCHINS, 1938), inbreeding depression was not a significant factor affecting any of the traits measured for the population in this study. GHADERI & LOWER (1979) found that the degree of heterozygosity had significant positive linear effects in 5 of the 6 crosses of pickling cucumber inbreds and cultivars that they studied. They also pointed out that, although linear effects of heterozygosity were greater than nonlinear effects, there was a possibility that epistasis was involved in the response. SENTZ et al. (1954) reported that epistasis was an important factor affecting the re-

Table 3. Performance of S_6 lines (developed from NCMP cucumber population) and their F_1 hybrids with the inbred Gy 14A in 2 seasons (spring and summer, 1983) for yield, earliness and fruit quality traits.

Family means	Yield		Earliness[2]	Fruit quality[3]		
	total	marketable		shape	seedcell	color
Spring test						
Parent 1 (Gy 14A)	24.4	22.8	51.1	5.9	5.2	4.8
Parent 2 (22 S_6 lines)	38.7	34.7	56.9	5.2	5.2	5.9
Midparent	31.6	28.8	54.0	5.6	5.2	5.4
F_1 (Gy 14A × 22 S_6 lines)	33.2	29.8	54.3	5.5	5.0	5.2
Midparent heterosis[4]	5.1	3.5	0.6	−1.8	−3.8	−3.7
No. F_1 > midparent[5]	13	11	6	6	12	11
No. F_1 > high parent[5]	4	5	6	6	12	5
Summer test						
Parent 1 (Gy 14A)	27.9	24.9	26.5	5.1	3.1	3.4
Parent 2 (23 S_6 lines)	25.9	21.4	17.5	5.4	5.2	6.1
Midparent	26.9	23.2	22.0	5.3	4.2	4.8
F_1 (Gy 14A × 23 S_6 lines)	28.9	25.5	27.1	5.6	4.5	5.3
Midparent heterosis	7.4	9.9	23.3	5.7	7.1	10.4
No. F_1 > midparent	13	15	20	16	14	17
No. F_1 > high parent	13	10	12	16	4	3

[1] Data for 2 S_6 lines in the spring test and 1 S_6 line in the summer test were missing.
[2] Earliness is the number of days from planting to harvest for the spring test, and number of oversized fruits (diameter > 51 mm) per plot at harvest for the summer test.
[3] Quality is scored 1 to 9 (1 = poor, 5 = average, 9 = excellent).
[4] Midparent heterosis (%) = 100 (F_1 − midparent)/midparent, except for earliness in the spring which was 100 (midparent − F_1)/midparent. (That permitted positive heterosis to be in the direction of fewer days to harvest).
[5] No. F_1 < midparent or high parent for earliness in the spring test.

sponse to heterozygosity for certain traits in maize.

The lack of inbreeding depression implies that dominance and dominance × dominance forms of epistasis played a nonsignificant role in the NCMBP population for the traits evaluated. SMITH et al. (1978) reported that most of the genetic variance was additive for fruit number, carpel wall thickness (similar to seedcell score in this study), and several other traits in a monoecious pickling cucumber population. Absence of inbreeding depression does not rule out the use of hybrids for commercial cultivars, since hybrids offer the advauages of combined parental disease resistance, and protection of proprietary inbreds. However, inbreds can be used directly as cultivars if fruit yield and fruit quality are the major considerations.

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REFERENCES

ALLARD, R. W., 1960. Principles of plant breeding. John Wiley and Sons, Inc., New York, p. 38.

GHADERI, A. & R. L. LOWER, 1978. Heterosis and phenotypic stability of F_1 hybrids in cucumber under controlled environment. J. Amer. Soc. Hort. Sci. 103: 275–278.

GHADERI, A. & R. L. LOWER, 1979. Heterosis and inbreeding depression for yield in populations derived from six crosses of cucumber. J. Amer. Soc. Hort. Sci. 104: 564–567.

HAYES, H. K. & D. F. JONES, 1916. First generation crosses in cucumbers. Conn. Agr. Exp. Sta. Ann. Rep. p. 319–322.

HUTCHINS, A. E., 1938. Some examples of heterosis in cucumber, *Cucumis sativus* L. Proc. Amer. Soc. Hort. Sci. 36: 660–664.

JENKINS, J. M., JR., 1942. Natural self-pollination in cucumber. Proc. Amer. Soc. Hort. Sci. 40: 411–412.

MILLER, C. H. & G. R. HUGHES, 1969. Harvest indices for pickling cucumbers in once-over harvested systems. J. Amer. Soc. Hort. Sci. 94: 485–487.

ROBINSON, R. W., H. M. MUNGER, T. W. WHITAKER & G. W. BOHN, 1976. Genes of the cucurbitaceae. HortScience 11: 554–568.

SCOTT, G. W., 1933. Inbreeding studies with *Cucumis melo*. Proc. Amer. Soc. Hort. Sci. 29: 485 (abstr.).

SENTZ, J. C., H. F. ROBINSON & R. E. COMSTOCK, 1954. Relation between heterozygosis and hybrid vigor in maize. Agron. J. 46: 514–520.

SHULL, G. H., 1980. The composition of a field of maize. Amer. Breeders Assoc. Rep. 4: 296–301.

SMITH, O. S., R. L. LOWER & R. H. MOLL, 1978. Estimates of heritability and variance components in pickling cucumber. J. Amer. Soc. Hort. Sci. 103: 222–225.

WEHNER, T. C., 1984. Estimates of heritabilities and variance components for low-termperature germination ability in cucumber. J. Amer. Soc. Hort. Sci. 109: 664–667.

WEHNER, T. C., T. J. MONACO & A. R. BONNANNO, 1984. Chemical defoliation of cucumber vines for simulation of once-over harvest in small-plot yield trials. HortScience 19: 671–673.