J. Amer. Soc. Hort. Sci. 106(3):365–370. 1981.

Combining Ability and Genetic Variances of G x H F_1 Hybrids for Parthenocarpic Yield in Gynoecious Pickling Cucumber for Once-over Mechanical Harvest[1]

I. I. S. El-Shawaf and L. R. Baker[2]
Department of Horticulture, Michigan State University, East Lansing, MI 48824

Additional index words. Cucumis sativus, vegetable breeding

***Abstract*. The parthenocarpic yield and associated traits of 20 gynoecious hybrids of pickling cucumber (*Cucumis sativus* L.) were measured by crossing 4 gynoecious with 5 hermaphroditic lines. The experimental hybrids were grown in the field and harvested for the once-over harvest system. Additive genetic variance was greater than non-additive for yield and associated characters, except gynoecious expression where non-additive was more important. The GCA for harvest-time, gynoecious expression, and yield of the female parents was greater than that of the male parents in this population. The converse was true for flowering-time. The dominance estimates indicated complete dominance for early flowering and over-dominance for gynoecious expression. The remaining characters appeared to be under the control of genes with additive effects and partial dominance. Narrow sense heritabilities of half-sibs (males and females) for fruit no. and fruit wt/plant were 53 to 60% and 32 to 65%, respectively. The genotypic and phenotypic correlations for flowering-time and nodal position of first-pistillate flower were high as was nodal position of first-pistillate flower with parthenocarpic yield.**

The breeding and development of parthenocarpic cultivars of pickling cucumber with gynoecious expression for field production has received increasing attention from cucumber breeders (1, 4, 14, 20, 21). The possible advantages of more yield and seedless fruit for parthenocarpic over seeded cultivars are important considerations (1, 4, 5, 20, 21, 25).

Low light, short daylength, low night temperature and late season enhance parthenocarpic fruit-set in pickling cucumber especially on well developed vines (9, 21, 25). These phenomena were confirmed by growing cucumbers under controlled conditions (21, 25). The combination of short days and low night temperatures enhanced parthenocarpic yields. In the former study (21), the number of parthenocarpic fruits was dramatically increased in the last two weeks of the harvest when daylengths became short (12 hr).

The presence of seeded fruits on cucumber vines inhibits vegetative growth and further fruiting as opposed to parthenocarpic or seedless fruits (4). Moreover, seed development has a dual effect on the development of fruit tissue, since the development of the seeds is at the expense of fruit tissue (4). Development of parthenocarpic hybrid cvs. for field production would increase yield potentials by maximizing fruit number and weight for once-over mechanical harvesting. The genetics of parthenocarpic fruiting was hypothesized to be under monogenic control with incomplete dominance (20) for parthenocarpy. Conversely, one recessive gene might be responsible for the expression of parthenocarpy (12); whereas, many recessive genes have also been proposed to control parthenocarpy (16). Currently, 3 independent, isomeric major genes with additive action together with epistasis have been assigned responsible for parthenocarpic fruiting in cucumber (22). The latter model was based on data from glasshouse experiments with multiple harvests.

The heritability and genetic variances for parthenocarpic yield in gynoecious pickling cucumbers for once-over mechanical harvest under field conditions would be valuable information for the development of parthenocarpic cultivars. The purpose of our investigation was to estimate genetic variance components and combining ability for parthenocarpic yield and associated characters from the performance of gynoecious x hermaphroditic hybrids.

Materials and Methods

Five hermaphroditic (H) lines from the Michigan State University (MSU) breeding program (661H, 669H, 319H, 581H and 532H) were crossed with four gynoecious (G) lines (Gy14, 921G, 364G, and 402G) to make twenty F_1 (G x H) hybrids. The parental lines were described earlier (5, 6). The twenty F_1 hybrids and 4 gynoecious lines were seeded in a randomized complete block design with 5 replications on June 22, 1978 at the Horticultural Research Center of Michigan State University near East Lansing. Each experimental plot was a single row 7.6 m long with 1.8 m between rows. Plants were thinned to 25 cm in the row with a minimum no. of 20 plants/plot. Standard cultural practices were used (19). The field was isolated from other cucumbers by at least 1 mile.

Before flowering, 10 plants were chosen at random to obtain data on flowering time, sex expression and nodal position of the first-pistillate flower. Staminate flower buds were rogued daily from all plants. Plants which produced staminate buds were considered predominantly female (PF). Plots were hand-harvested when 10% (by weight) of the fruits in a plot were judged oversized (>5 cm diameter) as suggested for once-over harvest (17). Yield data (average number and weight of fruit/plant) were obtained from the individual plots.

Data were analyzed using a 2-way classification model with interaction to obtain general combining ability (GCA) and specific combining ability (SCA) estimates. The sums of squares for the interactions, replication x male and replication x female, were pooled with the error term since these interactions were not signif-

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[1] Received for publication September 20, 1979. Michigan State University Agricultural Experiment Station Journal Article No. 9163. Portion of a thesis submitted by senior author in partial fulfillment for the PhD degree.

The cost of publishing this paper was defrayed in part by the payment of page charges. Under postal regulations, this paper therefore must be hereby marked *advertisement* solely to indicate this fact.

[2] Graduate student and Professor, respectively. Current addresses of authors are College of Agriculture, Tanta University, Tanta, Egypt, and Asgrow Seed Company, Kalamazoo, MI 49001, respectively. This research supported in part by a grant from Pickle Packers International, St. Charles, Ill.

icant. Thus, the statistical model was:

$$Y_{hijk} = \mu + \alpha_i + \beta_j + (\alpha\beta)_{ij} + R_h + E_{hijk}$$

Where, Y_{hijk} = the observation for the kth full-sib progeny in a plot of the hth replication of the ith hermaphroditic pollen parent and the jth gynoecious seed parent. And, μ = the constant which is common to all observations; and αi and βj are the random effect of the ith male parent and the jth female parent, respectiely; $(\alpha\beta)ij$ = random effect of the interaction of male and female parents; R_h = fixed effect of the hth replication; and E_{hijk} = environmental effect and the remainder of the genetic effect between full sibs on the same plot. The following analysis of variance was used to estimate the genetic and phenotypic variances:

Source of Variation	df	MS	EMS
Replications	R-1	MS_R	
Males	M-1	MS_m	$6^2{}_e + r6^2{}_{mf} + rf6^2{}_m$
Females	F-1	MS_f	$6^2{}_e + r6^2{}_{mf} + rm6^2{}_f$
Males x Females	(M-1) (F-1)	MS_{mf}	$6^2{}_e + r6^2{}_f$
Error	(R-1) (MF-1)	MS_E	$6^2{}_e$

where; $6^2{}_e$ = environmental variance, $6^2{}_m$ = variance of male effects, $6^2{}_f$ = variance of female effects, and $6^2{}_{mf}$ = variance due to interaction of male and female effects. The model description and the assumptions involved were reported previously (2, 3, 10).

The GCA effects for hermaphroditic male and gynoecious female lines were estimated by subtracting the mean of all hybrids from the mean of each male and female line for their hybrid performance. The SCA effects were obtained by summing the mean for a particular hybrid with the grand mean of all hybrids; then, subtracting the grand means for both the male and female line for that particular hybrid. The GCA:SCA ratios were estimated by $(6^2{}_m + 6^2{}_f)/6^2{}_{mf}$.

The degree of dominance was estimated by the square root of 2 $6^2{}_{mf}/6^2{}_m$; and the maternal effects by $(6^2{}_f - 6^2{}_m)/2$. Narrow sense heritability ratios were computed by multiplying $6^2{}_m$ or $6^2{}_f$ by 4, then dividing by $6^2{}_p$ which equals $(6^2{}_m + 6^2{}_f + 6^2{}_{mf} + 6^2{}_e)$. Genotypic and phenotypic associations between characters were estimated from both variance and covariance components (13, 28). Genotypic (rG_{ij}) and phenotypic (rP_{ij}) associations for character pairs, i and j, were estimated from:

$$rG_{ij} = (6_{mij} + 6_{fij}) / (6^2{}_{mi} + 6^2{}_{fi})^{1/2} \; (6^2{}_{mj} + 6^2{}_{fj})^{1/2}, \text{ and}$$
$$rG_{ij} = (6_{P(fs)ij}) / (6^2{}_{P(fs)i} \bullet 6^2{}_{P(fs)j})^{1/2}$$

respectively. The numerators were estimated by covariance analysis by using analysis of variance of cross products for all factor pairs; and denominators from the analysis of variance.

Results and Discussion

The mean squares for hybrid performance revealed significant differences among the crosses for most characters (Table 1). The mean squares for the male (hermaphroditic parents) performance were significant for all characters. The same was observed for the females (gynoecious parents) except for flowering-time. However, only the mean square for gynoecious expression was significant for male x female performance.

Hybrid vigor was expressed for earlier flowering (8 days), earlier pistillate node (0.7 nodes), earlier harvest date (7 days), and higher gynoecious expression (10%) when compared to the female parents (Table 2). Fruit number per plants was similar for female parents and their hybrids except for 364G. Comparisons

Table 1. Mean squares from analysis of variance for parthenocarpic yield and certain associated components for 20 gynoecious by hermaphroditic crosses of gynoecious pickling cucumbers grown near East Lansing, Michigan in the summer of 1978.

Factor	df	Flowering time	Node no. first ♀ flower	Harvest-time	Gynoecious expression	Avg yield/plant No.	Avg yield/plant Wt.
Replication	4	81.20**	2.26**	188.23**	11.00	1.65*	37812**
Male	4	19.90**	0.65**	41.28**	98.50**	2.64**	25959*
Female	3	4.55	0.90**	77.51**	211.67**	3.56**	53139**
Male x female	12	4.21	0.14	10.45	89.17**	0.44	8440
Error	76	2.16	0.14	10.01	14.68	0.57	8244

*,** Significant at the 5% (*) and 1% (**) levels.

Table 2. Means of gynoecious F_1 (GxH) parthenocarpic hybrids in pickling cucumber with one common parent and means of common gynoecious seed parents.

MSU parent	Flowering time (days)		Node first ♀ flower (no.)		Harvest time (days)		Gynoecious (%)		Avg. yield per plant			
									No. Fruit		Wt. fruit (g)	
	F_1	P	F_1	P	F_1	P	F_1	P	F_1	P	F_1	P
Females[z]												
Gy14	37.8a	47.8a	2.1a	2.5a	58.1ab	68.6bc	99.2b	100b	1.2a	1.3a	124.9a	148.8a
921G	37.8a	46.3a	2.1a	4.2b	60.1b	69.2bc	100.0b	100b	1.8b	2.0a	152.2ab	181.4a
364G	37.8a	45.3a	2.5b	2.5a	57.1ab	64.1b	98.8b	100b	1.9b	1.0a	200.0bc	97.6a
402G	37.4a	44.2a	2.3ab	2.4a	55.8a	59.2a	93.6a	50a	2.0b	2.2a	226.9c	268.9a
Mean	37.7	45.9	2.2	2.9	57.8	65.3	97.9	87.5	1.7	1.6	176.1	170.4
Males[z]												
661H	38.1ab	-	2.1a	-	57.4a	-	99.5a	-	1.2a	-	145.7a	-
669H	36.8a	-	2.1a	-	57.2a	-	99.0a	-	1.5ab	-	160.3a	-
319H	37.2ab	-	2.3ab	-	59.2a	-	95.5a	-	2.1b	-	207.1a	-
581H	39.3b	-	2.5b	-	59.6a	-	95.5a	-	1.8ab	-	145.2a	-
532H	37.2ab	-	2.1a	-	56.2a	-	100.0a	-	1.9ab	-	221.9a	-
Mean	37.7	-	2.2	-	57.8	-	97.9	-	1.7	-	176.1	-

[z] Mean separation within columns by Tukey's Multiple Range Test, 5% level.

could not be made with the male lines and their respective hybrids since the male parents are bisexual which precludes parthenocarpic fruiting. By observation, 402G and 319H were judged the better female and male parent lines, respectively, for fruit no. per plant, although not significant from most other lines.

The relative effects for GCA and SCA were obtained for all characters (Tables 3-5). Based on hybrid performance, the earliest flowering was observed for 669H and 402G among the male and female lines, respectively. They were considered to exhibit high GCA for early flowering; whereas, the male line 581H, showed high GCA for late flowering. Hybrids Gy14 x 581H, 921G x 669H, and 402G x 661H showed high SCA for early flowering, as opposed to the hybrid cross 402G x 581H as the latest in flowering time.

Hybrid crosses from the female parent, 364G and male parent, 581H, showed strong GCA for higher nodes with first pistillate flowers. The hybrids of 921G x 669H, 402G x 661H, and 364G x 532H displayed good SCA for lower nodes bearing first pistillate flowers.

For harvest-time, only 402G showed high GCA effects with respect to early parthenocarpic fruit-set among the female lines (Table 4). Conversely, the female line, 921G, demonstrated high GCA effects for late parthenocarpic fruiting. Extreme values were not observed for either GCA effects among the male lines or for SCA effect among their hybrids for days to first-harvest.

The best combiners among the female and male lines with respect to gynoecious expression were 921G and 532H, respectively (Table 4). The female line, 402G, was generally a poor combiner for gynoecious expression. High SCAs were exhibited by 402G x 669H, 402G x 532H, 364G x 319H, and Gy14 x 319H for gynoecious expression; whereas, low SCA was demonstrated by 402G when crossed with either 319H or 581H and by 364G x 669H.

The best GCA effects for yield (number fruit/plant) were noted for the male parent, 319H, and for the female parent, 402G (Table 5). The SCAs among all the hybrids was quite low. For yield as weight (g/plant), the greatest GCA effects were exhibited by 532H and 402G for male and female lines, respectively. The highest value for SCA effects on weight/plant was obtained from the hybrid of the above two parents.

The variance components of the F_1 hybrids from 100 plots (5 replications x 20 populations) for all characters were used to cal-

Table 3. Estimates of combining ability effects for flowering time and nodal position of first-pistillate flower from 20 F_1 (G x H) hybrids of gynoecious pickling cucumber grown summer of 1978.

MSU male parental line	Specific effects (SCA) Females Gy14	921G	364G	402G	General effects of males (GCA)
	Flowering time				
661H	+0.57	+0.30	+0.21	−1.10	+0.38
669H	+0.50	−0.97	+0.10	+0.37	−0.89
319H	+0.16	−0.31	+0.96	−0.81	−0.53
581H	−1.15	+0.24	−0.73	+1.62	+1.57
532H	−0.08	+0.73	−0.56	−0.11	−0.53
General effects of females (GCA)	+0.12	+0.12	+0.12	−0.36	-
	Node no. of the first-pistillate flower				
661H	+0.01	+0.02	+0.06	−0.20	−0.15
669H	−0.02	−0.30	+0.05	+0.10	−0.15
319H	+0.01	−0.02	+0.14	−0.14	+0.10
581H	−0.10	+0.10	−0.04	+0.20	+0.30
532H	−0.09	−0.10	−0.20	+0.11	−0.10
General effects of females (GCA)	−0.10	−0.10	+0.20	−0.00	-

Table 4. Estimates of combining ability effects for harvesting-time and gynoecious expression based on 20 F_1 (G x H) gynoecious hybrids of pickling cucumbers grown in the summer of 1978.

MSU male parental line	Specific effects (SCA) Females Gy14	921G	364G	402G	General effects of males (GCA)
	Harvest-time				
661H	−0.42	+0.82	+0.70	−1.70	−0.50
669H	+0.78	−1.38	−0.30	+0.90	−0.70
319H	−1.57	−0.13	−1.33	−0.85	+1.25
581H	−0.22	−1.22	−1.90	−0.90	+1.70
532H	+1.43	−0.53	−1.05	+0.15	−1.75
General effects of females (GCA)	+0.22	+2.18	−0.30	−2.10	-
	Gynoecious plants (%)				
661H	−0.80	−2.00	−0.40	+2.80	+1.60
669H	−0.30	−1.10	−3.90	+5.30	+1.10
319H	+3.20	+2.40	+3.60	−9.20	−2.40
581H	−0.80	+2.40	+1.60	−3.20	−2.40
532H	−1.30	−2.10	−0.90	+4.30	+2.10
General effects of females (GCA)	+1.30	+2.10	+0.90	−4.30	-

Table 5. Estimates of combining ability effects for yield based on 20 F_1 hybrids of pickling cucumbers grown in the summer of 1978.

MSU male parental line	Specific efects (SCA) Females Gy14	921G	364G	402G	General effects of males (GCA)
	Fruit no./plant				
661H	−0.05	−0.72	−0.61	−0.21	−0.52
669H	−0.50	−0.65	−0.36	−0.46	−0.24
319H	−0.57	−0.46	−0.73	−0.22	+0.42
581H	−0.46	+0.06	+0.55	−1.05	+0.13
532H	−0.49	−0.72	−0.25	−0.54	+0.21
General effects of females (GCA)	−0.50	+0.10	+0.10	+0.30	-
	Fruit wt (g)/plant				
661H	+6.60	−4.89	−30.62	+28.88	−30.33
669H	−15.78	+22.85	+9.55	+29.39	−15.75
319H	+1.80	+3.65	+32.94	−38.42	+31.02
581H	+39.76	+50.03	−17.57	−72.26	−30.85
532H	−32.17	−25.98	+5.83	+52.46	+45.91
General effects of females (GCA)	−51.17	−24.04	+24.38	+50.83	-

culate the ratios of GCA:SCA (Table 6). The ratios for GCA:SCA ranged from 2 to 68 depending on the trait. A high ratio for nodal position of the first-pistillate flower is also probable, but could not be calculated because the SCA approximated 0. Additive genetic effects were more than non-additive effects for all characters with the exception of percent gynoecious expression. The SCA for sex expression was some 3 x as important as GCA which suggested a strong contribution by non-additive genes as found by previous workers (14, 15). However, the GCA for yield was generally more important than SCA, even though our parental lines had been previously selected. The large differences for GCA among the female lines (combined with larger variances of 6^2_f) for characters such as harvest-time, gynoecious expression, and yield indicate that the female lines were responsible for the majority of additive gene effects for these characters. Accordingly, genetic improvement could be realized by selection among the female lines for harvest-time, gynoecious expression and yield.

The model and the material used did not permit estimation of the variance component for epistasis; therefore, estimation of additive and especially non-additive components of genetic variance could be biased (13). The unequal value of 6^2_m and 6^2_f could be explained by maternal effects (cytoplasmic inheritance) or linkage disequilibrium (2, 3, 23). Reciprocal crosses would be the best estimate of maternal effects, especially for characters that showed differences in magnitude between 6^2_m and 6^2_f, but the cross of hermaphrodite x gynoecious is not easily made.

The high degree of dominance for flowering-time (0.99) indicated complete dominance for the gene(s) that controls this trait. Previous workers (18, 26), reported that 1 or 2 genes controlled flowering-time. The high degree of dominance for gynoecious expression (7.56) could be explained by over-dominance. This high value for degree of dominance could be biased by both linkage disequilibrium and epistasis (3, 10). This is probable because gynoecious expression is under the control of relatively few genes with dominance and epistatic effects (14, 15, 24).

Differences existed between 6^2_m and 6^2_f for characters such as flowering-time, harvesting-time, gynoecious expression, and yield (Table 6). The degree of dominance was equal or less than unity for all characters except for over-dominance for gynoecious expression (7.5). Narrow-sense heritability estimates for half-sibs (male or female parents) were somewhat high for most characters (Table 6); yield estimates ranged from 0.32 to 0.65. Differences in heritabilities between males and females for all characters were detected for half-sibs estimates. High narrow-sense her-

Table 6. Estimates of combining ability and heritability of parthenocarpic yield from gynoecious x hermaphroditic crosses of cucumber from 1978 field trials.

Component	Flowering time	Node first ♀ flower	Harvest-time	Gynoecious (%)	Avg yield/plant Fruit no.	Fruit wt
Male (GCA) 6^2_m	0.78	0.026	1.54	0.47	0.11	875.9
	±0.58	±0.019	±1.20	±3.30	±0.08	±766.2
Female (GCA) 6^2_f	0.01	0.030	2.68	4.90	0.12	1787.9
	±0.13	±0.023	±1.96	±5.50	±0.09	±1350.4
MxF (SCA) 6^2_{mf}	0.39	0.000	0.09	14.89	0.02	39.2
	±0.32	±0.011	±0.85	±15.11	±0.04	±690.3
Maternal effect 6^2_{mat}	−0.38	0.002	0.57	2.19	0.01	456.0
Error	2.16	0.140	10.01	14.68	0.57	8244.7
Ratio GCA:SCA	2.05:1	[z]	47:1	0.36:1	9.4:1	68:1
Degree of dominance	0.99	0.003	0.34	7.56	0.67	0.30
h^2_nmale	0.93	0.53	0.43	0.05	0.53	0.32
	±0.69	±0.38	±0.33	±0.37	±0.38	±0.27
h^2_nfemale	0.02	0.61	0.75	0.56	0.60	0.65
	±0.15	±0.46	±0.54	±0.62	±0.43	±0.49

[z] SCA approximated zero, so ratio could not be calculated.

Table 7. Phenotypic and genetic correlations for parthenocarpic yield and associated characters from 20 F_1 (G x H) gynoecious hybrids of pickling cucumbers grown in summer 1978.

Character[z]	Flowering time (1)	Node first ♀ flower (2)	Harvest-time (3)	Gynoecious (%) (4)	Avg yield/plant Fruit no. (5)	Avg yield/plant Fruit wt (6)
Flowering (1)	-	+0.72	+0.30	−0.12	−0.45	−0.16
Node (2)	+0.58	-	+0.21	−0.24	+0.02	−0.02
Harvest time (3)	−0.13	−0.05	-	−0.02	+0.14	+0.07
Gynoecious (%) (4)	−0.95	−0.68	+0.21	-	−0.15	−0.03
Fruit no. (5)	−0.02	+0.47	+0.04	−0.88	-	+0.65
Fruit wt (6)	−0.16	+0.79	−0.75	−1.20[y]	+0.87	-

[z] Phenotypic correlation above diagonal; genetic correlation below diagonal.

[y] Values are assumed to approximate unity.

itability among the parents and a high ratio of GCA:SCA suggested that most of the variation was additive for nodal position of the first-pistillate flower, harvest-time, and yield. Thus, genetic progress could be made for yield (fruit number) by selection among the high-performance parents. Further improvement could be achieved by testing selected parents for SCA in hybrid combinations. Low heritability estimates among female lines for flowering-time and among male lines for gynoecious expression were due to small additive genetic variances.

Genotypic and phenotypic correlations were estimated for all pairs of characters (Table 7). The phenotypic correlation coefficients were high between flowering time and nodal positon of first-pistillate flower (0.72), as well as harvest-time (0.30) and yield expressed as fruit number per plant (−0.45). A positive correlation was detected for nodal position of first-pistillate flower with harvest-time (0.21). A strong association was found for yield measurements of fruit number with fruit weight/plant (r =0.65).

The genetic correlation coefficient for flowering-time and nodal number of first-pistillate flower was 0.58; whereas, flowering time and percent gynoecious plants was −0.95. Positive genetic correlations for nodal number of first-pistillate flower and yield (0.47 and 0.79) were observed. Conversely, negative genetic correlations were calculated for position of first-pistillate flower with gynoecious expression (−0.68) and between gynoecious expression and yield. As expected, a strong positive genetic association was found between fruit number and fruit weight.

Phenotypic correlations among yield and associated characters were in agreement for sign and magnitude with previous reports for seeded cucumber cultivars (11, 18, 27). Genetic correlations among certain characters suggested strong genetic associations between these characters (Table 7). Relatively high genetic correlations suggest genetic linkage and/or pleiotropy (23). The presence of negative correlations between certain characters; viz., flowering-time and gynoecious expression, node number of first-pistillate flower and gynoecious expression, and gynoecious expression and yield, could be due to pleiotropy (23) and/or selection. The high negative correlations between gynoecious expression and various yield characters could also be due to the small values of 6^2_m. Independent genetic associations between characters might be the result of environmental effects and/or interactions. This could be especially true when different characters develop sequentially to a final product; e.g., flowering to yield of fruits which occurs over time and is subject to many environmental influences (7, 8). The advantage of a gentic correlation between flowering-time and nodal positon of the first-pistillate flower and between the latter and yield could be used as a guide for selection of a line(s) expected to produce both early and high yields of parthenocarpic fruits.

Based on the present and related studies (1, 5, 6, 21, 22), the authors suggest that the development of parthenocarpic hybrid cultivars of pickling cucumber with the required gynoecious expression is possible for once-over mechanical harvest. The hybrid seed would be produced from the cross of gynoecious parthenocarpic seed parent with hermaphroditic parthenocarpic pollen parent. Hermaphroditic pollen parents with high parthenocarpic yields might be developed by backcrossing the *m* gene (24) for hermaphroditic expression into a high yielding parthenocarpic line from the array of parthenocarpic gynoecious parents. Hybrid crosses could then be evaluated to identify superior combinations for cultivar adaptation.

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J. Amer. Soc. Hort. Sci. 106(3):370–373. 1981.

Comparison of Single and Three-way Crosses of Pickling Cucumber Hybrids for Femaleness and Yield by Once-over Harvest[1]

M. Tasdighi and L. R. Baker[2]
Department of Horticulture, Michigan State University, East Lansing, MI 48824

Additional index words. vegetable breeding, *Cucumis sativus*, mechanical harvest

Abstract. **An array of 102 single and 3-way cross hybrids of pickling cucumbers (*Cucumis sativus* L.) were evaluated for yield over 2 years under field conditions. Hybrids were produced by crossing lines with gynoecious, monoecious, hermaphroditic, and androecious expression. The significant correlations between femaleness (percent pistillate nodes) and marketable yield were 0.34 for single cross and 0.45 for 3-way cross hybrids. Highest yields were obtained from the single crosses of gynoecious x androecious, and gynoecious x hermaphrodite, followed by the 3-way cross of (gynoecious x hermaphrodite) x androecious, on the basis of either total or marketable fruits per plant. Hybrids having androecious pollen parents exhibited more femaleness and produced higher yields than those with monoecious pollen parents. The possible use of these high yielding parental sex combinations as hybrid cultivars in place of conventional single crosses (gynoecious x monoecious) might improve the production of pickling cucumbers for once-over mechanical harvest.**

Pickling cucumber production in Michigan for 1978 was estimated to have a farm value of $15 million; most of which was harvested once-over (USDA, Statistical Reporting Service). Production of pickling cucumbers for mechanical harvest differs greatly from that for hand-harvest (7, 8). The entire crop is harvested when the greatest number of fruits is judged marketable (6). Thus, the success of once-over mechanical harvest is based on inherent yield potential and uniformity which in turn depends upon many factors including the cultivar, environment, and grower (7, 8). The average yield of pickling cucumber by once-over mechanical harvest is respectable at 450 bu(10.23 MT)/ha (USDA, Statistical Reporting Service), but the yield potential is likely to be higher.

Highly female expression in hybrid cultivars is important for a highly concentrated fruit-set that is needed for once-over mechanical harvest. Commercial hybrid cultivars of pickling cucumber are predominantly female (PF) with various percentages of staminate and pistillate flowers. The staminate flowers commonly occur on the early nodes (1 to 9) followed by a continuous pistillate stage. Improvements in the percentage and stability of pistillate flowering (femaleness) of these hybrids should improve the uniformity of fruit-set and yield for once-over harvest. Recent attention focused on the use of hermaphroditic (9, 12, 13) and androecious (14) pollen parent lines, in place of the commonly used monoecious lines (10), for hybrid seed production of pickling cucumber. Compared to monoecious, androecious pollen parents usually produced hybrids with a higher percentage of gynoecious plants (14). There is no evidence to indicate whether all-female, gynoecious cultivars yield higher than PF cultivars when harvested once-over.

The objectives of our study were to compare single and 3-way cross hybrids of pickling cucumbers, to compare androecious and monoecious pollen parents for their effect upon hybrid sex expression and subsequent yield, and to determine the association of sex with yield in a once-over harvest.

Materials and Methods

Plant materials. Thirteen parental lines were selected from publicly released and Michigan State University (MSU) germplasm (Table 1). In January 1978, appropriate stock seeds were

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[1] Received for publication May 29, 1980. Michigan Agricultural Experiment Station Journal Article No. 9475. Portion of a thesis submitted by the senior author in partial fulfillment for the PhD degree.

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[2] Graduate student and Professor, respectively. L. R. Baker address is Asgrow Seed Company, Kalamazoo, MI 49001. This research supported in part by a grant from Pickle Packers International, St. Charles, Ill.