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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]

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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

[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.

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.

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Table 1. Parental lines of pickling cucumber used to produce single and 3-way cross hybrids.

Sex phenotype	Parental line	Source	Status	Origin
Gynoecious	Gy14	Clemson Univ.	Released	Gy 3 x SMR18
	368G	MSU	Experimental	Gy3 x (713-5 x (35G x "Spotvrige")
	551F	Cornell Univ.	Released	MSU713-5 x SR551
Hermaphrodite	661H	MSU	Experimental	SC40A x MSU7154H
	669H	MSU	Experimental	MSU844G x MSU4108H
	319H	MSU	Experimental	SC40A x MSU7172H
	581H	MSU	Experimental	(MSU394G x 4108H)
Monoecious	SC36A	Clemson Univ.	Experimental	Unknown
	SC38A	Clemson Univ.	Released	(Gy3 x SMR18) x SC587
	316M	MSU	Experimental	MSU9402 x SC 23
Androecious	5802A	MSU	Experimental	MSU394G x 1A2
	5803A	MSU	Experimental	MSU394G x 1A1
	5804A	MSU	Experimental	Tablegreen 68G x 1A3

Table 2. Hybridization for single and 3-way cross hybrids of pickling cucumber to compare for femaleness and for yield by once-over harvest.

Parental sexes of crosses	type of cross	Sex of hybrid	No. hybrids
Single cross hybrids			
Gynoecious x hermaphrodite	G x H	Gynoecious	12
Gynoecious x androecious	G x A	Predominantly female	9
Gynoecious x monoecious	G x M	Predominantly female	9
Three-way cross hybrids			
(Gynoecious x hermaphrodite) x androecious	(G x H) x A	Predominantly female	36
(Gynoecious x hermaphrodite) x monoecious	(G x H) x M	Predominantly female	36
Grand total			102

sent to Linda Vista near Cartago, Costa Rica, to produce all the hybrid seeds (Table 2) for this experiment. Seed production was in plastic houses with screened sides to exclude pollinating insects; seeds were produced by hand-pollination.

Field trials. Seeds were sown at the Clarksville Horticultural Experiment Station (near Grand Rapids, Michigan) in a sandy loam soil during the 1978 and 1979 growing seasons. The plots were arranged in a partially balanced triple lattice design. Each plot was 6 m long on a 4-row flat bed with 45 cm between rows. The seedlings were thinned to 30 cm between plants in the row, which approximated 65,000 plants per ha. Standard cultural practices (8) were used including sprinkler irrigation and bees for pollination (3 hives/ha.). The seed lots of single crosses with '5804A' germinated poorly and were eliminated from the experiment.

A random sample of 12 plants per plot was classified for femaleness by recording the sex of individual flowers on the first 10 nodes of the main stem. Nodes were classified as females when they developed either pistillate flowers or both pistillate and staminate flowers (functionally female) on the same node. The other 2 classes were staminate or barren nodes which lack the potential to bear fruit.

Individual plots were hand-harvested when approximately 10% of the fruits by weight were judged over-size (>5.1 cm diameter) to estimate once-over harvest yields. This grade size distribution was suggested to be the optimum harvest time for once-over harvest (6, 7). Each plot for a given hybrid entry was harvested individually because the time required for 10% over-size differed. The number of marketable and total fruits were recorded for each plot.

The data were statistically analyzed using yield per plant. Variances over 2 years were tested using a 2-tailed F test (16) and found to be homogeneous so the data were pooled.

Results and Discussion

The interaction of year with many of the parental lines and hybrids was significant for sex expression and for total and marketable numbers of fruits per plant (Table 3). However, the hybrids of gynoecious (G) by hermaphroditic (H) crosses were stable from year to year for sex expression as measured by percent female nodes. This observation supports research which showed that H pollen parents improved and stabilized the gynoecious expression of hybrids made with G seed parents (2, 5, 9, 13). The parental G and H lines were also stable across years (Table 3).

Over-estimation of yield by total weight is often caused by a later harvest resulting in a high proportion of large, over-sized (unmarketable) fruits. Accordingly, yield can be more accurately estimated by the number of fruits per plant as suggested previously for once-over harvest yields (6, 15). However, we did find highly significant ($\alpha = .01$) correlations of 0.74 between total number and total weight of fruits per plant, and 0.77 between marketable number and marketable weight of fruits per plant. These high correlations were probably due to the timeliness of the harvest of individual plots.

For the parents used in this study, G lines exhibited the highest percent female nodes with 94%, and monoecious (M) lines had 12% female nodes (Table 4). Of course, H lines produce only bisexual and androecious (A) lines bear only staminate flowers. The G and M parental lines did not differ for total fruit yield, but there was a significant difference between them for marketable number of fruits per plant (Table 5).

Single-cross hybrids. Hybrids from G x H crosses produced the highest percent pistillate nodes (Table 4) and were phenotypically stable for gynoecious expression since the difference in female-

Table 3. Mean squares for the effect of year and genotype on femaleness and yield of pickling cucumber for once-over harvest.

Source of variation[z]	df	Mean square[y] Pistillate nodes (%)	Total no. fruit/plant	No. marketable fruit/plant
G x H F_1s	11	10.83	1.48**	1.43**
Year	1	78.65	0.33	1.46**
G x H F_1s x year	11	10.63	1.51**	1.39**
G x A F_1s	5	643.64**	4.93**	4.08**
Year	1	11392.92**	8.05**	12.00**
G x AF_1s x year	5	768.46**	1.43**	1.44**
G x M F_1s	8	1346.05**	0.53**	0.44*
Year	1	24257.27**	2.28**	6.47**
G x M F_1s x year	8	1234.16**	0.88**	0.91**
(G x H) x A F_1s	35	1018.88**	0.93**	0.95**
Year	1	16079.60**	6.22**	10.70**
(G x H) x A F_1s x year	35	549.26**	0.84**	0.68**
(G x H) x M F_1s	35	1295.08**	0.79**	0.97**
Year	1	67478.48**	32.32**	45.43**
(G x H) x M F_1s x year	35	836.85**	0.37**	0.43**
G	2	112.29	0.10	0.26
Year	1	2.57	1.84**	1.48**
G x Year	2	1.93	1.21**	0.86**
H	3	14.07	15.75**	28.03**
Year	1	2.30	2.99**	10.15**
H x Year	3	22.58	3.16**	1.17**
M	2	215.08**	1.90**	0.97**
Year	1	7.66	2.53**	0.74**
M x Year	2	219.49**	1.00**	0.11**
Pooled error	450	41.96	0.21	0.18

[z]G = gynoecious; H = hermaphrodite; A = androecious; M = monoecious sexes.
[y]* = F value significant at 5% level; ** = F value significant at 1% level.

ness between years was not significant (Table 3). However, all other hybrid combinations for single crosses were significantly different over years for percent pistillate nodes. The differences for yield between hybrids made from the crosses G x H, G x A, and G x M were significant (Table 5). The G x H hybrids had the highest total number and marketable number of fruit in the first year, but G x A hybrids had the highest yields. However, the G x A hybrids out-yielded the other 2 sets of single-cross hybrids in the 2nd year. Overall, the G x A hybrids were higher yielding than either the G x H or G x M hybrids. The correlation coefficients of 0.25 for percent pistillate nodes and total yield and 0.34 between percent pistillate nodes and marketable yield were both significant ($\alpha = .05$). The higher correlation of marketable yield with percent pistillate nodes indicates that there may be more difference between hybrids for marketable yield than for total yield.

Three-way cross hybrids. The (G x H) x A hybrids had higher percent pistillate nodes and higher yield than (G x H) x M hybrids indicating superiority of A lines over M lines as pollen parents (Table 4). The correlation coefficients between percent pistillate nodes and total yield, and between percent pistillate nodes and marketable yield were 0.35 and 0.45, respectively, and were highly significant ($\alpha = .01$). These values were higher than those calculated for single-cross hybrids which indicated more variation among 3-way cross hybrids for yield. The correlations between the same traits for single and 3-way cross hybrids were less for the second year than the first year, but in both years 3-way hybrids had higher correlation coefficients than single-cross hybrids. Moreover, marketable yield was more closely correlated with percent pistillate nodes than total yield was with percent pistillate nodes. This high correlation between percent pistillate

Table 4. Means of parental lines and different hybrid crosses for femaleness and yield of pickling cucumber for once-over harvest.[z]

Line/hybrid cross	Pistillate nodes (%)	Total no. fruit/plant	No. marketable fruit/plant
Gynoecious	94	1.7	1.6
Monoecious	12	1.7	1.4
Hermaphrodite	0[y]	4.0[x]	3.2[x]
Gynoecious x hermaphrodite	97	2.3	2.2
Gynoecious x androecious	85	2.5	2.3
Gynoecious x monoecious	81	2.0	1.8
(Gynoecious x hermaphrodite) x androecious	86	2.2	2.1
(Gynoecious x hermaphrodite) x monoecious	83	2.0	1.8
Grand mean of hybrids	85	2.1	2.0

[z]See Table 5 for the separation of the means.
[y]All bisexual flowers on nodes.
[x]Fruits were round to oblong shape, typical of hermaphrodites, small in size and unmarketable.

Table 5. Mean squares for the effect of hybrid cross on femaleness and yield of pickling cucumber for once-over harvest.

Source of variation[z]	df	Mean square[y] Pistillate nodes (%)	Total no. fruit/plant	No. marketable
Between				
G parents	2	224.58	0.20	0.53
M parents	2	430.17**	3.80**	1.94**
Single crosses	2	25100.24**	21.80**	17.21**
3-way crosses	1	9111.65**	32.29**	46.10**
G vs. M	1	369396.10**	0.02	1.40*
G vs. G x H	1	402.18**	23.36**	27.42**
G vs. G x A	1	7649.24**	48.93**	34.12**
G vs. G x M	1	14195.59**	5.94**	3.83**
G vs. (G x H) x A	1	6280.46**	22.89**	22.05**
G vs. (G x H) x M	1	13616.39**	6.53**	4.13**
M vs. G x H	1	311135.38**	14.96**	22.59**
M vs. G x A	1	215768.63**	25.46**	26.61**
M vs. G x M	1	190912.56**	6.28**	11.64**
M vs. (G x H) x A	1	278677.87**	12.20**	19.90**
M vs. (G x H) x M	1	202853.68**	7.35**	13.28**
G x H vs. G x A	1	26109.19**	7.73**	1.41*
G x H vs. G x M	1	43884.73**	17.80**	21.90**
G x H vs. (G x H) x A	1	8450.63**	0.68	0.62
G x H vs. (G x H) x M	1	15609.48**	16.28**	20.75**
G x A vs. G x M	1	2007.87**	42.88**	30.16**
G x A vs. (G x H) x A	1	821.74**	23.04**	8.28**
G x A vs. (G x H) x M	1	1004.60**	70.45**	51.42**
G x M vs. (G x H) x A	1	7285.11**	12.13**	16.56**
G x M vs. (G x H) x M	1	624.33**	0.01	0.05
Error	540	93.43	0.26	0.22

[z]G = gynoecious; H = hermaphrodite; A = androecious; M = monoecious sexes.
[y]* = F value significant at 5% level; ** = F value significant at 1% level.

nodes and marketable yield indicated that hybrids with more pistillate flowers would be more likely to produce high marketable yields.

Single-cross vs. 3-way cross hybrids. The G x H crosses produced the highest percent of pistillate nodes, followed by (G x H) x A, G x A, (G x H) x M, and G x M in descending order. The ranking of hybrids for yield was the same whether measured by total or marketable number of fruit per plant; viz., G x A, G x H, (G x H) x A, (G x H) x M, and G x M. The (G x H) x M and G x M hybrids were not significantly different for yield, nor were the G x H and (G x H) x A hybrids (Table 5). The G x A hybrids produced 9% more marketable fruits than (G x H) x A hybrids (Table 4). Hybrid vigor for yield was expressed (ignoring hermaphroditic parent lines) as the average number of marketable fruits which was 2.0 for hybrids and 1.5 for the parental G and M lines (Table 4). Hybrid vigor in cucumber has been previously reported (3, 4). The A lines do not produce fruits, as only staminate flowers are produced.

Based on these data, the use of A lines rather than the commonly used M lines (1, 11, 12) as pollen parents for single and 3-way hybrids resulted in greater femaleness and higher yield. Therefore, we would suggest the use of A lines as pollen parents for either single-cross or 3-way cross hybrids in place of M lines where the hybrids are to be harvested once-over. However, the adoption of androecious in place of monoecious pollen parents for hybrid seed production can only be proposed as was suggested previously (14), since A lines are unavailable to seedsmen. The parental combinations giving more female expression did result in higher yield potentials than the current G x M hybrid cultivars. A high percent of female nodes resulted in a more concentrated and uniform fruit-set which is necessary for maximum yields in once-over mechanical harvest. These traits were expressed most strongly by the G x A, G x H, and (G x H) x A hybrids.

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