

Mixtures of Cucumber Cultigens Affect Yield in a Multiple-harvest System

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Abstract. Seeds of cucumber (*Cucumis sativus* L.) cultigens were mixed and compared for fruit yield (Mg·ha⁻¹) and crop value (\$/ha). Three cultigen pairs (Gy 14A + M 21, Gy 4 + WI 2757, and 'Regal' + 'Carolina') and five component ratios of each cultigen pair (0:100, 25:75, 50:50, 75:25, and 100:0) were evaluated in five plantings over a 3-year period. Fruits were harvested six to eight times for each planting date. Early and total fruit yields and crop values were greatest when either Gy 14A or Gy 4 were planted as pure stands. As the ratio of Gy 14A or Gy 4 increased in the seed mixture, the yield and crop value increased. However, when the two predominantly gynoeious hybrids, 'Regal' and 'Carolina', were mixed, the yield and crop value were greater than those of pure stands of either hybrid. The combination of 75% 'Regal' and 25% 'Carolina' resulted in higher early and total fruit yields and crop value than the other ratios of the same cultigen pair. The 'Regal' + 'Carolina' pair produced significantly higher early yield and early crop value (first two harvests) than did the other cultigen pairs tested. However, total yield and total value for 'Regal' + 'Carolina' did not differ from the Gy 14A + M 21 pair. The practice of mixing two cultivars in arbitrary combinations does not offer an advantage over single cultivars in a multiple-harvest system. In some cases, predominantly gynoeious-predominantly gynoeious mixtures may have advantages over monoecious-predominantly gynoeious cultigen mixtures if pollination is not limiting. Seed mixtures need to be evaluated to determine whether specific combinations offer advantages, as this study indicated that superior mixtures may exist.

In some production areas of the United States (i.e., Ohio), seeds of different cucumber cultivars are mixed before planting to improve or stabilize yield. Currently, most commercial cultivars of pickling cucumbers used in the United States are predominantly gynoeious, having a 9 pistillate : 1 staminate flower ratio (McMurray and Miller, 1969). Predominantly gynoeious cultivars are blended with a monoecious inbred or hybrid to provide the pollen necessary for fruit set, with 10% to 15% monoecious plants being optimum (Miller, 1976; Peterson, 1960; Peterson and De Zeeuw, 1963).

Brim and Schutz (1968) reported that soybean (*Glycine max* L.) yield was improved by using mixtures of inbreds rather than a single inbred. Mixing cultivars has increased yield in other crops, including rice (*Oryza sativa* L.) (Roy, 1960) and barley (*Hordeum vulgare* L.) (Gustafson, 1953). Cultivar mixtures also pro-

vide a stabilizing effect on yield over time (Probst, 1957). However, lower yields were reported for maize (*Zea mays* L.) using some mixtures (Funk and Anderson, 1964; Stringfield, 1959). Miller (1976) reported

higher early yield with mixtures of monoecious and predominantly gynoeious cucumber cultivars having a high proportion of the predominantly gynoeious cultivar. However, total yield did not differ.

Properly selected combinations of cultivars may result in increased early and total yield, better competition with weeds, or a reduction in disease incidence. However, arbitrarily combining cultivars may not optimize yield potential in comparison with singly grown cultivars. We know of no research on the effects of mixing various proportions of diverse cucumber types (i.e., high- and low-yielding, early and late flowering, determinate and indeterminate, gynoeious and monoecious, predominantly gynoeious and predominantly gynoeious, or gynoeious and gynoeious) on early and total yield. Thus, specific cultigen seed ratios may offer yield advantages as well as disease reduction in comparison with a single cultigen. The objective of this study was to determine whether mixtures of cucumber cultigens improve yields and economic return compared with single cultigens.

Materials and Methods

Studies were conducted at the Horticultural Crops Research Station, Clinton, N.C., over 3 years with a total of five planting dates (Spring 1989, 1991, and 1992, and Summer 1989 and 1992). Seeds of the cultivars ('Regal' and 'Carolina') were obtained from commercial seed companies; seeds of the inbreds (Gy 4, Gy 14A, M 21, and WI 2757) were obtained from the North Carolina State Univ. cucumber breeding program.

Seeds were sown in preformed furrows 10 to 15 mm deep. Sixty plants were grown in 6-

Table 1. General characteristics of the cucumber cultigens (cultivars or breeding lines) used in this study.²

Cultigen	Adaptation	Yield potential	Plant type	Fruit type	Line type	Sex
Regal	S	H	IN	P	H	PG
Carolina	S	H	IN	P	H	PG
Gy 14A	S	H	IN	P	I	G
M 21	S	H	D	P	I	M
Gy 4	S	H	IN	P	I	G
WI 2757	N	L	IN	B	I	G

²All cultigens tested have white spines and are resistant to anthracnose (*Colletotrichum orbiculare*). S = southern United States; N = northern United States; H = high; L = low; IN = indeterminate; D = determinate; P = pickle; B = 'Beit Alpha'; H = hybrid; I = inbred; PG = predominantly gynoeious; G = gynoeious; M = monoecious.

Table 2. Analysis of variance for main and interaction effects for yield (Mg·ha⁻¹) and value (\$/ha) over all planting dates.²

Source	Yield		Value	
	Early	Total	Early	Total
Planting date (PD)	***	***	***	***
Cultigen pair (CP)	***	***	***	***
PD × CP	NS	NS	NS	***
Component ratio (CR)	NS	**	NS	NS
CP × CR	NS	NS	*y	NS
PD × CR	NS	NS	NS	NS
PD × CP × CR	NS	NS	NS	NS

²Early harvest = sum of the first two harvests.

³Significant interaction was due to a difference in response (regression slope), rather than a change in rank (no crossover of regression curves).

ns, *, **, ***Nonsignificant or significant at $P \leq 0.05$, 0.01, or 0.0001, respectively.

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Table 3. Effects of planting date on early and total cucumber yield and value.^a

Environment	Yield (Mg·ha ⁻¹)		Value (\$/ha)	
	Early	Total	Early	Total
<i>Spring</i>				
1989	5.0	29.7	926	4082
1991	6.6	19.6	1403	3909
1992	18.8	34.5	1999	3983
Mean	10.1	28.1	1442	4000
<i>Summer</i>				
1989	4.5	8.5	930	1820
1992	5.4	13.8	866	2460
Mean	5.0	11.1	898	2140
LSD ($P \leq 0.05$) ^b	3.4	8.0	472	1109

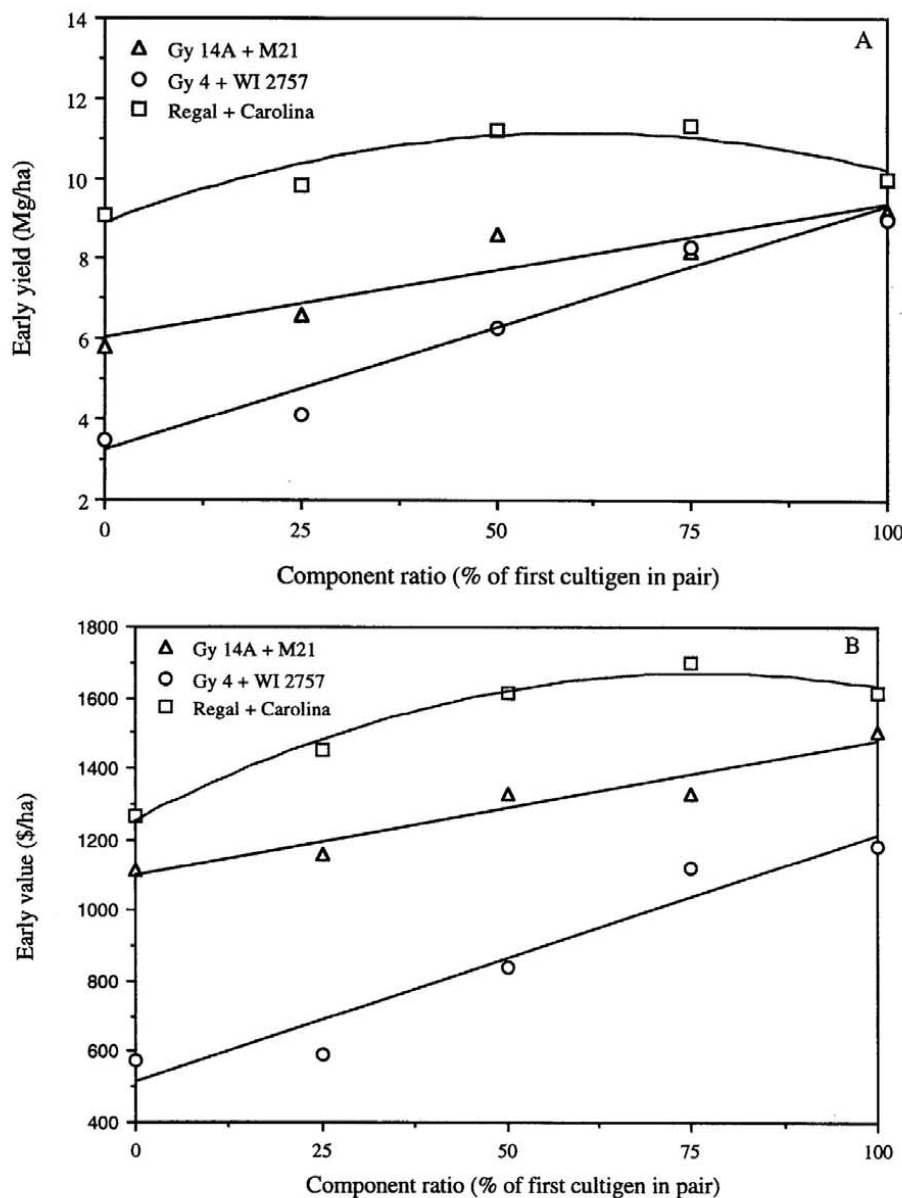
^aEarly harvest = sum of the first two harvests.^bSignificance for mean values for season within columns.

Fig. 1. Regression of (A) early yield and (B) early value on component ratio for three cultigen pairs. Data pooled over five planting dates at Clinton, N.C., 1989–92. In (A) $y = 6 + 0.035(x)$, $R^2 = 0.87$ for Gy 14A + M 21, $y = 3.2 + 0.061(x)$, $R^2 = 0.96$ for Gy 4 + WI 2757, and $y = 8.9 + 0.0738(x) - 0.000606(x^2)$, $R^2 = 0.86$ for 'Regal' + 'Carolina'. In (B) $y = 1096.8 + 3.776(x)$, $R^2 = 0.93$ for Gy 14A + M 21, $y = 511.8 + 6.952(x)$, $R^2 = 0.94$ for Gy 4 + WI 2757, and $y = 1251.4 + 10.854(x) - 7.086(x^2)$, $R^2 = 0.98$ for 'Regal' + 'Carolina'.

Table 4. Correlation (r) coefficients for cucumber yield (Mg·ha⁻¹) and value (\$/ha) vs. yield in each grade over all planting dates.^a

Grade	Yield		Value	
	Early	Total	Early	Total
1	0.30	0.41	0.71	0.77
2	0.77	0.85	0.96	0.98
3	0.95	0.96	0.77	0.80
4	0.88	0.87	0.50	0.53

^aEarly harvest = sum of the first two harvests. All correlations are significant at $P \leq 0.0001$.

m-long plots. Plant spacing was 0.08 to 0.12 m within rows and 1.5 m between rows. Standard cultural practices (Schultheis, 1990) and pest control practices (College of Agricultural and Life Sciences, 1989) were followed until harvest. Treatments were three pairs of cultigens ('Regal' + 'Carolina', Gy 14A + M 21, Gy 4 + WI 2757) in five component ratios (0:100, 25:75, 50:50, 75:25, and 100:0) arranged in a 3×5 factorial in a randomized complete block with three replications. Pollination was not limiting in the plots that were predominantly gynoecious since borders were planted with 'Sumter' as the pollinizer.

Cultigens were chosen for the mixtures as follows: 'Regal' and 'Carolina' are both indeterminate, high-yielding, predominantly gynoecious hybrids; Gy 14A is an indeterminate, high-yielding, tall, gynoecious inbred; M 21 is a determinate, high-yielding, dwarf, monoecious inbred; Gy 4 is an indeterminate, early, high-yielding, gynoecious inbred, and WI 2757 is a late, low-yielding, indeterminate, gynoecious inbred (Table 1). WI 2757 is not a pickling type, but is a Middle Eastern ('Beit Alpha' type) cucumber with fruits having light-green, smooth, thin skin. Cultigens were paired to provide contrasts of interest to plant breeders and cucumber producers as follows: early vs. late; indeterminate vs. determinate; and two similar, predominantly gynoecious hybrids. The latter mixture type is the one currently used by commercial growers in some regions of the United States.

Fruits were hand-harvested twice a week for a total of six to eight harvests for each planting date. Harvested fruits were graded according to North Carolina standards (Wehner, 1986) and weighed. Grades 1, 2, 3, and 4 consisted of fruits 0 to 27 mm, 28 to 38 mm, 39 to 51 mm, and >51 mm in diameter, respectively. Dollar value was calculated based on industry values per metric ton of \$320, \$180, \$100, and \$0 for grades 1, 2, 3, and 4, respectively (P. Denlinger, Mt. Olive Pickle Co., N.C., personal communication). Data were collected for yield, vine size (rated 1 to 9, 1 = shortest, 5 = intermediate, and 9 = longest), and disease resistance (disease rated 0 = none, 1–2 = trace, 3–4 = slight, 5–6 = moderate, 7–8 = advanced, 9 = plant dead). Data were analyzed using correlation, regression, and analysis of variance (SAS Institute, 1989). Data for each season were combined and analyzed across planting dates for yield and value. Yields of each of the four grades were correlated with total yield to determine the effect of each grade on yield.

Results and Discussion

Fruit yield and crop value differed ($P \leq 0.0001$) among planting dates and cultigen pairs (main effects) (Table 2). Early and total yields and value were higher with the spring planting dates than with the summer planting dates (Table 3). Typically, more disease occurs on cucumbers in the summer planting compared to the spring planting. This was similar to Stoffella and Maynard (1988), who reported more disease in late-season plantings of tomatoes, which led to lower yields. Yield and crop values differed with season; however, planting dates did not interact with cultigen pair or component ratio (Table 2). Therefore, data from the five planting dates were pooled. Total yields ($\text{Mg} \cdot \text{ha}^{-1}$) and dollar value ($\$/\text{ha}$) were similar for all planting dates for cultigen pair and component ratio (data not shown).

Planting date and cultigen pair interaction was significant ($P \leq 0.01$) for total value, while the cultigen pair and component ratio interaction was significant ($P \leq 0.05$) for early value (Table 2). Why some cultigen pairs had a greater total value at some planting dates than at others is not apparent, especially since planting date and cultigen pair interaction for total yields was nonsignificant. Although interaction of cultigen pair and component ratio for early value was significant, it was nonsignificant for early yields. Furthermore, the interaction for early value was due to a difference in response (regression slope), rather than to a change in rank (no crossover of regression curves) of cultigen pairs (data not shown).

Grade 3 fruits were most important in influencing early and total yield (Table 4). Yield of grade 1 fruits (highest value per Mg) was least correlated with early ($r = 0.30$) and total yield ($r = 0.41$). Grade 4 fruits have no dollar value, but their yield was highly correlated with early and total yield, given the large number of oversized fruits at harvest. Fruits might have been harvested three times a week rather than two to give a more accurate measurement of dollar value, as fruits were larger by the time they were weighed (i.e., grade 1 to grade 2, grade 2 to grade 3, and grade 3 to grade 4) due to less frequent harvests. A low correlation of dollar value with grade 4 fruits was obtained (Table 4). With more frequent harvests, fruit weight and value would have been estimated more accurately; however, the focus of this study was on the various seed percentage ratios for the cultigen pairs tested.

Anthraxnose [*Colletotrichum orbiculare* (Berk. and Mont.) Arx.] and gummy stem blight [*Didymella bryoniae* (Auersw.) Rehm.] diseases were more prevalent in the summer than in the spring plantings. However, the incidence of these diseases was not significantly affected by the various mixtures evaluated (data not shown).

Plant size is an important consideration since it can influence competition and yield. The size of plants did not differ among the five planting dates, so the data were pooled. F values for cultigen pairs, component ratios, and the cultigen pair $\times$ component ratio inter-

action were significant. Component ratios differed for plant size for the Gy 14A + M 21 pair, but not for the Gy 4 + WI 2757 and 'Regal' + 'Carolina' pairs. That was expected since the pair consisted of one determinate and one indeterminate cultigen. M 21 plants were only 59% of the size of the Gy 14A plants. As the proportion of Gy 14A plants increased in the Gy 14A + M 21 mixture, plant size increased linearly [(plant size rating) = $4.28 + 0.03$ (% Gy 14A in mix), $R^2 = 0.96$, $P = 0.0038$].

The Gy 14A + M 21 and Gy 4 + WI 2757 pairs responded similarly for the various component ratios. Early and total fruit yield, and dollar value were greatest when Gy 14A and Gy 4 were planted in pure stands (0% of the other cultigen) (Figs. 1 and 2). There was a linear increase in early and total yield and

early and total dollar value per hectare for the highest yielding cultigen of the Gy 14A + M 21 and Gy 4 + WI 2757 pairs (Figs. 1 and 2). This suggests that the greater the proportion of a gynoecious cultigen in a gynoecious-monoecious pair, or the greater the proportion of a high-yielding gynoecious cultigen in a gynoecious-gynoecious pair, the higher the yield and value when pollen is not a limiting factor. Pollination was not limiting in the plots that were predominantly gynoecious since borders were planted with 'Sumter' as the pollinizer.

The predominantly gynoecious hybrid pair of 'Regal' + 'Carolina' was the best performing cultigen pair overall, with high early and total yields as well as dollar value. The early and total yield and dollar value of this mixture

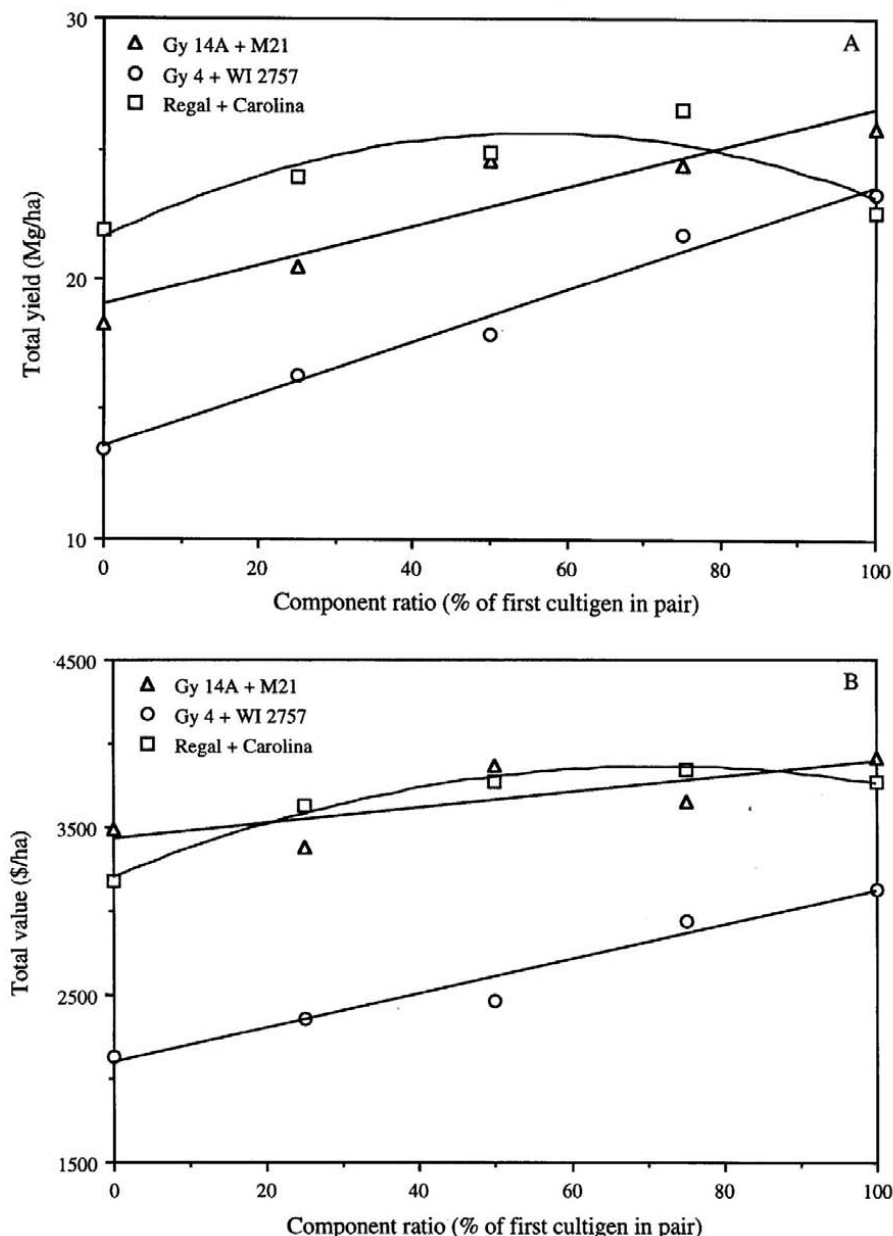


Fig. 2. Regression of (A) total yield and (B) total value on component ratio for three cultigen pairs. Data pooled over five planting dates at Clinton, N.C., 1989–92. In (A) $y = 18.9 + 0.0756(x)$, $R^2 = 0.89$ for Gy 14A + M 21, $y = 13.5 + 0.1(x)$, $R^2 = 0.99$ for Gy 4 + WI 2757, and $y = 21.56 + 0.144(x) - 0.00128(x^2)$, $R^2 = 0.79$ for 'Regal' + 'Carolina'. In (B) $y = 3434.4 + 4.512(x)$, $R^2 = 0.59$ for Gy 14A + M 21, $y = 2089.4 + 10.348(x)$, $R^2 = 0.96$ for Gy 4 + WI 2757, and $y = 3199.857 + 18.4(x) - 0.128(x^2)$, $R^2 = 0.99$ for 'Regal' + 'Carolina'.

were greater than with pure stands of either hybrid. This may be due to greater early yields with 'Regal' than 'Carolina', while in later harvests 'Carolina' may have yielded more than 'Regal', leading to some compensatory yield. For this pair, quadratic models fit the data best, illustrating that the mixture was better than either hybrid grown in a pure stand (Figs. 1 and 2). Plants from the combination of 75% 'Regal' and 25% 'Carolina' had higher early and total fruit yield and dollar value than the other component ratios of that pair. This may indicate overcompensation between these two hybrids, i.e., the case when a mixture of two or more cultigens yield better than the average of the cultigens grown singly.

For early harvest, the 'Regal' + 'Carolina' pair was significantly better than the other pairs tested for yield and value (Fig. 1). The yield ($\text{Mg}\cdot\text{ha}^{-1}$) of plants from this pair was 133% and 164% greater, and the dollar value per hectare was 119% and 179% greater than the Gy 14A + M 21 and Gy 4 + WI 2757 pairs, respectively. However, the 'Regal' + 'Carolina' and Gy 14A + M 21 pairs did not differ in total yield or value per hectare. Similar to the finding of Miller (1976), this indicates that high-yielding monoecious cucumber plants can yield as well or better than predominantly gynoeceous plants if harvested several times during the growing season. However, predominantly gynoeceous plants yield better than monoecious plants if harvested only once.

Thus, predominantly gynoeceous hybrids are well suited for once-over harvest systems (Motes, 1977). Total yield and value of the Gy 4 + WI 2757 pair were significantly lower than the 'Regal' + 'Carolina' and Gy 14A + M 21 pairs. We thought that the earliness and high yield of Gy 4 might complement the lateness and low yield of WI 2757; however, compensatory yield of this cultigen pair was not achieved, since maturity was too late and yield too low in WI 2757. Gy 4 as a pure stand had high yield and value, whereas a pure stand of WI 2757 had low yield and value (Figs. 1 and 2).

The practice of mixing two cultivars in arbitrary combinations does not offer an advantage over growing single cultivars in a multiple-harvest system. Although yield advantages occurred in some combinations, such as 'Regal' + 'Carolina', the advantage was slight relative to single cultivars. This study indicates that superior mixtures might be produced. Future research should be directed at cultivars that exhibit overcompensation in mixtures.

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