EVALUATION OF F_1 HYBRID PICKLING CUCUMBERS

By

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AN ABSTRACT

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Abstract

The value of hybrid pickling cucumbers for use in commercial production was investigated. To accomplish this purpose observations were recorded on four experiments conducted during 1955 and 1956. Two of these were composed of single hill plots in a latin square design, planted with four variety and their six possible hybrids. In these trial plants in the 6-7 leaf stage were inoculated with cucumber mosaic virus 1. The other two experiments had large plots in a randomized block design with three replications. Observations were recorded for yield, mosaic fruit symptoms as a mosaic index, fruit shape, length-width ratios, salt stock quality and pressure tests of the fruit, both fresh and from salt stock.

Some hybrids were at least equal to the best variety in yield and mosaic index, although none was statistically better in all trials. The results of the observations made on the types of unsatisfactory fruit shape did not allow any conclusion to be formed concerning the relationship between hybrids and standard varieties, because results for the two years were not consistant. This lack of correlation between years may indicate that hybrids have greater ability to produce in years of abnormal growing conditions.

Observations on length-width ratios indicate that the hybrids have ratios intermediate between the parents in most cases. This presents the possibility of utilizing in hybrids superior inbreds which do not have acceptable length-width ratios. A hybrid can be produced with a specified length-width ratio in one year by testing a number of such combinations. Whereas, if an attempt is made to produce a variety with a certain length-

width ratio in combination with the other desired characteristics, it would probably take many years.

The results obtained from quality evaluations of salt stock and pressure tests on the fruit were not conclusive and indicate the need for further experiments with processed material.

The true value of hybrids becomes apparent only if these data are considered as a group. Although none of the hybrids was statistically superior to the standard varieties in any one characteristic, in 1956 the hybrid SMR 18-7 x MR 25 rated best when all criteria for evaluation were considered. This combination of good qualities was not found in any of the standard varieties.

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I. Introduction

The application of heterosis to a crop of commercial value was first realized with the production of hybrid seed corn. Although heterosis in corn was observed by Beal (1) in 1880 and greatly publicized by Shull (36) and East (10) in 1909, seed corn was not produced on a commercial scale until 1930. By 1940 ninety per cent of the corn acreage in the United States was planted with hybrid seed. The commercial success of hybrid corn provided the necessary incentive for plant breeders to investigate the possibilities of using hybrids of other crops. At present, hybrid seed is produced commercially in the following vegetable crops: sweet corn, onions, tomatoes, squash, eggplant, and slicing cucumbers (Hayes, 16).

Since hybrid seed is always more expensive to produce, its advantages must be important enough to more than outweigh the added production expense. Otherwise, a hybrid could not gain commercial acceptance. The slicing cucumber hybrid has passed this test and is widely accepted in commercial production.

Hybrid vigor, measured by yield alone, is generally not as striking in cucurbits as in some of the other crops. Therefore, if hybrids are to be of value in cucumber and related crops, attributes other than yield increases should be investigated.

This study was undertaken to determine the possible advantages in using F_1 hybrid pickling cucumbers. The evaluation is concerned with quality factors and disease resistance, as well as early and total yield.

II. Review of Literature

A. History of Heterosis

Since various authors have employed the term heterosis to cover different concepts in the past, it would appear advisable to define the term. According to Shull (37), who introduced the term, "heterosis is the greater vigor or capacity for growth frequently displayed by crossbred animals or plants as compared with those resulting from inbreeding". He also stated that heterosis and hybrid vigor are synonymous. These definitions will be used in this dissertation with the additional stipulation that to be commercially important a hybrid must also exceed the standard variety in yield and/or quality.

Many excellent reviews of literature on the subject of heterosis are in existance. In the symposium "Heterosis" (12) the first three papers written by Zirkle, Shull, and Hayes are particularly applicable. In addition, East and Hayes (11) give an excellent review of the early literature and Hayes, Immer and Smith (17) of the more recent material. Since the literature on heterosis is very extensive and has already received excellent treatment in the above publications, this review of the general subject will be confined principally to the most important papers since 1900.

In a thorough study of cross and self fertilization, Darwin (7) found self fertilization to be detrimental and cross fertilization to be beneficial in many instances. However, since the method of transmission of characteristics from parent to offspring were not understood at that time, he was unable to explain his findings on a genetic basis.

The work of Mendel (31), which showed that plant characteristics were inherited in a definite manner, was rediscovered in 1900. With this knowledge Shull (36) and East (10) were able to conclude that inbreeding was a process of obtaining homozygous lines and not just a process of degeneration as believed by Darwin (7). Since Shull and East knew what

happened during inbreeding, they were able to propose a valid theory concerning the reason for the increase in vigor of the hybrid progeny over that of the parents. According to this theory the highest degree of hybrid vigor is obtained by crossing two lines which are heterozygous at the highest number of loci. Their conclusions were based mainly on data from field corn experiments such as the one reported by Shull (36) in which the average height of the parent inbreds was 19.28 dm. while that of the F_1 was 25.00 dm. The average yield in bushels per acre was 29.04 for the inbreds and 68.07 for the F_1. Open-pollinated corn derived from the same original material averaged 22.94 dm. in height and yielded 61.52 bushels per acre. According to the theory proposed by Shull and East the hybrid is not only more heterozygous than its inbred parents but also more heterozygous than the open-pollinated material.

D. F. Jones (21) proposed a different theory to explain hybrid vigor. He contended that the increased vigor found in hybrids was the result of an accumulation of additive growth factors inherited from both parents. His explanation of the reason that open-pollinated corn is not as vigorous as hybrid corn is that deleterious genes are linked with many of these growth factors. These deleterious genes accumulate in open-pollinated corn but many of them may be eliminated through inbreeding. Thus the inbred parents contain the growth factors without as many of the deleterious genes as found in the open-pollinated varieties of corn.

Subsequent experiments by Jones (23) revealed instances in which crosses between inbred lines, differing by only a single gene, resulted in a significant yield increase. This would mean that heterozygosity at one locus could cause hybrid vigor as hypothesized by Shull (36) and East (10).

In contrast to the expression of heterosis caused by allelic interaction,

as described above, Powers (34) concluded that heterosis in tomatoes may be caused by interaction of non-alleles. When a tomato inbred which produced a few large fruit was crossed with an inbred producing many small fruit, the average number of fruits produced by the hybrid was below the mean of the two inbred parents. Likewise, the average size of fruit was smaller than the mean of the two inbred parents. In total yield of ripe fruit, however, the hybrid exceeded the highest yielding parent. Thus it would appear that the non-allelic yield factor concerned interact in a manner which is multiplicative in respect to total yield.

In their review of the experiments dealing with heterosis, Hayes, Immer, and Smith (17) state that "heterosis, like other size characters, results from the combined action and interaction of allelic and nonallelic factors." It appears that in the opinion of these authors no single theory offers a complete explanation of the phenomenon of heterosis. Instead they have used a combination of the theories of Shull (36), East (10), Jones (21), and Powers (34) for their explanation. Since these theories have proven to be sound in specific instances, it would seem proper that a general statement as to the factors responsible for heterosis should include all four.

B. Some hybrids used in commercial production

When hybrid corn was first discovered, it was thought to be of no practical value to the farmer, because controlled pollination and low seed yield made the hybrid seed too expensive. The added expense of producing hybrid seed must be lower than the increase in profit from its use. However, D. F. Jones (22), by using the double cross method, was able to increase the seed yield without materially reducing the amount of hybrid vigor. This proved to be the beginning of the hybrid seed era. The greater part

of the corn acreage in the United States is now planted with hybrid seed. Hybrid vigor also has proven to be of commercial value in many other crops, particularly in the vegetable industry.

In hybrid sweet corn the results obtained and production methods involved are similar to those of field corn with one exception. It is possible to use the single cross hybrid for commercial seed because the inbreds used as female parents produce a proportionally greater amount of seed than those in field corn. In addition to the increased yield, hybrid sweet corn has the advantage of producing more uniform ears than the open-pollinated varieties. This improves its appearance, and therefore its value, when sold on the fresh market. The uniformity of hybrid sweet corn also makes possible mechanical harvesting and handling which are so important in the processing industry. This characteristic also would be beneficial in other crops in which more than one harvest is required because of uneven maturation of the plants.

However, corn is the only crop in which pollination can be controlled by such a simple procedure as detasseling. Although the sexes are also in separate inflorescences in most cucurbits, the number of male inflorescences is much greater than in corn and flowering continues over a more prolonged period. In other species, such as the onion, the male and female flower parts are found in the same flower. These facts make hand emasculation, as practiced in corn, too expensive for commercial seed production in the majority of other crops. Thus, it is necessary to find methods of reducing or even eliminating costly hand emasculation before hybrid seed of most vegetable crops could be economically produced.

The discovery of a male sterile onion plant in the Italian Red variety by Jones and Emsweller (26) solved the problem of hand emasculation in this crop. Male sterility in the onion was found by Jones and Clarke (24) to

result from the interaction of genetic and cytoplasmic factors. They also described the method by which these factors could be introduced into a desirable inbred for use as the female parent in hybrid seed production.

As in other crops, increased yield is not the only advantage gained through use of hybrid onions. Jones and Davis (25) noted that keeping quality, reduction in bolting, and uniformity in size and shape were other desirable qualities which had been secured. However, these qualities are not the result of hybrid vigor as such, but instead depend on the selection of the proper inbreds to be used in the hybrid combination. Inbreeding of onions results in a reduction of vigor and yield so that, although the inbreds are of high quality, their commercial production would not be economical. Therefore, a hybrid which can combine yielding ability equal to or better than the standard variety with other qualities superior to the standard would be of commercial importance.

An example of this would be the hybrid Bonanza (27) which yielded 692 50-pound bags at Parma, Idaho, compared to 528 for the standard, Brigham Yellow Globe. This difference was significant at the one percent level. In addition, the ratings made after storage for firmness, scale retention, absence of root growth, and color were higher in every case for Bonanza. Similar results were obtained in two different years and at another location.

In the self-pollinated crops, such as tomato, where inbreeding does not reduce yield, yet a different benefit of heterosis becomes apparent. Many hybrids will begin bearing earlier than either parent. This is important for the fresh market because the first few pickings often are worth more than all those which come later and in the case of indeterminate tomatoes which generally bear until frost, the longer the bearing season,

the higher the total yield will be. Wellington (43) found not only increased early yield, but also an increase in midseason and late yield in some hybrids. This could result from the fact that this hybrid reached its peak maturity earlier. Burgess (2) found the hybrid Pritchard x Red River 44-9 to be superior in early yield to the standard varieties usually grown in Maine. However, a statistical analysis was not performed in either of the above experiments.

In eggplant, a close relative of the tomato, Odland and Noll (33) found that the yields of some hybrids were significantly better than that of their parents which were standard commercial varieties. The hybrids had greater early and total yield, as well as a more uniform fruit shape, but fruit size of the hybrid fruit was near the mean of the parents.

Unlike some crops that can be either self or cross-pollinated in nature, the squash, Cucurbita maxima and C. pepo, generally do not lose vigor upon inbreeding. In this respect they behave like the normally self-pollinated crops. Haber (14) was able to maintain the yield, size of fruit, and quality factors of a C. pepo at or above the level of the commercial varieties during ten generations of inbreeding. Cummings and Jenkins (5) obtained the same results with an inbred strain of C. maxima.

In reference to hybrid vigor in squash, Bushnell (3) reported very little increased yield from hybrids as compared to the parent inbreds derived from C. maxima. However, these inbreds were closely related so little hybrid vigor should have been expected. Hutchins and Croston (20), working with C. maxima inbreds of more diverse origin, found that hybrids outyielded the higher yielding parent by a statistically significant difference in seven out of ten crosses. Curtis (6) observed hybrid vigor in a C. pepo hybrid although his data were confined to early yield. Curtis also outlined a method of hybrid seed production for bush type squash which

set only a small number of blossoms. He suggested that if the rows used as females were hand-emasculated three times and the fruit set during this period were marked, a good supply of hybrid seed could be harvested from the marked fruit. The amount of extra labor involved should add little to the cost of the seed.

C. Heterosis in the cucumber

The first report of heterosis in the cucumber was by Hayes and Jones (18). When the variety White Spine was crossed with Fordhook Famous and London Long Green, the average increase of the hybrids over the higher parent in number of fruit per plant was 6.4 in the first cross and 8.0 in the second. These hybrids also showed an increase in average weight of fruit per plant of 4.3 and 2.7 pounds respectively. Average weight of individual hybrid fruits was intermediate between that of the parents in each case. In this example, hybrid vigor was manifested chiefly in the number of fruits per plant. When Fordhook Famous was crossed with London Long Green no hybrid vigor was secured. The authors concluded that this failure to exhibit hybrid vigor might have been due to genetic similarity since the two parents were similar in appearance.

Hutchins (19) obtained similar results by crossing an early-bearing pickling variety with several late-bearing slicing types. In addition, the hybrids produced early yields which were much larger than the average of the parent varieties.

Lindsey (30) made crosses between inbred lines of slicing types instead of using commercial varieties as parents. One of his crosses out-yielded its parents by 50 percent, but no comparison was made with a standard variety. The hybrids also were of higher quality than their parents as measured by percent of No. 1 fruits.

A pickling cucumber hybrid developed by Graham (13) did not outyield certain other varieties under ideal climatic conditions, but it did surpass these same varieties when the weather was cold and wet or when the plants were subjected to periods of drought during the growing season. A similar instance of increased resistance to adverse environmental conditions was observed in certain tomato hybrids by Walkof and Nuttall (42). Thus, another advantage of some hybrids is the ability to stand adverse growing conditions. It is possible that whereever this characteristic appears it may cause the average yield for the hybrid to be higher over a period of years even though it may be lower in individual years when growing conditions are favorable.

In the field of disease resistance, Doolittle (8) found that the hybrid, Tokyo Long Green x Vickery Forcing showed considerable resistance to bacterial wilt (B. tracheiphilus EFS). A direct comparison between the hybrid and its parents was not included in the data, but the hybrid was more resistant than the standard varieties.

Shifriss, et al (35) tested several hybrids for resistance to cucumber mosaic virus I by inoculating plants in the cotyledon stage. Hybrids of symptomless x susceptible lines showed slight symptoms but recovered quickly and maintained luxuriant growth. Hybrids of tolerant x susceptible were somewhat stunted in early stages, but eventually they overcame this condition while susceptible parents were severely stunted under the same conditions. The statement was made that from a practical standpoint this resistance is dominant.

One of the most important considerations to the practicability of commercial utilization of hybrid cucumbers is method of seed production. The available information concerning the production of slicing cucumber

hybrids by the seed companies indicates that hand pollination is employed exclusively. Other less expensive methods are being sought for the production of hybrid pickling cucumber seed.

One of these methods is based on the reduction of the staminate-pistilate ratio by maleic hydrazide as described by Wittwer and Hillyer (44). Wittwer and Peterson (45) conducted a trial crossing block using this method. The rows to be used as females were sprayed with 750 ppm. of maleic hydrozide at the first true leaf stage and again at the 4 to 5 leaf stage. The male rows were untreated. The normal staminate to pistilate ratio in the summer season would be between 10:1 and 30:1. The varieties differed considerably in their response to the maleic hydrazide treatment as is shown by the following staminate to pistilate ratios determined from data collected between August 6 and August 25, 1954: SMR 12, 2.3/1; SMR 9, 0.6/1; Dark Green National, 2.1/1; Model, 1.3/1; MR 25, 0.9/1; SR 6, 1.4/1. During this period the staminate flowers were removed before anthesis and the fruit which had set between these dates were marked for identification at harvest. The mechanics of this method are similar to those used by Curtis (6) to produce hybrid seed of Cucurbita pepo.

Another possible method for the production of hybrid cucumber seed, similar to that being used by Jones, et al (28) for producing hybrid spinach seed, is being studied now at Michigan State University. This method depends on the use of the gynomonoecious character found in the Korean variety Shogoin. In this variety, approximately fifty percent of plants are gynoecious and the remainder are monoecious instead of all the plants being monoecious as in the standard varieties being grown in this country. An attempt is being made to introduce this character into inbreds which might be used as the female parents in hybrid seed

production. If such a parent line should be developed it would be necessary to remove all the monoecious plants from the rows planted to this female parent, as well as, any fruit already set on the gynoecious plants at the time of rogueing. Because of the unpredictable flowering habit of cucumbers it is considered advisable to check the supposedly gynoecious plants as often as possible and remove any that bear staminate flowers. If too many staminate flowers are found on the plants of the female parent then all the fruits must again be removed from the gynoecious plants because of the possibility of sib-pollinations. It may be possible, according to present information, to develop gynomonoecious lines that contain 50 percent or more gynoecious plants. If this goal is attained then the extra labor involved in the production of hybrid cucumber seed would be nominal.

III. Materials and Methods

A. Field Trials

During the 1955 growing season four cucumber varieties and the six possible hybrids between them were grown in a 10 x 10 latin square as outlined by Cochran and Cox (4). The varieties included in this trial were SR 6, SMR 12, MR 25, and MR 17. SR 6 is a scab resistance, mosaic susceptible variety which yields well early in the season. Its fruit shape is considered satisfactory by most processers when the fruit do not show severe symptoms of mosaic. SMR 12 is resistant to both scab and mosaic. It also yields well early in the season. Its fruit shape is satisfactory in a moderate climate, but the fruit tend to have a severe blossom end taper under hot dry conditions. MR 25 is a scab susceptible, mosaic resistant variety with a very poor early yield. However, its fruit have better shape under a wide range of climatic conditions than most other varieties. MR 17 is also scab susceptible and mosaic resistant. Its fruit shape is not as good as that of MR 25, but it is a better yielder early in the season.

Each plot in this design consisted of a single hill containing three plants. The plants were started in the greenhouse in four inch pots, each hill in a pot, to provide more uniform conditions for germination and early growth. The plants were transplanted to the field when the first leaf was one-half expanded. Five plants were placed in each hill and later thinned to three.

A similar procedure was followed during the 1956 growing season, but two of the varieties were different. The experimental varieties MSU 1 and SMR 18-7, both of which have scab and mosaic resistance, were planted in place of MR 17 and SMR 12, causing five of the six hybrids to differ also.

The plots were picked twice a week during 1955 between July 23 and August 31. The number of fruits and the weight of the fruits in grams was recorded for each plot. The cool, wet weather in 1956 made it impractical to pick twice a week, so no set schedule was followed. Instead the cucumbers were picked between July 23 and September 11 whenever they reached satisfactory size. The weight of the fruit was recorded to the nearest one-tenth of a pound in 1956.

Certain of the varieties and hybrids studied in the single hill plot experiments described above were also included in larger yield trials connected with evaluation of varieties. In 1955, the varieties, MR 17 and SMR 12, along with their hybrid, were included in this type of yield trial. The plots, two rows wide and fifty feet long, were replicated three times. Weight of fruit was recorded in pounds per plot and converted to bushels per acre.

A similar large plot test was conducted in 1956. This trial included the varieties SMR 12, MR 17, MR 25, MSU 1 and SMR 18-7 and the hybrids between MR 25 and each of the other varieties. Weight of fruit was recorded for both early and total yield.

B. Determination of Mosaic Resistance

When the plants were in the 6 to 7 leaf stage, the terminal leaves were inoculated with cucumber mosaic virus I. Expressed sap from infected cucumber and Nicotiana glutinosa plants in approximately 1:1 dilution with distilled water was used as the inoculum. This material, with a small amount of 00 carborundun added, was applied to the growing points by an atomizer under a pressure of 20 psi.

The variety SR 6, which was included in both trials, was very susceptible to cucumber mosaic virus I. All the other varieties used

were tolerant to this disease to the degree that the plants showed very few symptoms when inoculated in the 6-7 leaf stage. However, the fruit of all varieties showed some symptoms. Fruit symptoms, instead of plant symptoms, are the most important to the pickling industry, and, according to Sinclair and Walker (38), they are the most reliable criteria for judging resistance. Munger and Newhall (32) found little correlation between the appearance of the plant and fruit symptoms. Therefore, it was decided to make observations for mosaic resistant on the basis of fruit symptoms.

The fruit were divided into four classes according to the severity of symptom expression. These classes were none, slight, moderate, and severe. The class with no symptoms is self-explanatory. Slight included those fruit which had a faint mottle in the dark-colored section on the stem end of the fruit. In the moderate class were those fruit which had a distinct mottle showing well defined areas of alternating light and dark green. Severely affected fruit were of two types: Distorted fruit with dark green raised areas and fruit that were uniformly a very light, glossy green color. The latter type is commonly known in the processing industry as "white pickle".

As a means of comparison, mosaic ratings were computed for the various varieties and hybrid for each of the three pickings on which observations were made. To compute a rating these classes were assigned values as follows: none-0, slight-1, moderate-2, and severe-3. The number of cucumbers in each class was then multiplied by the assigned value and the resulting products for each variety were totaled. This total was divided by three times the number of fruit in all classes for the variety being considered. The results of this division, multiplied

by 100, was used as the mosaic rating. An example follows.

Class	No. of fruits	Assigned value	Products
None	40	0	0
Slight	25	1	25
Moderate	10	2	20
Severe	5	3	15
Totals	80		60

$$\text{Mosaic Rating} = \frac{60}{3 \times 80} \times 100 = 25$$

The ratings range from 0 to 100. A variety with a mosaic rating of 0 would bear fruit which would be free of any symptoms of the disease. If the rating were 100, all the fruit would be severely affected. The intermediate ratings indicate increasing severity of infection as the numbers become larger. The calculated ratings for three pickings each year were analyzed statistically.

C. Shape and Quality of the Fruit

One method of indicating the general shape of a cucumber is the length-width ratio. Such measurements were made in this experiment with the use of an instrument which gives the length-width ratio directly. The principle by which this is accomplished is shown in Figure 1. The ratios were determined on cucumbers which were 7/8 to 1 1/8 inches in diameter. Difficulty in making such measurements was encountered during the latter part of the picking season because the fruit shape was not always typical, particularly in varieties and hybrids which were in some degree susceptible to cucumber mosaic virus I.

For a more precise comparison of shape the individual fruit of each variety or hybrid were placed in one of four classes: normal, tapered

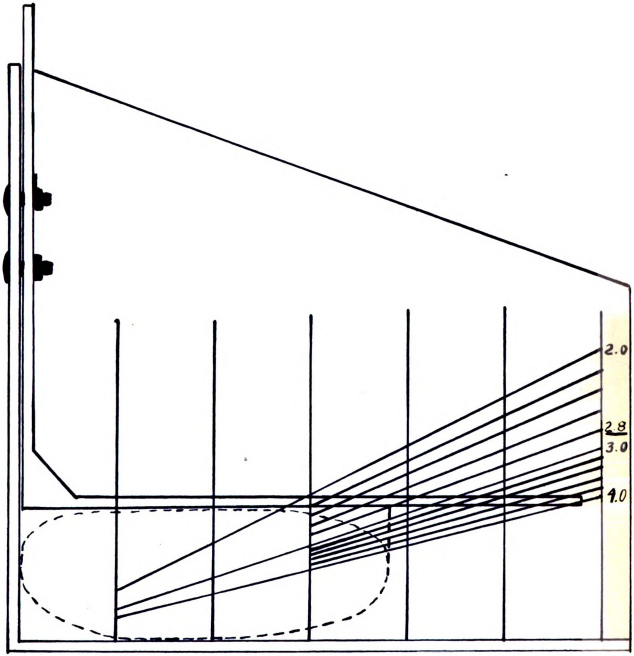

Figure I. Instrument for measurement of length-width ratios of the fruit of pickling cucumbers with sample in place.

stem end, tapered blossom end, and curved. During the 1955 season difficulty was encountered in placing some of the fruit in any of these four classes because of a type of deformity characterized by a constriction in the center of the fruit. In the 1956 season a fifth class was added to include these constricted fruits. Outlines of the longitudinal sections of these five classes are illustrated in Figure II.

Each of the above classes was subdivided into two groups, slight and severe, according to the amount of deformity. Those in the severe group was misshapen to such an extent as to be unacceptable for processing as whole pickles and would be called culls by the processers. The slight group included cucumbers which, although deformed to a small degree, would still be acceptable for processing as pickles. The latter group, therefore, would be the same as normal pickles from a commercial standpoint. However, such information should be of value to a plant breeder for the purpose of establishing varietal trends as far as shape is concerned.

The results of this classification were tabulated to present the percentages of fruit which were judged to show slight or severe expression of the four types of defects for each of three pickings. No attempt was made to analyze statistically these data in this form. Instead, the percentages of culls, including all types of defective fruits, were analyzed.

In order to compare the salt stock quality of a hybrid with its parents, samples of the hybrid MR 17 x SMR 12 and its parents from the 1955 large plot trial were bagged and placed in brine tanks at a salting station. When curing was completed, an evaluation of the fruit was conducted by a panel of commercial processers on the basis of the following

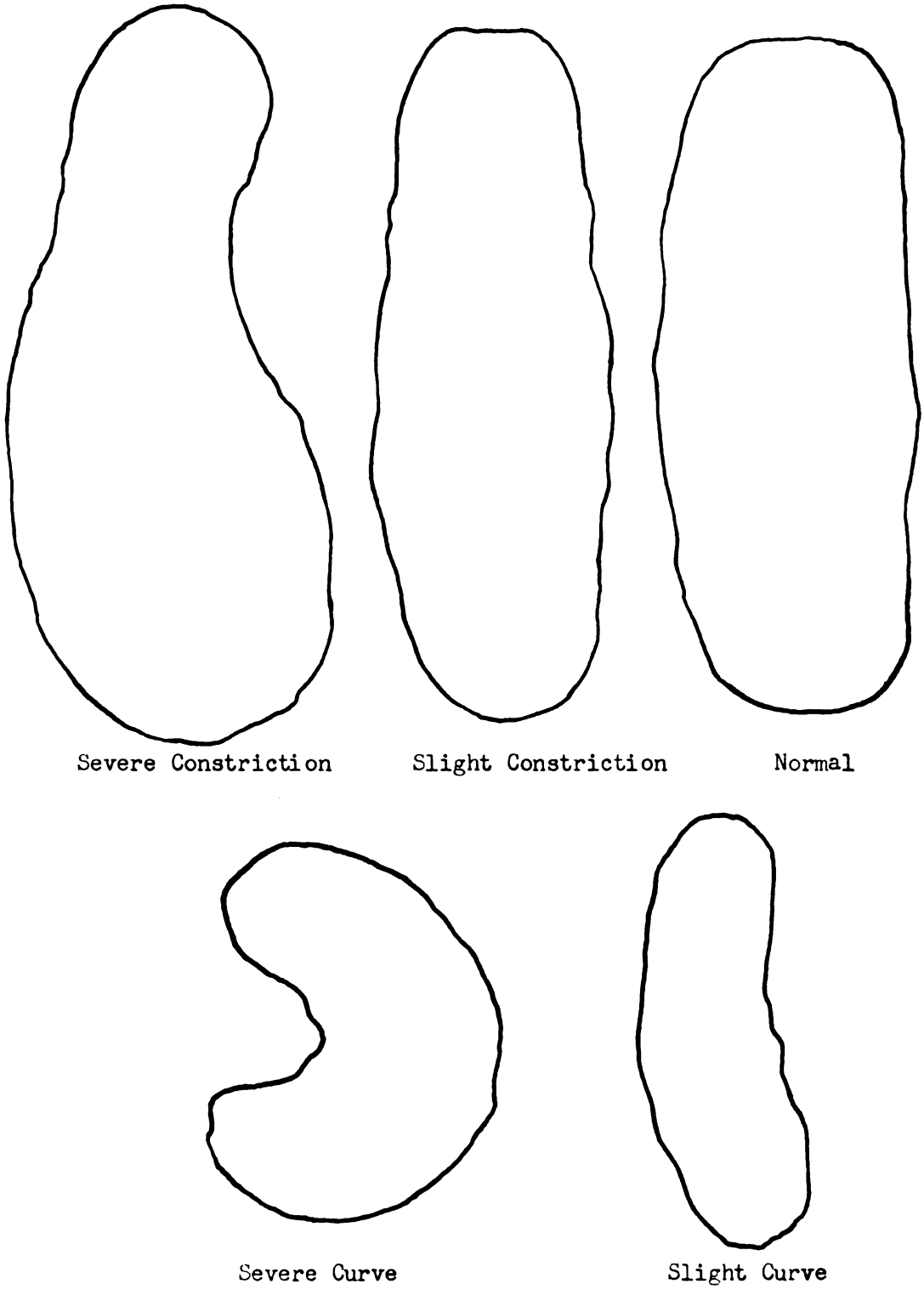

Figure II. Longitudinal sections of pickling cucumber fruit in the various shape classes. (Figure continued on the next page).

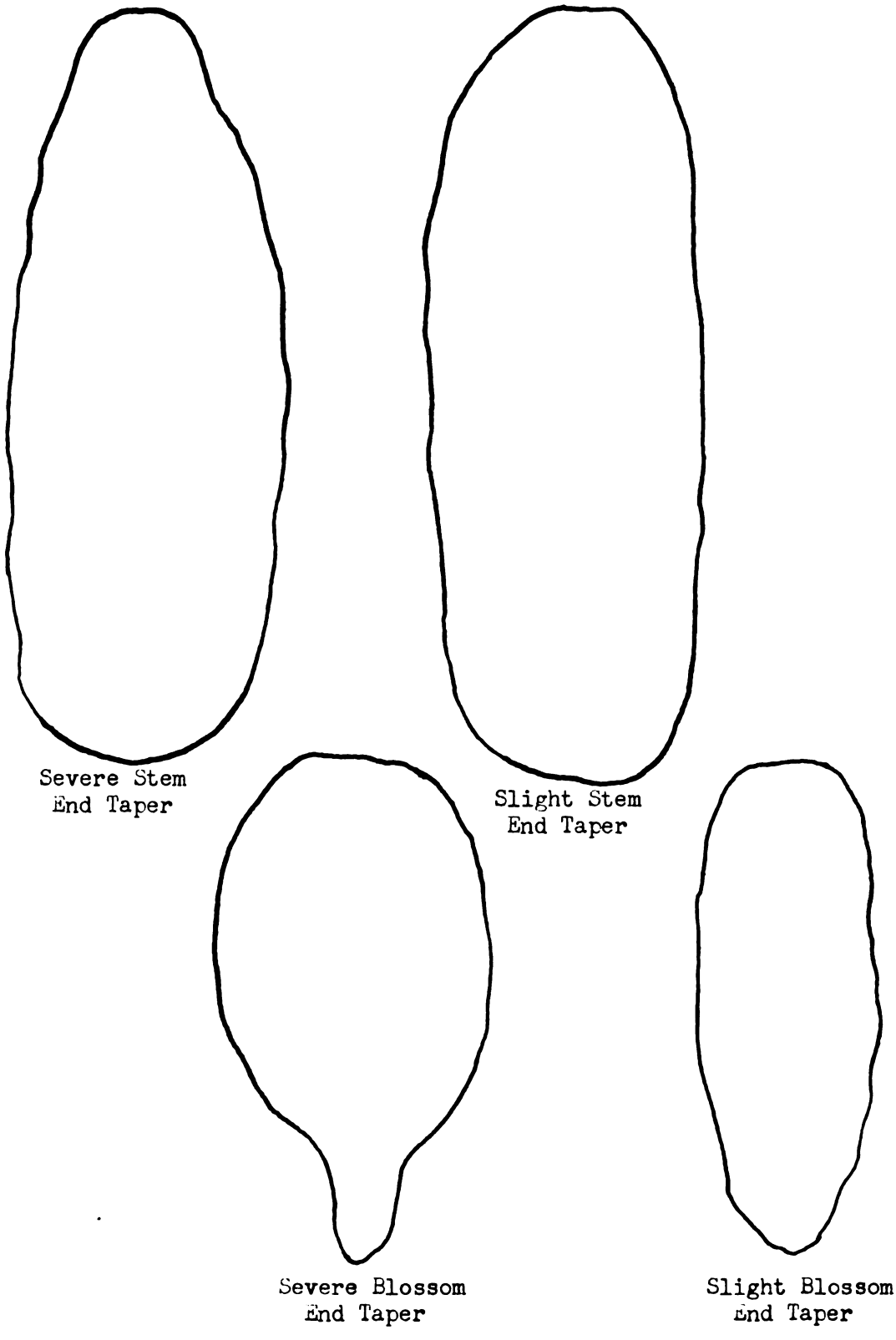

Figure II (continued). Longitudinal sections of pickling cucumber fruit in the various shape classes.

factors: color, shape, firmness and general acceptability. Since Jones and Etchells (29) found that pressure readings were a good indication of firmness in salt stock, such a test was conducted on these fruit with a modified Magness-Taylor pressure tester with a 5/16 inch head (Haller, 15). Jones and Etchells also indicated that the relationships between pressure readings of varieties in salt stock should be similar to those of the fresh fruit. Therefore, in 1956, pressure readings were determined on the fresh fruit of the varieties and hybrids in both the single hill plot trial and the large plot trial.

D. Statistical Methods

Significant differences between means were determined by the New Multiple Range Test as proposed by Duncan (9). For the application of this method the means were ranked in decending order. Each pair of means has a different least significant range; the size of which depends on the position of the two means in the ranked order. If the two means are one after another in rank, then the least significant range will be at its smallest. However, if the two means are at the extremes of the ranked order, then the least significant range will be at its largest. This variation in the size of the least significant range allows an accurate test of significance to be determined for any pair of means within a particular experiment.

The percentages of culls were transformed to angles before the analyses of variance were calculated from these data. The methods used have been outlined by Snedecor (40).

IV. Experimental Results

The analyses of variance of the number and weight of fruits, both early and total yield, for 1955 are recorded in Table I. It should be noted that the varieties and hybrids differ at the one percent level of significance in all four analyses. The mean yields from these data, shown in Table II, indicate that SR 6 is significantly lower than the other entries in all four methods of estimating yields. The other varieties MR 25, MR 17, and SMR 12, are significantly different from one another in yields based upon weight of fruit (Table II, C and D). These varieties ranked from low to high as listed above. This same order appears in Table II, A and B, where mean yields are based upon the number of fruit, although not all of the differences are significant. In overall yielding ability the hybrids having SR 6 as one parent are among the lower entries (Table II). This is particularly true of the hybrid MR 17 x SR 6. The yield of the hybrid MR 17 x MR 25 is intermediate, while SMR 12 x MR 17 and SMR 12 x MR 25 along with the variety SMR 12 are in the highest yielding group. Thus, the latter three hybrids yielded approximately equal to their higher yielding parent. The hybrid MR 25 x SR 6 not only produced as many fruit as its higher yielding parent MR 25, but also a greater weight of fruit than this same parent. The other two hybrids were intermediate between their parents.

Highly significant differences among the yields of the varieties and hybrids grown in 1956 are indicated in the analyses of variance in Table III. The comparisons of means from this data are found in Table IV. Again, SR 6 is the lowest yielder in all four methods of measurement, but it is not significantly lower in early yield than the varieties, MR 25 and MSU 1 (Table IV, A and C). Although MSU 1 is also low in total

Table I. Analyses of variance of numbers and weights of pickling cucumber fruits obtained from the 1955 mosaic-inoculated, single hill plot trial.

A. Number of fruits from the first 6 pickings

Source	df	Sums of Squares	Mean Squares	F Values
Total	99	13573		
Varieties	9	7929	881	16.62**
Replications	9	1001	111	2.09*
Columns	9	849	94	1.77
Error	72	3794	53	

B. Total number of fruits

Source	df	Sums of Squares	Mean Squares	F Values
Total	99	78114		
Varieties	9	51036	5670	23.82**
Replications	9	5716	635	2.67*
Columns	9	3983	443	1.86
Error	72	17397	238	

C. Weight of fruits from the first 6 pickings

Source	df	Sums of Squares	Mean Squares	F Values
Total	99	1007738		
Varieties	9	574919	63880	18.13**
Replications	9	119328	13259	3.76**
Columns	9	59800	6644	1.89
Error	72	253691	3523	

D. Total weight of fruits

Source	df	Sums of Squares	Mean Squares	F Values
Total	99	2252637		
Varieties	9	1526085	169565	26.77**
Replications	9	153000	17000	2.68**
Columns	9	117550	13061	2.06*
Error	72	456002	6363	

* Significant difference at the 5% level
** Significant difference at the 1% level

Table II. Mean number and weight of pickling cucumber fruit from the varieties and hybrids in the mosaic inoculated, single hill plot yield trial during 1955.

A. Number of fruit, first 6 pickings

Variety or hybrid	Mean
SR 6	23 a*
MR 17 x SR 6	33 b
MR 25	38 bc
MR 25 x SR 6	38 bc
MR 17 x MR 25	38 bc
SR 6 x SMR 12	41 c
MR 17	48 d
SMR 12 x MR 17	49 d
SMR 12 x MR 25	49 d
SMR 12	55 d

B. Total number of fruit

Variety or hybrid	Mean
SR 6	42 a
MR 17 x SR 6	66 b
SR 6 x SMR 12	86 c
MR 25	87 c
MR 25 x SR 6	90 c
MR 17 x MR 25	91 c
MR 17	93 c
SMR 12 x MR 17	113 d
SMR 12 x MR 25	117 d
SMR 12	120 d

C. Weight of fruit, first 6 pickings

Variety or hybrid	Mean **
SR 6	138 a
MR 25	209 b
MR 17 x SR 6	226 bc
MR 17 x MR 25	266 cd
MR 25 x SR 6	293 de
SR 6 x SMR 12	296 de
MR 17	309 de
SMR 12 x MR 25	345 ef
SMR 12 x MR 17	387 f
SMR 12	394 f

D. Total weight of fruit

Variety or hybrid	Mean
SR 6	199 a
MR 17 x SR 6	338 b
MR 25	378 b
SR 6 x SMR 12	454 c
MR 25 x SR 6	477 c
MR 17	480 c
MR 17 x MR 25	488 c
SMR 12	595 d
SMR 12 x MR 25	601 d
SMR 12 x MR 17	612 d

*Means not followed by the same letter are significantly different from each other at the 5% level. For example, MR 17 differs from SR 6 and MR 17 in number of fruit in Section A.

**Mean weight of fruit is recorded to the nearest 10 grams.

Table III. Analyses of variance of numbers and weights of pickling cucumber fruits from the 1956 mosaic-inoculated, single hill plot trial.

A. Number of fruits from the first 5 pickings

Source	df	Sums of Squares	Mean Squares	F Values
Total	99	5280		
Varieties	9	1571	175	5.30**
Replications	9	977	109	3.30**
Columns	9	321	36	1.09
Error	72	2411	33	

B. Total number of fruits

Source	df	Sums of Squares	Mean Squares	F Values
Total	99	28571		
Varieties	9	10111	1123	7.25**
Replications	9	4118	458	2.95**
Columns	9	3205	356	2.30*
Error	72	11137	155	

C. Weight of fruits from the first 5 pickings

Source	df	Sums of Squares	Mean Squares	F Values
Total	99	209.98		
Varieties	9	66.65	7.41	4.09**
Replications	9	9.52	1.05	.58
Columns	9	3.53	.39	.22
Error	72	130.28	1.81	

D. Total weight of fruits

Source	df	Sums of Squares	Mean Squares	F Values
Total	99	800.11		
Varieties	9	317.03	35.23	8.55**
Replications	9	146.42	16.26	3.95**
Columns	9	40.38	4.49	1.09
Error	72	296.28	4.12	

* Significant difference at the 5% level
** Significant difference at the 1% level

Table IV. Mean number and weight of pickling cucumber fruit harvested from the varieties and hybrids in the mosaic inoculated, single hill plot yield trial during 1956.

A. Number of fruit, first 5 pickings

Variety or hybrid	Mean
SR 6	16 a*
MR 25	20 ab
MSU 1	20 ab
MSU 1 x SR 6	23 bc
SMR 18-7 x SR 6	24 bc
MSU 1 x SMR 18-7	24 bc
SMR 18-7	25 bc
SR 6 x MR 25	25 bc
MSU 1 x MR 25	27 cd
SMR 18-7 x MR 25	31 d

B. Total number of fruit

Variety or hybrid	Mean
SR 6	32 a
MSU 1	47 b
MSU 1 x SR 6	48 b
SMR 18-7 x SR 6	50 b
MSU 1 x SMR 18-7	53 bc
MR 25	54 bc
SMR 18-7	58 bcd
SR 6 x MR 25	59 bcd
MSU 1 x MR 25	64 cd
SMR 18-7 x MR 25	70 d

C. Weight of fruit, first 5 pickings

Variety or hybrid	Mean **
SR 6	1.9 a
MR 25	2.3 ab
MSU 1	2.4 ab
MSU 1 x SR 6	3.1 abc
SMR 18-7 x SR 6	3.1 abc
SMR 18-7	3.2 bc
SR 6 x MR 25	3.4 bc
MSU 1 x SMR 18-7	3.5 bc
MSU 1 x MR 25	3.8 cd
SMR 18-7 x MR 25	4.9 d

D. Total weight of fruit

Variety or hybrid	Mean
SR 6	3.7 a
MSU 1	5.6 b
MSU 1 x SR 6	6.2 bc
SMR 18-7 x SR 6	6.9 bc
SMR 18-7	7.3 bcd
MSU 1 x SMR 18-7	7.4 bcd
MR 25	7.9 cd
SR 6 x MR 25	8.2 cd
MSU 1 x MR 25	9.2 de
SMR 18-7 x MR 25	10.5 e

* Means not followed by the same letter are significantly different from each other at the 5% level.

** Mean weight of fruit is recorded to the nearest one-tenth of a pound.

yield, MR 25 has a relatively better ranking (Table IV, A and C). The hybrid SMR 18-7 x MR 25 produced the highest yield based upon both number and weight of fruit in early and total pickings. In doing so it yielded significantly better than either parent in all methods of measurement except total number of fruit. The other two hybrids containing MR 25 as one parent did nearly as well.

As shown by the analyses of variance in Table V, the mosaic indices differ with high significance in the years, 1955 and 1956. Section C and D of Table V indicate that SR 6 has a mosaic index which is significantly higher than the other entries in both years. In 1955 the mosaic indices of hybrids containing SR 6 as one parent were higher than all the other entries except SR 6. However, this is not true in 1956 as shown in Table V, D. Here the hybrid SR 6 x MR 25 is grouped statistically with the resistant entries which include its other parent MR 25. This resistant group also include its other parent MR 25. This resistant group also includes the other two hybrids having MR 25 as one parent. Overall, the mosaic indices were considerably lower in 1956 than in 1955, indicating that the disease was much less severe in 1956.

Table VI expresses the percentages of fruit from the 1955 harvest which fell into the various shape classes. These data point to a certain pattern of shape among the varieties tested. The main defect in the shape of MR 25 appeared to be stem end taper, while MR 17 had a tendency to curve or taper on the blossom end. The variety SMR 12 was particularly susceptible to severe blossom end taper. SR 6 was not included in these tabulations because the majority of its fruit were distorted by mosaic virus. The data in Table VI indicate that hybrids have the shape defects of both parents. The percentages of total culls are also recorded in this

Table V. Analyses of variance and mean of the mosaic indices of pickling cucumber fruit from mosaic inoculated trials in 1955 and 1956.

A. Analysis of variance, 1955

Source	df	Sums of Squares	Mean Squares	F Values
Total	29	8811		
Varieties	9	8180	909	36.36**
Replications	2	174	87	3.48
Error	18	457	25	

B. Analysis of variance, 1956

Source	df	Sums of Squares	Mean Squares	F Values
Total	29	4920		
Varieties	9	4504	500	26.32**
Replications	2	73	37	1.95
Error	18	343	19	

C. Mosaic indices, 1955

Variety or hybrid	Mean
MR 17 X MR 25	7 a*
MR 25	9 a
MR 17	10 ab
SMR 12	12 ab
SMR 12	15 abc
SMR 12 x MR 25	18 bcd
MR 25 x SR 6	23 cde
SR 6 x SMR 12	25 de
MR 17 x SR 6	30 e
SR 6	66 f

D. Mosaic indices, 1956

Variety or hybrid	Mean
SMR 18-7 x MR 25	1 a
MSU 1 x MR 25	3 ab
MR 25	4 ab
SR 6 x MR 25	5 ab
MSU 1 x SMR 18-7	7 abc
SMR 18-7	7 abc
MSU 1	10 bc
SMR 18-7 x SR 6	11 bc
MSU 1 x SR 6	15 c
SR 6	46 d

* Means not followed by the same letter are significantly different from each other at the 5% level.

** Significant difference at the 1% level.

Table VI. Shape classifications, expressed as percentages, of pickling cucumber fruit harvested from the varieties and hybrids in the mosaic inoculated, single hill plot trials during 1955.

Variety or Hybrid	Curved fruit		Stem end taper		Blossom end taper		Normal	Total of Culls*
	Slight	Severe	Slight	Severe	Slight	Severe		
MR 25	19	5	22	9	13	3	29	17
MR 17	23	7	11	0	31	10	18	17
SMR 12	14	2	12	6	29	29	8	37
MR 25 x SR 6	23	4	23	10	15	9	16	22
MR 17 x MR 25	20	4	18	2	24	11	21	18
MR 17 x SR 6	14	3	23	9	18	18	15	30
SMR 12 x MR 17	11	4	14	5	19	30	17	33
SMR 12 x MR 25	10	4	21	13	22	15	15	31
SR 6 x SMR 12	14	4	16	14	23	14	15	32

* Percentage of fruit having a severe defect of any type as computed from the original data.

table. In spite of the fact that they range from 17 to 38, the differences among the percentage were not significant because of the extreme variability of the samples.

The data for 1956 (Table VII) indicate that the major defect of all the varieties and hybrids tested was blossom end taper. In addition, the variety MR 25 had a tendency for constricted centers and curved fruit, while the added defect for MSU 1 was constricted centers and for SMR 18-7 it was curved fruit. The data for 1956 summarized in Table VII indicate that hybrids have a combination of the defects of both parents as they did in 1955, although the percentage of any one defect is not as great as that of the highest parent. Another result similar to that obtained in the previous year is the lack of significant differences among the percentages of total culls.

The varieties planted in 1955 show some variation in length-width ratios as illustrated in Table VIII, A. The variety MR 17, with a length-width ratio of 3.0, was relatively long and slender compared to MR 25 and SMR 12, both of which had a ratio of 2.6. SR 6 was omitted because the mosaic effect would cause such measurements to be out of proportion. When the variety MR 17 was crossed with either of the blockier varieties, MR 25 or SMR 12, the resultant hybrids had intermediate length-width ratios. When two varieties with the same ratio, such as SMR 12 and MR 25, were crossed, the ratio for the hybrid was identical to that of the parents. Similar fruit shape relationships are shown in Table VIII, B for the 1956 season.

In part C of Table VIII the 1956 pressure readings are recorded. The pressure reading for the hybrid MSU 1 x SR 6 is shown as intermediate between its parents, while the reading for SMR 18-7 x SR 6 is indicated

Table VII. Shape classifications, expressed as percentages, of pickling cucumber fruit harvested from the varieties and hybrids in the mosaic inoculated, single hill plot trial during 1956.

Variety or Hybrid	Stem end taper		Blossom end taper		Constricted center		Curved fruit		Normal	Total of culls*
	Slight	Severe	Slight	Severe	Slight	Severe	Slight	Severe		
MSU 1	9	5	25	10	24	6	9	1	11	23
MR 25	5	1	15	11	15	5	18	8	22	24
SMR 18-7	6	5	26	22	12	2	13	6	8	35
SR 6 x MR 25	20	4	20	6	12	2	19	2	15	15
MSU 1 x MR 25	5	0	26	13	13	4	16	3	20	19
SMR 18-7 x MR 25	10	1	25	17	9	1	14	2	21	21
SMR 18-7 x SR 6	13	5	32	17	11	0	9	4	9	26
MSU 1 x SMR 18-7	7	2	26	14	20	5	12	3	11	24
MSU 1 x SR 6	10	3	34	10	15	2	13	3	10	17

* Percentage of fruit having a severe defect of any type as computed from the original data.

Table VIII. Length-width ratios and pressure readings of pickling cucumber fruit harvested from the varieties and hybrids in the mosaic inoculated, single hill plot trials during 1955 and 1956.

A. Length-width ratios, 1955

Variety or hybrid	Mean
SR 6 x SMR 12	2.5
MR 17 x SR 6	2.5
MR 25	2.6
SMR 12	2.6
SMR 12 x MR 25	2.6
MR 25 x SR 6	2.7
SMR 12 x MR 17	2.7
MR 17 x MR 25	2.8
MR 17	3.0

B. Length-width ratios, 1956

Variety or hybrid	Mean
MR 25	2.5
MSU 1	2.6
SR 6 x MR 25	2.6
MSU 1 x MR 25	2.6
SMR 18-7 x MR 25	2.6
SMR 18-7 x SR 6	2.6
MSU 1 x SMR 18-7	2.6
MSU 1 x SR 6	2.6
SMR 18-7	2.7

C. Pressure readings in psi., 1956

Variety or hybrid	Mean
SMR 18-7 x SR 6	16.0
MSU 1	16.5
SMR 18-7 x MR 25	17.0
MSU 1 x SMR 18-7	17.0
MSU 1 x SR 6	18.0
SR 6	19.0
MR 25	19.0
SR 6 x MR 25	19.0
MSU 1 x MR 25	19.5
SMR 18-7	20.0

as well below either parent. In contrast to this, the hybrid MSU 1 x MR 25 had a pressure reading above both parents. Therefore, no constant pattern in the relationship between hybrids and parents can be found in these data.

The two varieties, MR 17 and SMR 12, and their hybrid were included in a large plot yield planted in 1955. Their yields were not significantly different, but some interesting data were obtained about quality factors and pressure readings on samples from salt stock as shown in Table IX.

Table IX. Quality Evaluation of Pickling Cucumbers from Salt Stock.

Variety or Hybrid	Quality Factors*				Pressure Readings
	Color	Shape	Firmness	Acceptability	
MR 17	12	10	13	10	15.8
MR 17 x SMR 12	15	15	15	14	14.2
SMR 12	14	13	15	13	13.8

* The four quality factors were rated by a panel of four processers giving a value of 1-4 for each. The best possible score for each factor is 16.

The hybrid appears to be superior to both parents in quality, and in this instance the pressure reading was between the parents.

The rankings of mean yields obtained in the 1956 large plot tests (Table XI, A and B) show similar order to those obtained with the single hill plots (Tables II and IV). The hybrids, SMR 18-7 x MR 25 and SMR 12 x MR 25, yielded the best in this trial, as they did in the smaller trials. Likewise the yield of the variety SMR 12 was not significantly different from that of its hybrid SMR 12 x MR 25 in both types of trials. However, Table IV, D shows the relative rankings of MR 25 and MSU 1 x MR 25 as much higher than those calculated from the large plot results.

Table X. Analyses of variance of weights, length-width ratios, and pressure readings of fruits of pickling cucumbers from the 1956 large plot trial.

A. Weight of fruits, first 6 pickings

Source	df	Sums of Squares	Mean Squares	F Values
Total	35	5573.32		
Varieties	11	3186.08	289.64	5.53**
Replications	2	1235.04	617.52	11.79**
Error	22	1152.20	52.37	

B. Total weight of fruits

Source	df	Sums of Squares	Mean Squares	F Values
Total	35	12320.12		
Varieties	11	8512.43	773.86	10.31**
Replications	2	2157.10	107.86	1.44
Error	22	1650.59	75.03	

C. Length-width ratios of fruits

Source	df	Sums of Squares	Mean Squares	F Values
Total	39	.63		
Varieties	9	.40	.044	7.33**
Replications	3	.07	.023	3.83*
Error	27	.16	.006	

D. Pressure readings of fruits

Source	df	Sums of Squares	Mean Squares	F Values
Total	59	130.72		
Varieties	9	46.18	5.13	6.04**
Replications	5	54.70	1.09	1.28
Error	35	29.84	.85	

* Significant difference at the 5% level
** Significant difference at the 1% level

Table XI. Yield, length-width ratios, and pressure readings of pickling cucumber fruit harvested from the 1956 large plot trial.

A. Yield in bu./A., first 6 pickings

Variety or hybrid	Mean
MR 25	68 a*
MSU 1	82 b
MR 17	84 bc
MSU 1 x MR 25	95 c
SMR 18-7	109 d
MR 17 x MR 25	111 de
SMR 18-7 x MR 25	116 def
SMR 12 x MR 25	122 ef
SMR 12	125 f

B. Total in bu./A.

Variety or hybrid	Mean
MR 25	198 a
MSU 1	201 a
MR 17	218 b
MR 17 x MR 25	235 c
MSU 1 x MR 25	240 c
SMR 18-7	269 d
SMR 12	280 de
SMR 12 x MR 25	284 e
SMR 18-7 x MR 25	291 e

C. Length-width Ratios

Variety or hybrid	Mean
SMR 12	2.5 a
MR 25	2.6 ab
MSU 1 x MR 25	2.6 ab
SMR 12 x MR 25	2.6 ab
SMR 18-7	2.7 bc
MSU 1	2.7 bc
MR 17 x MR 25	2.7 bc
SMR 18-7 x MR 25	2.7 bc
MR 17	2.8 c

D. Pressure readings in psi.

Variety or hybrid	Mean
SMR 12	13.5 a
MSU 1	14.5 ab
SMR 12 x MR 25	14.5 ab
MR 17	15.0 bc
SMR 18-7	15.0 bc
MSU 1 x MR 25	15.5 bc
MR 25	16.0 c
MR 17 x MR 25	16.0 c
SMR 18-7 x MR 25	16.0 c

* Means not followed by the same letter are significantly different from each other at the 5% level.

Because of the lack of significant differences among the majority of the length-width ratios recorded in Table XI, C, it is not possible to make any direct observations. Nevertheless, these data indicate a similar relationship between hybrid and parents as found in Table VIII, A and B.

The same type of situation also exists among the mean pressure readings (Table XI, D). Although the extreme values are statistically different, the intermediate values are not. However, a tendency is observed in these data for the pressure reading of the hybrid either to fall between the two parents or to be equal to the higher parent.

V. Discussion

When evaluating a newly introduced variety, growers generally show the greatest interest in its yield as compared to standard varieties. Therefore, the first consideration as to the desirability of hybrid pickling cucumbers should be a comparison of the yields of hybrids with those of standard varieties. Hutchins (19) and Hayes and Jones (18) have reported that hybrids gave greater yields than standard varieties, but these results were obtained with the slicing instead of the pickling type of cucumber.

In this thesis data are presented from four yield trials conducted during 1955 and 1956, which included pickling cucumber hybrids. Only in the 1956 small plot trial did a hybrid have a significantly higher yield than the best variety. This hybrid was SMR 18-7 x MR 25 and the highest yielding variety in the trial was MR 25. Unfortunately, this trial did not include SMR 12 which had outyielded MR 25 in other experiments. Moreover, when this hybrid was grown with SMR 12 during the same season in the large plot trial, the yields of the two were not significantly different. Thus, a statement that a hybrid had yielded higher than the standard varieties could not be substantiated by these data.

This does not mean that hybrid vigor as expressed by increased yield can not be found in pickling cucumber hybrids. Quite possibly the parents used in these experiments were not as diverse in genetic origin as those used to make the slicing cucumber hybrids which have shown yield heterosis. The pickling varieties now grown in Michigan are all closely related because the same sources of resistance to the scab and mosaic diseases were used in their breeding. In addition, the variety National Pickling was generally used as the pickle type parent.

If inbreds are developed from material of wider genetic origin, it should be possible to find a hybrid combination that would outyield the best variety under Michigan conditions. The variety MR 25 should be a source of good inbreds as it exhibited excellent general combining ability in all trials. Such an inbred may be one parent of a future successful pickling cucumber hybrid.

Disease resistance could be considered a part of yielding ability because a variety without the proper resistance will be unable to produce a satisfactory yield. The Variety, National Pickling, formerly was the favorite in Michigan, but since it is susceptible to both scab and mosaic disease, it is no longer used by Michigan growers. The newer variety SR 6 yields very well in regions where the mosaic disease is not prevalent. However, data from the two mosaic inoculation trials presented here show what happens to SR 6 when it is attacked by the mosaic virus. Not only did the yield decrease, but most of the fruit produced were not acceptable for processing.

According to Munger and Newhall (32), the inheritance of mosaic resistance is controlled by many genes. This makes it difficult to combine in one variety a high level of mosaic resistance with the many genes for yield and quality. It would be much easier to fix as many of these factors as possible in each of two inbreds and then cross them to make a hybrid which should contain a larger number of the desired genes than could be retained in a variety produced by selection. It is also possible that hybrid vigor in itself might provide an increase in disease resistance in addition to that controlled directly by the resistance genes.

Although they were not significantly different from the standard varieties, hybrids did have the lowest mosaic indices as calculated from

inoculated trials. However, it should be noted that the varieties with the low mosaic indices appear to have been bred primarily for mosaic resistance with a resultant deficiency in either quality or yield. The superiority of a hybrid becomes apparent when all three factors yield, mosaic resistance and quality are considered. An example is the cross, SMR 18-7 x MR 25 which, in 1956, was higher in yield but lower in percentage of culls and mosaic index than the standard varieties. One of the most important factors concerned with quality of cucumbers in their fresh state is the percentage of culls. In order to accomplish a more thorough study of culls, the fruits were divided into groups according to the type of deformity. In 1955 the hybrids showed no advantage over the best-shaped varieties. In fact the trend was in the opposite direction. However, in 1956 this trend was reversed. One explanation of this occurrance may be found in the work of Graham (13). In his trials one hybrid produced better quality fruit than the standard varieties, but mainly in years of abnormal climatic conditions. The unusually cool, wet, season of 1956 provided abnormal conditions for that trial at East Lansing in which hybrids made their best showing.

The relationship between cucumber fruit shape and environment was investigated by Tiedjens (41). He found that anything interfering with the development of the embryo influences the shape of the fruit because uneven distribution of the seed necessarily produces an irregularly shaped fruit. Some of the factors found to be responsible for misshapen fruit were interruption of growth, lowered carbohydrate supply and late pollination. Any of these could be caused by the environmental conditions associated with a cool, wet season like that experienced during 1956 in East Lansing.

It appears possible that the lower percentage of culls produced by hybrids in years with unusual climatic conditions may be the result of the ability of the hybrid to adapt to an unusual environment. However, since the climate is satisfactory for growth of the standard varieties in most years, this characteristic of some hybrids would be of small advantage unless the hybrid could also at least equal the yielding ability of the standard varieties during normal years.

Environment is not the only factor involved in control of fruit shape. It would be impossible to obtain fruit of good shape from a hybrid, if its parents had genes for poor fruit shape, regardless of the environment to which it was subjected. It appears that the fruit shape in the cucumber is controlled by many genes as found in the related crop, Cucurbita pepo by Sinnott (39). Thus, the difficulty of breeding pickling cucumber varieties which produce a minimum number of culls would be the same as that involved in breeding for mosaic resistance. The particular hybrids tested in this study emphasize the need for developing parent inbreds which produce better shaped fruit.

The length-width ratio is a measurement of overall shape. It is of value to the processor for indicating the general shape of the pickle he wishes to pack so that he may have a uniform product from year to year. In addition, the glassware for fancy packs is designed to accomodate a certain size and shape of pickle. Therefore, if the length-width ratio of the pickles were to be changed considerably, it would detract from the appearance of the packaged product.

Thus, length-width ratios are of concern to the breeder if he is to produce a variety acceptable to the processing industry. However, if superior lines are found whose ratios deviate greatly from the accepted

norm, they need not be discarded completely. As indicated from the data presented in this thesis, a cross between two varieties having quite different length-width ratios generally will produce fruit which have a ratio intermediate between the two parents. Therefore, a breeding program for development of hybrids could utilize exceptionally good lines which might otherwise be discarded because their length-width ratios make them unacceptable as varieties. By crossing a line having long, narrow fruit with one that produce short, wide fruit, a hybrid cucumber with a satisfactory length-width ratio should be produced.

Even though a cucumber has the desired shape and length-width ratio it will not be acceptable to the pickling industry unless it processes satisfactorily and remains attractive until sold to the consumer. To evaluate any variety or hybrid for processing quality it is necessary to actually process the cucumber in brine and observe the resultant salt stock. Only one hybrid was subjected to such a test and, as shown in Table IX, it was rated superior to its parents by a panel of four processors. However, one such test is not sufficient evidence on which to base an opinion. The results of this trial indicate the need for additional work on quality evaluation of processed hybrids and parent lines.

Firmness of the fruit also can be estimated by a fruit pressure tester according to Jones and Etchells (29). They found that the relative differences between varieties indicated by pressure testing were very similar to those obtained by manual testing. However, an exception to this similarity of results of the two methods can be found in the data shown in Table IX. In this trial the variety MR 17 had the highest pressure reading of all the entries but was given the lowest firmness

rating by the panel. Possibly MR 17 has a tough peel, which would cause the pressure reading to be high, and a soft interior, which would result in a low firmness rating when tested manually. If this is true, it would indicate a need for a revision in the method of pressure testing in order to increase its correlation with actual firmness of the pickle. Perhaps, if a small section of the peel were removed as is done in pressure testing the apple, the results of the pressure tests on cucumber salt stock would be more accurate.

The relationship of hybrids and parents with regard to pressure test value is not clear. It appears that the inheritance of the factors in the fruit which are responsible for this value are controlled by many genes. Additional experiments should be planned to investigate this relationship more thoroughly.

Although hybrids were not statistically superior to standard varieties when the different criteria for evaluation were considered singly, they appeared to have merit if the results of all the criteria were combined. An example has been given of a hybrid which was the best in the three most important tests: yield, mosaic index and acceptable shape. Since these results were obtained by crossing the available, rather heterozygous commercial varieties, it should be possible to produce superior hybrids through a long term breeding program which would include the development of superior inbred lines to be used in production of F_1 hybrids.

VI. Summary and Conclusions

The value of hybrid pickling cucumbers for use in commercial production was investigated. To accomplish this purpose observations were recorded on four experiments conducted during 1955 and 1956. Two of these were composed of single hill plots in a latin square design, planted with four variety and their six possible hybrids. In these trials plants in the 6-7 leaf stage were inoculated with cucumber mosaic virus 1. The other two experiments had large plots in a randomized block design with three replications. Observations were recorded for yield, mosaic fruit symptoms as a mosaic index, fruit shape, length-width ratios, salt stock quality and pressure tests of the fruit, both fresh and from salt stock.

Some hybrids were at least equal to the best variety in yield and mosaic index, although none was statistically better in all trials. The results of the observations made on the types of unsatisfactory fruit shape did not allow any conclusion to be formed concerning the relationship between hybrids and standard varieties, because results for the two years were not consistant. This lack of correlation between years may indicate that hybrids have greater ability to produce in years of abnormal growing conditions.

Observations on length-width ratios indicate that the hybrids have ratios intermediate between the parents in most cases. This presents the possibility of utilizing in hybrids superior inbreds which do not have acceptable length-width ratios. A hybrid can be produced with a specified length-width ratio in one year by testing a number of such combinations. Whereas, if an attempt is made to produce a variety with a certain length-

width ratio in combination with the other desired characteristics, it would probably take many years.

The results obtained from quality evaluations of salt stock and pressure tests on the fruit were not conclusive and indicate the need for further experiments with processed material.

The true value of hybrids becomes apparent only if these data are considered as a group. Although none of the hybrids was statistically superior to the standard varieties in any one characteristic, in 1956 the hybrid SMR 18-7 x MR 25 rated best when all criteria for evaluation were considered. This combination of good qualities was not found in any of the standard varieties.

VII. Literature Cited

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