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Two watermelon fruits grown in the greenhouse, weighing 22 and 23 pounds each. The seed of one of these melons is sufficient to raise over five hundred transplants, more than enough to plant one acre of watermelons.

MISSISSIPPI STATE UNIVERSITY
AGRICULTURAL EXPERIMENT STATION
HENRY LEVECK, Director
STATE COLLEGE MISSISSIPPI

The Marks of a Perfect Watermelon

Productive and vigorous

Early

Resistant to diseases, insects, drought, and sunburn

Form and size to meet trade requirements

Eating qualities—sweet crisp and tender

Color of rind and flesh according to preference

Tough rind, hard, thin, and flexible

WATERMELON HYBRIDS

By S. S. IVANOFF and R. C. ALBRITTON*

The use of first generation hybrids of watermelons for commercial purposes is practically unknown. Probably the chief reason for this is the high cost of seed production, combined with the relatively large amounts of seed ordinarily required to plant, **and often replant,** a field of watermelons. Perhaps still another reason is that not enough attention has been devoted to studying the various hybrid combinations and their advantages for commercial use.

Hybrid seed has been occasionally offered for sale to home gardeners in limited amounts and at high prices. Hybrids have been produced by plant breeders as a part of breeding new varieties and in order to study the manner of inheritance of various plant and fruit characteristics. (1,2,4,8,9,11,12).

The difficulty of seed requirements has been indirectly met to considerable extent by successfully growing transplants in perishable pots as reported earlier (3). With the use of such transplants not more than 500 seeds are needed to plant an acre, which is less than the number usually found in a single average-size watermelon.

The use of hybrids offers many possible advantages:

1 Production in one generation of a great variety of fixed fruit types in respect to shape, size, rind, flesh, eating, and other qualities.

2. Making use of the fact that many valuable characteristics are inherited in a dominant manner in the first generation, such as resistance to some diseases, toughness of rind, and other internal traits — this saves years of breeding work.

3. Assuring high uniformity of marketable melons, in appearance and time of harvesting.

4. Possibilities of producing early maturing types, earlier than either parent, as some observations have indicated. This refers to a type of heterosis which is not correlated with size of plant or vigor of growth.

5. Although oridinarily not exhibiting apparent hybrid vigor, watermelon hybrids in some tests seemed to show that they are better able to set fruit under drought conditions than the parents from which they originated.

What Kind of Parents Make the Best Hybrids?

There is considerable work yet to be done to find out what are the combining abilities of each of the various kinds of watermelons for making hybrids, and what kind of hybrid may be produced by crossing any two commercial kinds, particularly in regard to yields, earliness, and eating qualities. As far as our knowledge goes now the hybrid types may be predicted only in part. Much testing work is needed, as has been done and is being done with corn hybrids, to decide on the most desirable combinations. Perhaps it would be preferable to employ inbred parents of high homozygosity. Different hybrids may meet different purposes, needs, and tastes and a large number would have to be made from which to select the desired kinds. Numerous and interesting variations may be produced with relatively few parents. For instance, with 10 different par ents it is possible to make as many as 45 different crosses, not counting reciprocals; with 20 parents, 190 combinations; and with 30 parents, 435 different hybrids may be produced.

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Inheritance Tests

Attention was given to a critical re-investigation of the inheritance of some important characteristics such as resistance to anthracnose, toughness of rind, and color of flesh.

Resistance to anthracnose was studied with 11 particular hybrids, produced in the greenhouse by crossing in various ways 10 different varieties and selected Mississippi inbreds. The resistance of the parents and the crosses was measured by a reliable greenhouse technique previously used by another investigator (6). It was established that some of the parent varieties or strains had a high degree of resistance, others were susceptible, while still others were intermediate in that respect. Parents and crosses were tested at the same time and it was found that resistant × resistant parent gave a resistant hybrid; resistant × intermediate, produced a resistant hybrid; resistant × susceptible also gave a resistant hybrid.

In all of the hybrids resistance was inherited in what seemed to be completely dominant manner, as has been found out earlier in the case with other hybrids (6). It did not matter whether the resistant parent was the male or the female. Only susceptible × susceptible parent gave a susceptible hybrid as expected. The detailed results of these tests are shown in Table 1.

Resistance to fusarium wilt and its expression in the first generation hybrid is somewhat complicated. Resistance derived from certain citrons seems to be inherited as a recessive character. Resistance derived from other sources is reported to behave in a different manner (1, 9, 12). After weighing all the evidence presented by different investigators it appears that given a highly resistant parent carrying more than one genetic factor for resistance, gathered from diverse sources, the chances are that an intermediate to dominant expression would be the result in the hybrid.

Toughness of rind is very important in shipping. It is the ability of the melon to resist force without breaking. Previous work has shown that toughness is inherited in a dominant manner (8). In our own studies, two component qualities which make toughness have been genetically differentiated, namely, firm or hard texture on one hand and flexibility or resiliency on the other. These were found to be inherited independently of each other (2). Each seemed to be governed by a different gene or sets of genes, one relating to the firm, compact, solid, but brittle, tissue, the other to that quality of the rind which enables it to rebound or spring back intact after pressure has been applied to it.

When a melon with a tough rind was crossed with one that had a soft and

Table 1.—Reaction of watermelon hybrids to anthracnose as determined by the resistance of the two parents. (Results determined by artificial inoculations in the greenhouse.)

Parents (female x male)	Parents' degree of resistance to anthracnose	First generation (F-1) hybrid's resistance to anthracnose
Fairflax x Spaulding	resistant x resistant	resistant
Fairfax x Miss. 1800	resistant x intermediate	resistant
Congo x Miss. 1800	resistant x intermediate	resistant
Spaulding x Cobb Gem	resistant x very susceptible	resistant
Charleston Gray x Shipper	resistant x susceptible	resistant
Miss. S25-2-24 x Shipper	resistant x susceptible	resistant
Cobb Gem x Charleston Gray	very susceptible x resistant	resistant
Criss-Cross x Charleston Gray	susceptible x resistant	resistant
Desert King x Charleston Gray	susceptible x resistant	resistant
Desert King x Spaulding	susceptible x resistant	resistant
Cobb Gem x Shipper	very susceptible x susceptible	susceptible

inflexible rind, the resulting hybrid had a tough rind. Subsequent hybrid generations showed that hardness and flexibility are not only two distinct traits, inherited independently of each other, but that each is inherited in a dominant manner. This fact provides another inducement for using hybrids for commercial purposes, because it may enable the seedsman to produce, in only one season, a new fixed shipping type with select epicurean features by crossing a tough-rind melon with one of the non-shipping "old fashioned" home garden favorites.

The inheritance of color of the flesh is of practical importance because of consumer preferences. It has been reported that red color is dominant over yellow (8,11). In our studies crosses were made between a yellow-meated type melon on one hand, and several red-meated melons of different red intensities on the other. The resulting hybrids all had red color. However, there was a question of interpretation, whether the red color was completely dominant over yellow. Perhaps of some significance was the observation that when melons of deep yellow color were crossed with melons of deep crimson, a very attractive brilliant red color was produced, suggesting a color synthesis, or a degree of incomplete dominance. This may be of practical importance because by choosing the color intensities of the parents, new and varied hues and nuances of red colors, to enhance consumer appeal, may be created.

Although the great majority of buyers prefer melons with red flesh, the yellow meated varieties are of interest to the breeder and hybrid seed producer because they possess valuable traits in regard to meat tenderness and particularly to drought resistance. Such characteristics become valuable when they are inherited in a dominant or even intermediate manner.

Yield Tests

Eight selected Mississippi hybrids were tested in 3 locations in the State in replicated trials, comprising a total of 8 replications of 5 plants each. The purpose of these trials was chiefly to seek an indication of the yield potentialities of the various hybrid combinations for commercial use. Transplants were raised in the greenhouse in sterilized soil in 3-inch perishable "Ferto" pots commercially produced from pressed cow manure. The yield results from these tests are presented in Table 2. They show variations in the yield of the different hybrids, but above all they seem to indicate that very high yields are possible with certain hybrids when handled in the manner described.

The highest yield of 33.5 tons per acre of good quality marketable melons with an average weight of 30.3 lbs. was produced at the Northeast Mississippi Branch Experiment Station at Verona, Missis-

Table 2.—Marketable yields of watermelon hybrids in tons/A grown from transplants at 3 locations in Mississippi in 1961.*

Designation	Female x male parent	Aberdeen	State College	Verona	Average
1	Spaulding x Cobb Gem	13.6	22.5	33.5	23.3
2	Cobb Gem x Charleston Gray	15.8	17.5	20.9	18.0
3	Fairfax x Spaulding	16.9	12.3	14.4	14.5
4	Fairfax x Miss. 1800	15.3	20.1	28.5	21.3
5	Desert King x Charleston Gray	-----	-----	17.9	-----
6	Charleston Gray x Shipper	9.3	23.6	16.2	16.3
7	Congo x Miss. 1800	19.5	20.5	22.0	20.6
8	Miss. S25-22 x Shipper	-----	20.0	30.2	-----

*Melons 20 lbs. and over, without apparent defects, were considered marketable.

sippi, by the hybrid, Spaulding × Cobb Gem. This is a cross between one of the smallest-fruit variety with one of the largest-fruit variety available. The average yield for all the hybrids tested at that location was 22.8 tons per acre, which is considered above normal. At the two other localities, Aberdeen and State College, the average yields, with a somewhat different set-up, were 15.0 and 19.5 tons per acre, respectively. Lack of space prevented a direct comparison between the hybrids and their respective parents. In previous trials with individual hybrids, however, it was established that hybrids yielded as much or more than either parent.

Some Practical Considerations

Many observational tests were made to study the performance of various hybrids. From these tests some deductions may be summarized which may be of interest to future hybrid seed growers to serve as a practical guide in making hybrid combinations.

1. In trying to achieve higher productivity and higher sugar content in a hybrid, the best results may come from crosses involving a large-size melon variety with small-size, but prolific, variety or inbred. The hybrid fruit would be expected to be intermediate in size.

2. Usually there was a correlation between small fruit size and number of fruits produced in a variety or hybrid, this being generally observed in other species of fruits and vegetables. Likewise a correlation has been noted between short internodes on one hand and small fruit size, large number of fruits, larger number of leaves and smallness of leaves, on the other. When such small-fruited, prolific types are encountered in the breeding work, it may be best not to discard all of them because they could be useful in making certain desirable hybrid combinations.

3. The observation that some hybrids mature earlier than either parent is an interesting one. It deserves further study because it would be of obvious practical significance since earliness and high prices often go together. This phenomenon was first observed in a cantaloupe hybrid. It is more evident and more easily observed in this crop because the ripening process may be followed with much greater degree of accuracy than in watermelons.

4. To produce an abundance of hybrid seed, the female parent of the cross should be a good seed producer and should be given as much opportunity to grow to size and maturity as possible. However, the hybrid fruit (containing the second generation seed) would also likely be a good seed producer.

5. The use of sterilized soil for raising transplants is recommended. A simple and practical method for sterlizing small quantities of soil has been described (5).

The Economics of Hybrid Seed Production

At present, it seems relatively expensive to produce first generation hybrid seed of watermelons by hand pollination. The road to efficiency and success lies most likely through the use of cytoplasmic male-sterile parents, genetic markers, or by male sterility artificially induced by chemical or other means (7, 10). Until such methods become a practice in commercial seed production, hybrid seed will remain relatively expensive.

Yet the watermelon crop has one very unusual advantage other vegetables do not have which has a bearing on the seed economy, namely, it takes less than 500 plants to fill an acre, if planted at the usual spacing of 10' x 10'. Under present practice, however, many times more seed are needed to plant an acre because difficulties often exist in getting a stand with seed directly planted in the field. Watermelon seed is very susceptible to rotting, by dry rots, wet rots, and damp-

ing-off, even when the seed has been treated with fungicides. Low temperatures also delay and interrupt germination, which weakens the seed. Replanting adds to the expense. but what is even more important, it eventually delays the harvest, and the grower misses the good prices for early melons. This is the reason many find it necessary to plant ten or more seeds per hill, and more hills than needed, with the hope of getting a satisfactory stand.

All these difficulties of getting a good stand with economy of seed may be avoided if transplants are used, since in raising transplants only one seed per pot is planted. It is by way of transplants that planting of hybrids may seem feasible at present. The seeds produced within a single average size watermelon by hand-pollination would be sufficient to plant an entire acre with transplants.

Perhaps it will be by transplants that hybrids of other crops, such as cotton—with all the benefits they offer—will eventually be introduced to cultivation.

First generation hybrid seed was produced in the greenhouse by growing the vines in benches or in crocks. Contrary to general belief, good size watermelons may be raised in greenhouses, averaging up to 20 pounds and yielding 600 seeds or more. On some occasions twenty-five

Many inbred and hybrid fruits growing in crocks in the greenhouse. They are made by controlled hand pollination. Each small fruit may contain from 25 to 150 seeds. Photo made in Experiment Station pathology greenhouse at State College, Miss.

Two watermelon transplants 3 and 5 weeks old in perishable pots. The pots disintegrate soon after transplanting.

pound fruits have been produced in the greenhouse, but in most cases fruits raised in crocks have been small. On a greenhouse bench area of about 130 square feet, approximately 6,000 seeds from about 30 watermelons were obtained. Planting was made in late fall and the fruit harvested continuously through early spring. This seed was sufficient to plant 12 acres with transplants.

On the other hand, hand pollination of seed may be carried out in the field under ordinary growing conditions with much greater success, and less expense to the producer. A field-grown mature fruit of 30 or 40 lbs. may contain approximately 800 to over 1,000 seeds, weighing about 3 to 3-½ oz. Technically, the production of hybrid seed by hand is not too difficult. The time consumed in making a cross may be counted in seconds, and the number of "takes" is quite large, very often nearly 50 percent of the attempts made. (In contrast, the making of crosses with cantaloupes is much less successful, usually averaging 5 percent of "takes", sometimes even less.)

Eventually, with improved methods it may be found that even by hand pollination, production of hybrid seed will not be too uneconomical.

How to Produce Hybrid Seed in the Field

Each watermelon vine produces two distinct kinds of flowers, male and female. There are many more male flowers than female on each plant. The differences between male and female flowwers are easily learned. The male flow-

ers produce the pollen grains which contain the male generative cells. The female flowers are larger and each carries an ovary that terminates above in a 3-lobed stigma. The stigma is the receptive area of the pollen.

Occasionally female flowers, which also carry vestiges of pollen sacks have been encountered in the common varieties. Such flowers should be avoided when making hand pollinations. A few uncommon varieties are definitely hermaphroditic—they have both the fully developed male and female organs on the same flower.

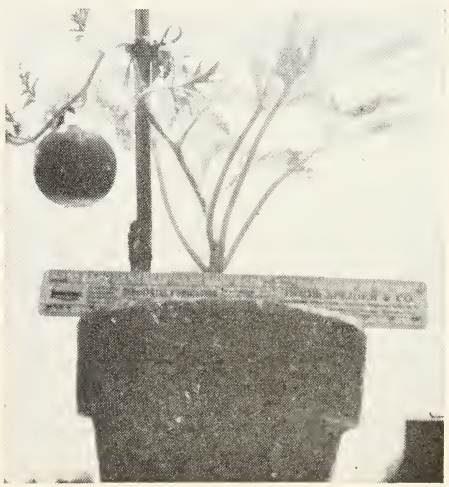
Hybrid seed may be produced in the following manner.

First Step: Start when vines have just begun to set fruit naturally. In late afternoon female blossom buds of one of the parents are covered with paper cups (small ice-cream cups will do) which are fastened to the ground by a stiff wire to keep them in place. Female buds with large ovaries on vigorous runners are the best. These buds will open early the following morning. The cups protect the bossoms from being visited and chance-pollinated by bees and other insects. Male buds of the other parent are likewise covered.

Second Step: The following morning, starting as early as possible, the male blossoms under the cup are gathered and placed in a small covered container and carried along. The female blossoms are now uncovered one by one and their receptive organ, the stigma, found in the center of the bossom, is lightly touched 3 times, once on each lobe, with one of the male blossoms. (One male blossom carried enough pollen to polinate several females.) After this is done, the blossom is again covered with the cup for protection from visiting bees and other insects. This hand pollination may continue until 9:00 a.m. or later, if the weather is cool and cloudy. In 3 hours 50 to 100 pollinations may be made by an experienced worker.

Third Step: The pollinated female blossoms are examined 3 to 4 days later to see if they have "taken", i.e., whether a fruit has been formed. The failures will show a wilted or withered blossom, the positive "takes" will show a small green fruit about ¼ to 1/3 inch across. This small fruit is then tagged and a small flag placed near it for future identification. Later the hybrid fruit may be marked on the rind with a nail or another sharp instrument. Under ordinary conditions about 30 to 50 percent of the pollinated flowers will produce a fruit. All fruits are left in the field until they are fully ripe.

When a very large number of pollinations are to be made, the male parent may be planted in isolation, about ½ mile from the female parent. Under such circumstances, the covering of male blossoms with cups would be unnecessary.



A mature watermelon, about one inch in diameter produced in a 4-inch pot. These thumb-size fruits are useful in making hybrid combinations for various studies. The unusually small size of the fruit is caused by the limited space in which "the vine" is growing.

Another field method to be tried is to plant the two parents in alternate rows and to keep all the male buds on the female row picked off. A colony of bees may be introduced by blossoming time to do the pollinating.

Male and female flower buds of a watermelon plant (enlarged about 3 times).

Summary

Watermelon hybrids for commercial use have been studied by the Mississippi Agricultural Experiment Station. One outstanding advantage of using first generation hybrids is that in them many very desirable characteristics of both parents are inherited in a dominant manner, such as resistance to some diseases, toughness of rind, sweetness, and other internal traits—which saves years of breeding work.

The hybrids offer possibilities of greater yields, a great variety of attractive types, great uniformity of marketable melons within a particular hybrid, possibilities of early maturity, better fruit setting under adverse conditions, and in some cases superior eating qualities.

Their cultivation may be made feasible through the use of transplants in perishable pots, which saves seed and offers other advantages. Suggestions for producing hybrid seed are given.

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