

## Efficient Methods for Breeding High Yielding Cucumbers

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Increased yield of cucumber (*Cucumis sativus* L.) has been a major objective of breeders for decades (Lower and Edwards, 1986; Wehner, 1989), although there is also much emphasis on other traits. Yield of pickling cucumbers in the U.S. increased from 4,685 kg/ha in 1949 to 11,455 kg/ha in 1979, an average of 226 kg/ha/year (Lower and Edwards, 1986). Similarly, yield trials of five popular gynoecious pickling hybrids from the Southeastern United States released between 1969 and 1987 had a yield increase of 400 kg/ha/year (Wehner, 1989). So yield has been increasing through breeding and improved cultural practices. However, increased use of machines for harvest of pickling cucumbers as well as world population growth have continued to increase the demand for higher yield of cucumber.

The three main stages of breeding cucumber for high yield are:

**population improvement --> inbred extraction --> hybrid development**

Population improvement for yield in cucumber can make use of half-sib family testing due to the ease of making that type of family through open-pollination. Also, selections can be intercrossed using honeybees for low resource inputs. In areas with a 5-month growing season, short generation time of elite cucumber germplasm makes it possible to get two crops in the field. In early summer, families can be evaluated at the immature fruit stage (60 days from planting to harvest), followed by intercrossing the selected families through seed harvest stage (75 to 90 days from planting to seed harvest). This permits rapid progress, with one complete cycle of recurrent half-sib family selection per year.

### Screening for high yield

Screening for high-yielding germplasm is useful to identify sources of new genes for yield. The study is made difficult by differences in sex expression in cucumber, since gynoecious accessions tend to have higher early yield than monoecious accessions. Andromonoecious accessions may have no fruit until late in the trial. However, screening can be done using ethrel treatment of the accessions or in hybrid combination with a gynoecious inbred tester (Wehner et al., 2000; Shetty and Wehner, 2002). High-yielding accessions have been identified of pickling and slicing cucumber type. Those accessions can be crossed with elite cultivars to develop populations for improvement using recurrent selection.

### Natural intercrossing rate

Selected families from each cycle of population testing can be intercrossed using honeybees. Outcrossing is increased if growth regulators are used to change the sex expression of the cucumber families. The rate of natural outcrossing ranged from 29 to 73% (depending on year) if ethrel was applied to 12-plant plots, and silver nitrate (or amino vinyl glycine) was applied to composite pollenizer rows in isolation blocks. Without growth regulators, the outcrossing rate was 11 to 46% (depending on year;

unpublished data). In another study, outcrossing in monoecious cucumbers ranged from 23 to 77% (depending on location) if no growth regulators were used (Wehner and Jenkins, 1985).

### **Early testing**

Each cycle of recurrent selection, families can be started from the improved populations. Inbreds can be developed from those families by selecting for yield and other traits of interest. In the first one or two generations of inbreeding, selection should be for high heritability traits. Selection for yield of S6 inbreds in early stages of inbreeding (S1 lines) is effective for combining ability, but not for performance *per se* (Rubino and Wehner, 1986).

If resources are limited, selections can be made from open-pollinated plants for the first generation or two. Most of the open-pollinations will be self-pollinations if the plants are grown at wide spacing (1.5 x 1.5m) in single-plant hills with the plants trained into a spiral pattern to keep them away from neighboring plants. After the first two generations of selection, plants can be self-pollinated in the greenhouse to advance the selections rapidly to S6 for use in hybrid production.

### **Optimum experiment size**

Lines can be tested for yield and other traits in small plots. Optimum plot size is 1.2 x 1.5m for once-over harvest of families tested in early stages of inbred development. For multi-harvest trials of inbred lines in later stages, and for hybrids, optimum plot size is 6.1 x 1.5m (Swallow and Wehner, 1986).

It is important to use the optimum experiment size to obtain the most information from available resources. Optimum experiment size favors trials having more seasons (planting dates) and years rather than locations and replications (Swallow and Wehner, 1989). Thus, if there were sufficient seeds to test 6 plots of each inbred or hybrid, one might use 3 seasons and 2 locations of 1 replication in each year of testing.

### **Plot border rows**

Multiple-row (3- or 4-row) plots with unharvest borders are not necessary for testing yield of different inbreds in cucumber trials. Single-row plots are sufficient, even when determinate and indeterminate types are being tested in adjacent rows (Wehner and Miller, 1990).

Furthermore, plot end-borders are not necessary to distinguish among cultigens in small-plot tests, since there is no interaction of end-border with cultigen. However, end borders are useful to prevent inflation of yield by 15% due to extra space given the end plants in a plot, if realistic yield estimates are needed (Wehner, 1988).

### **Sex expression**

Inbreds should be developed with the production of gynoeocious hybrids in mind. Thus, gynoeocious inbreds should be developed for use as the female parent of the hybrid. Monoecious inbreds should be developed for use as the male parent of the hybrid. They can be developed from different populations, or from the same population since there is no heterosis in cucumber (Cramer and Wehner, 1999).

Sex expression is also useful for obtaining high early yield in cucumber. 'Meridian' ('Marketmore' x 'Tablegreen') slicer is available in gynoeocious x gynoeocious (GxG), gynoeocious x monoecious (GxM) and monoecious x monoecious (MxM) versions. Those

versions were used to demonstrate the advantage of gynoecey for yield. The GxG and GxM versions had higher early yield, but the same total yield as MxM hybrids over 8 harvests made during a 4-week period (Wehner and Miller, 1985). Thus, GxG and GxM hybrids should be developed to maximize early yield.

### **Test method**

Once the inbred lines have been selected for yield and used to produce hybrids, there is a need to develop efficient trials for testing and release. The equation for correlated gain from selection can be used to determine the most efficient testing method. In this case, the correlated gain should be calculated by comparison with the final trialing method having multiple harvests, replications, and environments. A study by Wehner (1986) indicated that a single-harvest trial at immature fruit stage using small plots in 2 replications was the most efficient method. That method was superior to trials using single-plant hills harvested at immature fruit stage, or small plots harvested at the mature seed stage.

### **Selection intensity**

Important traits for cucumber include high yield, early maturity, fruit quality, disease resistance, and stress tolerance (Strefeler and Wehner, 1986a). Other traits often selected include machine harvest adaptation, plant type, fruit type, sex expression, and insect resistance. An effective index for four main traits is:

$$(SWI=0.2x(\text{NoTotal}/3)+0.3x(\text{NoEarly})+0.2x(\% \text{Marketable}/6)+0.3x \text{Quality}).$$

Selection for multiple traits will reduce the amount of progress made for each, so yield is not improved as rapidly if other traits are receiving attention in the selection program. For example, a selection intensity of 10% for a combined trait index puts a much lower selection intensity of 56% ( $.10=.56x.56x.56x.56$ ) on each of the four traits in the group.

### **Selection among populations**

Predicted gain over cycles, along with initial mean will allow selection among populations. The best populations can be used for improvement through recurrent selection. For example, a wide-base, medium-base and elite population were reported to produce different predicted gains for yield (Strefeler and Wehner, 1986b). Once the best populations have been selected, they can be improved using multiple cycles of recurrent selection. Each cycle, each population will provide families for use in the development of inbreds.

### **Selection within populations**

Recurrent selection produces improved populations, with new S0 families ready for inbreeding after each selection cycle. The population improvement system can be run efficiently using all of the above information. An efficient program might have 5 populations (wide, medium, elite, multi-branched, determinate) of 2 crop types (pickling, slicing) tested in 2 seasons (planting dates) with 2 replications of 352 half-sib families. The 352 families in each replication could be tested using Gardner's grid with 22 cells of 16 families each. The best 2 families would be selected from each of the 22 cells, and further selected for a final count of 40 families. The highest performing families would

be planted in an isolation intercross block with 1 row of composite pollenizer (mixture of the 40 families) alternating with 2 rows of the 40 families.

The system has been used to produce significant progress for yield, earliness, quality and resistance in 3 pickling (Wehner and Cramer, 1996a) and 3 slicing (Wehner and Cramer, 1996b) cucumber populations.

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