agricultural research in general nor mechanization research in particular, for society would surely be the loser. Rather, additional research needs to be undertaken—research that is directed at social problem-solving.

Change has been integral to agricultural development, and research has been an important part of the process. Today in America, one commercial farm operator provides the raw food and fiber for 125 Americans and many in other countries as well. The others in the nation's vast food and fiber system are in farm input manufacturing industries, food processing plants, transportation, textile mills, clothing manufacture, wholesale and retail trade, and restaurants. Still others are freed from any direct connection with the food and fiber system. Consumers in America enjoy variety, quality, and abundance of reasonably-priced food and fiber products unrivaled anywhere else in the world and at a level never before attained. Much of this success is thanks to what can literally be called "seed money"—the public's investment in agricultural research.

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Spider mite damage to soybean plots at the West Side Field Station at Five Points.

The search is on to find a way to reduce chemical control of two major soybean pests.

Testing soybeans for resistance to spider mites

Elmer C. Carlson □ Benjamin H. Beard □ Ronald Tarailo □ Robert L. Witt

Spider mites [*Tetranychus urticae* (Koch) and *T. pacificus* (McGregor)] have been the most important pests on soybeans grown in California in at least five of the last seven years. While it may be possible to control these pests with chemicals or even with integrated pest management, host-plant resistance would be more satisfactory. As early as 1966, potential for this was found at the West Side Field Station when a few cultivars were found to have lower mite infestation and damage levels.

Testing procedures have been developed to find spider mite-resistant soybean germplasm as a first step in developing resistant cultivars for commercial production in California. Field and greenhouse tests are useful and necessary to determine resistant lines. Since testing began in 1967 we have found that B-106, B-107, L62-561, L67-3388, and P.I.86,452 are resistant lines compared with Wells, Chippewa 64, or Portage, which are used as susceptible checks.

How damage starts

Damage to soybeans begins when a small number of mites feed, causing a white-stippled type of injury to appear on the upper surface of the leaflet. Increasing numbers of mites cause leaflets to turn yellowish and then brown and to drop prematurely. Defoliation reduces seed yield significantly, particularly if it occurs early in the growing season.

Yield loss is difficult to correlate with actual mite counts because the relationship varies from one leaflet to another and mite numbers vary from one to another area of the same leaflet. Experiments have indicated, however, that five or more mites in a 12.7 mm circle on a leaflet (about 100 mites per leaflet) will lead to leaf yellowing and some yield loss. At counts above 25 per circle (1,000 or more mites per leaflet), leaflets quickly turn yellow, then brown, and dry up. These severely affected plants show extreme defoliation and greatly reduced seed and pod development.

Evaluating varieties

Varietal differences in resistance were evaluated in terms of average numbers of mites contained within two holes, 12.7 mm (1/2 inch) in diameter, drilled through a strap hinge; the area of each circle was 127 mm^2. One hole was drilled close to the base; a second was drilled near the center of one side of the hinge. Samples of each soybean cultivar consisted of 20 leaflets picked at random from each of five substations within a plot; the leaflets from each plot were placed in a jar and refrigerated at 6° C (41° F) until a count could be made. The leaflets were place between the halves of the hinge with the leaflet base against the hinge joint and the underside visible through the drilled holes. Live mites trapped within each circle were counted under a stereo microscope (12 to 15 times magnification).

The terms "resistant" and "tolerant" are used here to have meanings similar to those used for disease reactions. A decrease in spider mite reproductive capacity is called resistance, while less damage, (either visible leaflet damage or maintenance of yield with similar numbers of spider mites) is called tolerance. For example, the cultivar Williams shows lower damage than do other varieties and thus appears to be tolerant, but it does not have any measurable resistance because it supports relatively large mite populations.

Rating system

Observations of differences in numbers of mites on different cultivars led to an evaluation of the USDA Soybean World Collection of maturity groups II and III. However, with approximately 3,500 lines planted at the West Side Field Station in 1967, it was physically impossible to make the number of mite counts and a faster method was required. We used a rating system with 1 equal to no visible mite damage and 5 equal to severe stippling over most leaflets. There were no lines that were rated 1, but a few were consistently rated 2. Ratings differed greatly, depending on when the ratings were made. Many times a plot that received a 2 rating one month would rate 5 the following month. At the end of the season there were 12 plots with low ratings.

Greenhouse studies

These selected lines were planted at different times in the greenhouse beginning in 1967. Mite biotic potential was measured by introducing one female twospotted mite into a small plastic cage lightly clamped on the underside of a soybean leaflet. Each mite was carefully transferred with a Number 1 to 3 bristled camel's hair brush to the surface of a leaflet inside a cage. Ten replications of these cages, each enclosing a mite, were placed on several plants for each line in each test. Two weeks later all eggs, live nymphs, and adults that had developed in each cage were counted. Thus, the relationship of mite reproductive capacity was assessed on each line and compared with the susceptible cultivar Chippewa 64. This method resulted in a critical evaluation of each line inasmuch as the mites were confined to a single leaflet and could not move to other plants.

Because this test gives the best assessment of differences between lines, we have tried to find combinations that will be the most efficient, although it will never be useful to evaluate more than a few lines at a time. In 1972 several tests were conducted in small cages in the greenhouse to determine whether it was advisable to introduce two female mites per cage and whether the number of replications could be reduced. The results (table 1) indicated that the introduction of two mites increased mite development in only one test on one of the varieties. Three replications were apparently sufficient to determine significant differences between varieties. Because a female occasionally dies, a single replication (data not shown) is not adequate, especially when only one female is originally introduced. We now put two females into each cage and use three or four replications, each of which is on a different plant which represents a line. Because the greenhouse environment can not be adequately controlled, counts of all mites in all cages are made when the number of mites per cage on the susceptible check variety reaches approximately 60 nymphs plus adults. We use Wells, Chippewa 64, and Portage as susceptible check cultivars.

Field studies

Field evaluation of spider mite resistance is complicated by nonuniform infestations from one area to another, by migration of the spider mites from plot to plot, and by natural predators that are sometimes present. Even so, careful evaluation in the field has verified the greenhouse tests. Table 2 shows data obtained in 1973 from the field planting of several soybean cultivars, lines, and selected segregates from two crosses. All the entries showed significantly fewer mites than did the most susceptible cultivar, Portage. Line B-106 appeared to have the fewest mites, although not significantly fewer than seven other entries. The percentage of visible leaflet damage was evaluated as light for 100 percent of the leaflets of five entries.

In addition to the resistant lines shown in table 2, a greenhouse small-cage experiment

TABLE 1. Greenhouse Cage Tests Comparing the Introduction of 1 female Mite Versus 2 and 5 Replications Versus 3, Davis, 1972*

Plant Variety and Number of Mites Used	Mean Number of Mites: 5 replications				3 replications	
	days after inoculation					
	7	14	21	28	7	14
B 106						
1 adult	8.01a	7.6 a	—	—	—	—
2 adults	18.0 ab	16.6 ab	11.0 a	10.2 a	12.0 a	11.0 a
Portage						
1 adult	10.6 a	24.0 bc	—	—	—	—
2 adults	46.0 b	34.0 c	20.6 ab	69.0 ab	25.0 ab	83.0 ab
Chippewa						
1 adult	20.0 a	24.0 bc	—	—	—	—
2 adults	38.0 ab	23.0 bc	29.0 b	210.0 c	28.3 b	217.0 c

*Values followed by the same letter do not differ significantly (P = 0.05), Duncan's Multiple Range Test.

TABLE 2. Soybean Plant Resistance to Spider Mites in Field Plantings of Several Varieties, Lines, and Hybrids, Davis, 1973.*

Variety or Line	Number of Mites Per 12.7 mm Unit/Leaflet†	Percent of Visible Leaflet Damage: Light	Moderate to Severe
B-106	0.3 a	100	0
M-59-213	2.5 ab	100	0
S-100	4.4 ab	50	50
D65-3054	4.9 ab	50	50
B-107	5.1 abc	100	0
Wayne	8.1 abc	100	0
Hill	9.2 abc	10	90
B-106 x Kent	13.4 bc	100	0
B-106 x Portage	29.5 de	60	40
Harkness	33.4 e	60	40
Kent	35.2 e	40	60
Portage	62.5 f	0	100

*Counts and observations were made on 8/15 and 8/16, before predaceous mites and thrips had made significant reductions of mite populations in all varieties. Mite counts are averages of 2, 12.7 mm (1/2 inch) units/10 leaflets/variety and are the sum of adults and nymphs.

†Values followed by the same letter do not differ significantly (P = 0.05), Duncan's Multiple Range Test.

in 1975 resulted in the discovery of three new lines (L62-561, L67-3388, P.I.86,452) that reduced mite development as well as B-107 did and which were significantly better than Williams and Chippewa 64.

To compare more lines than can be done in small-cage tests we have devised other types of greenhouse experiments. In 1974, several varieties were compared by planting a single row of each variety in a greenhouse flat. There were three replications in a single large cage. Spider mites were introduced onto each row by scattering small pieces of common bean (*Phaseolus vulgaris* L.) leaves that were infested with the twospotted spider mite. The results were only fair, because the mites developed rapidly and may have migrated across rows. Even so, B-107, although not significantly different from Williams, had significantly fewer mites than did Wells, S-100, and Chippewa 64.

In another test we tried to evaluate the inheritance of spider mite resistance. We had F_2 populations from 126 crosses that involved either resistant x susceptible lines or resistant x resistant lines. In a small greenhouse, we planted 21 seeds from each F_2 population, plus resistant and susceptible check varieties. Mites were introduced onto each seedling, and mites on a single leaflet from each plant were counted two weeks later using the strap-hinge method. Although there were significant differences between the means of the susceptible and resistant check lines, there was large plant-to-plant variation, and on a single-plant basis many plants were incorrectly classified. We also found that 21 plants per cross is too small a sample; at least 60 plants per cross should be used.

We have shown that a good method is available for critical evaluation of a small number of lines, but we do not have a reliable testing procedure for evaluating hundreds of lines nor for classifying many single plants. Proper evaluation of cultivars for resistance or tolerance requires both greenhouse and field experiments, although there has been a consistent correlation between tests and both are useful. Mite buildup is under more positive control in the greenhouse. Spider mite control by means of host-plant resistance would be an important development, because it would reduce need for chemical control, reduce environmental pollution, and decrease predator mortality.

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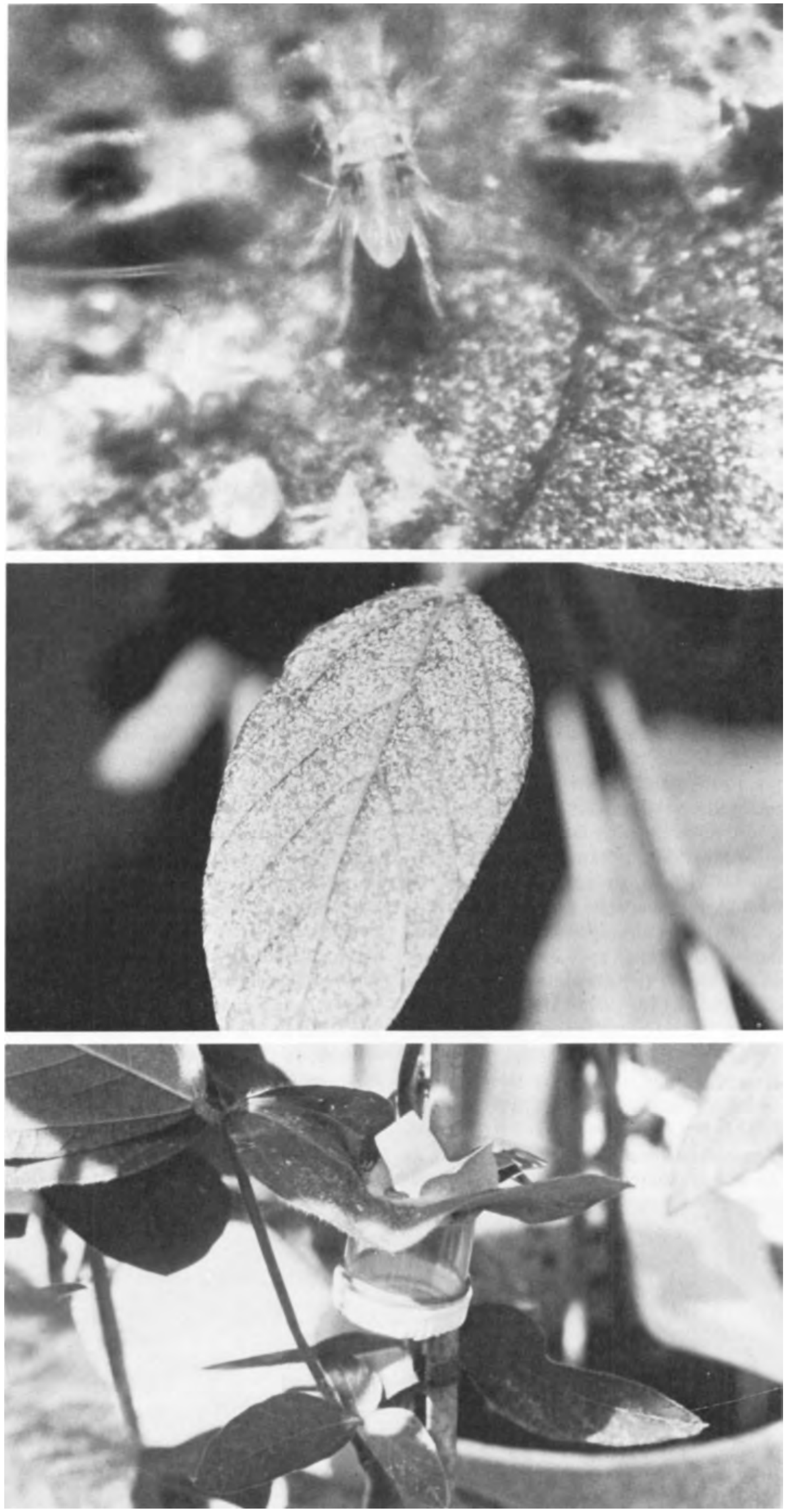

A twospotted spider mite and egg, magnified 100 times, are seen in upper photo, while photo in middle shows damage to soybean leaves by the pest. Lower photo shows plastic cages used to contain spider mites during tests for soybean resistance.