Reprinted from
HAWAII FARM SCIENCE
Vol. 9, No. 3, pp. 1–3

Hawaii
FARM
SCIENCE
AGRICULTURAL PROGRESS QUARTERLY

Hawaii Agricultural Experiment Station, College of Tropical Agriculture, University of Hawaii

J. C. Gilbert, D. C. McGuire, and Jack Tanaka

INDETERMINATE TOMATO HYBRIDS WITH RESISTANCE TO EIGHT DISEASES

MULTIPLE RESISTANT F_1 hybrid tomatoes with inherited resistance to as many as eight different diseases are now being grown in Hawaii. These hybrids are surviving longer under severe disease conditions in old infested fields than anything seen in previous trials at the Hawaii Agricultural Experiment Station.

Origin and Description Of the Hybrids

These new hybrids were made by crossing multiple resistant but quite unrelated tomato lines from Florida and Hawaii. With most of these diseases, the genes for resistance were dominant and therefore expressed in the hybrid if present in one or the other of the parents. In the case of some of the diseases, both of the parent lines were resistant. This was true of *Fusarium* wilt, gray leaf spot, and tobacco mosaic virus resistance in hybrid N-56. In addition, this hybrid received root knot and spotted wilt resistance from its Hawaiian parent, and leaf mold and early blight tolerance from its Florida parent. Some tolerance to *Phomopsis* and vascular browning in Hawaii, along with resistance to radial cracking, was also present. The multiple resistant F_1 hybrids produced to date by crossing Hawaii lines with recent southeastern tomato lines have all been indeterminate in vine habit. They also have immature fruit color of the "green shoulder" type and are resistant to blossom end rot of the fruit.

to page 2

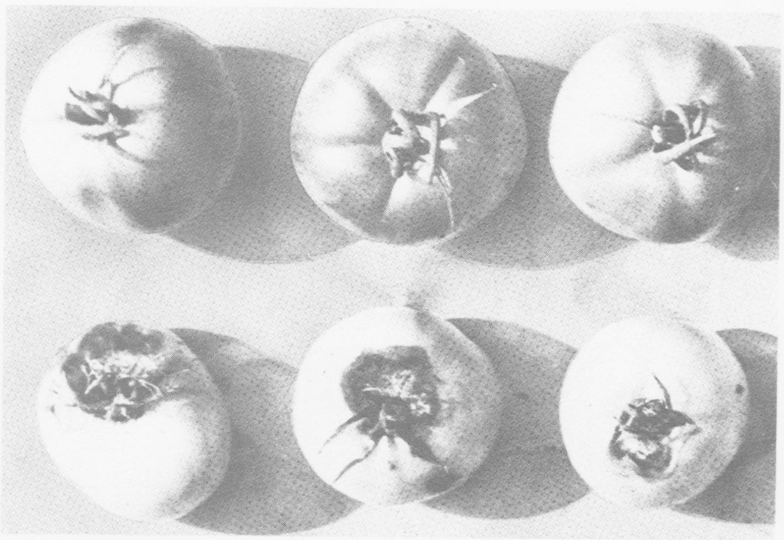


Fig. 2. Genetic difference in susceptibility to early blight (Alternaria) damage to unsprayed fruits. The two varieties represented are both resistant to root knot nematodes and several other diseases. The sound fruit was found only on the newer line with the added resistance to early blight.

TOP PHOTO: Fig. 1. Cluster of unsprayed fruit of new multiple resistant tomato line in early blight infested field. Note freedom from lesions in spite of moist weather. This plant was also exposed to severe root knot nematode and tobacco mosaic disease at an early age but showed very little injury. Poamoho, December 1960.

IN THIS ISSUE

Vol. 9 JANUARY 1961 No. 3

ing Hawaii lines with tomatoes from the southeast U.S.A.

Yields Compared with the Rutgers Variety

The well-known Rutgers variety was included among the 15 tomatoes in this trial at Poamoho farm in the summer of 1960. N-56 was not included in the trial. The yields of the three Hawaii entries listed above were double those of the Rutgers variety in each case. In total yields, none of the nine entries representing recent highly selected new southern tomato lines equalled any of the six Hawaii lines and hybrids included in the Poamoho trials. The total yields ranged from 36,342 lbs/acre for the leading Hawaii line down to 15,739.68 for a mainland line which had done well here in previous years but was hurt by both two-spotted mites and root knot nematodes in this year's trials. Yields of marketable fruits in the trial ranged from 24,858 lbs/acre for hybrid N-11 down to 11,722 lbs/acre for the lightest yielding line in the trial. The marketable yields include only good-sized fruits undamaged by cracks, soil rots, or other defects which would impair market acceptability. Total yield figures represent all the tomatoes produced during the harvest period regardless of any damage which might have occurred to them before they were picked and, of course, these figures are larger than those for marketable yields.

Extended Viability of 8-way Resistant Hybrids

Perhaps the most interesting aspect of the 1960 tomato trials here is not the heavier yields of the locally selected tomato lines because this has been observed in each year's trials in the past. It is rather the more reliable performance and greater longevity of the F_1 hybrids with multiple disease resistance extending over a greater range of diseases than either of the parent lines. In the Poamoho yield trial the only 8-way disease resistant F_1 hybrid represented was N-51; and when the other tomatoes were through producing and starting to die from the effects of one or another of the diseases present, the plants of this hybrid were still in very good condition and starting to set an entirely new crop of fruit even though they had already produced a crop of over 16 tons per acre in rather poor soil. One parent of this hybrid was the line which yielded lowest of any in the test. The particular set of disease resistances it has did not happen to fit the requirements of this test although it had done quite well in some other trials. The other parent of this hybrid, HES 6351, with four kinds of disease resistance has been hurt at times by some of the diseases which do not seriously injure the line described above. By combining the two in an F_1 hybrid, the major weaknesses of the two parental lines appear to be cancelled out and with the added hybrid vigor, this extended range of disease resistance has lengthened the life and decreased the hazards of growing the tomato plants. This was observed repeatedly in various station and commercial plantings in several parts of Hawaii in 1960.

Commercial Use of 8-way Resistant Hybrids

Since the tobacco mosaic virus resistance in these new hybrids must be found to some extent in both parents for best results against various strains of the disease, no highly TMV susceptible lines can be used in making these hybrids. That meant that some tolerance to this virus had to be combined with root knot nematode and spotted wilt resistance in the Hawaiian lines before they could be used to make the TMV and multiple disease resistant hybrids with the Florida parent (STEP 305). Neither the Hawaii nor the Florida parental lines have been released to commercial seed producers as yet, since they need further refinement in certain horticultural characters before being considered satisfactory as pure lines. HES 6578 and 6351 were used in making hybrids N-56 and N-51, respectively, but neither these nor STEP 305 are named varieties and they remain under experiment station control for the time being although the hybrids can be used for commercial tomato production. Preference will be given to Hawaiian growers until seed stocks of the F_1 hybrids are increased. This system of retaining control of the inbred lines used to make new F_1 hybrid combinations will not involve an indefinite withholding of parental stocks as in the case of hybrid corn production at some institutions. It will, however, allow the station more time to make desired changes in the inbred lines while at the same time allowing early use of the new disease resistant combinations in commercial farming.

Dr. J. C. Gilbert is Associate Olericulturist at the Station, Head of the Department of Vegetable Crops, College of Tropical Agriculture, and Associate Professor of Agriculture, University of Hawaii.

Dr. D. C. McGuire is Associate Olericulturist at the Station, and Associate Professor of Agriculture, University of Hawaii.

Jack Tanaka is Junior Olericulturist at the Station.

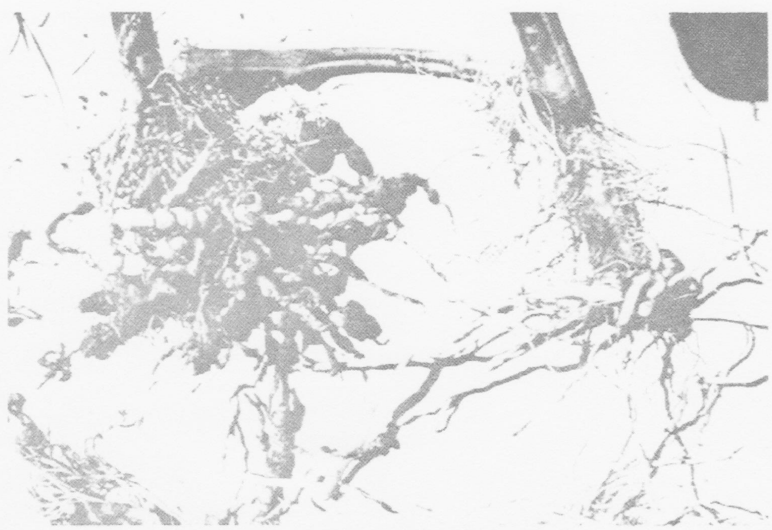


Fig. 5. Roots of new 8-way multiple resistant hybrid at right show freedom from root knot nematode galls when grown in heavily infected field. Roots of nearby plants which did not have the gene for gall resistance are shown at left.

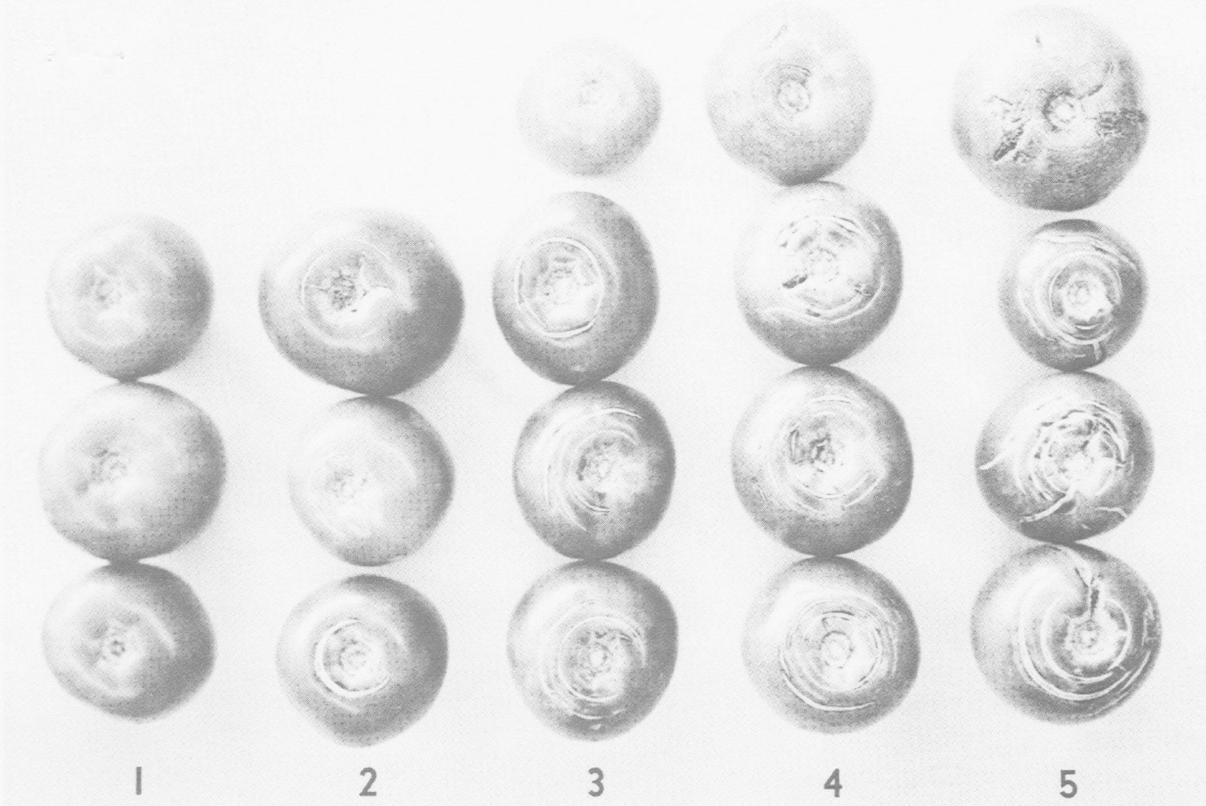


FIGURE 1. Concentric cracking of tomatoes grouped in five classes of severity. Earlier disease resistant tomato varieties produced fruit of the class 4 or 5 type under some weather conditions. Recent varieties now look more like class 1 or 2.

of the wild relatives of the tomato in advance generation progenies of backcrosses made to the large-fruited but disease susceptible parents.

2. Emergence of new or distinct physiological races of the disease, capable of breaking the resistance conferred by certain genes from the wild tomato relatives.
3. Inability to find satisfactory sources of resistance to a certain disease in any of the source materials observed to date. Late blight on tomatoes in Hawaii is a good example of a disease which has not been controllable as yet with resistant varieties here.

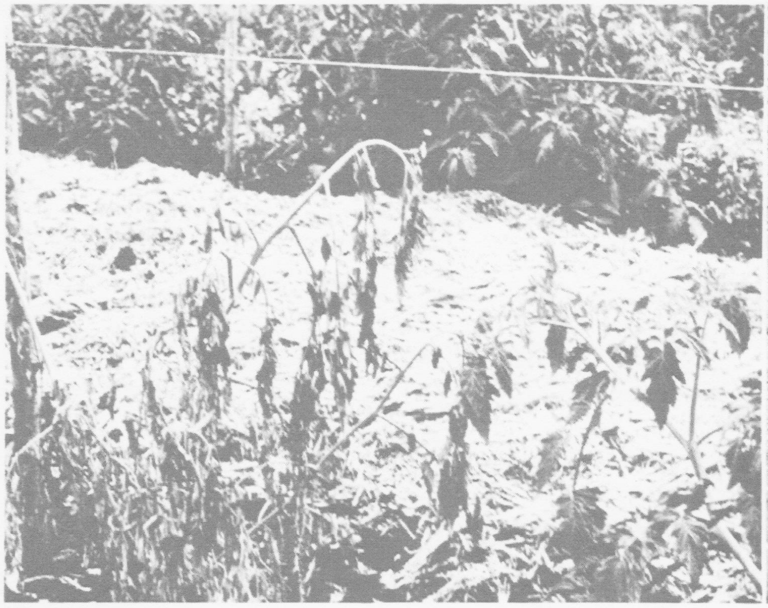
Continued testing of new sources of breeding materials at experimental farms and nurseries sometimes meets the last of these three obstacles. The second problem has not been as serious with tomatoes in Hawaii as with some other crops elsewhere. New sources of resistance or combinations of genetic resistance with other methods of disease control may help here.

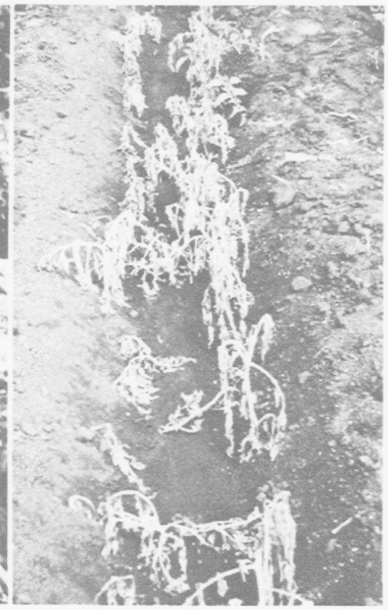
LINKAGE PROBLEMS

Difficulties in the horticultural improvement of tomato lines under selection for disease resistance obtained through crosses with very small-fruited wild types are always possible. In such cases, there have been apparent genetic linkages between the desirable genes for disease resistance and genes for certain undesirable or noncommercial plant characters. This means that selecting for the disease resistance in segregating populations of these plants will usually yield plants inferior to their disease susceptible parents in some quality traits such as crack resistance in the fruit, internal colors, ovary wall thickness, and other characters of market value. The occurrence of these genes close together on the same chromosome is the usual explanation of this failure to recombine easily. This may cost the plant breeder years of extra time and effort before satisfactory new combinations can be found. In some cases the desired new type may be hard to find because of physiological limitations. Early maturity and heavy fruit set has been hard to combine with some kinds of disease resistance, for example.

FRUIT CRACKING AND FRUIT SIZE

It has not been difficult to improve fruit size in disease resistant tomato lines in Hawaii except in those under selection for resistance to southern bacterial wilt and in some cases where resistance to concentric cracking of the fruit is being combined with resistance to half a dozen diseases in true breed-





LEFT PHOTO: Figure 2. Bacterial wilt of tomatoes. Healthy plants in background. Mulching material is cane bagasse (on a farm near Hilo). RIGHT PHOTO: Figure 3. Testing the segregating of tomato progenies for susceptibility to bacterial wilt in the field at Poamoho, Oahu.

Disease Resistant Tomatoes

(continued from page 5)

ing lines. The first large-fruited root knot resistant tomato lines were more susceptible to concentric cracking than commercial lines without the gene for root knot resistance from the wild *Lycopersicon peruvianum* parent. This was somewhat improved by further breeding work. When tobacco mosaic virus tolerance was brought into the combination, more genes for cracking susceptibility had to be dealt with from this source. Combined resistance in true breeding form to both of these diseases has been obtained, but the largest fruit sizes found in such new combinations are not as crack resistant as some commercial tomato lines susceptible to tobacco mosaic virus. Progress in reducing this susceptibility to concentric cracking in true breeding lines resistant to these and some four other diseases has yielded some prolific but slightly smaller-fruited lines. The very large-fruited types in this combination of disease resistance have not yet occurred here in good crack resistant selections.

BACTERIAL WILT RESISTANT TOMATOES

Progress in breeding good quality, large-fruited, bacterial wilt resistant tomato lines from a very small-fruited *L. pimpinellifolium* parent has likewise been difficult in respect to several desired horticultural characters. In segregating populations, higher levels of resistance to this disease have appeared to be associated with smaller fruit sizes. Thin ovary walls and green gel color around the seeds of ripening fruits have also persisted in most bacterial wilt resistant lines grown here. Attempts to increase fruit size have resulted in somewhat oblate shapes in most of these (with quarter-pound fruits). Flavors are satisfactory and resistance to the wilt disease is good enough to allow a plant to produce 50 to 100 fruits whereas the bacterial wilt susceptible plants all died before any tomatoes could develop on them. New crosses to further improve fruit size and correct horticultural defects have been made, but it will take some time to recover good resistance to bacterial wilt. Other types of disease resistance are also needed in these lines.

When it is necessary to recombine genes for many characters and some adverse linkage problems appear, as seems likely in this case, the usual result is some sort of compromise. The very best levels of disease resistance may not occur in plants with the highest degree of horticultural excellence in respect to such qualities as fruit size, shape, internal color, ovary wall thickness, firmness, crack resistance, etc. The severity of southern bacterial wilt with its lethal effects on tomatoes in moist warm soils is such that it does not seem advisable to accept a compromise with lower levels of resistance in order to recover more quickly the desired commercial horticultural qualities. For those parts of the tropics where southern bacterial wilt has effectively stopped tomato production, these new resistant lines with medium size, good tasting but not very fancy-looking fruits may be welcome until something better can be obtained.

Dr. James C. Gilbert is Associate Horticulturist at the Station; Chairman, Department of Horticulture, College of Tropical Agriculture; and Associate Professor of Horticulture, University of Hawaii.

Jack S. Tanaka is Junior Horticulturist at the Station.

genes for disease resistance. Its vine and fruit characteristics are generally recessive to the other parent. When crossed with the variety 'Manalucie,' for example, it has produced a more productive and disease resistant tomato (Hybrid N55) than either parent, but the vine and fruit type closely resemble 'Manalucie.' 'Anahu' has a vigorous but determinate plant type with uniformly ripening fruits.

In the annual yield trials with new tomato lines from the southern states, Hawaii, and Puerto Rico, which are conducted at the Poamoho Farm on Oahu, there has been no year in which the 'Anahu' hybrids or 'Anahu' itself has failed to outyield the competing entries here. This record started in 1959 when these hybrids were first introduced. Those years (1962 and 1965) when 'Anahu' itself outyielded its hybrids with close to 40,000 pounds/acre were years of severe spider mite infestation. Resistance to these mites is not completely dominant and crosses between 'Anahu' and a mite susceptible line will tend to be intermediate between the parents in degree of defoliation from spider mites.[3]

Growing tomatoes year after year on the same land in tropical or subtropical areas can be expected to result in a gradual build-up of tomato pathogens. Rotation to clean fields not previously used for this crop is difficult in Hawaii and other islands with a shortage of available cropland. Extensive use of pesticides is another solution to this problem but it has undesirable after-effects on the environment. The ability of the multiple disease resistant F_1 tomato hybrids to survive in old tomato fields without chemical plant protection has been demonstrated repeatedly at Poamoho during the last 12 years.[4] This suggests that the combination of multiple disease resistance with hybrid vigor can make continuous cropping possible for tomatoes in these latitudes. Improvement of the parental stocks for resistance to new diseases is a recurring necessity and the 'Anahu' tomato derivatives are included in this work at the Hawaii Agricultural Experiment Station.

[3] ———, J. T. Chinn, and J. S. Tanaka. 1966. Spider mite tolerance in multiple disease resistant tomatoes. *Proceedings of the American Society for Horticultural Science* 89:559-562.

[4] ———, et al. 1970. *Vegetable Improvement at the Hawaii Agricultural Experiment Station.* Hawaii Agricultural Experiment Station, Research Report 175. 16 p.

FIGURE 3. This tomato lacks resistance to the spotted wilt virus which has attacked it. 'Anahu' and its hybrids carry the SW-1 gene which gives them resistance to the common strains of disease.

FIGURE 2. Continued survival is characteristic of the 'Anahu' F_1 hybrids. This comparison, at 5 months of age, between a new tomato line from a southern state experiment station (right) and an 'Anahu' hybrid (left), shows this persistence. While the one tomato has died, the 'Anahu' hybrid is sending out new flowers and leaf growth following the main harvest season. This persistence has been demonstrated every year for 10 years at Poamoho Farm.

This tomato cultivar was named in honor of Bill Anahu, former Kamehameha Schools agriculture student and football star who was killed as a fighter pilot in World War II.

For information about the availability of 'Anahu' tomato seed, or the seed of its hybrids, write to the Seed Distribution Program, Department of Horticulture, College of Tropical Agriculture, Plant Science Building, 3190 Maile Way, Honolulu, Hawaii 96822.

James C. Gilbert is Horticulturist, Hawaii Agricultural Experiment Station, and Professor of Horticulture, University of Hawaii.

Jack S. Tanaka is Assistant Horticulturist, Hawaii Agricultural Experiment Station.

'Anahu,' An Outstanding Hybrid Maker

James C. Gilbert
Jack S. Tanaka

FIGURE 1. The tiny bacterial-wilt-resistant primitive tomato (left) was improved by two crosses to the 'Anahu' variety. The new line at the right now has improved fruit size, multiple disease resistance and high productivity. New varieties of this sort are not officially released, but are being used in tropical areas outside of Hawaii.

Many promising new vegetable varieties come out of the various state experiment stations each year. Some suffer poor reputations after only a few seasons, when hidden undesirable genetic traits pop up. Others are abandoned when better new cultivars come along. One of the truest measures of the value of any cultivar is the length of time it remains popular as a field or garden variety, or commands use as a parent in the breeding of high-yielding new commercial types. Hawaii's 'Anahu' tomato, developed from a cross made in 1952,[1] has a 15-year record as a very useful breeding line and garden sort and the promise of continued relevance in the years just ahead.

Other indexes to this vigorous tomato's outstanding performance as a parent of F_1 hybrids are the test results from the Southern Tomato Exchange Program trials. F_1 hybrids, with 'Anahu' used as one parent and various southeastern mainland selections as the other, placed first in replicated yield trials whenever they were entered. This happened 7 times in the 1960-69 period. The effect of the 'Anahu' parent on these hybrids (N11, N52, N55, N63, N64, N65, N69) can be evaluated from the fact that the other parent, in itself, was often not considered good enough for official release as a named variety by its originators. Many experimental crosses with 'Anahu' have been observed and no case of a poor hybrid has yet been found. This suggests that this tomato may be a "general combiner" which should continue to be widely useful as a parent for F_1 hybrid tomatoes.

Representing 4 crosses to *L. esculentum* from the wild *L. peruvianum* and 7 generations of subsequent selfed selection, 'Anahu' is a source of resistance to a combination of fusarium wilt, root knot nematodes, stemphylium leaf spot, and spotted wilt virus (SW-1). It also has a series of other useful characteristics including desirable fruit size, a tendency to continue setting fruit clusters, spider mite resistance, low nitrogen requirement in early plant growth, and ability of seedlings to recover from poor starts.

An 'Anahu' derivative, 'Kalohi,' was selected by USDA plant breeders at the Beltsville Plant Industry Station to serve as the foundation line for spider mite resistance in their canning type tomatoes. With this source of mite resistance, the program obtained its objectives in 3 years instead of the probable 12 to 15 years needed with wild relatives of the tomato as a source of resistance.

Although widely used as a straight variety in areas with problems involving viruses, spider mites, root knot, *Fusarium* sp., and low soil fertility, the 'Anahu' tomato was intended by its University of Hawaii tomato breeders to be used primarily as a parent in F_1 hybrids.[2] It offers a set of dominant

[1]Gilbert, J. C., and D. C. McGuire. 1952. Root knot resistance in commercial type tomatoes in Hawaii. *Proceedings of the American Society for Horticultural Science* 60:401-411.

[2]———, D. C. McGuire, and J. S. Tanaka. 1961. Indeterminate tomato hybrids with resistance to eight diseases. *Hawaii Farm Science* 9(3):1-3.

Hawaii Farm Science Jan. 1963

Sweet Corn Hybrids

(continued from page 3)

STAGE 3. ADVANCED YIELD TRIALS

About 30 outstanding hybrids are undergoing advanced, replicated yield trials during 1964–1966, with both winter and summer plantings on at least five experimental farms and branch stations (Waimanalo and Poamoho on Oahu, Kapaa on Kauai, Kamuela on Hawaii, and Haleakala on Maui). Check varieties are being included for comparison.

Advanced yield trials have been made of all commercially important mainland hybrids and varieties. The data from these trials are summarized in table 2. The outstanding hybrids, Golden Security and Golden Cross, are the only hybrids grown extensively in Hawaii. Neither is resistant to mosaic; Golden Security has rather better earworm resistance (although inferior to most Hawaiian hybrids); Golden Cross is noted for its extraordinary taste and succulence. In overcast winter months, neither hybrid retains its quality, plants are stunted, and yields often drop to less than half the yields of the Hapa-Hawaiian hybrids.

Comparison of growth of Golden Cross and a Hapa-Hawaiian hybrid in April can be seen in figure 1. As noted before, none of the lines in table 2 are resistant to sweet corn mosaic, transmitted by the corn leafhopper, *Peregrinus maidis*. Almost all "early" or short-season mainland hybrids should be entirely avoided by Hawaiian growers.

STAGE 4. RELEASE OF HAWAIIAN HYBRIDS

It is notoriously hazardous for breeders to predict when they will release a new variety or hybrid. However, small seed lots of certain outstanding Hapa-Hawaiian hybrids will be available on an experimental basis to growers late in 1965. State support will be required before any hybrids can be produced and released on a commercial scale.

More than adapted hybrids will be needed, however, before the Hawaiian housewife will be able to buy top-quality, field-fresh corn any day of the year. Even the most succulent ear of corn becomes a pallid, chewy specimen upon poor handling and storage. For sugar alone, the loss exceeds 50% in a few hours at 80° F. Ideally, sweet corn should be chilled within minutes of picking, and kept under 45° F. until eaten. Florida's $20,000,000 winter crop of sweet corn is handled almost entirely in this way, with hydro-cooling in the field followed by refrigerated shipping and handling (Showalter et al., 1961[2]). Studies by agricultural engineers at the University of Hawaii reveal even greater need in Hawaii for careful post-harvest handling and marketing procedures.

It is a pleasure to acknowledge the extensive assistance in this program from Mr. Herbert Waki and Mr. Jack Kanazawa, of the HAES Waimanalo Experimental Farm; Dr. David D. F. Williams, Maui Branch Station; Dr. Richard W. Hartmann, Manoa Central Station; Mr. Noboru Kanda, Poamoho Experimental Farm; Dr. Joseph A. Crozier, Jr., Kauai Branch Station; and Dr. Philip J. Ito and Dr. Takumi Izuno, Hawaii Branch Station.

[2]Showalter, R. K., A. H. Spurlock, W. S. Grieg, C. S. Parsons, and K. D. Demaree. 1961. *Long Distance Marketing of Fresh Sweet Corn.* Florida Agricultural Experiment Station Bulletin 638.

Dr. James L. Brewbaker is Horticulturist at the Station and Professor of Horticulture, University of Hawaii.

Horticultural Refinement of Multiple Disease Resistant Tomatoes in Hawaii

James C. Gilbert and Jack S. Tanaka

When tomatoes as a cultivated crop became widely grown in Europe, North America, and other temperate zone regions, they were selected for horticultural characters affecting fruit size, shape, flavor, color, firmness and fleshiness of the fruits, and various other improvements over their wild relatives. The ability of the vines to survive attacks by disease organisms was largely lost by this selection for other characters in new environments free of most of the diseases found in and around their native home. In time, the diseases of tomatoes tend to follow the crop into any area where it is grown repeatedly and environmental conditions are favorable to the organisms. This is particularly true in tropical or subtropical moist climates and the repeated cultivation of horticulturally improved but disease susceptible varieties from the temperate regions becomes difficult. The answer to this has been crop rotation in some cases, with chemical control measures (sprays, soil fumigants) and recovery of genetic resistance in others.

COMBINING DISEASE RESISTANCE WITH COMMERCIAL QUALITIES

This recombination of genetic traits for disease resistance from wild relatives of the tomato with the horticultural types previously developed for human use in places where few diseases were present is now making it possible to grow tomatoes in tropical areas. The new types show less interference from such troubles as tobacco mosaic virus, *Stemphylium* leaf spot, spotted wilt virus, common races of root knot nematodes, *Fusarium* wilt, *Alternaria* fruit rot, and southern bacterial wilt *(Pseudomonas solanacearum)*. Three major obstacles to the success of this process of recombining disease resistance with improved horticultural types in tomatoes have emerged. None of these obstacles are unexpected, since similar situations have occurred in the breeding of new varieties in other crops. They are:

1. Persistence of some of the undesirable horticultural characters