VEGETABLE CROPS IMPROVEMENT

W. A. Frazier, Horticulture Department,
Oregon State College,
Corvallis, Oregon

INTRODUCTION

I appreciate this opportunity to write a paper for the Pacific Science Congress and sincerely regret that distance and time prevent my presence at your meetings. I recall ten exceedingly pleasant years spent in Hawaii and shall always have an interest in vegetable crops problems of the Pacific.

While my work is now only fifty miles or so from Pacific shores, the climate of our productive Willamette Valley of Oregon is more like that of England or the Scandinavian countries than it is of Hawaii or the Philippines! The difference in problems of vegetable crops improvement here where the northern Pacific winds blow in during summer at 55°F., compared to some of the tropical areas 70 to 90°F., trade winds is indeed great.

I shall make no attempt to discuss, in detail, improvement problems with vegetable crops in various Pacific areas, since my knowledge of such problems, other than in Hawaii, is limited. Yet there are many developments in plant improvement which are of interest to all of us, regardless of location, and so I should like to build my discussion around them, with occasional reference to their application in the breeding of certain vegetables popular in the tropics.

My main topics will, therefore, involve: disease resistance, insect resistance, climate vs. generation turnover, complex crosses, quantitative characters, backcrossing, the increasingly exacting demands placed upon plant breeders, the search for germ plasm, problems of technique, F_1 hybrids, and male sterility.

DISEASE RESISTANCE

In the past two decades, increasing attention has been given to incorporation of disease resistance in vegetable crop plants. The problems and techniques involved in such work have been discussed in several papers in recent years (1), (8), (25), and need not be repeated here. There are, however, a few points which I should like to discuss briefly.

The breeder must be ever conscious of "balancing" the emphasis he places on resistance and on horticultural characteristics. It is not enough to have the one without the other. There is a heavy responsibility placed on the breeder to insure that all available techniques and facts relative to the pathogen and its variability, as well as the host, and its variability, be taken into account. Physiologic races of certain destructive fungi have been known for many years, and breeders of major crop plants are constantly dipping into their "banks" of germ plasm to meet new threats as they arise. Now it is becoming clear, also, that many viruses present a somewhat similar picture. In Australia, (6), the inter-relations of strains of the virus causing spotted wilt, with resistance in various tomato varieties, has been clarified. This was of special interest to me. When we released Pearl Harbor (18), for resistance to spotted wilt in Hawaii, we had hoped that this variety, with several desirable horticultural characters, would be of major value to other areas of the world - localities in Australia, Africa, California - where the disease is extremely destructive. In California, the resistance was only partly effective, while in Australia and Africa, the variety was actually highly susceptible. It has turned out that resistance to strains of the virus present in these latter areas is found in the tomato, but that the resistance is conditioned by genes other than those present in Pearl Harbor.

The occurrence of many strains of a virus is no longer surprising in view of recent research on bacteriophages. It has been shown that a sex mechanism exists in these organisms, permitting recombinations that account for differential behavior of the virus "strains". It should hardly be taken for granted that such behavior is universal in the viruses, yet the implications are clear.

In the future, we are likely to be called upon to breed for resistance, in a given crop plant, to two or more diseases. There appears to be a division of opinion among plant breeders as to the correct approach to be made in securing combined resistance to diseases. Some prefer to breed for resistance to one disease at a time, others to combine in complex hybrids at the earliest possible time, the genes for resistance to the various diseases, and to develop a system of testing progeny that will permit isolation of homozygous segregants carrying such bombined resistance. From the standpoint of selection efficiency, this latter approach appears justified (12). The method was used in Hawaii in combining resistance to spotted wilt, fusarium wilt, and gray leaf spot in commercial type tomatoes, and in adding resistance to two additional diseases - tobacco mosaic, and root knot, in improved breeding lines.

It would be unwise to dwell in generalities relative to the handling of combined resistance programs. Successive inoculations of the same plant with different organisms should be explored, and, if feasible, is definitely the efficient method to use. If there be antagonisms, they should of course be taken into account. This applies to virus diseases also, for one may even find, as the preliminary work of Baggett (2), at this station indicates, that use of more than one virus can result in more well defined symptoms of differential resistance to a given virus than if only one were present in the plant's tissues!

We may be sure of one expectation in biological science - the unexpected. The breeder, with experience, becomes particularly aware of this. In the hybridization of varieties and production of F_2 progeny he shuffles a "gene card deck" numbering probably several thousand units. The recombination possibilities are beyond the imagination. While one may dwell, with ease, in generalities, and admonitions, the fact is that an improvement program in a given location, often involves problems peculiar to that particular locale. There is a constant challenge to one's ingenuity to meet, and solve these problems.

INSECT RESISTANCE

While disease resistance appears to be receiving proper attention in vegetable breeding work, one may question whether this is true of insect resistance.

One of the most destructive pests with which I have come in contact is the melon fly. It is a veritable scourge in production of many vegetables in Hawaii, and surely it must be highly destructive in other tropical areas. It is unfortunate that these warm areas, so well fitted climatically for melon and tomato production, should harbor such a pest. Several years ago, I made a modest collection of muskmelons from various parts of the world, including several introductions from India, with the idea of possibly finding resistance to the insect. I recall that plants from a few of the Indian varieties appeared to resist the insect to a moderate degree, and produced a few small melons of low edible quality - while plants of our common varieties were destroyed before fruits were set. It was not possible to continue with the work but there appeared to be at least the possibility that, if a program of great intensity and scope were launched, such a seemingly impossible problem could be partially solved through breeding.

Instances of resistance or partial resistance of muskmelons to aphids; of corn to corn ear worm and corn borer; of wheat to hessian fly; and of sweet potato to rose beetle, are known. In some of these cases, appreciable breeding work has been done, but on the whole, there are fertile, new horizons for plant breeders and entomologists to explore in this field.

CLIMATE VS. GENERATION TURNOVER

It is a characteristic of many good scientists that they must see to believe. A few years ago I made the suggestion - immediately challenged - that the rapid, low cost, turnover of generations of the tomato in tropical areas might well be taken advantage of in certain disease resistance and backcross programs being conducted for short season areas where only one crop could be grown per year, or where greenhouse facilities were limited and costly (10).

It should hardly be necessary to explain that this was not a suggestion to carry on selection, within the tropics, for horticultural types to be used in temperate zones. Nor was it inspired by a chamber of commerce attitude arising as a result of the soothing breezes or beauty of Waikiki beach. It did (and does) mean that many desirable genes and gene combinations may be added to present day genotypes much more efficiently in the tropics than in other areas. The final selection, from segregating progeny - perhaps even final hybridization - would be necessary as a rule in the locality where the variety is to be used. For certainly the evidence has long been overwhelming that superb varietal adaptation may be restricted to very small areas.

Tomato breeders in several states are now developing tomato lines resistant to root knot nematodes. They are using breeding lines developed in Hawaii (19), after many generations of crossing of Lycopersicon esculentum horticultural varieties to a single plant selection found in segregating progeny of the cross L. esculentum x L. peruvianum, made by Smith (24) in California. It is difficult to perceive how this work could have been carried along so rapidly in climates other than the tropics. Year round favorable temperatures for both plant and nematode permitted turn-over of three generations per year, and the use of such large plant numbers under field conditions that duplication by means of artificial handling in greenhouses would have been economically unsound. Gilbert, and others, have recently released an F_1 hybrid tomato resistant to root knot nematode in Hawaii. These pests are causing heavy damage to tomatoes in many areas of the world. Here, again, the universality of resistance may fail, but thus far the resistance to these particular species of nematodes appear to have been maintained in widely scattered locations. Preliminary work of Jensen (16) in Oregon has indicated that there is no resistance in these lines to entirely different species of nematodes.

COMPLEX CROSSES

When a good recurrent parent is not available and when it is obvious that combinations of genes from many varieties are needed in a new type, there is no alternative but to make complex crosses and to grow large plant populations, from which improved selections may be made.

Sweet corn, though not popular in many areas of the Pacific, is likely to become more important in the future. The USDA 34 variety had been, until recently, a logical choice for tropical areas because of its day-length adaptation and resistance to the virus causing corn mosaic. Yet improvement for many characters, such as pericarp tenderness, sugar content and kernel color have been needed. Mangelsdorf's approach was to combine genes from several higher quality types with those of USDA 34, to establish a superior open pollinated variety, Hawaiian Sugar. Del Valle (5), in Cuba, developed a high sugar variety, Pajimaca, by crossing a locally adapted variety, Provincia, with U.S. sweet corns.

These Cuban and Hawaiian introductions should be of considerable value in a program of inbreeding for the ultimate utilization of F_1 hybrids in production of tropical sweet corns. Perhaps there has not, as yet, been a demand great enough to justify the development of such hybrids. Even so, one can well imagine, in the light of experience with corn hybrids in other areas of the world, that inbred combinations could be developed that would far surpass any other corn now used in tropical areas.

The new combinations of genes made possible through multiple varietal crosses is of value, not only in meeting local needs for adaptation to disease, insect, and environmental problems; if plant breeders throughout the world will freely exchange derivatives thus obtained, the backlog of diverse germ plasm would be found ultimately to be of great benefit to people everywhere.

Even complex species hybrids may, at times, be justified. Four tomato species were involved in hybrids made to secure resistance to the tobacco mosaic virus (7). The idea was to capitalize upon more than one type of resistance - the tendency to esaape infection noted in Lycopersicon peruvianum and the ability to grow in spite of the virus in L. hirsutum and L. pimpinellifolium. L. esculentum was used, of course, for commercial characters, since the "wild" species are, indeed, far removed from the modern tomato in numerous fruit characteristics. Several years have passed since the complex hybrids were obtained, and no assurance can yet be given that mosaic resistance in commercial types will be obtained; on the other hand, derivatives continue to show promise for resistance to this virus - certainly one of the most ubiquitous of tomato diseases. It is, unfortunately, true that many of our most important breeding problems with crop plants require a great deal of time, energy, and money to meet the need for a reasonable method of attack.

The possible advantageous use of bulking - or massing - of seed from large numbers of plants in early segregating generations, where many genes are involved in the improvement program, should perhaps be more widely used. Aside from reduction in "book-keeping", chances for uncovering the most desirable combinations are thereby enhanced, as in the use of sib mating under such circumstances.

It should hardly be necessary for me to warn that one should generally see a definite need for complex crosses; otherwise, persistent heterogeneity and undesirable gene combinations may slow progress of the breeding objectives.

QUANTITATIVE CHARACTERS

A difficult problem, shared constantly by all breeders of self-fertilized crop plants, is that concerning the most efficient and logical approaches to be used in securing desirable combinations of genes controlling quantitative characters. We know now that quantitative characters are generally controlled by many genes, that extremely large numbers of plants are required to find a homozygous genotype with the combination of genes which will result in an "ideal" plant type, and that it is often impractical for the breeder to grow these large numbers of plants. While one never finds the ideal plant, it is not uncommon to find segregates somewhat better than the parents, indicating that at least a few additional genes controlling the quantitative characters have been brought together. Further crossing between these highly desirable (though not perfect) lines will result in progeny having high frequencies of the desired gene combinations. This simply means that we may be making a mistake if we are content to continue with simple selections within existing promising lines rather than with further crossing of such lines, to bring together ever increasing numbers of desired genes. This approach has been pointed out clearly by Palmer (19), of New Zealand. Indications of its effectiveness have been noted recently in our breeding program with green beans at the Oregon Agricultural Experiment Station. We have been hybridizing the Blue Lake variety of pole bean with bush beans in the hope that we can develop a bush bean having more desirable pod characters. Many genes are involved. In the segregates, only a few plants of promise have appeared, and none, certainly, have been ideal. We have found the most desirable bush plants in progeny of crosses between the most promising bush segregates out of the pole x bush cross. Thus, sib mating appears to be resulting in timely combination of genes required for the best horticultural types.

THE BACKCROSS

We are also using, in connection with this and other work a method long in use, yet we believe not fully appreciated nor fully exploited by vegetable breeders to the extent that it merits. This is the back-cross. Repeated crossing (backcrossing) to a desirable horticultural type, while maintaining a few desirable major genes new to the recurrent parent has been used with success in many crops. Munger, in New York, has incorporated resistance to fusarium wilt in muskmelon, and mosaic in cucumber, by means of the backcross. Resistance to yellows of cabbage, and fusarium wilt in the tomato, have also been secured in this manner. In no case can it be said that the new variety developed by backcrossing is an exact duplication of the recurrent parent, but the similarity of appearance and behavior has generally been satisfactory for considerable commercial usage.

A few years ago, it was commonly thought that three backcrosses would suffice in such a program. Experience has shown, however, that it is safer to use five or six backcrosses, accompanied by rather rigid selection, especially in early backcross generations.

This method is conservative, and almost foolproof, if a desirable recurrent parent is available, for one thereby takes advantage of a genetic entity that has been under development by human beings in the immediate locality, or elsewhere, for perhaps hundreds of years.

There are no doubt many breeding problems with tropical crops in which the backcross might be used to great advantage. In legumes, for example, root knot nematode resistance of Alabama No. 1 pole green bean, or the root knot resistance of the California Blackeye cowpeas could be transferred to varieties with more desirable over-all adaptation.

An excellent review of the backcross method in plant breeding has been published recently by Briggs and Allard (3).

INCREASINGLY EXACTING DEMANDS

Vegetable breeders have never been - and will never be - short of problems. Each year seems to add to the demands for their services. The mechanization and chemicalization of agriculture will add - has added - immeasurably to these problems, many of which could not have been foreseen a few years ago. Phytotoxicity of chemicals applied for insect, disease, weed control, fruit set, nutrition, or other purposes varies widely between species and varieties of vegetable crops. When usage of these materials has become more stabilized - as we hope it may - there should be many opportunities to develop, where necessary, varieties resistant to their phototoxic effects.

The superb quality, appearance, the yield of the Blue Lake pole bean green, when grown in the cool temperatures of Western Oregon's summer, has enabled us to lead all states in production of green beans for processing. In order to maintain that advantage, in the face of appreciable reduction of picking costs in other areas through use of the bean picker, leaders here are backing development of a pole bean picker. One cannot predict final outcome of the project, but a working model has been in operation. It may require a new type of pole bean, with long prominent racemes bearing a large percentage of their pods extended well beyond the foliage. I believe that the plant breeder should make every effort to foresee improvement problems and to attack them before they become bottlenecks in crop production. In this case, I must admit to being caught unaware. We are in the position of having to attempt development of a bush Blue Lake type bean, in case the pole bean picker fails, while at the same time attempting to develop a new raceme type of Blue Lake in case the picker does not fail.

Needless to say, it would be simpler for the plant breeder if machines were built to fit the variety, rather than vice versa!

Continued advances in the science and art of food preservation through canning and freezing, and possibly other means, may result in more widespread usage of such methods, even in areas where the environment is conducive to year round production of vegetable crops. Such methods of preservation multiply varietal problems, since appearance, taste, and nutritive value, may be differentially altered during preservation. Recent work with sweet potato varieties for canning offers a good example of such behavior (14).

THE SEARCH FOR GERM PLASM

One can never be sure where valuable germ plasm may be found. Stress has been placed, with good reason, on search in native habitats, in perimeters surrounding apparent places of origin, and in agricultural areas long in cultivation. We were surprised this year to find that the earliest tomato, in our breeding plots at Oregon State College, was a line originating in the Philippines. "Long day" varieties of onions are not well adapted to the "short day" tropics, yet some of their horticultural characteristics would be of value if they were transferred to short day types. Perlasca (20) has recently found a few plants in Imperial Yellow 49, a long day onion, which bulbed well in Venezuela. He concluded, logically, that more widespread trial of long day types appeared justified in tropical areas. I point this out simply to indicate that, while our introductions should often come, most logically, from environments similar to those of our own, the world, rather than restricted areas, should be our treasure house. And the world's plant breeders, rather than our own limited circles of acquaintances - all of us working toward common goals - should be the nucleus around which free interchange of materials and ideas should revolve.

In connection with programs of introduction of seed and vegetative materials from outside sources, it is well to take every precaution that destructive diseases and insects are not introduced into an area free of their destructiveness. Internal cork of sweet potato, for example, could readily be widely disseminated in this manner. Resistance to the disease has been found (15), but if one takes the stand that resistance is the answer, it would be well to insure that a well adapted variety of acceptable consumer preference, is available before, rather than after, introduction of the disease.

The Food and Agriculture Organization of the United Nations has facilitated exchange of information and materials through publication of their LISTS OF WORLD PLANT BREEDERS AND PLANT BREEDERS IN THE UNITED STATES AND CANADA. Many nations have provided means of making plant introductions, and have spent considerable sums in exploration work; yet there is vast room for improvement from the standpoint of international governmental cooperation as well as cooperation and contact between plant breeders of the world. Means of reducing language barriers, and of organizing individual crop improvement associations of world-wide scope, should be sought. It is the plant breeders themselves who should assume an appreciable share of such responsibilities, for back of their efforts would be a never-ending enthusiasm based on the knowledge that plant breeding - as an art and a science - has much to offer in adding to the health and happiness of the world's peoples.

NEW TECHNIQUES

A continual sifting of the literature of plant science is necessary for the breeder to keep abreast of the times. It is to be expected that he will watch new developments in genetics, but, as in the search for valuable germ plasm, he can never tell where he may find research results that may directly or indirectly make his work more effective and efficient. As a down-to-earth example, I recall the report of Frings (11) a few years ago. Jones and Emsweller some years before had demonstrated a means of rearing maggots of blow flies in meat, after which pupae were collected in trays, removed to cold storage and taken out as needed for their efficient job of pollinating onions. Frings showed how to eliminate the stench and the costly meat problem by rearing the flies in dog biscuits - not glamorous, but certainly practical.

Uses for plant growth regulators continue to grow more numerous. Whitaker and Pryor (26) showed 4-chloro-phenoxyacetic acid useful in securing improved seed production from cantaloupe crosses. Capinpin and Natividad (4) in the Philippines, showed 25 ppm 2,4-D spray was effective in speeding up maturity of fruits of melon and watermelon. We may expect growth regulators to be used more widely in the future to speed up flowering and to facilitate seed production and hybridization in many ways. Is it not possible that such a substance may be found to render self-incompatible plants, such as cabbage, compatible? This would mean much to cabbage breeders, in their desire to develop selfed lines.

Is it possible that a chemical may be found which would induce sweet potatoes to set heavier crops of seed? Even in tropical and sub-tropical areas many varieties of sweet potatoes are largely unfruitful. Another answer to this difficulty lies in the isolation of self-compatible types - apparently possible, as shown by Poole (21). Development of an appreciable number of such lines would be a boon to genetic studies with this plant, a hexaploid (6n) species within a genus largely diploid.

One of the long-time goals of vegetable breeders should be the isolation of varieties which can more efficiently utilize soil nutrients. Such improvement has been, from the standpoint of technique or genetic knowledge, purely hit or miss. The recent papers of Pope and Munger (22) (23) are of interest because they demonstrate how simple the inheritance of nutrient utilization may be, at least in some instances. They showed that in celery a single gene (designated Mg) is responsible for utilization of magnesium, and that boron deficiency is conditioned, also, by a single gene. It is of interest, further, to note that they would not have been able to demonstrate this genetic control without employing certain water culture techniques and nutrient concentrations which, when perfected, opened the way for their basic findings.

This dependence, of plant breeders, upon techniques and discoveries in other fields is illustrated, again, by Holmes' work with plant viruses. He first demonstrated the value of local lesions in measurement of virus concentrations, and then utilized given concentrations to test resistance of tomato lines to tobacco mosaic virus. He found (13) that resistance of one line of tomatoes was accounted for by a single dominant gene, providing that the tests were made with a given concentration of innoculum.

F_1 HYBRIDS AND MALE STERILITY

No discussion of new developments in vegetable breeding would be complete without mention of the expanding use of F_1 hybrids in commercial production; and the practical implications of male sterility in several of our vegetables are of such importance that we shall find the two terms being used with increasing regularity in the future.

Sweet corn, which I have already discussed briefly, set the pattern for practical use of F_1 hybrids. Use of cytoplasmic male steriles, in conjunction with inbreds having a "restorer" gene for pollen production in the hybrid, is at our door step.

Use of F_1 hybrid onions is expanding and has been based largely upon the male sterility work of Jones (17). In onions, as in sweet corn, and apparently in several other plants, the male sterility is conditioned by a recessive nuclear gene, ms, and a cytoplasmic factor, S, carried through the egg. Normal cytoplasm (N) always results in viable pollen being produced. The male sterility nuclear gene must be carried along with S, for the genotype Sms ms, which results in sterility. Any other genotype is male fertile. Commercial varieties of the genotype Nms ms are used to backcross to Sms ms plants to maintain the sterile lines.

The necessity of hand pollination has retarded use of F_1 hybrid tomatoes, although vigor and yielding ability of many hybrids has been outstanding. With improved methods of pollen collection and use of long-styled male steriles which do not require emasculation, we may yet see F_1 hybrid tomatoes grown on a large scale.

In addition to sweet corn, onions, and tomatoes, commercial F_1 hybrids of eggplant, cucumber, summer squash and watermelons are being grown. Hybrids of cabbage and asparagus are being tested.

Not only may the hybrids be of value because of the heterosis they exhibit; but as progress is made in the numerous programs for incorporating disease resistance in vegetable crops, it will be found that advantage can be taken of the many instances in which resistance is conditioned by major dominant genes. With the parents carrying resistance to different diseases, it will be possible to combine resistance to several diseases in a single hybrid, probably long before homozygous lines, which carry such combinations, can be developed.

PLANT BREEDING - POSSIBILITIES AND INGREDIENTS

There shall always be a great deal of art and intuition in plant breeding and selection, but it is now generally recognized that scientific facts are playing an increasing role in plant improvement work. Geneticists, cytogeneticists, pathologists, horticulturists, in fact all scientists in various ways are contributing to an enlightened knowledge of how to conduct plant breeding programs. It is a simple example of the mutual benefits of scientific endeavour - of the unity of science.

The tremendously deep wells of variability existing within - and between - vegetable species offer limitless opportunity for generations of plant breeders to come, to alter vegetable crop plants so that they may meet a large part of the quantitative and qualitative food needs of the world's peoples. The breeder may well be proud of such contributions to the happiness and content of the earth's millions. What are the requirements for success? Here are some of them: Well defined objectives; imagination in seeking new genic combinations; faith and enthusiasm in their accomplishment; an open mind, to permit alteration of attack; immediate usage of new findings, wherever applicable, in all biological fields; freedom from bonds of convention; and persistently applied energy in driving toward the goal.

I wish I were present with you today, to partake of the good wine of fellowship, to exchange ideas in our mutual spheres of interest, to enjoy the beauty of the setting and the famed hospitality of the Philippines.

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