study by committees since 1949. Early reports stressed the fact that while seed introductions were being adequately handled, the preservation of vegetatively reproduced materials was still being done by agencies and individuals according to their interest and facilities. A general survey of the status of fruit clones was undertaken.

Independent from the plant introduction program, another project (IR-2) was initiated in 1955. This project, "Obtaining and Preserving Virus-Free Deciduous Tree Fruit Stocks" was cooperative between the State Experiment Stations and the USDA. It established an inter-regional field laboratory, with a plant pathologist in charge at Prosser, Washington. Virus-free stocks have been established in a limited number of fruits, and these have been offered for distribution to interested researchers.

It will be difficult to do justice to the extensive study and to the serious thought on the part of many horticulturalists in making a series of recommendations for action over the period of the last 12 years in regard to the needs for national repositories for maintenance of valuable germ plasm of asexually propagated plant materials. A comprehensive report in 1959 (10) pointed out that the significant actions taken for seed introductions, and in establishment of a national seed storage served as a justification for similar action on vegetatively propagated materials. It cited independent resolutions by the northeastern, north central, western, and southern regions supporting the concept of national repositories for this germ plasm. The general content of such proposed repositories was defined as:

1) Species, strains, and cultivars which have been shown to have special merit in breeding.
2) Special strains and cultivars which might have specific uses such as those serving as rootstocks, intermediate stocks, disease indicators, etc.
3) Commercially important varieties, including specific bud mutations where it would seem desirable to maintain such mutations as separate entities.
4) Primitive species whose potential is suspected but unknown. Larson elaborated on this need at a Germ Plasm Symposium in 1961 (8).

Inventories of various fruit and nut crops were recommended, and several have been completed. Published lists are available for apples (2), stone fruits (3), and pears, nuts, and other fruit clones (4).

Resolutions by the Northeastern, Southern, and Western Associations of Experiment Station Directors in 1966 recommended to ARS, USDA that clonal repositories for tree fruits be established. Likewise, the Entomology and Plant Science Advisory Committee of the USDA recommended to the Secretary of Agriculture in 1967 that steps be taken to develop such repositories.

Thus far, it would appear that the time is not ripe for definitive action establishing the fruit repositories. Inventories taken several years apart have shown appreciable depletion of the germ plasm banks at both State Experiment Stations and USDA collections.

It has been my objective here to review programs, some well structured and some proposed, which have the goal of insuring the collection, evaluation, and preservation of a broad base of horticultural germ plasm. To leave this important subject with a mood of complacency would be a grave error. Existing programs must be nourished by support of knowledgeable people. Program deficiencies must be corrected, and where money for such programs is needed, high priorities for need must be established and supported. As horticulturalists, this support should be a mission in which each of us is involved. Let me close with some thoughts for individual and collective effort.

1) Do we adequately support our national program of plant introductions by documenting uses we have made of these materials? Payoffs are fine, but not all genetic and breeding uses involve these. It may be equally important to document the searches of germ plasm which have led to a fruitless end, because what we want has not yet been found.
2) Have we supplied to the National Seed Storage valuable germ plasm in our possession which otherwise may be lost to future generations of scientists?
3) Are we actively encouraging the development of support for establishment of repositories for vegetatively propagated fruits to provide fruit researchers the same access to a broad gene base that is provided to researchers of seed propagated crops? A strong ground swell of concern from scientists, organizations, and industry is needed to get this program underway.
4) Do we have needs for exploration for horticultural germ plasm that are not being met? The mechanism exists for making such recommendations through the regional plant introduction stations. Only through documented interest and need can new explorations evolve.

In the past 20 years, the services which have developed to provide horticulturalists in this country with germ plasm have been augmented impressively. Our collective goal should be to make effective use of these services and strive for needed improvements.

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IMPLICATIONS OF THE NEW GENETICS IN HORTICULTURAL PLANT BREEDING

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This is an age of transition for horticultural plant breeding. The recent developments in physiological and biochemical genetics and their application to plant breeding signify only the beginning of this new era. To define the term *New Genetics* is extremely difficult especially when it is applied to horticultural plant breeding. For the purpose of this paper *New Genetics* will mean all of those methods, machines, ideas and information that can assist in the future breeding of better horticultural plants.

Two important objectives summarize the future needs of plant breeding:

1. To develop improved cultivars of horticultural crops
2. To develop methods which will make future crop improvement more efficient.

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NEW GENETICS AND CULTIVAR DEVELOPMENT

Plant breeding is the study of plant variation and the selection of variants which satisfy some horticultural need. The major problem facing plant breeders is the accurate assessment of future horticultural needs. In the past plant breeders have been satisfied to develop new cultivars and to let the horticulturist or physiologist develop cultural and chemical means to assure the production of an acceptable horticultural product. In the future, plant breeders must develop cultivars that are adapted to optimum cultural conditions. The alternatives are: Do we take a genetically tall cultivar of some flowering pot plant which is otherwise desirable, and spend thousands of dollars of research funds to develop an environmental or chemical method to control plant height, or do we develop a cultivar that is genetically the optimum height when grown under optimum cultural conditions? If the first alternative is chosen, the technique must be adapted to the commercial grower. If control is by chemical means there are obvious problems that must be solved in regard to concentrations, application times, methods and safety precautions. The second alternative not only avoids these problems, but is also a more permanent solution.

What are optimum cultural conditions? I feel sure that they are related to efficiency and economics; physiology and pathology and to a great extent to genetics. Horticulturists have taken for granted that they will always be forced to spray, dust, treat, fumigate, light, shade, pinch and prune our cultivars. The solution to many problems has been to adjust the culture which more often than not increases the cost of production. This is not always the case and the development of a mechanically harvested tomato is perhaps the most outstanding example of the type of progress that is needed in the future. The *Wall Street Journal* acknowledged this as an important breakthrough by plant breeders (9). This is not an isolated case; however, breakthroughs of this caliber have been limited.

Optimum cultural conditions as related to the physiology and genetics of horticultural plants have not received enough attention. It appears, after an exhausting search of the literature, that plant breeders and physiologists have not experienced adequate communication. Much of the blame I believe rests with the plant breeder-geneticist. They have not considered the physiological aspects in breeding programs and have not communicated the necessary genetic information to the physiologist. Two examples of the above problem are: the plant breeder who tests hundreds of accessions of breeding or genetic materials under sub-optimum cultural conditions and the physiologist who conducts extensive research on one cultivar of a species. In the future there must be closer cooperation between the plant breeder and the physiologist if we are to achieve progress.

Plant breeding literature is limited in regard to the inheritance and gene action of many physiological characters. It is requisite that the recent physiological and basic genetic information be synthesized into horticultural breeding programs. As geneticists, we know that the plant is the summation of many simple biochemical reactions that are genetically controlled. The gene-enzyme-biochemical product pathway can be used to explain most physiological reactions in the plant. It is recognized that external factors may affect but usually not alter the basic genotype. The basis of plant improvement must be the use of the genotype x external factor interaction in the production of a specific phenotype. It is through this interaction that cultivars can be selected for optimum cultural conditions. In the future, plant breeders must solve problems in three general areas of horticulture: propagation, plant growth and development and postharvest quality of horticultural products. In all of these areas cultivars must be developed that are efficient for horticultural production.

Propagation

The inheritance of plant propagation is probably the least understood of all higher plant characteristics. Recent studies have provided a wealth of information on the physiology and biochemistry of seed germination and root initiation; however, the genetic implications in propagation are obscure.

Seed Germination: The literature indicates both interspecific and intraspecific variability for seed germination. Seeds of some species germinate only in warm soils, some are light sensitive, some require seed treatment such as scarification or freezing and others require prolonged periods of cold, warm or alternating temperatures. Cultural recommendations are usually made for a species; however, cultivar differences or even intracultivar differences are common. These differences are indicative of genetic control. Barton (3) indicated that in hard seeded species there is a wide variability in the degree of impermeability of individual seeds. She further stated "there is little doubt that the hard seeded character is inherited- -". This has been confirmed by Kyle and Randall (34) in beans and by Mikolajczyk (41) in *Lupinus angustifolius.* In both cases the hard seeded character was simply inherited. Kyle and Randall determined that the cause of the hard seeded condition was a difference in water absorption in the hilum and raphe areas of the testa. Moore and Scott (42) concluded that the inherent germination ability among various progenies of strawberry hybrids was more important than the effect of seed age.

It is apparent that germination is genetically controlled and that variability exists for use in breeding programs. However, germination is not one character, it is a summation of biochemical and physiological reactions. The major external factors affecting seed germination are light, water, oxygen and temperature. Cathey (10) has classified 58 petunia cultivars into light requiring and non-light requiring groups in regard to seed germination. With adequate germ plasm, the plant breeder has the opportunity to develop cultivars for the optimum light condition. The light reaction in petunias and probably in most other species is controlled by the phytochrome system. Since this system controls a great number of physiological reactions in the plant, selection for light sensitive types would be advantageous in certain crops.

Germination of geranium seeds is inhibited by a hard seed coat which is impermeable to either water or oxygen or both. Craig and Walker (15) developed a scarification technique that yielded 100% germination in two weeks versus 40% for the control. Today scarification is universally used for commercially produced geranium seeds. The germination percentage of the untreated seed lots suggested the possibility of inherent variation. Using unscarified seed of inbred lines, Fries (23) selected for rate of germination. After three generations of selection, lines were isolated that yielded 100% germination without scarification. Further work on inheritance and gene action is in progress. Nilsson (45) selected seeds of *Cucumis melo* L. for optimum germination at various temperatures. His results indicated that there was a genetically conditioned variation in germination both between and within cultivars in regard to temperature response.

Very few species have been critically studied for seed germination. Cultivars and breeding lines of many horticultural species should be screened for germination under optimum cultural conditions. This type of research seems requisite for those species which exhibit various types of seed dormancy, particularly the leguminous crops and woody ornamentals. Germination percentage and time are important horticultural characters particularly in view of automated production.

Asexual Propagation: Similar reasoning can be extended to other propagation methods such as rooting, rhizome formation and grafting. Cultivar differences have been noted by several researchers for the rooting ability of several ornamental plant species. Research on the physiological-genetic aspects of root initiation would be of tremendous practical significance in the development of cultivars for efficient horticultural production.

Plant Growth and Development

There has been much physiological information published on the vegetative and reproductive growth of horticultural plants. However relatively limited research has been conducted on the genetic control and gene action involved in these complex phenomena. Most research has dealt with the gross characters of growth; however, progress will be made only when the components of growth are studied. Growth is affected by many environmental, chemical and cultural factors. Certain aspects that require study are utilization of light, water, nutrients, carbon dioxide and temperature. There are reports in the literature which have provided initial information on these reactions; however, they do not solve the fundamental questions of gene action and inheritance. Most horticultural crops are selected under natural conditions which may or may not be most efficient in future horticultural crop production.

Light: Von Wettstein (71) indicated that the structure and function of chloroplasts is under the strict control of nuclear genes. The use of genetic and biochemical data from chlorophyll deficient mutants may provide basic information on the light-chlorophyll interaction in photosynthesis. The efficiency of horticultural plant growth is dependent on photosynthesis. Research is required on the inheritance and gene action associated with the leaf as a photo-receptive organ. Leaf position, leaf thickness, amount of chlorophyll and intraplant competition for light energy are all important factors that must be considered in the efficiency of the photosynthetic reaction.

The inheritance of photoperiodism has been studied by Barber (2) in peas and by Coyne (13) in beans. Russell and Galston (54) compared a phytochrome mediated growth response in internodes of tall and dwarf genotypes of peas. Although there was no difference in the energy required to activate the two phytochrome systems, the P_{fr} form remains stable and active in the dwarf genotype (Progress No. 9) but decays rapidly in the tall genotype (Alaska).

Parlevliet (46) investigated the photoperiod x genotype interaction in spinach as part of a breeding program. He indicated that selection of lines must be conducted under two distinct photoperiods since earliness was a reflection of laylength, rate of growth and the interaction of growth and development. Chailakhyan (11) in a review of the internal factors affecting plant flowering points out the importance of genetics for a better understanding of flowering processes.

This research is representative of the *New Genetics,* however it is only the beginning. It is a gross study of photoperiodic control and it should be related to the basic physiological processes that are involved. Research must be conducted to provide information on the inheritance and biochemistry of the phytochrome system. If photoperiodic control of growth is important, then plant breeders must use this character as a selection agent. The phytochrome system, with its precise action, allows for accurate timing of plants. It seems obvious that an automated horticulture will require this type of timing in the future.

Foley (22) related plant growth under Idaho conditions to solar radiation destruction of plant hormones in species with exposed growing points. He noted that species with protected growing points were more resistant to solar radiation damage. Craig and Walker (16) related flowering in the geranium to cumulative solar radiation. Further work has shown that selection for this character is possible.

The production of horticultural plants under constant light during early or all stages of growth is a distinct possibility in the future. Under the intensive cultural conditions of greenhouses or growth rooms the use of constant light can produce optimum growth in certain species. Selection of cultivars for specific light conditions is genetically feasible, if the required physiological-genetic knowledge can be accumulated.

Temperature: Many breeding programs have been based on the selection of cultivars under extreme temperature conditions. In addition, the genetics and gene action of several agronomic and horticultural species in response to extreme temperatures have been investigated. Volz (70) reported research on the selection of geranium cultivars that could withstand high temperatures. Mowry (43) studied the inheritance of cold hardiness in peaches. There have been relatively few studies on the inheritance and selection of horticultural cultivars for optimum temperatures. Optimum temperature might be defined as a temperature that yields the greatest economic return per unit area. Greenhouse temperatures are more easily regulated but plant response x temperature x economic interaction follows the law of diminishing returns. For example, an increase in temperature is not always arithmetically related to costs but may be geometrically related in certain temperature ranges. Field temperatures cannot easily be controlled and economically present far more serious consequences as far as crop response is concerned.

Plant breeders must study the inheritance and gene action associated with the temperature response in horticultural plants. One important step in this direction was the investigation by Kemp (33) of the inheritance of fruit set in tomatoes at low temperatures. He indicated the possibility of using this character in breeding programs. Langridge (36) reviewed the biochemical aspects of temperature response. His review mainly covers extreme temperature variations with lower organisms; however, he presents information on several horticultural crops including tomatoes, peas and cosmos. Biochemical information on the temperature response must be related to specific genes and related enzymes which control plant growth. The importance of the temperature response and its interaction with other environmental factors makes further study mandatory. The economics of temperature regulation demands efficient horticultural cultivars both for greenhouse and field production.

Nutrition: The growth of horticultural plants, as well as, the nutritional and aesthetic quality are determined to a great extent by the nutrient relationships within the plant. The effects of nutrition on horticultural plants have been the subject of much research. The physiology and biochemistry of nutrition have also been studied in detail. In addition, there are several reports of the relationship between genetics and plant nutrition. Pope and Munger (49, 50) studied the inheritance of magnesium utilization and susceptibility to boron deficiency in celery. Wall and Andrus (72) investigated the inheritance and physiology of boron response in tomato. Shea, Gabelman and Gerloff (57) determined that potassium utilization in snap beans was simply inherited. They stated that certain lines were able to produce normal growth when grown under severe potassium stress conditions. The accumulation of both major and minor elements in maize has been reported by Gorsline, Thomas and Baker (29) to be gentically controlled. The selection of the celery cultivar 'Penncrisp' was accomplished by Bergman (6) in nutrient solution using calcium concentration as a screening agent for blackheart susceptibility and resistance. Maynard, Barker and Lachman (39) reported variation among tomato lines in respect to ammonium tolerance. They suggested a genetic approach to the problem of developing tolerant cultivars.

The previous research indicates that genetic variability for nutrient uptake and utilization has been found within several horticultural species. The future use of this variability and the development of proper screening methods can do much to improve the quality of horticultural crops.

Atmosphere: Atmospheric content can greatly affect plant growth, yield and quality. Of particular importance to horticulturists are carbon dioxide, water vapor and various pollutants. Wittwer (77) cited research on the differential response of cultivars of several horticultural crops to elevated carbon dioxide levels. For crops grown in structures where the concentration of carbon dioxide can be economically increased there is a need for cultivars that yield an optimum growth response. Conversely for outdoor production cultivars which respond to normal carbon dioxide levels must be selected. There is little doubt that there is genetic control of carbon dioxide utilization in higher plants. Studies of diverse genotypes could provide information on the gene action involved in the response of plants to normal and elevated carbon dioxide levels and possibly provide further information on a genetic basis for photosynthesis.

Relative humidity can greatly influence plant growth under both greenhouse and field conditions. Cotter and Walker (12) stated that high relative humidity is desirable for optimum plant growth; however, it predisposes the plant to certain physiological and pathological disorders. Genetic studies and the screening of breeding materials under high relative humidity conditions might produce cultivars that are adapted to optimum cultural conditions. In addition such studies could provide basic physiological-genetic information on the process of transpiration.

The differential response of various horticultural species and cultivars to air pollutants has been pointed out by several researchers. In 1968, Ross *et al.* (53) conducted an extensive study on resistance of gladiolus to fluoride injury. They stated that innate, genetically determined anatomical and biochemical factors are correlated with resistance to fluoride. Similar studies have been conducted on roses by Brewer, Sutherland and Guillemet (7) and on onions by Engle and Gabelman (20). Studies on the genetics and associated gene action of plant resistance to various air pollutants could provide cultivars that can be grown more efficiently under urban conditions.

Other Factors: Many other factors are important in the efficient production of horticultural crops. Some of these are distribution of root systems in relation to growth, sensitivity of plants to the various chemicals that are used in horticultural crop production, water relationships, resistance to low and high pH and saline conditions and factors affecting the efficient harvesting of horticultural crops. Genetic variability has been noted for many of these factors and breeding programs have been developed for specific species. Many of these factors can be utilized in other breeding programs not only for extreme conditions but for optimum growth conditions.

Postharvest Quality

The postharvest quality of horticultural crops is a reflection of genetic, physiological and biochemical factors. In this discussion quality shall refer to those sensory, nutritional and utility factors that are important at the consumer level. Most plant breeding programs are based on subjective rather than objective quality evaluation. Often the evaluation is made on finished cultivars rather than on inbreds or segregating germ plasm. Characterization of the biochemical composition of many horticultural crops can be found in the literature while research on the inheritance and gene action of postharvest quality is limited. Some of the factors which affect postharvest quality of horticultural products are presented in Table 1.

Sensory: Sensory quality factors are difficult to characterize because of variation in consumer preferences. Quality of horticultural products is greatly dependent on visual, olfactory and tactile factors.

Visual quality evaluation is reflected by color, size, shape and texture. Each of these has been the subject of numerous breeding and genetic studies. Cultivar use is greatly influenced by visual factors. Color of fruit, flowers and vegetables is important both for fresh and processed products. Much biochemical information is available on the various pigment systems that produce color in plants. Manipulation of genes which condition pigment synthesis may result in the development of commercially important cultivars. This has been demonstrated by Thompson *et al.* (68) for crimson fruit color in tomato. This research is characteristic of *New Genetics* in that a visual phenotype is characterized both genetically and biochemically. Similar studies on flower color have been conducted by numerous researchers.

Size, shape and texture of horticultural products, as perceived visually, are important factors in postharvest quality and their genetic control has been demonstrated by many researchers. Biochemical factors that affect size, shape and texture are obviously related to internal growth regulators, but this area remains obscure except for various plant and flower characters. Several other factors that affect the visual quality of horticultural products are insect, disease and virus damage, environmental, physiological and nutritional disorders, and harvest injury.

Stevens and Frazier (63) used a gas chromatographic technique to study the inheritance of two flavor components in canned snap beans. Murphy, Hepler and True (44) evaluated inbred lines of squash for flavor, color and texture by the use of taste panels. They indicated that assessment of total quality could be made by considering the interaction of the three factors with a discriminant function. Creech (17) also used taste panels to evaluate 30 genotypes of maize for sweetness of kernel. The taste data were shown to be related to the amounts of sugar, starch and water soluble polysaccharide in each genotype. Inheritance data on carbohydrate synthesis in sweet corn is extensive and enzyme studies are in progress. The flavor of many horticultural products is determined by soluble solids content and acidity. The inheritance of these factors has been studied in tomatoes by Lower and Thompson (38) and by Duewer and Zych (18) in strawberries.

Great progress has been made on the genetic-biochemical basis of sensory quality of horticultural products. In the future research must be extended to additional horticultural species.

Nutritional: The genetic-nutritional aspects of postharvest quality represent one of the most important areas for future study. Nutritional value per unit of product will be more important than increases in yield. Maintenance of nutritional quality during processing and storage must be related to genetic and biochemical factors.

It would be impossible to review all of the different biochemical factors that are related to nutritional quality. There are; however, several recent reports on the inheritance of chemical elements, carbohydrates and proteins that are representative of future horticultural needs. Thomas and Baker (67) have shown that chemical element accumulation in leaf tissue of maize is under partial genetic control. Creech (17) indicated that certain mutant genotypes of sweet corn produce significantly less amounts of starch and more sugar than the normal genotype. Mertz, Bates and Nelson (40) have reported both qualitative and quantitative changes in amino acids and proteins as affected by genotype in maize.

The development of cultivars with improved nutritional quality must be a prime objective of future horticultural breeding programs.

Utility: The utility value of horticultural crops is determined by both consumer and processor preferences. Utility for fresh market consumption is greatly determined by the sensory factors previously discussed. There are many other utility factors that are important in the quality of horticultural products. Among these, processing and storage factors are of major importance. These characters have been reported to be genetically controlled and follow the gene-enzyme-biochemical product pathway.

Gfeller and Halstead (24) indicated that good cooking quality of field peas appeared to be controlled by two recessive genes; however, they noted a genotype x environment interaction for this factor. Watada and Morris (73) investigated the shelf life of nine snap bean cultivars in response to chilling temperatures. The cultivars differed significantly in their sensitivity to chilling and shelf life. They indicated the importance of incorporating postharvest quality into breeding programs. James, Bass and Clark (32) observed significant varietal differences which they considered to be of genetic origin in seed longevity of several horticultural crops. Smock (61) demonstrated that optimum storage conditions varied for different apple and pear cultivars. Cultivar differences for postharvest quality following storage have been demonstrated for flower, fruit and vegetable crops.

Most keeping quality studies have been limited to one or two cultivars thus eliminating genetic implications. The response of horticultural products to optimum storage conditions must be included as a selection criterion in breeding programs. In addition inheritance and gene action studies will provide the basis for further cultivar improvement for postharvest quality.

NEW GENETICS AND BREEDING EFFICIENCY

The development of improved horticultural cultivars must be more efficient in the future. It appears, from present trends, that plant breeders must do more research with less funds. Most other industries have solved this problem through innovation and automation. In the future plant breeders must be able to react quickly to new situations through increased breeding efficiency. *New Genetics* is indicative of total efficiency in research and the application of this efficiency to plant breeding is requisite. Three areas of increased importance in future plant breeding will be: reproduction, breeding aids and biological accounting.

Reproduction

The major trend in horticultural breeding is the development of F_1 hybrids in almost all sexually produced crops. Other trends include increased breeding activity in both fruit and ornamentals and the change from asexual to sexual reproduction in several other crops. These trends have created certain problems for the plant breeder. The solution of these problems is important to the future of horticulture.

Table 1. Postharvest quality characteristics of horticultural crops that are important in breeding programs.

Sensory	Color	Touch
	Fragrance-Odor	Size
	Taste	Shape
	Texture	
Nutritional	Elements	Vitamins
	Carbohydrates	Amino Acids
	Proteins	
	Lipids	
Utility	Processing quality (including cooking, drying and freezing)	
	Storage quality	
	Keeping quality	
	Size and shape	

F_1 Hybrids: There are two important reasons for the development of F_1 hybrid cultivars. First and probably most important is the exclusiveness of the variety in regard to breeder protection. Secondly, in many crops, F_1 hybrids are superior to inbred cultivars.

Hybrid superiority requires additional genetic and physiological characterization in horticultural plants. Several genetic theories have been proposed to explain heterosis but none have been completely acceptable. Sarkissian (55) related the physiological basis of heterosis to mitochondrial activity. He was able to demonstrate the presence of a "hybrid mitochondria" fraction in addition to parental fractions in F_1 hybrid maize. Srb (62) presented an explanation of heterosis based on the gene-enzyme concept.

F_1 hybrids are expensive to breed and expensive to produce. The use of pollen sterility and incompatibility has resulted in a more efficient production of F_1 hybrid cultivars but has also caused numerous problems for researchers and producers. Pollen sterility and incompatibility have been studied genetically, cytologically and biochemically for a wide range of horticultural crops. Weeks, Hedin and Singletary (74) observed qualitative and quantitative differences in amino acid content of sterile and fertile watermelon lines. Methionine was found as an additional component in the male sterile line. This work is important since male sterility is simply inherited in watermelon and it thus relates biochemical differences to the action of a single gene. Linskens and Tupy (37) observed shifts in the composition of amino acid patterns in petunia styles during the self-incompatibility reaction. Although their data do not yield conclusive results, they provide further information on the gene action associated with gametophytic self-incompatibility. Godfrey and Linskens (26) showed that there were no net changes in nucleic acids in petunia styles during pollen tube growth.

The previous studies demonstrated that pollen sterility and self-incompatibility can be studied at the biochemical level. Additional information is needed on the influence of environment on these characters. There is also a need for research on dominant and cytoplasmic male sterile breeding lines that could provide added breeder protection and possibly extend the keeping life of many horticultural products.

A more efficient method of obtaining pollen sterility might be through the use of gametocides. Most gametocides which are now available are either non-selective or not dependable when used under a wide range of conditions. Biochemical studies on natural sterility might provide specific chemicals for pollen control in F_1 hybrid production.

Apomixis: With the tremendous advances in the development of F_1 hybrids it seems inefficient to make the same cross pollination over and over again. With the use of apomixis a particular hybrid could be produced exactly without the problems or costs of hybridization. Burton (8) reviewed the genetic control of apomixis and proposed its use in breeding. Several of the important turf grasses are produced apomictically. It seems certain that apomixis follows the gene-enzyme-biochemical product pathway. Most plant breeders have never screened their breeding materials for apomictic plants. Methods should be developed to achieve either environmental or chemical control of apomixis. Before this is possible apomictic lines must be isolated and studied genetically as well as biochemically. Controlled apomixis is very desirable in horticultural plant breeding and must be viewed a a distinct possibility in the future.

The controlled development of haploid sporophytes would provide plant breeders with a useful tool in the production of inbred lines. Genetic control of both parthenogenesis and androgenesis appears certain. These processes can result in the development of maternal or paternal haploids. In either case, plants so derived can be treated with colchicine for the production of homozygous diploid lines. Even though haploid progeny are frequently reported in the horticultural literature only limited research is in progress on haploid development. Much of the basic and applied research has been conducted with maize. The effect of specific chemicals and environmental factors on the development of haploids has received only limited attention. Rogers and Ellis (52) presented some initial data on the effect of toluidine blue on pollen nuclear division in *Vinca rosea* L. Their data indicated that division of the generative nucleus could be prevented under *in vitro* conditions. Further research in this area is needed.

Tissue Culture: Tissue culture offers the plant breeder an exciting challenge. Takatori, Murashige and Stillman (65) developed a tissue culture technique for the asexual propagation of asparagus. Similar techniques have been developed for the pathogen-free propagation of several ornamental plants. The tissue culture technique can be used for mass multiplication of either breeding lines or asexually reporduced clonal materials. It seems possible that certain genotypes may be more adapted than others to this procedure.

Artificial fertilization has been demonstrated in poppy by Indian researchers (1). In a study to overcome incompatibility, an *in vitro* technique was developed that produces normal embryos and endosperm tissue. This type of research is indicative of future progress in plant breeding.

The culture of plant embryos has been utilized in many horticultural breeding programs. Successful results have been obtained with brussels sprouts by Wilmar and Hellendoorn (75), with iris by Randolf and Randolf (51), with viburnum by Egolf (19), with cherry by Tukey (69) and with other species.

Breeding Cycles: Probably the most important asset to any cultivar development program is a short breeding cycle. In many cases the generation time forhorticultural breeding is much too long. Techniques, both cultural and possibly genetic must be developed to shorten breeding cycles. This is true for all horticultural crops but particularly so for fruits and woody ornamentals. It appears that a close look at breeding materials might uncover genetic lines that are more adapted to future breeding needs.

Breeding Aids

In the past few years, we have seen greater use of sophisticated equipment, techniques and chemicals in horticultural plant breeding. Modern research tools have produced more precise, and more efficient improvement schemes for many horticultural species. Three areas which seem to be important in the future of plant breeding are: the characterization of gene action, improved selection techniques, and the use of chemicals in plant breeding.

Characterization of Gene Action: The phenotype as represented by its biochemical genotype is the ultimate horticultural product. To improve the phenotype the plant breeder must have information on the genotype and its associated biochemical reactions. Gene action is ultimately based on biochemistry; however, it is often reflected by physiological, morphological, anatomical or cytological variation. To study gene action researchers have used a great variety of modern research equipment and methods. In the following discussion selected research will be cited which demonstrates the *New Genetic* approach to the characterization of gene action.

Simons (59) suggested the use of an electron microscope for anatomical and morphological studies of horticultural plants. He indicated that useful magnification under his research conditions was 20,000 x to 30,000 x. This technique could be useful in many plant breeding and genetic investigations. Stoddard (64) and Shutak and Dayawon (58) suggested two different methods for studying leaf epidermal characters of plants. In addition Stoddard demonstrated the usefulness of the leaf impression technique for identification of cultivars. Harney (31) and Singh and Thompson (60) and several other researchers have used chromatography to identify biochemical constituents of various cultivars of horticultural crops. Paper, column and thin-layer chromatography have been used extensively in the characterization of pigments, amino acids and many other compounds. Benepal and Hall (4) used 2-dimensional paper chromatography to study amino acid content of cabbage as related to genetically controlled insect resistance.

Finney and Norris (21) used sonic resonant methods to measure properties associated with texture of potatoes and sweet potatoes. Electrophoresis has been the primary technique used to study gene action at the enzyme level. In addition spectrometers, gas chromatographs and amino acid analyzers have been used for characterization of gene action.

Selection Techniques: Successful plant breeding is dependent upon the selection pressure applied for various horticultural characteristics. Selection for any particular character can be practiced at several critical periods of plant growth. Prior to propagation, selection is based on past performance of breeding lines (i.e. combining ability). After propagation linked genes, pleiotropic effects and seedling response to various factors may form the basis of selection; however, most selection is based on the performance of mature plants. The efficiency of selection decreases with the length of time required for selection. Several recent reports furnish information on efficient selection methods.

Pieringer and Edwards (48) described an infrared spectroscopic technique for the identification of nucellar and zygotic citrus seedlings. Infrared analysis of leaf oils was successful in the separation of the two seedling types. Handke (30) developed a technique for the assessment of anthocyanin formation in asparagus at the seedling stage. This technique is reported to save 15 months when compared to normal selection procedures.

The methods described in the discussion of gene action characterization suggest a number of selection procedures. Of particular importance in biochemical selection procedures is the bio-assay. Bio-assay at the seedling stage could be of great importance in breeding programs. Techniques have been described in the literature for bio-assay of certain auxins and other growth regulating substances. Bentley-Mowat (5) described a radish-leaf bio-assay for kinetin and kinetin-like substances in algae.

Precise definition and maintenance of selection conditions is necessary for efficient plant breeding programs. Many of the methods developed for lower organisms could be adapted for higher plants. The most practical technique for plant breeding would be selection at the seed or seedling stage. Various morphological, biochemical and physiological methods have been utilized for several crops. These methods should be extended to other horticultural species.

Chemicals: The use of chemicals in commercial horticulture has increased greatly during the past decade. Many of these chemicals can be used to increase the efficiency of plant breeding programs. Growth regulators such as phosfon, cycocel and alar are useful in producing plants that are easier to maintain under greenhouse conditions; thus, making seed production more efficient. Gibberellins have been used in hybridization of cucumbers, for reversing genetic dwarfism in corn, peas and other crops and for precise control of the flowering response in many floricultural species. It is not possible to review all of the research on the use of chemicals in horticulture. However, plant breeders should be aware of the effects of these chemicals and their interactions with the many factors involved in the physiological-genetic constitution of the plant.

Investigations of the biochemical and physiological response of plants to various chemicals could provide the plant breeder with information on endogenous substances in horticultural crops that are genetically conditioned. It seems probable that this type of information could be used for the more efficient development of horticultural cultivars.

Biological Accounting

The use of automation in all phases of plant breeding is mandatory. The commercial seed industry has automated most of its production facilities; however, the breeding phases have been largely ignored. Plant breeding requires a great deal of biological accounting; however, this is usually accomplished manually. Biological accounting includes plant and seed inventories, breeding records, data acquisition, statistical analyses and visual presentation of results. There is no other major industry that does its accounting manually. In research the time between the termination of an experiment and the complete summation of results is important not only for early publication of results but also for the planning of subsequent research. In crops where several generations may be grown in one year, promptness in data analysis allows the breeder to make effective decisions for more efficient research.

The age of the computer presents the plant breeder with an exciting challenge. Many breeders have used the computer for routine statistical analyses; however, computers are useful in many phases of plant breeding.

Data Acquisition: Most plant breeders collect and store voluminous records, many of which are never analyzed because time does not permit. In genetic research and in the pedigree system of breeding it is often necessary to maintain records on each progeny that is grown, In addition, auxilliary data such as temperature, rainfall, light intensity and frost occurence adds to the ever increasing stack of records. With the advent of electronics, the amount of analytical equipment used by plant breeders is increasing. These also produce data; many times, more than researchers would like.

Thus we have two problems: data acquisition and data storage. The computer is particularly useful in solving both of these problems. Data are easily stored either on punched cards or on paper or magnetic tape. There are several advantages to this system: each record is immediately available for analysis, editing can be easily accomplished, data can be accumulated over several generations or years and merged with previous data and summation results can be synthesized into graphs or charts for visual observation.

Data from many analytical or recording devices can be transferred automatically to paper or magnetic tape. The major drawback in the use of cards is the actual keypunch procedure. Even though the computer can save on total time, many researchers are hesitant about the use of punched cards. The future will bring many exciting developments for more efficient data acquisition. The alternatives seem to be either visual interpretation, vocal interpretation or perhaps a portable data-writer. Many computers are already adapted with some of these features. Remote entry into a computer is common, as is long distance data transfer over telephone lines. A stopgap measure for more efficient data acquisition might be a tape recorder or dictaphone whose tape can be transcribed by a key puncher.

Data analysis: There are several advantages of using a computer for data analysis. Many different statistical or summary analyses may be performed on the same set of data and the number of observations and variables is almost unlimited. Routine statistical analyses that are available for most computers (i.e. library programs) will not be discussed. A review of computers, programs and programming in relation to agricultural research has been published by Gorsline (27). Of greater importance are those analyses that are particularly adapted to plant breeding. Computers must be programmed to perform specific analyses; thus, it is advisable that the plant breeder know a programming language. I have observed that plant breeders are particularly adept programmers. At Penn State the computers have been used in breeding programs for more than 9 years. The computer is efficient for transforming data into a form acceptable for statistical analysis. In addition to the square root, log and arc sine transformations it is possible to add, subtract, multiply or divide by constants. Two other uses are the development of ratios of two variables or the development of indices based on several variables. One particular program transforms a flowering or harvest date into the number of days from sowing or transplanting and automatically calculates the cumulative solar radiation for that time period. For genetic studies Craig (14) developed a chi square program that accepts either raw data or totals, performs the analysis and presents in table form the results including the exact probability value. The program is now being modified to accept alphabetic in addition to numeric data. A program by Winter and Henault (76) has been used successfully on quantitative genetic data. Results are presented in histograms for ease of interpretation. Gorsline (28) described a method of computer analysis for quantitative or semiquantitative genetic data following the methods developed by Mather, Allard, Castle-Wright, Powers and logical extensions of these. Scheinberg (56) presented a computer approach for studies of selection for genetic gain. He stated, "The use of computers should be encouraged and emphasized to experimenters."

It is obvious that computer analysis must be used in future breeding programs. The sophistication of the hardware (i.e. computers) and the development of appropriate software (i.e. programs) for plant breeding and genetic studies will allow for more efficient breeding programs. A national index of computer programs adapted for genetics and breeding research should also be developed.

Model testing and prediction: Computers because of their speed and flexibility can be used to simulate theoretical genetic situations. The most simple example would be the fitting of certain data to a number of different genetic models. In addition, purely theoretical situations can be studied by use of a computer. Gill (25) reviewed research on the simulation of genetic systems by use of a computer. Investigations have included simulation of dominance, linkage, epistasis, reproductive rate and intensity of selection. The computer can also be used for prediction studies. Actual data can then be used to verify proposed models.

Of particular interest to plant breeders would be prediction of combining ability based on past performance. Especially in long range breeding programs where individual parents have been used in many crosses, a summation of combining ability would be useful in predicting future hybrid combinations. This technique could be used advantageously in the breeding of asexually produced plants such as roses and various fruit and ornamental species.

Presentation of Results: For most statistical and genetic analyses a tabular presentation of results is most efficient for interpretation. In addition to this type of presentation much plant breeding data can be presented graphically. Programs and graphic devices are available at most computer centers for graphic presentation. The output can often be photographed for graphs or charts for publication. In the future it might even be possible to have results presented in the form of slides, pictures or even microfilm.

Accessory Breeding Uses: The computer can be used for many other phases of plant breeding research. LaBastide (35) described a computer program for the layout of seed orchards. Planting plans can be generated including randomization of individual plots. Inventories of breeding materials can be maintained on a computer. It should be possible to trace individual pedigrees and to output all pertinent information in relation to the pedigrees. A program which produces precoded field plans, data sheets and cards as well as labels for breeding tags or seed envelopes has been developed by Pfeifer and Henninger (47). Tan Creti (66) described a computer technique for the preparations of numbered paper inserts for serial sections. Innovation in the area of computer use can provide the plant breeder with greater efficiency in breeding programs and as a result might shorten the development phase of new horticultural cultivars.

CONCLUSIONS

The application of *New Genetics* to horticultural plant breeding is both a challenge and an adventure. It is a challenge that horticultural plantbreeders cannot ignore, since the nutritional and psychological well-being of future generations is at stake. Improved fruit and vegetable cultivars will be of increased importance in maintaining and improving the nutritional status of the world's people. The development of improved floricultural and ornamental cultivars will provide the aesthetic balance required in a modern technological society. Future plant breeding will be an adventure in *innovative research.* This research will lead to the solution of many of today's problems and also of problems which have not yet been stated. This is an exciting age for plant breeding because never before have we had the knowledge and tools necessary for relating horticultural characters to genes and their biochemical products. The application of *New Genetics* to horticultural plant breeding implies a serious commitment by plant breeders to the future of horticulture and to the future of the world.

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