GENETICS AND ITS RELATIONSHIP TO THE IMPROVEMENT OF PLANTS

by

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As we look around this room, we can easily see that differences are occurring between the individuals here. What do you think is causing these differences? The variation may be genotypic or environmental or a combination of the two.

No two individuals in this room have the same genetic makeup or genotype. No two people here had exactly the same environment in development. There is a quotation, "Heredity deals the cards and environment plays them." For an organism to develop into a superior individual, the genetic potential must be there first of all. No matter how good the environment is, if the genetic potentiality is not there, the individual is limited in its development. Dorman (4) has discussed hereditary variation as the basis for selecting superior forest trees in a 1952 paper. Later today we will be hearing more about hereditary variations in slash, loblolly, and shortleaf pines.

Genetics as a Science

Genetics is the science of heredity and variation. However, genetics was not always a science. In fact, the word genetics was not suggested until the year of 1906 by Bateson, The foundation for genetics as a science burst forth in 1900 with the rediscovery of Mendel's famous 1866 paper by three men working independently of each other--Correns (Germany), DeVries (Holland), and von Tschermak (Austria).

Thousands of generations of farmers and herders tried to improve their crops and herds by trial and error. These ancient people knew something about reproduction, but their concepts were often incorrect. Some 5,000 years ago the Babylonians and Assyrians carried out the process of pollination to obtain fruit set in their date palms (dioecioue plant). They did not know why they were doing this other than the fact that it had to be done before any fruit was produced. Likewise, the ancient people did not understand animal reproduction, although they knew that animals mated before offspring were produced.

In 1694 man discovered sex in plants. In 1719 Thomas Fairchild produced a new variety of pinks by artificial hybridization. A number of workers made successful crosses of varieties within various crops before 1900. Nevertheless, most of the results were unpredictable until the rediscovery of Mendel's paper. With the turn of the century a new era in plant breeding began. Breeders became interested in the development of new varieties for a specific purpose. Our methods of breeding today are based upon a knowledge of genetics.

Since 1900 countless experiments and discoveries have been made in the field of genetics. This basic information is being applied in many ways for the improvement of plants and animals. Fundamental genetic principles are the same for all organisms. A knowledge of the genetic fundamentals, mode of inheritance, linkage relationships, and heritability enables the breeder to plan the most effective breeding program. Many of the most important economic characters are inherited in a quantitative manner and controlled by a large number of genes. Nilsson-Ehle from Sweden and East from the United States were the first to show that this group of characters is inherited in a Mendelian manner. They published in 1908 and 1910, respectively, their papers.

Economic Importance of Plant Breeding

The development of hybrid corn has been termed the outstanding scientific accomplishment of the 20th century. Its value must not be restricted to corn alone. Principles applied to the development of hybrid corn and its utilization of heterosis are being applied now to many other plants and animals.

In the words of Paul C. Mangelsdorf (10) of Harvard, "In my opinion hybrid corn is the most far-reaching development of this century, not only in applied genetics, but in the entire field of applied biology. It has already affected more lives, I venture to guess, than any of the epoch-making discoveries in medical biology of the same period. Insulin and penicillin have saved thousands of lives in the past twenty-five years, but the new abundance of foodstuffs which hybrid corn has created has saved millions of lives in this same period of the world's history.

Approximately 90% of the corn acreage in the U. S. today is planted to hybrid corn. In 1933 less than 1% of the corn acreage was planted to hybrids. American farmers are producing more corn today on 82 million acres than was produced on 103 million acres a generation ago. Extra bushels produced by hybrid corns in one year are worth enough to pay for all the research ever performed with cereal crops (11).

Improved varieties of wheats have increased the production of this vital bread grain by 20% on a given acreage. This gain is represented by approximately 200 million bushels worth $400,000,000 per year.

There are over 50,000 crop diseases. In 1950 the most vicious race of stem rust (*Puccinia graminis tritici*) found in North America hit the northern wheat belt. The race, known as 15B, was a hybrid produced by a natural cross on barberry bushes. At that time all the commercial wheats, both spring and winter, were suceptible to 15B. An estimated 10 million bushels of wheat were lost in 1950 due to the stem rust. Over 13,000 different varieties and strains of wheat in the U.S.D.A. world collection were subjected to tests in the greenhouse to find resistant germ plasm. After finding resistance, plant breeders began transferring genes for this resistance to otherwise adapted varieties.

In the 300 years that tobacco has been cultivated in this country, disease problems have multiplied. To help overcome three of these problems U.S.D.A. scientsts made selections for resistance to nematode root rot, root knot, and Granville bacterial wilt. It took a year of travel by two trained collectors and six years of intensive testing and selection before adapted strains were found to control these diseases. Adequate control has been obtained for these diseases and three other diseases--all of which caused an estimated loss of 107. of the tobacco crop or $2:;,000,000 in 1940 (2).

Dr. Glenn Burton, Principal Geneticist, Georgia Coastal Plain Experiment Station, has obtained 50-75% increases in yields of single crosses of cattail millet over commercial millet.

Coastal Bermuda grass is immune to the root-knot nematode and produces 116 pounds more beef per acre than common Bermuda (1). Coastal Bermuda is a hybrid between Tift Bermuda and en introduction from South Africa.

Corn brdeders are transferring cytoplasmic male-sterility and fertility restoring genes to inbred lines to reduce detasseling cost in the production field. Deteseeling in the doube-cross production field usually costs from $10 to $20 per acre without the use of cytoplasmic male sterility. The cytoplasmic male sterility is transmitted by plasmagenes through the cytoplasm, However, certain genes on the chromosomes have the ability to restore fertility when present in the genotype.

Hybrid grain sorghum is being developed through the use of male-sterile lines. The estimated potential value of hybrid grain sorghums in Texas alone is easily $20,000,000 annually.

Hybrid Bahia grass, utilizing self-sterility, is in the eyperimental stage. Alfalfa breeders have predeced a number of synthetic varieties. Hybrid alfalfas, similar to double crosses in corn, may be produced commercially in the future by planting self-sterile clones in isolated blocks. By using asexual reproduction in the maintenance of clones, I believe that some self-sterility might be advantageous in a tree-breeding program.

One of the broad general ways in which plants serve the needs of man in addition to providing necessities of life is the provision of raw materials for industry. Let us take the story of rubber. In 1830. the entire world consumed only 156 tons of it (10). Today the world consumes 1,000,000 tons or more annually. or modern methods of transportation are completely dependent upon it. In peace time alone some 50,000 different articles are made from it. Man has not solved the problem entirely with synthetic rubber. Natural rubber is still needed for blending with the synthetic. More than 95% of the world's natural rubber comes from a tropical tree, Hevea brasiliensis. The yield of rubber from this tree has been increased from a few pounds per acre in the wild state to 400 pounds per acre per year. Hybrid strains promise to increase the production up to 2000 pounds per acre per year.

Methods of Breeding

There are three general methods of breeding: (a) introduction (b) selection (c) hybridization.

Introduction is merely testing and introducing a variety or strain into a new area. Korean lespedeza is an example of an introduction in the southern states. One source of plant introductions is through the Primary Plant Introduction Station. Four of these stations are located in the United States. The one for the southern region is at Experiment, Georgia. From its establishment in 1949 until 1955 approximately 9,000 introductions had been obtained by this station (8).

Selection, another general method of breeding, may be made on an individual-plant basis or on a group mass basis. Selection has yielded some outstanding varieties in the past. Rustproof-14 oats is a selection from the Appler variety. Grimm alfalfa, which at one time was one of the leading alfalfas in the U. S., was developed by mass selection. Mr. Grimm planted some alfalfa from Germany on his Carver-Country Minnesota farm. Most of the resulting plants were killed by the severe winter. A few of the plants were sufficiently winter-hardy to survive. Mr. Grimm saved seed from these plants. The end product became Grimm alfalfa.

Selection apparently offers one of our first steps in forest tree improvement. Too often, superior trees have been cut, leaving only the inferior ones to produce future generations. With cross-pollinated plants, selection has two primary disadvantages: (a) selection is based on the phenotype of a plant (b) selection is generally restricted to half the total inheritance because the male parentage is not considered.

Hybridization is the most widely used general method of plant breeding today. Hybridization as a method of breeding does not necessarily mean that the final product of the program will be a hybrid. As an example--many of our small grain varieties which are naturally self-pollinated were developed by the hybridization method. Yet, these varieties are not hybrids.

The objective in utilizing hybridization is to combine in a single variety desirable characteristics of two or more lines, varieties, or species. Some of the specific methods of breeding classified under the hybridization method are: (a) the pedigree method (b) backcross method (c) bulk method (d) multiple crosses (e) recurrent selection. Time does not permit a discussion of each one of these methods here.

Combining ability and genetic diversity must not be overlooked in a breeding program. Combining ability as defined by Hayes, Immer, and Smith (7) is the relative ability of a biotype to transmit desirable performance to its crosses. Thus, an evaluation of combining ability is actually based on the progeny test which was advocated by Vilmorin around 1850.

If a line combines well with a source of heterozygous germ plasm such as an open-pollinated variety, we say that this line has good general combining ability. Specific combining ability refers to the performance of a line in a cross with another specific line. Some lines will combine much better with each other than with other lines. Lines or strains which constitute a hybrid or synthetic variety should be tested for combining ability before putting them together in the new product. By doing so, the lines with poor combining ability may be eliminated. Perhaps some of the older synthetic varieties would have given much better performances if the lines had been evaluated for specific combining ability as well as for general combining ability.

Gentic diversity may be even more important than combining ability. Results by Eckhardt and Bryan (5) Johnson and Hayes (9), and Cowan (3) along with a number of other investigations in both the plant and animals fields emphasize the importance of genetic diversity. Crosses between inbreds that originate from different varieties, in general, are superior on the average to comparable crosses from inbreds that originate from the same variety. Crossing two genetically diverse individuals provides more heterozygosity and a greater accumulation of favorable dominant growth genes, which in turn, provide more heterosis or hybrid vigor. Animal breeders have begun to take advantage of this fact by using rotational crossbreeding instead of crossing within the breed.

We mentioned synthetic varieties a few minutes ago. Someday in the future commercial hubrids may be used on a wide scale for reforestation. However, before that stage is attained, maybe we should consider the possibility of developing synthetic verities. Synthetic varieties are used extensively today in forage crops which are open-pollinated as are our southern pines.

A synthetic variety is produced by the combination of selected lines or plants, followed by normal pollination in an isolated area. Tysda and Crandall (14) define a synthetic variety as a variety developed by crossing, compositing, or interplanting two or more strains or clones; harvesting and replanting the bulked seed of successive generations.

Genetic principles as applied to a forage breeding program of a naturally cross-pollinated plant are similar to those developed in our corn-breeding programs. I think that we can safely expect the same principles to apply to the breeding of trees. Richey (12) gives a review of corn breeding. Tysdal, Kiesselhack and Westover (13) outline an alfalfa breeding program. They discuss the use of synthetics and double-cross hybrids in alfalfa. Hanson and Carnahan (6) review the breeding of perennial forage grasses in a recent U.S.D.A. technical bulletin.

With improvement by selection and the evaluation of clones by progeny tests one of the next logical steps in a tree-breeding program could be the development of synthetic varieties. Use of synthetic varieties will probably precede the use of hybrids on a commercial basis. Synthetic varieties could be used in the seed orchards to supply nurseries with seed.

Let us turn our attention now to a specific example of improvement in one of our southern forage crops--white clover, a naturally cross-pollinated plant. As we briefly discuss the development of Louisiana S1 white clover, let us think how the genetic principles and breeding methods as used in corn and forage crops may be applied to the improvement of our forest trees.

Louisiana S1 white clover was developed by the Louisiana Agricultural Experiment Station to produce a good forage yield and to tolerate the hot, dry weather. Heat toleration increases length of grazing season. Louisiana S1 is a synthetic variety made by intercrossing five clonal lines selected from Louisiana stocks of white clover. Improvements over common white clover enable Louisiana S1 to live through the summer and fall of most years and to revive from stolons in the fall. It can be grazed six to eight weeks earlier than ordinary white clover. It also may be grazed several weeks longer in the late spring and early fall.

This white-clover breeding program was initiated in 1945 by making a survey of the clover fields in the state from plants which had survived the summer. From approximately 4000 progeny seedlings transplanted in the nursery in April, only 25 were selected the following October to be evaluated as clones in the polycross nursery.

From agronomic notes and the polycross test finally five superior clones were selected. The next step was to combine these five superior clones into a synthetic variety. Clones were transplanted into an isolated intercrossing block, allowing random pollination to occur with the aid of honey bees. Seed was harvested from all clones and bulked for planting seed increase fields (seed orchards in forestry) of the new synthetic.

Summary

In summary we have discussed:

(a) genetics, the science of heredity and variation
(b) application of the principles of genetics to all organisms
(c) utilization of fundamental principles of genetics in the improvement of plants
(d) economic importance of plant breeding
(e) some methods of breeding
(f) combining ability and genetic diversity
(g) synthetic varieties and an example in forage breeding in which methods may be directly related to a tree-breeding program.

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