Cereals

This is the first article in a series of brief progress reports on the application of the science of genetics to commercial agriculture.

transfer of genes in the development of disease resistant wheat, oats and barley

Fred N. Briggs

Farmers now may plant varieties of wheat and other cereal crops—and plan for their harvest—without fear of having them ravaged by one or more diseases.

In 1940 stem rust reduced the California wheat crop to 16.7% below the ten-year average. The prospects were for better than normal yields that year. Even with wheat at just under $1.60 per hundred, this represented a loss to California farmers of over $1,500,000.

Had such a rust epidemic occurred in 1947 or 1948, the loss to growers would have been around $4,500,000 but such a loss could not have occurred in those years because farmers now can choose from five rust resistant varieties—and 90% of California's acreage is planted to them.

During the past decade the College of Agriculture has made available to farmers in California a number of disease resistant varieties of cereal crops such as bunt, stem rust, and Hessian fly resistant wheats; stem and leaf rust resistant oats; and mildew and scald resistant barley.

The development of genetics furnished the basis for scientific plant breeding.

The science of genetics deals with the way the genes—hereditary units—which control characters such as plant height, grain color, disease resistance maturity and yield in cereal varieties, are transmitted and recombined in hybrid progeny.

The science of genetics has enabled the plant breeder to solve some of his problems with great exactness and within certain limits to make a combination of genes which will produce the sort of disease resistant plant desired.

Having determined the number of genes involved in resistance to a given disease calculations may be made to determine the frequency with which they will combine with the other desired genes.

That this type of plant breeding may be reduced to simple mathematics will be shown by considering the behavior of two or three gene pairs which control contrasting characters in wheat. Genes occur in pairs in an individual, one of each pair being contributed by each parent.

The characters may be represented by letters with the capital letter representing the dominant character:

W = Gene for red kernel color
A = Gene for awnlessness
w = Gene for white kernel color
a = Gene for awned condition
F_1 = Offspring of first generation
F_2 = Offspring of second generation

If two varieties which differ only with respect to one of the character pairs, say kernel color, are crossed the results may be set down as follows:

Red Wheat crossed with White Wheat
WW ww

F_1 Ww = Red – heterozygous (not true breeding)
F_2 1 WW = Red – homozygous (true breeding)
2 Ww = Red – heterozygous
1 ww = White – homozygous

In the next generation the homozygous sorts will continue to breed that way, but Ww plants will break as in the F_2. At the end of several years practically all plants will be homozygous, and the population will be equally divided between red and white. Nothing new will have appeared.

Any gene pair would behave as above. With two there would be combinations not present in the parents.

Awnless Red Wheat × Awned White Wheat

F_1 AaWw = Awnless Red – heterozygous
F_2 1 AAWW = Awnless Red – homozygous
2 AaWW = Awnless Red – heterozygous
2 AAWw = Awnless Red – heterozygous
4 AaWw = Awnless Red – heterozygous
1 AAww = Awnless White – homozygous
2 aaww = Awnless White – heterozygous
1 aaWW = Awned Red – homozygous
2 aaWw = Awned Red – heterozygous
1 aaww = Awned White – homozygous

There are four ways in which two contrasting characters may be combined.

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***Left* Stem rust resistant wheat developed at Davis. *Right* Nonresistant wheat ravaged by stem rust.**

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One of each of these will breed true. The other 12 plants will be unstable with reference to one or both characters. However, the population would eventually be equally divided among the four types.

If an awnless white plant were wanted, one plant in 16 would satisfy the requirements. Eventually one in four would be of the desired type. If an awned, white, bunt resistant variety were wanted, one in 64 in the second generation would have these characters and eventually one in eight.

An actual problem which arose in the transfer of stem rust resistance from Hope wheat to Baart is an example of the process. Hope is wholly unsuited for production in this state but does have the one valuable character of resistance to stem rust. On the other hand Baart is an excellent variety for California conditions, being more desirable with respect to grain color, maturity, height, yield and quality, etc., characters which are controlled by a number of genes. Thus Baart has 20 desirable genes and one undesirable—one to be replaced by a good one from Hope giving a total difference of 21 gene pairs.

Instead of growing 16 or 64 plants in F_2 as described above, 4,398,046,511,104 would be needed. About 50 million acres of land would be required to grow such a population. Even though there would be 2,097,152 homozygous plants and the population would eventually settle out into that many sorts, there is no conceivable way of handling such numbers in order to get the single plant wanted.

If instead of allowing the plants in F_1 and subsequent generations to pollinate themselves, they were backcrossed to Baart—pollinated with pollen from Baart—the problem becomes simple. Under these conditions all plants which become homozygous will be exactly like Baart and at the end of 6 backcrosses 8 out of 10 would be exactly what was wanted with reference to the 20 desirable genes of Baart. In order to keep the plants from becoming homozygous for susceptibility to rust, the gene for resistance must be carried by selection. As long as backcrossing continues this pair of genes either will be heterozygous resistant or homozygous susceptible. Heterozygous resistant plants can be identified by appropriate tests. Three generations of self pollination after the last backcross will get this gene into the homozygous resistant condition.

Instead of growing millions of acres of hybrids each year, a few thousand plants were sufficient.

Genes for resistance to other diseases, or additional genes for resistance to the same disease may be added just as readily without danger of jeopardizing improvements already made.

Atlas 46 barley is resistant to mildew and scald disease. Big Club 43 wheat is resistant to bunt, stem rust, and Hessian fly. Four other wheat varieties are resistant to bunt and stem rust, and six are resistant only to bunt.

All of these have been bred by the backcross method and in no case was there a failure to reach the objective.

It must be emphasized that this method is possible only because characters such as disease resistance are determined by specific hereditary factors or substances, the genes, and that the genes are so constant that they can be transferred as units from one variety to another without altering the characteristics which they produce. The success of the backcross method is one demonstration that this fundamental principle of genetics is true.

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NEW PUBLICATIONS

A copy of the publications listed here may be obtained without charge from the local office of the Farm Advisor or by addressing a request to Publications Office, College of Agriculture, University of California, Berkeley 4, California.

THE CHICKEN BUSINESS IN CALIFORNIA, 1948, by Arthur Shultis and W. E. Newlon, Cir. 147, November, 1948.

This circular covers the business aspects of chicken raising.

POULTRY HOUSES AND EQUIPMENT, 1949, by J. E. Dougherty and H. L. Belton, Bull. 476, Revised by H. L. Belton and V. S. Asmundson, February, 1949.

This bulletin gives plans and construction details for all styles of poultry houses from concrete floored weatherproof structures to open cage houses.

DONATIONS FOR AGRICULTURAL RESEARCH

Gifts to the University of California for research by the College of Agriculture accepted in February, 1949

BERKELEY

Dr. William H. Boynton $183.28
Veterinary Science

California Spray Chemical Corporation ..... 1 gallon Rix Spray
Plant Pathology

Corn Industries Research Foundation $1,500.00
Plant Nutrition

E. I. DuPont De Nemours & Co. ..... 25 lbs. Fermate
Plant Pathology

Lederle Laboratories Division ..... 60 lbs. animal protein factor
Poultry Husbandry

Merck & Company ..... 633.8 grams of Streptomycin base
Veterinary Science

Merck & Company ..... 1 gram animal protein factor concentrate
Poultry Husbandry

Sugar Research Foundation, Inc. $1,000.00
Food Technology

Sugar Research Foundation, Inc. $702.00
Plant Nutrition

Swift & Company ..... 100 lbs. mustard seed meal
Poultry Husbandry

U. S. Public Health Service $3,983.55
Plant Nutrition

Julius Hyman & Company ..... Entomology ..... 1 gal. compound 118 emulsifiable concentrate
1 50-lb. bag 1% compound 118 dust; 1 50-lb. bag 2½% compound 118 dust
1 25-lb. bag 2½% compound 118 dust; Batch W-4
In acknowledging this donation in the March, 1949, issue of California Agriculture, it was erroneously credited to Klauss-White.

DAVIS

Stanley Anderson Hatchery ..... 100 day-old cockerels
Poultry Husbandry

California Committee on the Relation of Electricity to Agriculture $3,375.00
Agricultural Engineering

E. I. DuPont De Nemours & Co. ..... 1 pound D1-Lysine Monohydrochloride
Poultry Husbandry

Fox Products Company ..... 1 automatic valve for poultry waterer
Poultry Husbandry

Lederle Laboratories Division ..... 3 gms. Folvite powder
Poultry Husbandry

Merck & Company ..... 2 lbs. Vitamin B12 concentrate—25 MGX AMP Biotin
Poultry Husbandry

L. P. McChesney ..... Two poultry waterers
Poultry Husbandry

Charles Mumford ..... 1 galvanized iron water trough
Poultry Husbandry

Penick & Ford ..... 25 lbs. corn germ
Poultry Husbandry

Research Corporation $4,000.00
Chemistry

Wyman-Foorman Co. ..... 25 lbs. corn germ
Poultry Husbandry

RIVERSIDE

American Cyanamid Company $2,000.00
For investigations on evaluation of organic materials for insecticidal and fungicidal value against fruit pests