Proceedings of the Iowa Academy of Science

Volume 48 | Annual Issue Article 7

1941

Recent Advances in Applied Plant Genetics - Paper Presented at the Fifty-Fifth Annual Meeting

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RECENT ADVANCES IN APPLIED PLANT GENETICS

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One has but to compare the present-day methods with those of the pre-Mendelian era to realize fully the extent to which recent advances in genetics have been utilized in the improvement of plants. Modern plant breeding research not only utilizes the information from fundamental genetic investigations but also formulates basic facts that may result from the more practical phases of work.

In the early periods of plant breeding when the different crops consisted of many biotypes, improvement was comparatively easy and often consisted of but simple selection of the strains best suited to the new environments. When this initial improvement had been made the problem of efficient production was far from permanently solved for with increased intensity of agriculture came new problems and hazards in crop production. The solution of these problems has been possible largely because of the advances made in genetics and closely related branches of science.

Although many illustrations may be used only a few of the recent accomplishments will be cited to show the relation of genetics to plant breeding. Perhaps examples in the improvement of two of the naturally self-pollinated crops, wheat and oats, will serve to illustrate how modern genetics operates as the working tools of a plant breeder. It should be emphasized that these illustrations could have been selected with equal effectiveness in any of the naturally cross-pollinated plants such as corn and many forage crops.

For many years the greatest hazard to successful spring and winter wheat production was the frequent losses resulting from epiphytotics of black stem rust caused by the pathogen *Puccinia graminis tritici.* None of the varieties of *Triticum vulgare,* the commonly grown hexaploid wheat species, possessed adequate protection against the many physiologic races of this disease when environmental conditions were favorable for infection. It had been observed by many investigators that most varieties and strains of *Triticum durum* and *Triticum dicoccum,* two tetraploid species, possessed a high type of resistance to many races of the pathogen. Studies on the phylogeny of the Triticum species had revealed the fact that in the inter-specific hybrids 14 of the chromosomes in the tetraploid species normally paired with 14 of the 21 in the vulgare or common wheats. These cytologic investigations therefore gave a genetic basis for the belief that genes for rust resistance could be transferred from the less desirable durum to the more desirable vulgare types. The selection of a stable 42 chromosome wheat from the cross of 28 and 42 chromosome parents could only result from the chance recombination of male and female gametes each having 21 chromosomes. The probability of such a recombination can be calculated from a knowledge of the cytologic behavior of the F_1 hybrids at meiosis. Since the F_1 hybrid has 35 chromosomes, 14 from the durum parent and 21 from the vulgare parent, or, in effect, 14 pairs and 7 univalents, a 21 chromosome sporocyte would result only when all 7 univalents by random assortment migrated to the same pole. The probability of this occurrence is .5 to the 7th power or once in 128 times for either egg cells or sperm cells. The chance mating of two such gametes would be the product of these probabilities or once in over 16,000 times. The possibility of finding such an individual would not be very great, but in actual breeding tests this recombination occurs more frequently than the calculated value since pollen grains with chromosome numbers intermediate between the parental types are non-viables.

Hayes and co-workers at the Minnesota Station were among the first to utilize the potential value of these interspecific hybrids in wheat improvement in the cross of the vulgare variety Marquis with a durum variety called Iumillo. In a relative small F_2 population no vulgare types were found but in the F_3 generation a few vulgare type plants were obtained highly resistant to stem rust. Progenies of these plants were crossed with a vulgare wheat of good milling quality and from among the many strains in subsequent generations of this second cross a spring wheat variety named Thatcher was selected and increased for distribution in 1935.

Table 1—Comparative yield and stem rust infection of Thatcher, Marquis, and Ceres Wheat in Minnesota in 1935.

Varieties Compared	No. of Trials	Bu. Per Acre	Weight Per Bu.	% Stem Rust
Thatcher	31	27.3	55.5	5
Marquis	31	6.5	43.4	86
Thatcher	26	24.1	53.5	6
Ceres	26	9.1	46.0	70

By 1938, 80 percent of the spring wheat grown in Minnesota and a considerable part of that grown in adjacent states as well as in Canada was of the variety Thatcher. The actual value of this plant breeding accomplishment as a means of protection against losses due to stem rust reflects the economic implications of modern plant genetics.

Shortly after the successful interspecific hybridization by Hayes of *Triticum vulgare* and *Triticum durum*. McFadden of South Dakota crossed *T. vulgare* with *T. diocum,* variety Yarslov Emmer. From this cross, the 42 chromosome wheat varieties Hope and H-44 were selected. These selections, like the one previously discussed are highly resistant in the adult plant stage of growth to all physiologic races of *Puccinia graminis tritici* when grown under normal environmental conditions. The stem rust resistance of these varieties is inherited in a simple Mendelian ratio with resistance dominant over susceptibility. A survey of the wheat breeding projects in the United States in both winter and spring types shows that this variety is almost universally employed as the source of genes for resistance to stem rust. At the present time it is almost as difficult to find rust susceptible material among the experimental selections in a wheat breeder's nursery as it was 10 years ago to find strains with only moderate protection against this pathogen. The genetic attack on this problem has for all practical purposes eliminated the greatest hazard to a stabilized wheat production.

Another example will be used to illustrate recent advances in plant genetics as applied to the improvement of oat varieties. In the oat crop, as in spring and winter wheat, breeding for disease resistance has occupied the attention of investigators in many states. The diseases most destructive to oats are loose and covered smut, caused by the pathogens *Ustilago avenae* and *U. levis,* respectively, stem rust, *Puccinia graminis avenae,* and crown rust, *Puccinia coronata avenae.* From previous investigations, the mode of inheritance of resistance to these diseases had been fairly well established. Stem rust resistance from a study of many crosses was shown to be inherited on a single factor basis with resistance dominant. In respect to crown rust, F_2 generation ratios of 3 resistant to 1 susceptible and of 9 resistant to 7 susceptible have been reported depending on the varieties used in the crosses. Similarly, in the inheritance of reaction to smut, either one or two major factors are involved. Both loose and covered smut reaction are controlled by the same genes. In all studies reported, reactions to these diseases are independently inherited—a factor of considerable importance in the recombination of genes for disease resistance.

Although resistance to these diseases was found separately in different oat varieties, the basic facts resulting from studies on their inheritance suggested the possibility of combining resistance to both of the rusts and to both of the smuts into a single well adapted variety. At the Iowa Experiment Station in cooperation with the United States Department of Agriculture a series of crosses were made of which one will be used to illustrate the procedure used. Victoria, a late maturing unadapted variety of *Avenae sativa* was selected from among several varieties surveyed as possible parental material because of its resistance to many physiologic forms of crown rust and because it also was very resistant to the races of smut common to this area. This variety was crossed with Richland or Iowa 105, a well adapted variety with very good resistance to stem rust. From among the segregates in this cross several early maturing strains were selected with combined resistance to the diseases under investigation. Two of these strains, Boone and Tama, have been increased and the variety Boone was distributed in 1940. The comparative performance of these two varieties with standard types grown extensively in this state under conditions of severe crown rust infection is shown in Table 2.

Table 2—Comparative yield of Boone, Tama, and Standard oat varieties in 1938.

Variety	Bushels Per Acre	
	Ames	Kanawha
Boone	70.6	70.0
Tama	65.6	85.3
Richland	41.9	37.2
Iogold	37.8	27.8
Gopher	42.2	43.9

An opportunity was afforded to study the relation between crown rust infection, yielding ability, among 442 selections grown in rod row trials at Ames and Kanawha in 1938. From these studies reported by Dr. Murphy the correlation between yield and crown rust was —.77 and the regression of yield on crown rust infection was .44. These results emphasize the importance of adding genes for crown rust resistance to oat varieties and illustrate how the application of genetic principles may solve important agronomic problems.

Although the illustrations of applied plant genetics in crop improvement have featured the development of disease resistant varieties, examples could have been used for many other major plant characters. The application of Mendelian principles in the improvement of varieties in respect to cold resistance, lodging resistance, quality and yielding ability are closely correlated with improvement in disease resistance. The inheritance of agronomic characters is not simple because many genes contribute to the expression of these characters. This fact does not minimize the value of a genetic approach to the solution of these problems. Multiple factor interactions differ primarily from those cited in that larger populations are needed to assure the recombination of desired germ plasm.

Although many noteworthy achievements have resulted from the application of genetic principles, the future should hold as much or even more promise. Future advances in genetics and cytology will undoubtedly open new and interesting fields in plant improvement.

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