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Double Cross: Agriculture and Genetics, 1930 to 1960

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This paper discusses the role of genetic technology and application in agriculture between 1930 and 1960. Topics covered include the role of genetics and the relationship that theory, education, administration, professionalism, economic and social considerations bore to genetics.

Source material was obtained from literature on various aspects of the subject, found at the libraries of Portland State University, the University of Washington, Oregon State University and the University of Oregon.

The facts reported in this paper indicate a dramatic increase in the use of genetic technology during this era. This increase was achieved largely by using analogic variants of very few true innovations. Also, as a by-product of this increase, there was a concurrent decrease in the diversity of cultivars used in agriculture. This decrease occurred in part due to neglect on the part individuals doing genetic research to develop and/or utilize statistical means to measure the relationship between increased use of one type of cultivar and concurrent decreases in other types of cultivars as a result of non-use.

DOUBLE CROSS:

AGRICULTURE AND GENETICS, 1930 to 1960

by

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PREFACE

Genetics is the study of heredity and heritable change. Through the period of 1930-1960, the study of agricultural genetics and genetics in general was pursued by gaining knowledge in the mechanisms of heredity in a multitude of cultivar types, and using this knowledge to manipulate genetic mechanisms with the goal of increasing productivity and quality. This era represents a transformation in that at the beginning of this era, geneticists primarily studied heredity, and by the end they were working for the first time to manipulate the potentials and attributes of heredity.

This paper discusses selected aspects of the development of genetic technology in its agricultural applications during this era. This time period is notable for developments in genetic techniques, the growth of professional genetic research and theory, and a significant decline in the number of farmers and land used for agricultural production in the United States as well as in the genetic diversity of cultivars.

There are several meanings inherent to "Double Cross," the title of this paper. These include the predominant technique used for agricultural genetics during this era, the effect(s) that about 3.2 million farmers who stopped farming, might have felt directly as a result of the widespread application of this technique, and the effects this technique has brought upon farming in general as well as the biosafety of the planet.

Additionally, the title has an ironic pertinence to what was not done, at least with regard to the apparent intentions of genetic researchers in agriculture. What was not done was to track the relation between an increased use of a select cultivar, and the reduction of other cultivars occurring as a by-product of this process. Research in agricultural genetics is for a positive end--providing increased quantities of nutritional food for a rapidly growing population. Due to this, the likelihood of any single geneticist or group of geneticists deliberately planning to promote one type of cultivar over another, with the thought in mind of causing the extension of other cultivars, is very slight. Yet that has been one effect of the double cross technique.

What was not done, may be seen as perhaps the most elaborate by-product of the double cross. That is, in part due to the use of this technique, tens of thousands of cultivars were lost between 1930-1960. To this end and in the larger issue of the use of Applied Genetics, the double cross has perhaps its most ironic (and cynical) application in the effect the process of scientific-agricultural research may be seen to have brought upon itself and the world at large due to its lack of attention during this era to the so called homogeneity issue. The irony is that by emphasizing very few cultivar types for production, the scientific field has overlooked the most fundamental means of perpetuating its product--diverse seed stock.

However, to emphasize that aspect of the issue would be to condemn that area of science beyond the role it played in the transformation. The research and increased use of hybrid technology was promoted due to the need for securing food for the people of the United States and other countries, and there is little doubt that these needs could have been met without increased technology. However, in providing a means to fulfill this need, it is perhaps a truth that the extent to which the double cross has been used has gone beyond that which was necessary.

With non-organic production, a tendency to emphasize one technique of production extensively over another for the purpose of ease of production as well as standardization of production is considered common wisdom. In organic production, this emphasis will lead to a high degree of specialization in the organisms produced. The difference is that with organic production, once the base material is gone, there is no current way to re-produce it: We can not just use another material or combinations of materials to produce the same thing.

This paper does not make a statement that there was a deliberate attempt to cause the destruction of thousands of cultivars; rather, that the emphasis was placed so strongly upon increasing agricultural production that the loss was a by-product which was neither expected or anticipated.

Histories of genetics emphasize the development of genetic technology and theory, usually without going into extensive details regarding the extent to which the technology has been applied. The emphasis in histories of genetics is primarily to show how the theory developed and the different aspects to which the technology has been adapted.

Agricultural histories, on the other hand, characteristically emphasize the diminishing numbers of farmers despite moves to organize farming by the use of unions and cooperatives to increase their stability as a productive force. The cause or blame of both the decrease and the need to organize is attributed primarily to changes in Federal policy.

This paper combines the development of genetic technology and agriculture in an attempt to create a synthesis in an area were historical information on these combined effects is lacking. The focus of this paper is on 1) the course that agricultural genetics followed and 2) the effects brought about by the transformation of genetics in the areas of theory, education, administration, professionalism, economic, and social considerations. The development of genetic technology has brought about many benefits and changes, as well as risks; for that reason, the primary issue raised by this paper is whether the benefits and changes outweigh the risks. Stated differently, may the result of these changes, for whatever reason, be seen as a double cross?

CHAPTER I

GENETIC TECHNOLOGY, 1930-1960

A. PRE-1930 BACKGROUND

The study of genetics was performed by observing hereditary attributes of a given organism in an attempt to determine the frequency that a given trait will occur through several generations. By observing, categorizing, and documenting his research, Gregor Mendel wrote the first account of hereditary transference in 1866, two years before Charles Darwin's study of the variation of Animals and Plants was published.[1]

Briefly, Mendel's formula for genetic recombination incorporated two so-called laws. The first law states that the ratio of recombinant dominance will be at approximately 3 to 1 (3:1) in the second generation. The second law, called the law of independent assortment, states that when three or four pairs of characters are crossed, their elements are independently assorted in the germ-cells of the next generation. Although the second law was later found to be true only in some instances, the utility of Mendel's perspective may be seen as both a fundamental change and an advancement over Darwin's perspective of heredity.

Darwin stated that the process of natural selection was why species evolved from more primitive species. He maintained that selection works spontaneously in nature. He pointed out that not all individuals of a species are exactly the same but, rather, that individuals have variations, and that some of these variations make improved adaptation to particular ecological conditions. Diversity is central to Darwin's perspective of the "survival of the fittest." Mendelism may be viewed as a change of perspective on evolution which utilizes an instrument to determine adaptation "to particular ecological conditions" by showing at what rate some aspects were dominant and others were not.

Mendel's perspective permitted an advancement in that by the 3:1 reproductive ratio, he in effect provided a way to determine specific traits for recombination. Further, due to his law of independent assortment, means or instruments were developed to examine the viability of this law. In short, by showing a consistent way to observe selection, Mendel provided a pattern useful in selecting hereditary transference. In turn, this provided the basis for the science of genetics.

B. INSTRUMENTATION PRIOR TO 1930

One instrument developed prior to 1930 was "linkage," the study of the behavior of sex chromosomes. This was studied partly to determine what traits were transferred by a given chromosome and partly to find a common basis for measuring the frequency of a given trait in successive generations. Incomplete linkage was researched by Bateson and Punnett in 1905 at Cambridge. In one experiment they found that two dominant characteristics were contributed by the same parent, a phenomenon called "coupling." In another experiment they found that one dominant and one recessive gene had been contributed from each parent, a phenomenon called "repulsion." The discovery of coupling and repulsion led to Bateson's postulate that linkage would work on either a 7:1 ratio or a 15:1 ratio, which he called reduplication. Unfortunately this postulate was wrong, but it led to the identification the male chromosome.

McClung, in 1901 at Columbia University, suggested that what is now known as the X chromosome is male determining, which was later found to be opposite of of what it is. (For a long time there was doubt that it was a chromosome; hence the designation "X.") This occurred in an attempt to count and identify chromosomes, which later, in 1905, was successful. In this later analysis, the Y chromosome was also found, providing the now familiar XX designation for female and XY for male.

Finding out which chromosome determined which sex provided a base of reference for variance on a perceived 1:1 ratio for male and female, the first ratio that incorporated linkage to sex.[2] (Later studies would show that males have a slightly larger reproductive ratio than females; however, they also have a higher lethal ratio, allowing the 1:1 ratio to stand.[3]) Having a ratio based on sex provided a greater potential of determining the frequency of a given trait. This was later aided by the study of crossing over, another instrument, developed by Morgan in 1911, at Columbia University.

Crossing over is a process that occurs during meiosis, whereby a part of one strand of chromosomes may be exchanged with an equivalent part from its partner. The result of crossing over is the transmission of parental genes. The higher the cross-over frequency, the more extensive the recombination of parental genes. Linkage and crossing over were two of the primary scientific means of determining heredity transference. In effect, they were primary instruments in the geneticist's tool box. These instruments were not significantly refined until the 1930's, when a third, older observational process, called "cytology" was integrated into genetic study.

Cytology, the study of cells, was one of the basic means of genetic research, and was existent earlier than Mendel's work. The early influence of cytology contributed to much of the later genetic research. In brief, cytology is a process by which the physical attributes of the cell may be determined. By 1924, knowledge of the location of the chromosomes within the nucleus were determined on a gross level, which led to increased study on several plants and animals, in an attempt to determine the the locations of crossing over and linkage.

In turn, cytological study provided a greater understanding of how given characteristics are reproduced in successive generations. The recombinant characteristics revealed by cytology show that when crossing, any given characteristic that will be transferred is dependent upon its position on the chromosome and how that interacts with its partner. That is, as the transference of heredity material is contingent on the physical position of the chromosomes during meiosis, and as these tend to act consistently, times when Mendel's law of independent assortment may apply are limited mostly to contingencies of environmental or other outside differences. This contingency was the reason for much of the work on recombination and environmental effects, and served to lay the foundation for later work.[5]

C. DEVELOPMENTS IN THEORETICAL GENETICS

From 1930 to 1960, called the Contemporary era of Genetics, the development of Genetic theory was significant for increased classification and resolution to determine heritable change. Including changes which may be observed on a cellular, chemical, and statistical level, as well as observable changes occurring on the progeny of a subject, Genetic studies incorporated many different aspects of biology, chemistry, and statistics to aid the development and codification of the subject.

The state of the art in genetic developments during 1931 was a dramatic comprehensive increase in the understanding of the relation between cytological and genetic phenomena. By 1930, work by Muller[6] and others who studied the effects of radiation causing mutation to specific parts of chromosomes, developed a basically codified understanding of the relation between some physical characteristics of a specimen, (primarily Drosphila Melanogaster--the fruit fly) and the relative positions of certain aspects of chromosomes on the cellular level. Harriet B. Creighton and Barbara McClintock[7] realized that, based on the combination of cytological mapping and observable heritable characteristics, there were specific phenomena originating on a cellular level which produced a specific trait in successive generations. By back crossing specimens with other specimens not having these traits, Creighton et al showed the relation of linkage to the reproductive frequency or rate of a given trait.

Creighton et al investigated Zea may, (Maze) and showed by a map of the frequency and type of evidence of a knob on the second smallest chromosome that the relation of the knob to the number of first generation offspring (F1) also having such a knob, when determined cytologically, was a consistent feature of the chromosome having that characteristic. That is, the relation of linkage and crossing over may be determined cytologically, and those findings tend to be consistent with the reproduced characteristics of the Zea may[8]. The significance of this correlation was the realization that paring chromosomes change parts at the same time they exchange genes, which is during meiosis, as well as providing cytological (observable) evidence of the phenomenon.

The relation that linkage and crossing over were determining aspects of heredity occurring during meiosis was allowed by the confluence of cytology and genetics. This confluence enabled a consistent measurement on two separate occasions, cellular and heritable, to show the rate of consistency or frequency of reproductive types, which provided a means or "instrument" of predetermining hereditary types. Growth in genetics during the 1930's consisted of continued combinations of different codified aspects of the biological sciences as well as the introduction of new aspects, which, focused on rapidly reproducing subject matter (homo- or heterozygously), permitted an acceleration of investigative techniques.

G. W. Beadle and E. L. Tatum[9] researched biochemical reactions in Neurospora (mold) during 1941, to determine the nature of genetic interaction on a chemical basis. It was accepted that although genes were themselves part of an overall organic system, they served to control or regulate specific actions within the system, either by serving as an enzyme or by determining the specifications of an enzyme. Beadle et al applied the known fact that an organism can be irradiated to eliminate its ability to perform a given internal process (in this case nutrient metabolism), and then placed the irradiated organism on an external medium which could provide this removed metabolic ability to synthesize nutrients.

In doing this with Neurospora, they were able to determine the relation between the rate of growth and the amount of pyridoxine (Vitamin B6) in the culture medium provided for the mold. This new procedure provided a means of determining what nutrients are necessary for the growth of Neurospora. By analogic application of this technique to other plants, an increase of plant growth knowledge followed. In addition, the potential discovery of new vitamins and vitamin-growth relationships became more probable. This development was significant toward the increased theoretical means of determining nutrient benefits.

Beadle et al investigated the relation between mutated specimens and cultures designed to permit growth despite the altered state of the organism, with a result of finding a predictable means of determining and inducing specific changes by chemical modifications. Oswald Avery, Colin

Macleod and Maclyn McCarty[10] took a similar approach, though on a more minute level, when they investigated the chemical nature of substances causing transformation in the Pneumococcal type bacteria from non-virulent to virulent. This research yielded the first account of the significance of desoxyribonucleic acid (DNA) as the primary material of heredity, and served to link bacteriology with genetics. The focus of Avery et al was "to isolate the active principle from crude bacterial extracts and to identify, if possible, its chemical nature or at least to characterize it sufficiently to place it in a general group of known chemical substances."[11] They were looking for a cause of the transformation of a strain from non-virulent to virulent, and the test results showed that DNA was the principal agent in the transformational process. This was the first time DNA had been isolated as the cause of such a transformation. Refined DNA, "an intracellular enzyme"[12] was released into an active colony of Pneumococcus type II and allowed the transformation to Pneumococcus type III. The DNA was extracted from type II and applied to type III, with the result that the culture colonies became type III.

This finding was dramatic to the field of genetics. It presented a means of explanation on the basis of sub-cellular activity to the question of hereditary transference. This led to a closer study of the mechanisms, physical and chemical, comprising DNA, with the primary aim of determining those characteristics and the secondary aim of manipulating DNA to effect the base mechanisms of heredity.

James D. Watson and Francis Crick[13] built the first model showing the double helical design of DNA. In doing so, they explained both its physical and chemical nature. The structure they defined has "two helical chains, each coiled around the same axis,"[14] held together by purine and pyrimidine bases which are joined together in pairs, making a single base from one chain which is hydrogen bonded to a single base on the other chain. The chemical compositions of the bases consist of "adenine (purine) with thiamine (pyrimidine) and guanine (purine) with cytosine (pyrimidine)."[15]

This model set the stage for increased verification of differing relations of DNA, with regard to the composition of paring types and their composition. Moreover, the DNA model provided a virtual stratification of genetic instrumentation ranging from the relation of Cytology and Genetics down to the physical characteristics of DNA. The model also showed how the structure permitted recombination as well as being the base mechanism of heredity.

On a statistical level, the development of so-called population genetics was adding interesting aspects to the question of heredity. From the 1930's onward, the question of genetic stability was investigated. A controlled environment is essential to determine genetic stability, which is rare in nature, to obtain accurate probability.[16] The Hardy-Weinberg formula of determining genetic stability, based on a Mendelian formulation, provided one acceptable means of theorizing about genetic stability.

The Hardy-Weinberg formula requires primarily 1) using a population large enough so that sampling errors may be statistically insignificant, 2) ensuring that no mutation occurs within the population, and 3) ensuring that there is no selective mating.[17] Based on these requirements and on the theoretical level only, it was found that in large populations, significant genetic changes tended to be prohibited by nature. Additionally, induced changes in populations tended to be eliminated through time due to the overall diversity in any given gene pool of predominating over specialized or selected traits. The significance of this to theoretical genetics tended to provide a sense of assurance that induced changes would have no lasting effect on any given gene pool. Population genetics experienced slow development, in part due to the lack of statistical knowledge, and in part due to a general lack of understanding of the utility of this instrument.

But for all these advances, genetic theory during this era had just begun to explain what was done in the form of applied genetics. Theoretical developments were slow and methodical, the norm for scientific development, and it was not until the Watson-Crick model that a highly stratified, diverse understanding of genetics begin to form. Meanwhile, applied genetics was finding wide spread utilization.

D. DEVELOPMENTS IN APPLIED GENETICS

The most significant developments in plant genetics occurred in hybridization as a result of the so-called double cross technique, originally developed by Donald F. Jones.[18] The double cross is a process in which first a strain having a given, desirable trait is self-fertilized. This process is repeated with at least three other strains, each having a select favorable trait, though not necessarily the same trait as the first one, with a result of at least four distinct or purified strains being produced. Following this, the strains are grown and the two groups of two purified strains are cross bred into one strain, with the result of a vigorous hybrid, showing all the selected aspects, being produced.

```
A \
   + = Aa\
a /       \
           + = AaBb
B \       /
   + = Bb/
b /
______________________
F1     F2      F3
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Figure 1. Model of double cross.

The above representation shows that there are three generations (F1, F2, F3) necessary for the production of double crossed hybrids. During the second generation (F2) there is a 50 per cent average drop in the plant's vigor which by the third generation (F3) is replaced by an approximate 125 to 150 per cent increase. Stated differently, if any of the strains in F1 will produce 10 ears of corn per square foot, in F3 they will produce 12.5 to 15 ears per square foot,[19] as well as being an effectively designed plant.

This innovation was developed in 1914, and although there was an initial hesitation to use this technique,[20] it was soon found that this process could be duplicated with virtually any heterozygous (self-fertilizing) plant[21] (with varying degrees of difficulty), with the result that by 1930 this process was introduced commercially and by 1940 it was widespread.[22] In 1930, however, this process was understood in terms of the frequency with which the genes in the F3 generation recombined, at a ratio of approximately 12.5 percent of each of the F1 generation and 25 percent of the F2 generation.

Double crossing allowed a shift in plant breeding, which earlier was based upon largely empirical data. Through double cross based innovations, genetic control of herbicide resistance, lodging, pest and disease control, and environmental adaptability were facilitated. Although attempts to control lodging originated at the turn of the century, it was not until the late 1940's, that effective modification of stem length in wheat crops, from longer to shorter, was attempted by the development of Gains wheat.[23] Experiments in Indiana showed an increase from about 1200 kilograms per hectare (kg/ha) to 1500 kg/ha from 1940-49 and to almost 2000 kg/ha by 1966. Similar results were found in London during the same periods. For cereals, lodging control was perhaps the most significant innovation. By this time, Gains wheat was explained genetically by both the statistical contributions of the preceding generations and the necessities of the wheat plant's vigor. This could also be understood in terms of the biomechanical nutritional necessities, showing the genetic necessity of select nutrients for a regulation of growth rate and, to a certain extent, growth type.

Lodging control was a means of strengthening plants against some levels of natural hazards, primarily high winds and heavy rains. Breeding for resistance to pests was more complex (and is still in experimental stages today). Fundamentally, breeding for resistance requires 1) the development of effective screening techniques, 2) finding sources of resistance, and 3) recombining resistant cultivars with other desired effects. The first partially successful attempts were made in the 1950's, under the so-called gene for gene theory.[24] This theory was applied by matching genes for resistance in the host with genes for pathogenesis in the pest or parasite. After the theory was first applied to provide rust resistance in Flax, it was soon found that fungus, bacteria, and "viruses" could also be genetically resisted. The limitation of this method lies in the diversity and adaptability of the parasite. The disadvantage is that by creating resistance to one parasite, invariably resistance to another diminishes.[25]

The discovery by Avery et al, showing that DNA determined heredity, contributed to selection for resistance by providing a means of classifying what types of mechanism in what relations are necessary for preferential traits. This type of hybridization required many generations of controlled experiments to develop vigorous cultivars. The increasing classification of what produces change, or in this case, change in the form of increased resistance as a heritable potentiality, allowed for an increased understanding of selection for this end.

Genetic pursuit of environmental adaptability involves selection of strains whose growth may be adapted to differing climates. Research of this type originally was developed to increase crop production at Katumani in Kenya, which has a tropical climate. In 1957, B. D. Dowker[26] used a technique for calculating the probability of the amount of rain fall over 60 day periods, and then bred both domestic and imported cultivars via double crossing so that they would show early vigor as well as early maturation, with successful results. This involved a different use of population genetics in that Dowker selected for a predominance of early developing cultivars (for a selected population) to accommodate the environmental necessities.

In temperate climates, growing seasons are determined by average temperature. Red beets, carrots and turnips are susceptible to "bolting," or flowering early due to temperature change and longer daylight hours. G. Bell did research in 1946, and found that bolting was a heritable characteristic. As above, by recombining select seed stock, he was able to increase the red beet's resistance to bolting. This permitted the beet to grow for an additional six weeks. This change permitted an increase in crop production from 25 tons/ha in 1940's to 35 tons/ha in the 1960's.

The employment of the double cross technique of hybridization in combination with an increased knowledge about adaptability, environmental necessities, and pest resistance, enabled a substantial improvement in overall crop quality and quantity. However, the double cross technique is utilizable only on heterozygous cultivars, which does not include animals.

Genetic research was also forming a basis in the animal industry, particularly in the hog industry. As mammals can not self-fertilize, it was not possible to incorporate the double cross technique or other means of direct in-breeding. What was done in the case of hogs was based on research done in Denmark, where the Wiltshire hog originated. Initially, 15 families of this hog were imported to the United States (beginning in the 1930's) and studied through successive generations for high meat to fat content. Four families having the most favorable ratios were selected, then bred so that two preferred animals were bred with the two next best. In turn, the offspring of these were out-bred with other hogs showing favorable characteristics, so that new, highly bred strains were developed. With this innovation came a more rigorous tagging of hogs to diminish the potential of accidental inbreeding,[27] and to adapt the previous role of tagging for pedigree lines, as well as the development of so called selection indexes, a codified chart of favorable physical characteristics.[28] Much like the dissemination of the hybrid tendency found in corn, the means and ability to up-breed hogs as well as horses, cows, goats, and sheep, followed suit. This form of genetic breeding rapidly gained momentum due to its simplicity, and of course, its productivity.

In the late 1940's, the use of artificial insemination (AI) was initiated. The advantages of this type of genetic control were two fold. The first advantage was that through the use of AI, semen could be safely stored in cooled carbon dioxide for several years, which increased a sire's reproductive longevity. The second advantage was that a single bull could greatly increase its breeding productivity at a reduced cost, compared to natural methods. By 1960, artificial insemination accounted for one-third of the cattle production in the United States and half of the production in Great Britain. Due to these advantages, artificial insemination rapidly gained wide popularity.[29]

In light of the utilization of genetic technology, it is apparent that on the part of both animal and plant geneticists, as well as the agricultural population at large, double crossing for plants and up-breeding and artificial insemination for animals gained great popularity and was used widely. This utilization was conducted despite the lack of theoretical knowledge to explain why it worked. What was important was that crossing technology worked and that it dramatically increased agricultural production while reducing costs. There was the additional perception that genetic breeding and crossing helped to stabilize crop production through providing increased quantities of production, which was permitted by the practice of predominantly using the most ostensibly favorable strains within a given species.

In light of the success of genetic breeding and crossing, it is not surprising that educational institutions tended to advance the belief that a steady increase in numbers of effectively purified strains would be beneficial. The perpetuation of this belief transformed the perspective of agricultural production from a Darwinian approach, which was prominent in the late nineteenth and early twentieth centuries, to a Mendelian approach--utilizing selection for predetermined ends--which was gaining popularity due to its expedience and economy, throughout this era.

CHAPTER II

EDUCATIONAL DEVELOPMENTS

A. TRAINING IN GENETICS

> What was worse, it was possible to get a university degree in biology without learning any genetics. That was not to say that the geneticists themselves provided any intellectual help. You would have thought that with all their talk about genes they should worry about what they were. Yet almost none of them seemed to take seriously the evidence that genes were made of DNA. This fact was unnecessarily chemical. All that most of them wanted out of life was to set their students onto uninterpretable details of chromosome behavior or to give elegantly phrased, fuzzy-minded speculations over the wireless on topics like the role of the geneticist in this transitional age of changing values.[30]

The so-called "land grant colleges" were established by the Morril Land Grant Act to help rural America maintain and increase productivity in the agricultural realm by education and educational extension into the community. As the land grant colleges were, in effect, designed for the purpose of maintaining this relationship with the community, it is no surprise that educational methods and the possibilities yielded by these institutions were traditionally focused toward applied technology rather than emphasizing developments in theory. It is due primarily to this vocational emphasis that the land grant colleges were rather slow in building an emphasis in the biological and theoretical considerations of agriculture, as opposed to technological considerations.

In part as a result of this emphasis, there was a slow increase in the educational possibilities in Genetics between 1930 and 1960. At the outset, training was almost nonexistent, and by 1960, there were the beginnings of training based on enormous amounts of information pertaining to crossing techniques, disease and pest resistance, environmental adaptation, and nutrients to increase crop and livestock production. However, education and guided experimentation in these developments did not begin to occur until the late 1950's. Leading to that development, education was modified by the perceived utility of genetic technological applications to serve agricultural production.

Training in agricultural genetics was, for the most part, focused on increasingly well known concepts of applied double-crossing, the use of fertilizers for nitrogen fixation and other nutrient benefits, a gradual increase in animal crossing, and, by the late 1950's, the use of artificial insemination. However, by the time artificial insemination was taught as a technology in general curriculum it, like other animal crossing techniques, was taught in veterinary schools, which was by then a study taught with distinct differences from agricultural education.

The general agricultural education curriculum included training in agricultural production, supplies, mechanics, products, horticulture, forestry, resource management and conservation.[31] Education in genetics played a comparatively small but significant role, having most exposure in the form of product development and equality.[32] By the mid 1960's, as part of a fundamental shift in educational emphasis, genetics was also included in resource management, in the form of "conservation."

In the 1930's, the classes used in agricultural education included in the first and second years geography, chemistry, mathematics, English composition, plant anatomy and physiology. In the third and fourth years there was an increased emphasis in laboratory training focused toward resource production and conservation.

The primary change in curriculum occurring between 1930 and 1960, lies in the gradual but steady shift in emphasis from lecture classes to an increase of research and experimentation. The origin of this shift occurred between 1946 and 1952, which was in part due to the general increase of PhD's trained in biology[33] beginning to work in the land grant institutions. Between 1956 and 1965, curricular options begin to include scientific, technological production, and business courses;[34] the former two are notable for their emphasis in experimentation. These transformations may also have been attributed to the increased national emphasis in the 50's to make the 50's the "decade of the physical sciences."[35]

These changes, as well as the increase of genetic theory by the 1950's, permitted a concomitant shift in lower division classes towards base explanations of heredity in the course of general biology classes, though the training was as incomplete as the knowledge at the time. The shift in emphasis was often paralleled in upper division classes by experiments in cross-induced hybridization and the relation of hybrid vigor to beneficial nutrient solutions, as well as to crossing techniques themselves. In addition to this, and as the knowledge and practice developed, through the 1950's, there was a gradual inclusion of preferential crop types for select environmental and climatic conditions. Although developing as a result of increased genetic technology, this is said to have become emphasized as a means of dealing with the increased consciousness of feeding a hungry world.[36]

This shift towards increased experimentation, of which genetic based manipulation was being gradually included, has been slow but steady since the turn of the century, with an acceleration between 1930 and 1960. The shift is attributed to the long standing emphasis on applied training in the land grant institutions. As well as the 1950's being the decade of the physical sciences, it was also a decade of anti-vocationalism,[37] which contributed greatly to the increased emphasis on experimentation. This shift enabled the curricula of the land grant institutions, which accounted for roughly 3.5 percent of the institutions of higher learning, to produce by 1958-59, 54 percent of the degrees in biology.

In summary, the development of genetic training within the undergraduate realm of education consisted of fundamental concepts with pertinence to those aspects contributing towards increased productivity and consistency, changing as the focus of educated individuals and national emphasis changed. However, through out this time, agricultural education revolved around technologies that were perceived to increase production and thereby improve the economy.

Subjects which tended to be excluded from study were as significant as those included. Subjects such as Taxonomy and Morphology of plant types, for example, which at their basis contribute to production by knowledge of indigenous (and thereby potentially preferential) cultivars, were considered more peripheral than the study of genetics.[38] The same was true of the study of Ecology. Through 1945 and after, there was a notable absence of ecological studies included in other biological and agricultural course work. One author noted that when studied, ecology was generally included as a fundamental part of introductory biology. She attributed this to two primary reasons:

> This condition has probably arisen from the adoption of either of two extreme premises ... first an over-simplification approach that regards elementary ecology as no more than grammar school natural history and hence unworthy of inclusion at the college level; secondly, an over-specialization approach, considering ecology as too advanced and difficult for incorporation in a freshman subject.[39]

What was studied that was often perceived as "ecological" was the conservation of renewable natural resources. Through the 1940's and 1950's, emphasis on ecology was fundamentally "custodial," and focused towards "protection against fire, insects, and disease, inventory of the resource, and the development of means to convert [the resources] to goods and services."[40] The role of genetics in this was to improve means of nutrient provisions and pest resistance, and determine favorable prolific types showing increased stability and productivity.

By the 1960's and later, conservation referred to optimizing the outputs of products for commerce, industry, and social services for the general population.[41] As a very late part of this shift, in 1970, the first "gene banks," or repositories of diverse seeds stock, began to develop.[42] This indicates the late entrance of ecologically or environmentally oriented conservation into agricultural education. Traditionally, resource conservation had little to do with concern for the ecology beyond what an eco-system would bear for immediate output.

Another subject not widely studied was population genetics, which, as mentioned in the previous chapter, originated in the 1930's and developed through the 1950's and later. One primary reason population genetics was not studied was that the level of mathematics necessary for demographic statistics was not well codified, though available in different forms. Population genetics and taxonomy were considered by some accounts the role of ecologists;[43] the exclusion of emphasizing the significance of genetic variation, in both the specific and general means provided by these two mediums, served to further separate agricultural education from potential ecological and environmental considerations brought about by increased hybridization and breeding trends experienced through 1960. In short, the knowledge of ecology and population genetics was not codified enough to be readily made into applied technology, and for at least that reason, ecological aspects of education tended not to be included in agricultural education.

By shaping agricultural education to serve the most immediate productive needs of America with a focus that produced agricultural scientists at an accelerated rate, the land grant colleges were able to help increase agricultural production by standardizing the productive means by an increase in genetic technology. Further, by turning out agricultural engineers with a primary knowledge of producing and maintaining agriculture from the perspective of economically increased production, the land grant colleges were able to industrialize agriculture in much the same way that mechanical and electrical industries were developed. Due to its decentralized nature, however, agricultural education was a very late comer in focusing education to provide a means of increased production.

Part of the reason for the late development of industrializing agriculture was that the experiment stations, affiliated with the land grant colleges, served as the primary means of advancing technology. Due to the national dependence on advancing productivity primarily through the use the experiment stations, and due to the predominantly decentralized nature of agriculture, private enterprise was not able to assert emphasis in the educational system directly. The perceived needs of agriculture were geared to the economic and social needs of society. Due to this, little emphasis was required to remind nation's leaders that education and technology were vital means of feeding a nation's population increasing by three million people per year.

B. AGRICULTURAL STUDIES

The land grant colleges were affiliated with the so-called "experiment stations", originating as a result of the Hatch Act of 1887. This act provided for the means of a technological basis to increase agricultural production as well as educational developments by founding a series of institutions to provide "research basic to the problems of agriculture in its broadest aspects..." by the use of agricultural experimentation.[44]

Many people who studied agriculture at the land grant colleges continued their training at the experiment stations. (There are estimates that as many as 70 percent of the people working at the experiment stations graduated from a land grant college.) Working both individually and as a network with other stations, the technology produced by the experiment stations served as the national repository for developing and providing refined principles of agriculture, introducing new technologies and cultivar types, and providing the general focuses of study in the land grant college system.

The experiment stations functioned to this end institutionally by focusing their emphasis on research and development, and promoting joint association for both students and faculty with the land grand institutions. As such, the experiment stations served as the institutions providing advanced professional guidance and training.

As research and development institutions, experiment stations were bountiful producers of hybrid innovation. Beginning with the work of George Shull, who did the original research on crossing that was successfully developed by Donald Jones, the inclusion of genetic principles of nutrients, mutations, and cross-breeding were most significant in developing agriculture through 1960.

A brief overview includes the development of double crossed hybrid corn and new rice cultivars in 1930, and the development and release of Thatcher Wheat. Additionally, in 1934, Danish hogs were imported for breeding experiments. The experiments with these hogs led to the Wiltshire hog, known for its high meat to fat ratio. In 1942, the release in the United States of DDT occurred. The year 1944 saw the development of the Beltsville Small White turkey, and by 1951, the use of Chelates, organic chemicals used to supplement natural deficiencies in a variety of plants was finding wide application. The following years saw the use of radioactive materials to eliminate the screwworm fly from the island of Curaco in 1955, and in 1958, the eradication of the Mediterranean fruit fly from the state of Florida (also by the use of radioactive materials). Finally, the development of the Pink Shipper, a wilt-resistant tomato provided a great increase in portability. The continued contributions of the experiment stations towards applied genetic technology is considerable.[45]

As a tool, genetics permitted cross-breeding, improving and introducing cultivars. Moreover, through the known use of the effects of radiation, genetics served to prove principles theretofore attempted only on an experimental basis and in the lab. In addition, being able to selectively determine which nutrients were beneficial for cultivars, as well as which pesticides were preferable, proved highly significant, as pesticides effected change without the often slow and limited process of inducing pest resistance into plants themselves. The training provided at the experiment stations facilitated this rapid development by integrating perceived agricultural necessities with a growing "biotechnology" geared for increased production.

So successful was the research carried out at the experiment stations that the technology of agriculture was often applied in other countries. This was permitted by funding provided by foundations in the form of research grants for improvement in other countries. For example, the Rockefeller Foundation's 1941 project[46] sent a group of agricultural scientists to Mexico to investigate conditions for increasing grain production there. The goal the Foundation sought was "increasing food supplies as quickly and directly as possible by means of the genetic and cultural improvement of the most important food and feed crops..."[47] As the climate in the area to be developed was semitropical, the approach used was to develop a disease-resistant seed stock from existent seed stock in that area, rather than using stock for a temperate zone, which would require a longer time to recombine for preferred traits. To the selection and development of seed stock were added modern irrigation, pesticides, fertilizers, production and distribution techniques. The scientists combined known theories of nurture with known theories of cultivar development for a rapid increase in agricultural production. Through projects of this type, agricultural education and technology were spread to developing countries, providing further education for both the scientists and the host area and helping the needs of developing countries.

C. EDUCATION AND CAREER SOURCES

Through education and the increase of applied genetics, several possibilities opened up for a career in agriculture, or "agribusiness," as the field was called after the 1950's. These possibilities included research and improvement in seed development and distribution, improving farm implements (for which hybridization was increasingly designed to accommodate), basic research aimed at determining genetic laws, and procedures to increase production. In addition, statistical analysis, horticulture, entomology, chemistry, teaching, and several other technical areas,[48] were avenues followed in applied genetics that created many uses in both public and private industry.

In the early 1960's, there was an anticipated need of at least three thousand more trained professionals annually to work in the scientific areas of agriculture alone,[49] and enough variously trained semi-professionals to accommodate the increase of the six million people involved with supplying equipment and materials for production to feed and clothe the one hundred eighty million people in the United States alone.[50]

Due to sheer financial needs, most trained agricultural professionals went to work for companies which could both afford and utilize their talents. In part, these companies included Greyhound, Dupont, Allied Chemical Company, Safeway, Swift and Company, Armour, Incorporated, Ralston Purina,[51] as well as the United States Government, state governments, and public and private regulatory agencies. Agricultural professionals tended to be employed by the wealthiest fifteen to thirty five percent of public and private industry.[52] The other sixty-five to eighty-five percent of industry--mostly independent family and small corporate farmers--were not financially able to directly employ the trained individuals.

The benefits drawn by the educational system allowed industry to develop and market what was increasingly a standardized commodity. Out of an estimated twenty thousand different cultivars nutritionally suitable for food, there were (and are) only about one hundred used, about twenty two of which are used on a global basis.[53] During this time, the emphasis was placed on increasing production of both agricultural education and commodities.

This approach may be seen as a change from a so-called Darwinian approach to education to a so-called Mendelian approach. The perspective of developing and retaining specialized knowledge for use by the few, as in the original intent of the Grange, for example, was replaced by the creation of the land grant colleges and experiment stations. These institutions disseminated this specialized knowledge to large numbers of people, many of whom came from low-income families. As a result, a class of professionals having the most necessary skills for increasing agricultural production was established. Within this transformation came the development of an educational focus aimed towards emphasizing select skills. As this focus was predetermined, it may be seen as being equated to selection for predetermined traits, central to Mendelian thought.

It was the emphasis on predetermination that molded educational curricula to serve the perceived (or equally pre-determined) needs of society. Further, it is likely that due to this perception that ecology, taxonomy, and population genetics were not emphasized in a curriculum otherwise devoted to increased production through standardization. By the same token, the lack of inclusion of these theoretical developments in agricultural genetic education tended to exclude this professional field from first hand knowledge that at least, in hind-sight, could have promoted an increased diversity in cultivar types and, at the same time, potentially stabilized production to accommodate the decentralized nature of agriculture.

But this was not the case. Education in hybrid genetics served production and industry. Both education and hybrid genetics where controlled to degrees by agricultural regulatory institutions, which served the larger community to which education and production needed to respond. Due to the perceived needs of the population, regulation served to emphasize higher standard technology. As such, the way technology was developed in these institutions consisted of establishing new techniques for increased production, which was often utilized in light of old perceptions of need. The result of this technological ability and perspective of need contributed greatly to the occurrence of a very slow change in ecological considerations.

CHAPTER III

ADMINISTRATIVE DEVELOPMENTS

A. FEDERAL AGRICULTURAL REGULATIONS

There was no direct regulation of genetic technologies during this era. However, Federal regulation of agriculture was central to the development of genetics. Due to consistent demand for increased productivity, agriculture shifted to the use of hybridization to provide economic and productive stability and to compensate for rising costs. Federal agricultural regulations served to affect what in agriculture was promoted. The means of the government to effect promotion was by compensation to farmers via conservation rebates and rental payments for stabilizing land and an inducement in the form of additional rebates to grow certain crop types. Finally, these rebates were based on values measured by agricultural commodity parity.

Agricultural commodity parity is an economic term that is used to refer to the measurement of two types of equivalence. Agricultural parity is the price needed to assure farmers a certain amount of purchasing power. The basis for comparison during at least the early part of this era was the so-called "golden years" of farming of 1910-14.

By controlling production with economic inducement, the Federal Government was able to promote hybridization and other crossing technologies as a means of maintaining and increasing production, even though there were consistent surpluses throughout this period.

As early as 1924, the McNary-Haugen bill was being planned to provide for the utilization of surplus, to be sold abroad at world prices. The chief elements of this proposed bill included the distribution of losses and operating costs among farmers by an equalization fee. This was a scrip device to collect the fee, and a price-ratio provision to determine fair prices. These provisions were to apply to eight agricultural commodities, including wheat, corn, cotton, wool, cattle, sheep, swine, and rice.[54] Although this bill was twice vetoed by President Cooligde, it represented a partially successful effort on the part of the "farm block" Congressmen to convince their colleagues to try to get the Federal Government involved in being responsible for agricultural prices. More implicitly, it reflected was the notice that as early as the 1920's, agricultural production exceeded demand. This suggested a need to regulate agricultural production to accommodate existent and future projections of demand for select commodities.

By 1933, as part of "New Deal" politics, the Agricultural Adjustment Act (AAA) was enacted. This Act reflected a change in Federal policy:

> to establish and maintain such balance between the production and consumption of agricultural commodities, and such marketing conditions therefore, as will reestablish prices to farmers at a level that will give agricultural commodities a purchasing power with respect to articles that farmers buy, equivalent to the purchasing power of agricultural commodities in the base period.[55]

To effect this restoration of balance, Henry A. Wallace, Secretary of Agriculture (1933-1940), was given a host of powers including incentives for voluntarily reducing agricultural acreage or production, and reimbursement whereby the land holder would receive compensation in the form of rental or benefit payments. In addition, Secretary Wallace was empowered to induce market pools (a form of horizontal integration) of producers, processors and others to regulate prices and discriminate against price undercutting. Funding for benefit and rental payments came from taxes generated by agricultural production, which were given back to the land holders who voluntarily contracted with the Secretary's requests.[56]

This act was originally effective in regulating wheat, tobacco, peanuts, and rice; by 1935, the provisions of the act also included regulating producers of milk, fruits and vegetables not otherwise included in production control. However, by 1936, the production control regulations were removed by the United States Supreme Court, being declared unconstitutional.

In 1936, the Soil Conservation and Domestic Allotment Act was enacted. A primary shift in this act was the the emphasis on agricultural conservation, rather than production control. Emphasizing conservation had been discussed on the Federal level since at least 1934, as a response:

> to the need for a conservation approach to the farm problem, a need which large-scale migration of "burned out" farmers and ranchers from the Great Plains and Middle West dramatized with tragic clarity. To encourage and promote the adoption of farming methods that would involve less rapid exploitation of soil resources, to reduce erosion of soils, and to use a smaller percentage of crop-land in the production of the major soil-depleting crops --these aims were sought by the farm program...[57]

As may be seen, the combined emphasis on less destructive methods and reduced land use for farming, tended to promote hybrid technologies due to the need on the part of the farmer to maintain productivity.

Prior to World War II, the trend towards soil conservation, with regard to reducing the amount of land, was due largely to the combination of droughts and the Great Depression. Agricultural production in the Mid-west was devastated by the droughts, and the Depression created a drastically reduced market outlet. Subsequently, many farmers (estimates of at least two million) were effectively without jobs, or at least their jobs were not economically productive at this time.

Shortly before the production control regulations of the AAA were removed, the Bankhead-Jones Act of 1935 was passed into law to provide for scientific, technical, economic and other research to investigate basic agricultural problems. The aim of the act was to develop new and improved methods of cultivars and other agricultural product production, as well as to find markets for agricultural products and by-products.[58] In effect, while the trend represented by the Agricultural Adjustment Act was working to limit production, the Bankhead-Jones Act was working to increase the productive means, making for a dualism consisting of output regulation or control and expansion of technology.

In this dualism of output regulation and technological expansion, the regulatory precedent for this era becomes apparent. There was a realization that surpluses existed and needed to be dealt with, and the realization that technology might be the only solution to properly increase marketability, potentially providing for the elimination of surpluses through production of better, and as seen, increasingly hybridized products. The combination of these realizations was the primary perception central to Federal regulation, which is shown clearly in economic considerations behind the Agricultural Adjustment Act:

> Regardless on how far we depend on withdrawal of land, or how far on regulation and control of the use of land actually in farms, we will continue to face the need of shifting farmers to other types of work.... By and large, though, most of the surplus population which recently has moved to the farms ... will be perfectly satisfied to move back into industry as soon as satisfactory jobs develop there...

> In the very long run, we may come to realize that real farm prosperity depends upon reducing the number of workers in agriculture as rapidly as productively per worker rises.[59]

This perspective may also be seen as reflecting the shift towards regarding agriculture from the same perspective as industries utilizing technology to increase efficiency and productivity. To this end, Secretary Wallace was a great contributor, emphasizing the predominant role of science in agriculture and extensively modifying the Department of Agriculture to accommodate increased emphasis on science.[60]

Two primary routes arising from this dualistic perspective of regulation and expansion included the increase in conservation techniques and increased insurance of the quality of agricultural products. On the part of increased conservation, regulations having the effect of requiring increased technology for enhanced conservation followed, which enabled the same or less physical area of soil to be more productive. Acts following this trait included the Second Agricultural Adjustment Act (1938) and the Steagall Amendment (1941). The Second Agricultural Adjustment Act emphasized reduced production and measures to accelerate agricultural income by increasing cash flow.[61] The Steagall Amendment provided for an extension of the Commodity Credit Corporation, to allow agricultural commodities deemed by the Secretary of Agriculture to need increased production for contribution to the war effort and have their prices supported at eighty-five percent of parity.[62] While the Second Agricultural Adjustment Act emphasized overall reduction, the Steagall Amendment provided for added support of select crop types.

These acts served to aid agriculture by artificially increasing prices during times of less than favorable market value and to increase and support the production of select commodities. Cultivars affected by the Steagall Amendment (or "Steagall commodities," as they were called to separate them from commodities coming under subsequent price supports) included cotton, corn, wheat, rice, tobacco, and peanuts.[63] All of these were focuses of hybridization processes. As may be seen in this emphasis, conservation on the Federal level equaled promotion of some commodities in increased numbers while promoting economical restraint on others.

On the side of technological expansion the Federal Food, Drug, and Cosmetic Act (1938) and again, the change of the USDA to consolidate research and direct the experiment stations to this end focused on technological expansion in the arena of agricultural science. The Federal Food, Drug, and Cosmetic Act emphasized penalties for mis-labeling, prohibition of selling harmful drugs, and setting higher standards for food products.[64] This resulted in increased need for scientific classification and quality control of commodities designated under this act. Further, it served to reduce market diversity by necessitating growth of certain cultivars for the insurance of purity and quality control as well as doing much the same in the interest of preservation for distribution and storage.

The beginning of the so-called Second American Agricultural Revolution (1941-1945), served to de-emphasize conservation in favor of war production. This was exemplified by President Roosevelt's Executive Order 9334, establishing the War Food Administration in 1943, by consolidating the Food Production Administration, the Food Distribution Administration, the Commodity Credit Corporation, and the Extension Service into the Department of Agriculture (USDA).[65] Executive Order 9334 was the directive serving thereafter to regulate agriculture on the state level through the USDA.

The Agricultural Adjustment Act of 1949 (a.k.a. the Gore-Anderson Bill), served to further promote price support on tobacco, corn, wheat and rice at between 75 and 90 percent of parity, contingent on production ranging from 130 percent of normal down to 102 percent.[66] The Agricultural Adjustment Act of 1954, served as the transitional act to reduce governmental subsidies to farmers. The act reduced basic crop support from 90 percent to a range of 82.5 to 90 percent until 1955, when the lower range dropped to 75 percent.[67] A partial reason for the change in subsidy rate was the Korean War, which generated increases in agricultural exports and prices.

The Agricultural Act of 1956 served to forestall further reduction of price support for one year. In addition, the act established the Soil Bank, providing corn growers with an inducement to reduce land development. It also prevented further cutbacks in acreage allotments for cotton and rice, and provided several other stop-gap measures to maintain production and market regulation. Central to the act was the endorsement of a two-price system which allowed the Commodity Credit Corporation to sell agricultural commodities abroad at prices lower than in the USA.[68] By this time, regulation served to limit land use and to allow expansion of production by "dumping" surplus abroad.

The Agricultural Adjustment Act of 1958 included a "permanent" limitation of production acreage for cotton and rice, with the understanding that the minimum parity level would be reduced to 65 percent by 1961. Corn and feed grain producers had the option of receiving price supports without production limitations or establishing acreage limitations based on the previous three year production averages and accepting support prices ranging from 75 to 90 percent of parity. Farmers chose to receive price support without production limitations.[69] By 1958, hybridization was so wide spread that it was deemed basic to maintaining production per-acre requirements.

From this choice, by 1959, the trend towards expansion and regulation had shown itself in the Agricultural Adjustment Act of that year to favor regulated expansion using standardized crops. A reason contributing to this trend was crop insurance, which was offered in various forms as early as 1938. By 1959, insurance offered protection against losses due to failure of spring planted crops, which served to emphasize regular growing cycles, convenient for hybrid production (which was geared to optimum climate conditions), as opposed to more risk-laden winter crop production. This insurance was used by more than three hundred thousand people growing wheat, cotton, flax, corn, and other select commodities.[70] Farmers still had a secure means of covering losses against the potential of short term gains--which was central to the trend of the last thirty years--through insurance and regulated production, despite a continued lack of attempt to reach a real solution to the problem of production in excess of demand. Thus, by 1950, a farmer could be virtually guaranteed of a return for his investment for spring planting, proper conservation, and select crop cultivation, and could have seed stock able enabling him to take increased advantage of these economic regulations. By 1960, the preference of the farmer apparently was to utilize these technologies to a greater extent for the maintenance of his income and security.

Federal policy served to set precedent for directions of agricultural production. In turn, policy provided for specialization of crop types while reducing the overall area of production of a given type. The primary means of doing this was by utilization of hybridization to accommodate an increasing production on decreasing tracts of land. Economic support, reimbursements, and restraint were the means of maintaining agricultural production at a surplus level during this time. By these means, the Federal Government sought to perpetuate agricultural production in a manner regulated by ideals that were perhaps out of date in comparison to supply and demand regulations imposed on other industries.

B. STATE AGRICULTURAL REGULATIONS

State regulation served to support the use of hybrids in agriculture by means of land use regulation. In addition to this, a state had the role of enacting support programs or "Grants in Aid," as exemplified by the establishment of the Hatch and Morril Acts, to which the Federal Government contributed greatly: "Through grants in aid, the National Government influences, and to some extent controls 75 percent of the total activities of State Governments."[71] Grants in aid were issued by the Federal Government and matched by state appropriations. These grants supported hybridization directly by practices at Land Grant Colleges and Experiment Stations. The combination of these two types of regulation administered at the state level served as the primary means by which agricultural technology was immediately affected.

The Smith Lever Act of 1914 was a Federal grant in aid which was administrated at the state level to provide agricultural extension work by farm agents or extension agents into the community. Through agricultural extension, the small farmer was able to indirectly enjoy the benefits of agricultural colleges and experiment stations. Further, to the end of benefits, the Smith-Lever Act represented the first time Federal standards were a factor in aid to education.[72]

State land use has been consistently allocated to protect agriculture, yet favor commercial development for increased tax revenues, and to better accommodate the needs of increasing populations. Because of this, agricultural land in the proximity of an expanding city area often was converted for other use--residential, industrial, and/or commercial. The reason for converting the land was partially economic and partially to ease the damage on some over used land. The need to accommodate an increasing population brought about an emphasis on optimizing land productivity, and as cities grew in size, farm land could often be more productive by being used for other than agricultural purposes.

Between 1930 and 1960, the amount of land used for crops decreased from about 450 million acres to about 400 million acres. Most of this reduction occurred after World War II, and is attributed (60 percent) to increased use for purposes other than agriculture. The remaining 40 percent of the decrease is attributed to abandonment and/or conversion of land to forest or pasture use.[73]

Zoning ordinances were designed to protect farmers, but there has been an unwritten understanding between landowners, developers, and governments that when an agricultural area was in the path of development, special exemptions and ordinance changes would be brought into effect, removing zoning restrictions on agricultural land for the purpose of non-agricultural utilization, or taxation on crop land was increased to where it was uneconomical to continue farming:[74]

> But when they [farmers] pay ever-higher property taxes to provide services that they don't need to a nearby subdivision, or when nearby residents file nuisance suits against them for conducting essential farm operations, the temptation to harvest the "last cash crop"--five or ten acre ranchetts--can become all but irresistible.[75]

Thus, in addition to surplus generated in accordance with Federal regulations, which kept profits down and helped reduce the number of farmers by over 2 million during this thirty year period (this trend has currently slowed to about 1,000 farmers per week), zoning allowed farmers near expanding city areas ("spillover" zones) to sell or subdivide their land and return a greater profit than by farming.

The state provided support for farmers choosing to continue their trade, primarily by the experiment stations and extension services, which, as stated above, were by 1943, under USDA control. The extension services department provided economic, scientific, and technical information pertaining to virtually every aspect of crop production. As early as 1938, information was provided by meetings, farmers' bulletins, press releases and other publications, as well as radio shows and films.[76] In all, over 3,000 publications were available in the 1940's, and their number increased annually.

Source material for publications originated primarily from results of work done by the experiment stations and economic statistics developed by the USDA. Thus, it is not surprising that this information tended to promote the latest technological innovations including land grading to stop soil erosion, the color of paint most reflecting sunlight (to keep houses cool in the summer), the latest designs in harvesting equipment, and of course, as early as 1937, the use of genetics in cultivation.

By dispersal of this information through state sources, there was the appearance that in fact a state was supporting these publications; in fact they were. However, the Federal government was often providing the resources for these publications, and in many cases, the editorial emphasis also.

Due to the need to maintain economic stability, farmers opted to follow the advice of publications, with excellent results. Between 1930 and 1960, there was a 250 percent increase in "farm output,"[77] despite decreases of fifty million acres of land and over 2 million farmers.

It is difficult to find fault with the regulatory agencies governing agriculture in this productivity increase. The benefits of regulation served to increase production while decreasing material and labor necessary for production. The financial cost of this to the United States has been minimal, and the net increase in production has surpassed that of virtually any other area of industry.

Through emphasizing standardized technology by promoting limited varieties of crop production, the Federal Government brought about a tremendous and vital transformation in the way agriculture was produced. State regulation served to maintain an economic equilibrium of land use by providing relatively easy zoning changes, which allowed agricultural land zoning to be changed to allow use for non-agricultural purposes as the need materialized. The outset of this era experienced difficulty due to supply in excess of demand, however, by 1960, although this was still the case, the standardization of this technology, as well as of the cultivars used, served to increase productivity by more than 200 percent.

CHAPTER IV

PROFESSIONALISM IN GENETIC-AGRICULTURAL RESEARCH

A. BACKGROUND

> Americans after 1870, but beginning after 1840, committed themselves to a culture of professionalism which over the years has established the thoughts, habits, and responses most modern Americans have taken for granted, a culture which has admirably served individuals who aspire to think very well of themselves.[78]

The scientific fields became professional early, beginning with the American Association for the Advancement of Science, in 1848.[79] The emergence of professionalism in science contributed greatly to advances in scientific methodologies, standardizations, team work, and the distribution by publication of a great wealth of knowledge. There is little doubt that without professionalism, the pace and direction of science would have followed a different path.

Industry was quick to incorporate scientific professionalism, finding the increased productivity yielded by scientific approaches to technological barriers all but irresistible. Due to this extreme interest on the part of industry toward professional scientists, there is little surprise that industry became closely tied with scientific training, providing a type of feedback that allowed science to serve industry by emphasizing what may be broadly described as elements of standard approaches to different problems during the training period. In turn, this worked to produce scientific professionals with training that permitted the rapid development that supported the needs of industry.

Subsequently, most industries developed by promoting commodities which were both created by and sold under standardized processes. The means of producing commodities themselves, becoming an effective by-product of scientific professional perspectives, provided a substantial contribution to the advancement of scientific professionalism (as well as production). If this process may be seen to have originated in 1848, with the American Association for the Advancement of Science, by 1930, it was well established. The uniformity provided by this foundation may be seen to have created the perspective used in genetic-agricultural research. This was true especially with regard to the emphasis on standardizing the productive means of agriculture as much as possible, despite the inherently diverse nature of agricultural materials.

B. PERSONAL INCENTIVES

The origins of professionalism in genetic-agricultural research were in well established academic traditions, and as agricultural research did not expressly serve industry in the way that, as example, the engineering field did, the solidification of the profession was based upon years of industry-science relations, but without direct influence from private industry. Professionalism in agricultural research may be seen to have become effectively codified due to two predominant factors, including established academic traditions, and individuals trained in physics and/or biology who had "switched" their profession to genetics. This served agricultural professionalism by providing methodological technologies to enhance the research capabilities and by organizing research units. The second factor, above, was primarily responsible for greatly accelerating both the types of research being performed and the pace at which research was carried out. In short, the combination of these two influences provided increased technology and guidance for professionalism in agriculture.

Increased methodological know-how created a form of professionalism that worked on the personal level by providing a means for an individual to gain a state administrated education, upon the completion of which the individual would have an opportunity to work for the state/Federal government in agricultural research. By, in effect, receiving an education and then a career from the state, the individual may have seen this progression as a means of obtaining the equivalent of state patronage. In turn, this progression may have been seen as a means for the individual to earn prestige on that basis as well as on the basis of being able to help society.

Throughout this era, the great majority of individuals who gained such an education were from "poor" families, many of whom were from families whose livelihood was oriented around agriculture. As such, becoming a professional in agriculture was seen by many as a means to help themselves (and their families, if only indirectly) by education and the eventual advancement of agricultural technology to enhance their lives and life in general. Professionalism provided a means for individuals to effect change in a manner that was perceived to help agricultural families and communities, as well as the nation and the world.

One of the necessities of professionalism is protection from outside influences and judgment which was provided for professionals in part by so called professional autonomy, which enabled professionals to pursue research with a sense of relative independence, protection and support, provided by institutions that were an extension of the Government:

> Basic science is unlike other professions in that its practitioners not only claim autonomy in determining procedures to be used in the course of the work and in evaluating the success of these procedures; they also claim the right to decide for themselves the problems they should select and, on the basis of their work and that of others, whether or not theories are true.[80]

Autonomy was considered important to ensure that research would not necessarily have to respond to the interests of a particular group. It was by the development of professional autonomy in agriculture that individuals were able to be seen as staying in agriculture--which had an ideological basis in the tradition of farming--yet earn their living and maintain a social status that was substantially different from what was possible in the past. Agricultural professionals were provided a means of obtaining the top levels of influence and protection in agriculture without necessarily having to personally own a great amount of prime top land to use in achieving their success. Because of their status as directors of research, professionals were perceived as the consultants of the trade.

Just as professionalism provided the individual with a means of security, it also provided a means of attaining power. A professional is a person who by status is seen as being superior to a non-professional, and agricultural professionals were, in effect, authorities who stood in charge of education, research, and production aspects of agriculture. Researchers in agricultural genetics were perhaps the highest in the levels of agricultural professionals, as they were the vehicle for increasing production, advancing and standardizing new technologies, and providing advanced education. The success of genetic research served as a means of perpetuating this role system because of its success, which facilitated the achievement of power in the form of authority that the geneticist was perceived by the farmer to possess.

This success may be seen as originating primarily from the analogic use of hybridization as a technology in many different cultivars and animals. Through this analogic adaptation, professionals were able to disseminate the knowledge necessary to increase production, reduce or eliminate pest problems and introduce new cultivars among the agricultural community at large. A professional was able to help in this success through his or her research, which contributed to research being done at virtually any land grant college or experiment station. This, in turn, contributed to research in other schools and experiment stations through publications, sabbaticals and other information exchange networks. This networking allowed for both the establishment and rapid increase of power for the individual professional in agricultural genetics, as well as other branches of agricultural professionals, while maintaining a distance from the productive force--the farmer--who was, in effect, also the industrial side of agriculture.

By having a profession that evolved out of the combination of academic traditions and imported methodological techniques (also based on academic traditions but developed through the uses of private industry), agricultural professionals had no direct responsibility to the industrial or commercial aspects of production. This separation served as an insulating factor that did not exist in other industries, and the security of agricultural professionals was ensured by this separation, as was the authority of the individual:

> The intellectual pretensions of these persons were specific in aim and definite in purpose. As professionals they attempted to define a total coherent system of necessary knowledge within a precise territory, to control the intrinsic relationships of their subject by making it a scholarly as well as applied science, to root social existence in the inner needs and possibilities of documentable worldly processes.[81]

Professional research was ideally done to advance science, which, although intended to help production, was not directly responsible for production increases or regulation. Those aspects were carried out by other facets of the USDA.[82] Due to his esoteric knowledge, the professional was put in a role of authority which created the necessity of the lay person--the farmer--to trust in the professional's integrity and authority. This worked dualistically in that the gratitude the professional received furthered his self-confidence, and at the same time, the more people, both lay and professional, who agreed with a given authority, created a reinforcement that perpetuated if not furthered a belief in a given system of knowledge. This served to create an image of agricultural professionals as a society that was truth determining. The truth of agricultural genetics was that it was successful.

Although to the outside world the effect of agricultural research seemed boundless, within the profession, agricultural research was extensively focused. Professional success was measured by how innovative the research was, in terms of what was innovated and how done. As stated above,[83] comparatively little innovation was done on the microbiological level during this time. However, there were highly significant but limited exceptions which resulted in increased knowledge of nutrients, virulence, and disease resistance. The focus of the profession primarily on hybridization created an effective necessity on the part of a researcher to annex known technology into new cultivars. This was the quickest route to success, since the means of becoming a successful researcher was mainly by publication of significant new findings.

Interestingly, agricultural research did not often find publication in journals outside the realm of agriculture.[84] This served to make agricultural genetics a profession that was, in effect, separate from other aspects of genetic research. The result was that agricultural genetics was not generally outwardly effective: Research in genetics in general might have an effect on agricultural genetics, but it was rare that agricultural genetics affected genetic research in general.

Despite this apparent limitation, there were many publications open to agricultural researchers.[85] Most of these publications were generated by an institution, an extension service, or the USDA itself. This created a means of success for the individual --a means that was independent of other aspects of the "industry," though in the case of publications, often dependent upon editorial preference.[86] Consequently, the success of research was often determined by, if not dependent on, who was the most popular within a professional community at a given time, as well as what he or she was researching.

Contributing to this tendency to extend popular research was the fact that patents for innovative research on biological cultivars were not available until the early 1970's,[87] with the invention of asexually reproducing oil consuming microbiological life forms. Because of the inability to patent a finding, the sense of propriety available to the individual professional was through publication and the rare advent of a highly useful strain of cultivar, exemplified by the cases of Thatcher and Gains wheat. For the most part, however, the principal route to success was to follow current trends in research. The inability to produce property may be seen as a central difference between agricultural and non-agricultural research.

The creation of "property" has been the central factor in the economic and social development of commerce in general,[88] and the exclusion of this avenue for agricultural research until very recently served to regulate the form of professionalism in agriculture (like most scientific professions) by creating a means of success that was often limited to researching a cultivar in increasing detail or attempting a similar approach on a different cultivar rather than necessarily attempting to perform research from a different perspective. The basis of studying cultivars in increased detail, as well as annexing techniques, is, of course, basic to the scientific method. In addition, "spillover" knowledge or techniques were expected from close study. In this system of effective individual control, it was usually necessary for the individual to follow in the foot steps of his or her peers, thereby creating an emphasis on team work rather than on individual competition.

C. PERSPECTIVES OF THE PROFESSIONAL COMMUNITY

The United Stated Department of Agriculture became the central regulatory agency for agricultural conservation and expansion in 1943. It served to administrate these policies from the level of the Federal Government downward to state governments and to educational and research institutions, and to enact policy within a given state or institution as deemed necessary. The USDA functioned by administrating from the Office of the Secretary to the departments of Research, Extension, Agricultural Resources Conservation, Commodity Adjustment, and Regulatory and Agricultural Credit.[89] The USDA approached genetics from much the same perspective as most any regulatory agency governs its area of concern:

Genetics was regarded as a commodity producing industry, and Federal regulation served to promote research in the form of institutional based activity rather than individual or private based activity. It is also of interest that geneticists rarely participated in the regulation of genetics from the Federal level, reflecting the late entry of geneticist into the administrative realm.

The means of initiating research were founded on any combination of several factors, all based upon perspectives of need, usually of short-term orientation. Broadly, these factors included grant writing, legislative and budget emphasis, as in the case of the Research and Marketing Act of 1946,[90] land use necessities, and beginning in the late 1950's, influence of some of the larger agribusiness interests. Among these means, the principal self-initiated route open to a professional or group of professionals was grant writing. In the ideal form, writing a grant necessitated first a review of existing literature on a given topic to determine the feasibility and viability of the researcher's idea. Following this characteristically extensive process, the researcher would then draft a proposal for submission outlining the history, current research, and proposed program to the appropriate granting institution, which was usually the Federal Government[91] and occasionally a private granting institution.[92] However, the researcher frequently would choose a topic utilizing previous literature (though cited) that served to substantiate the researcher's idea. Approaching grant writing in this latter way created (or caused) what has come to be known as "grantsmanship," in which popular and successful previous research, often originally done by an institutional leader, was extended into a "new" research proposal.

Approaching research in this manner allowed a researcher to reduce the potential risk of time loss due to a failed grant, which was perceived by the community as receiving a blow. At the same time, this approach tended to ensure a researcher of a shorter route to success in genetic manipulations, which was helped by the increased possibility that the necessary support would be more readily available due to the researcher having or knowing of other researchers with the needed skills.

Support for research was (and continues to be) a central factor in research. Any given project may require assistance from many people who worked on any one of several levels. Research in hybridization could require the use of a geneticist, who was often the person in charge of the research, a microbiologist, a physicist, a botanist, as well as technical support and general support usually provided by graduate research assistants and post-doctoral fellows.[93] The necessity of having a division of labor in research created the problem of on the first part who was to receive credit for the work, and on the second part, who was perceived as being capable of providing feedback on the initiation and progression of the project. It is noteworthy that there was a long term reticence on the part of principal researchers to utilize statisticians as part of their program. This is attributed partly to the tendency of the statistician to criticize the methodological approach of the researcher with regard to the viability of the results determined by the methodology used.[94] This reticence has probably contributed to the general tendency during this era to exclude population statistics from consideration in genetic research.

The problem of who was to receive credit was based on who provided "significant intellectual contributions." Graduate students, doctoral fellows and assistant or associate professors traditionally were not consulted for direction by a full professor. Technicians traditionally were hired labor and thereby were working to appease their employers; specialists were not necessarily concerned with the research problem in general, though, depending on the scale of their contributions, they were sometimes cited as contributing authors.[95] Many times in agricultural research, no authors are cited; rather an institution or group of institutions are cited. This usually occurs when research involves too many people of aspects to allow for a citable authorship. The significance of a contribution ultimately relates to the magnitude or innovation provided by an individual, as well as what else an individual might have previously achieved.

This division of labor has contributed to if not caused much of the emphasis on team work that existed both before and after 1943 in agricultural research, as well as the types of research attempted. Although an individual may feel at the outset of his or her career that the individual's contribution would be significant, such aspirations of greatness were soon vanquished for all but the most popular/successful leaders of research. This aspect is considered significant in the educational emphasis toward motivating people to become senior professional scientists having PH.D.s and post-doctoral fellowships, as opposed to technicians having only lesser degrees or no professional training beyond the PH.D. level.

D. REGULATING RESEARCH

The awarding of a research grant was contingent on how well researched and presented the project was initially, and more importantly, how much potential the granting institution perceived the project to have. The regulation of research in the form of grant awarding requires maintaining the fine line between funding for research and funding for problem solving as:

> To "do research" meant ... to contribute to the knowledge and understanding of a particular scientific discipline or sub-discipline, to gain the respect and envy of fellow scientists, to publish journal articles extensively, and, more importantly, to cultivate an aura of mystery surrounding scientific research which is designed to ensure an esoteric quality that would guarantee a minimum of direction and questioning regarding research appropriations.
>
> To "solve problems" meant ... to abandon scientific integrity for political expediency, to destroy scientific progress and to pursue short-run objectives, which at best would be "engineering" and not scientific in nature, and, more importantly, to transfer research management from scientists to cost accountants and economists.[96]

Characteristically what determined the awarding of grants was the perspective maintained by the granting institution of what possible and probable usefulness could be derived by the research. A project's outcome is difficult to accurately predetermine, and in place of directly determining the outcome of research, useful spillover knowledge or technology was always helpful. This was true particularly when the result of a project was seen to significantly increase the professional researchers' knowledge. Estimating a project's outcome on the level of expected spillover was helpful to basic research, where the practical outcome is usually zero, and in applied research where the outcome can be variable.

It is interesting that throughout this era and after, there has been little systematic administrative policy on awarding grants, beyond the requirement of formal accuracy. "There are few facts that shed any light on the implicit or explicit objective functions that guide allocation decisions."[97] Subsequent to this lack of policy has been a tendency on the part granting institutions to award research that serves predominantly short term goal orientation. Regulation of research in this way allows the scientist to do research that may be seen in the scientist's perspective as differing from problem solving. At the same time, by having the government as the predominant granting institution, properly choosing what types of research were awarded to an institution could serve to utilize team efforts much more effectively.

The emphasis on team work and grant type selection has contributed greatly towards the types of and speed at which research may be done. As increasing numbers of trained professionals expanded the ranks and boundaries of agriculture, the means of regulating speed and output of research created by these people has come about in the increasing bureaucratization. The most common form of this is an increase in responsibility, shown by increased paper work requirements involved in a project manager's monitoring of progress. In addition to this there has been an increasing tendency to utilize a professional for many different types of work simultaneously. For example, a researcher may have to work and/or administrate one or more grants at any given time while performing physical research at an experiment station, teaching classes, and sitting in on other professors' classes and presentations. The increased division of an individual's time reduces the amount of time he may spend on any one project, resulting in a decreased level of output at any given time. On a larger scale, this type of time utilization, in effect, slowed the pace of research.

E. EXPORTING PROFESSIONALISM

The means of developing a civilization has long been tied to the ability to feed the population to be developed. With the codification of professionalism came the exporting of agriculture to other countries. This took the form of sending professionals, technicians and other staff, seed stock, fertilizers, tools and the supporting cultivation techniques to countries in need of increased agricultural production. Thus, the development of professionalism as both a commodity and a commodity-producing industry has served to fulfill the needs of other countries by exporting American agricultural technology to them. The utilization of professionals to this end has provided a means of food production in other countries, as well as the education perceived to be necessary to enable the people of other countries to grow their own food. It was primarily by the use of institutionally based professional units in other countries that this technology has been exported.

There were many benefits for professionals participating in such programs. For example, research trips to other countries served to provide a professional with a means of testing his or her hypothesis on different soil, as well as exploring new soil for new cultivars. Also, a research project of this type provided the professional with a means of enhancing his own experience, which could be brought back to the class room to enhance the education of others.[98]

Finally, there was also the perceived benefit in the cases where a hybrid cultivar could be directly transplanted into another country, thereby increasing the stability of such cultivars through increased physical distribution of their placement. Although as often as not indigenous cultivars were considered preferable for hybridization, in either event, there were perceived to be no draw backs to such research.

On the part of the host country the benefits were also many, but these benefits were more often than not problem ridden. The chief reason for this was that to effectively grow "Western" agriculture, it was necessary to utilize Western techniques for cultivation, irrigation, storage, transportation, and road systems. The center of this problem was that an economically undeveloped country could be overwhelmed by the economic burden of accommodating technology that is so highly integrated.

The dilemma of the recipient country underscores both the importance and limitations of professionals serving to administrate and regulate agriculture. A fundamental role of the professional is to perpetuate the profession. Perpetuation serves the end of consistency in communication and scientific and administrative accuracy (though science and administration require separate types of accuracy). The fundamental role of perpetuation is to maintain the select perspectives of these procedural methodologies in increasing numbers of people as well as people of different cultural backgrounds. However, due to the economic limitations of a recipient country, in some places the profession has exceeded its functional bounds on an economic basis.

This limitation is attributed partly to the success of agricultural genetic research which originates via grant awarding at a level above the profession, and ultimately is responsive to perceptions of social need in the form of economic considerations which were most affected at a level below the profession.

This top-down form of administration created a means of stratifying agricultural research in much the same way as the Watson-Crick DNA model was to later stratify the science of genetics; that is, as a functional commodity, agricultural research, as well as the researchers, could be integrated in many locations and at levels to fit the design imposed by the dictations of Federal and institutional perspectives of need. To fulfill this need, professionalism tended towards uniformity of education, research principals and approaches, with variations for necessary aspects of research that have been shown to revolve around increasing hybridization. Because of its power and control from above, professional research tended to emphasize selection of standard yet preferential traits, which usually responded to predetermined characteristics and perceptions of need.

This is not to say that there was some surreptitious plot shared by the professional community; quite the opposite, the evidence suggests that at the very best, there was merely a lack of knowledge on the subject, and at the worst, a lack of interest or sense of importance given to the by-products of this productive means.

CHAPTER V

ECONOMIC ASPECTS OF APPLIED GENETICS

A. RESEARCH COSTS

Combined research in the land grant colleges and experiment stations, including genetic research, which is estimated at 1 percent of the overall research budget, comprised what is estimated to be less than half of the research performed between 1930 and 1960.[99] The remainder was performed by corporations and private companies. Private research did not develop significantly until mid-1940's. On the general pretense that from the time private research began, the private sector roughly equaled the public sector in terms of research expense, a rough estimate may be obtained through an examination of public sector research.

The cost of research and extension in the public sector for 1930 is estimated to have been $193 million. For 1940, the estimate is $335 million, for 1950, $390 million, and for 1960, $727 million, totaling $1.645 billion[100] for these four select years over a 30 year period. If the above one percent cost for genetic research is accurate, then the cost of genetic research in the public sector for these select years was $16.45 million dollars. This expense included labor, materials, some building structures, maintenance and miscellaneous costs. As government expenses go, this was a small investment both for genetic research, and general research and extension in total, and one which produced substantial returns.

With labor being the single most expensive cost (as it is in most business), it is interesting to note that the number of graduate students working as research assistants helped to substantially reduce the cost of research, as did the availability of land used for research, which was owned by the Federal and/or state government, and therefore was effectively without cost. These two factors were a great aid in maintaining the cost of research at this relatively low level, and accounts for most of the difference between private and public costs.

Government supported research permitted an advance in genetic technology, which served to facilitate enhanced cultivation techniques at a comparatively nominal cost. Research was one indirect aid to the farmer; other direct aid was available in the form of price support or parity. Although parity is mentioned above,[101] it is significant to add that parity support served in largely part to maintain surplus production due to economic incentives, and subsequently to keep prices low. Two effects of parity that had increasing effects as a world market developed were to minimize world standard pricing of agricultural products and to create spillover effects on the pricing of other commodities.[102]

Without a parity, it was perceived that the price of a given crop would increase due to potential decreases in crop production (which could also create a dangerous food shortage). With a parity, the added support provided by the government served to increase supply due to government incentives being based on quantities of production. Thus, because the government encouraged production surpluses--in effect creating a so called artificial market place in the process--the price of a crop remained low, both locally and on a world scale where the government could dump crops overseas, and return a significant fraction of the support provided internally despite the lower costs to other countries.

Parity served to create the effect of spillover, which occurred when price supports on maize, for example, kept the true cost to the farmer low; allowing him to feed his cattle more maize than he otherwise could have. When the cow went to slaughter, it would be heavier and return more money to the farmer. On a large scale, this kept the price of cattle down as, although cows were heavier, due to the increased supply, prices were less on a per-pound basis. Because parity created this spillover effect, the farmer would make more money as a result of the cow's increased poundage.[103] So, just as spillover worked in research to increase potential innovations, it worked economically for the farmer to increase revenues. Thus, government support served to increase production through research and to regulate prices via parity at only a moderate cost.

B. DETERMINING RETURNS ON INVESTMENT

There are several difficulties in determining the return on the investment in research. The primary difficulty is how to measure or determine the return at any given level as well as in total. A standard measurement, with regard to economic returns is to compare a return to what the return may have been if research facilitating a return had not been done. By using this approach, perceived returns generated year after year as a result of a discovery or innovation are considered perpetual. However, more often than not, technological innovations such as harvesting and processing equipment required to make full use of a genetic innovation were not accounted for in determining a return. Another factor is that measurements of the perpetuity of a return do not necessarily include inflation or increased competition. Thus, what is considered a perpetual return by this type of interpretation does not account for any diminishing factors or peripheral costs that are necessary to economically utilize an innovation. Hence, the return on investment should not necessarily be interpreted as profitability; rather, it is an indefinite gage against which the investment can be measured.

In addition, another difficulty stems from the United States Department of Agriculture's definition of what a return was. The USDA defined and determined most aspects of agriculture, and the difficulty arises due to the USDA's changing of its definitions.[104] Due to the definitive changes in what was considered a return on research, statistics (based on USDA definitions) taken by the census bureau from private business become difficult to discern with any significant degree of accuracy.

The USDA seems to like to ascribe the return on investment in genetic research at $600 million dollars per invention or innovation, and likes to state this as a perpetual return. How they come up with this number is not certain, but if this is true, just a few of the innovations brought about by genetic research yielded an initial return of at least $5.4 billion dollars and a total return of at least $162 billion dollars during this era, for innovations on cultivars.[105] Stated differently, by USDA perceptions, every dollar invested in research returned about $100 dollars. This perception makes the return on investment in research seem very well spent.

Most other economic researchers come up with different numbers, however. For example, the most successful genetic innovation, maize, produced an estimated gross return of about 700 percent.[106] That is, for every dollar invested, seven were returned, which is substantially less than the 1 to 100 stated by the USDA. Due to the necessity of having increased mechanical technology to facilitate biotechnology, however, determining the return on investment required several other factors. These included the cost of fertilizers necessary to help growth, increased land area to permit the best return for the cultivar type, farming equipment necessary to plant, grow and harvest the crop; other production, processing, transportation, and storing equipment. This peripheral hardware was necessary to get the maximum return for the biological innovation. Thus, due to these costs, which are hidden by USDA estimates, the true return in terms of profitability diminishes.

C. THE ECONOMICS OF SIZE

The foregoing factors bring up the determination of what is known as the "economics of size,"[107] which is a determination that accounts for the necessary investments in hardware as well as in biotechnology. Although the USDA likes to look at the big picture of overall return on investment, it is not directly responsible for what the farmer--"family" or "corporate"--needs to have to utilize advances in biotechnology. For this reason alone, the USDA's estimate of the return on investment becomes nebulous as it does not state whether if the return on research investment included the the price of the necessary hardware to grow the crop, or the profits yielded by new mechanical technology.

The farmer had to utilize the latest innovations in biotechnology to remain competitive. This necessity was based on the relative inelasticity of agricultural prices. Inelasticity refers to the range of profitability due to the supply of any cultivar compared to the demand, and as through this era for the most part supply has exceeded demand,[108] the variances in prices were quite slim. For this reason, if several farmers utilized new technology, the effect was to drive the sale price of a cultivar down to the point where, if a farmer did not utilize the new technology, a crop would cost more to grow than it was worth in the market place.

Often, the ability to change to a new technology was based on the farmer's ability to utilize the technology as well as his credit worthiness. If, for example, a farmer owned 160 acres of land that was used for growing corn, he could expect a return of N dollars on his land in an average year. To switch to hybrid maize, he would have had increase his use of fertilizer, which could have necessitated purchasing a new spreading machine. Additionally, he may have had to purchase a new harvesting machine designed to accommodate the average height of the new cultivar strain. The farmer may have found that the new fertilizing and harvesting tools cost so much that it was necessary to cultivate at least 800 acres per year, rather than the 160 acres he owned to economically operate the tools. Unless he could co-op the purchase price of the machinery with his neighbors, he could not economically afford the new technology. Further, even if he could form a cooperative with his neighbors, if they collectively had a bad year, their combined credit worthiness may not have been perceived by lending institutions to be a sound investment. In either case, unless the farmer had what was perceived to be an adequate ability to afford the latest in technology, the farmer's alternative was usually to sell his farm or go bankrupt by attempting to compete by utilizing economically obsolete approaches to cultivation. Thus, the economics of size was a central determinant of the ability to utilize a technological improvement, and one not necessarily accounted for in statistics reflecting investment returns.

There was an added effect to this determination in that the more farmers there were in a given area that found themselves in a financial dilemma, usually the more bankruptcies or farm sales resulted. This trend served to create an eventual change of ownership, with one person, or more often by the 1940's, a corporation,[109] purchasing several 160 acre tracts in a concentrated area to provide a large enough productive area to accommodate the new technology. The result of this increase of land per owner was more economical cultivation, which tended to drive down prices further and perpetuated the significance of the economics of size at an accelerated rate.

This trend towards the economics of size is mostly evidenced by the decrease in the number of farmers as well as changes in farm ownership. In 1935, there were an estimated 6.8 million farmers, and in 1960,there were about 3 million.[110] Additionally, in 1930, about 28 percent of farms held one thousand acres or more; in 1950, there were about 43 percent, and by the late 1960's, this percentage had increased to 54 percent.[111] With this change came an increase in joint ownership, which in 1945 amounted to 36 percent, and by the late 1960's, 53 percent. While this latter statistic is attributed in part to the post war boom, it may be seen to indicate the trend towards increasing size to accommodate economic necessities.

Food processing and packaging houses were benefited mostly by the economics of size. By 1950, a single processing house could purchase the production of as many as ten thousand farmers.[112] Companies such as Birdseye, Del Monte, Campbell Soup Company and others mentioned in previous chapters were among the companies and corporations to purchase crops and land under the aforementioned technical-economic conditions. Also, they utilized genetic research to aid in the selection of cultivars for the best results to maintain nutritional values during the manufacturing, storing, canning, and shipping of agricultural cultivars.[113] Many times crops would be grown to the specification of the processing house, which created the benefit of improved quality of the material to arrive for processing. While this was good for the processing house, it served as a further step to require farmers to apply the latest in technology. Thus, the economics of size may be seen to include the control that large processing houses may have exerted over a number of farmers.

Genetic research served to standardize sizes and grades of material before it arrived at a processing house. This helped to decrease the direct labor necessary for processing, and also helped in standardizing processing equipment by accounting for an overall decrease in size gradation and weight to volume and density factors. Due to these standardizations and to the increase in the volume produced, the profit margins of the production houses were able to be at least maintained, and in most cases, increased. Food processors did not usually suffer from the necessary over production to which farmers were subject. Indeed, vertical integration in the case of a farm being owned outright by a processing house served to allow a processing company to profit from the parity support system on the one side and from sales of a finished commodity on the other. The use of genetics permitted more precise selection and ultimately standardization of crops to serve the largely predetermined needs of the processors. A farm owned by a processing house could grow crops to the level of surplus, and at times sell off the surplus, using the remainder internally.

One example of fortuitous surplus utilization in the production industry was in the case of frozen foods. Prior to 1941, producers of frozen vegetables and fruits suffered poor sales due to the not unfounded belief on the part of the general public that frozen foods were of inferior quality. With the onset of World War II, however, this perspective changed due to a sudden, urgent need:

> The Armed Forces wanted 70 million pounds of frozen fruits and vegetables. Although several hundred packers of quick-frozen foods were now in business they were not enough. Everyone who could buy, rent, or requisition freezing equipment began packing quick-frozen foods. When in early 1944 frozen foods were removed from the ration list the public snapped up any package it could find.[114]

Thus, a type of commodity that originally was not generally wanted became scarce, and due to this scarcity the general public's concern about the quality of this type of commodity was removed (though measures were taken during this time to regulate the relation between quality and longevity of frozen foods). The advantage in this case was that because the foods were frozen and in great demand, the production house was able to sell off its surpluses without necessarily destroying old produce. Although this example is not the norm in business, it serves to show that due to the quantity of food necessary for normal production, agricultural production and packaging houses were generally not adversely affected by price or production regulation. Because of this and other factors, the production and processing houses tended to have success on both sides of the parity/research coin.

The effect of this parity and research dualism was to maintain low prices or expedience for the consumer. Food to feed four people, needing full preparation in 1950's dollars (from the store to the kitchen table), is estimated at requiring $4.90 and requiring 5.5 hours; fully prepared meals (frozen TV dinners, canned and frozen foods requiring only cooking time) are estimated at $6.70 and require 1.6 hours.[115] The urbanization of America and the increase in the number of working women have necessitated this change:

> The busy American woman either does not have the time, or at least refuses to devote the time, to preparing all the family means from scratch. To do so would cost her somewhat less but would take up a large proportion of her available hours. She values her time too highly to sell it for what amounts to 45 cents per hour.[116]

Thus, the economic bottom line was the necessity of a working family to maintain its productivity, requiring expediently prepared foods at a low cost, with a primary benefit of allowing the devotion of more people's time to more profitable ends.

Facilitating this end since 1930 has been the endless desire, apparently on the part of the American public, for new and improved foods. This desire contributed to the necessity of research, cultivar improvement and standardization, better processing, and ultimately higher cost to the consumer, though at a lesser percentage of consumers' incomes. In 1930, total agricultural production was valued at $20 billion. The population of the United States was about 130 million. This equals about $154.00 per person per year. In 1960, total agricultural production was valued at about $29 billion and total population was 180 million, equaling about $161.00 per person per year. Disposable income in 1930 equaled about $1,300.00 per capita, and in 1960, disposable income equaled about $1,800.00. This translates to food requiring about 12 percent of a person's 1930 income and about 9 percent of his/her 1960 income.[117]

An additional deduction may be made from this if one were to discount the sales of food to other countries. In 1960, for example, commercial food sales to other countries equaled just over $3.2 billion.[118] This lowered the total cost of food in the United States to $25.8 billion, reflecting a cost per consumer of about $143.00. The viability of this deduction is contingent on incorporating the amount of donations made, and by the time the calculations are made, the end result is a near-zero change. Thus, it may be seen that genetic research was a great contributor to this apparent 3 percent per capita (excluding sales to other countries) decline in the price of food. For this reason, genetic research leading to cultivar standardization was perceived as the most expedient means to support the feeding of America.

Agricultural cultivation is decentralized; that is, the physical cultivation of agriculture was performed by many thousands of family and corporate farmers. The center or common ground of agriculture is the commodities produced. Processing and packaging houses, the production side of agriculture, may be seen to be more centralized due to the aforementioned ability of one processing house to utilize the commodities produced by up to 10 thousand farmers. By the value of the material produced, this combination of a decentralized cultivation side of agriculture and a centralized production side shows that bio-technology worked to require farmers to increase productive size while under effective economic restraint: Land, hardware and technology had to be purchased, and the cultivated commodities needed to be sold at a controlled price. Because of this combination, farmers were by the same effect controlled by the elements of research and production. Farmers were the most numerous and least organized group in the business of agriculture, and as a group they suffered the most ostensive hardships during this period when farming changed its scale.

With respect to the cost of food to the consumer, the comparatively small financial change brought about during this era due to agricultural genetics may be seen to have indicated more an emphasized preference of utilizing genetic technology for the sake of standardization than it did a change in scientific technology to increase overall agricultural production. This is shown in part by the price of agricultural commodities: The price decreased moderately while the apparent quantity increased significantly.

Economic emphasis tended to place a necessity on the farmer of expenditures for reasons of competition over other reasons. Land use conservation and the limitations it placed on farmers to remain competitive, was a factor that limited means of competition, as was the ability of a farmer to survive economically under these circumstances. Due to this combination, considerations favoring economic selection for those using increased technology was dominant over other concepts (an extension of Mendelian thought); especially considerations regarding the primary contributor towards the future of agriculture: the cultivated species.

CHAPTER VI

SOCIAL CONSIDERATIONS

A. AGRICULTURE AS PUBLIC PROPERTY

The concept of property has been central to the foundation, maintenance, and security of the United States. During this time and before, knowledge was perceived as a form of property, particularly when it was "public knowledge;" that is, knowledge readily accessible or known to the average person was considered public knowledge. With regard to applied genetics, the increased yield of a cultivar that has been hybridized was well known, which made the process public knowledge, the equivalent of (or in this case, the means toward increasing) public property. This is especially true of agriculture, as agricultural seed stock was originally given to individuals free of charge from a branch of the United States Patent Office.

Due to the predominance of agricultural innovations originating in university laboratories and experiment stations and being disseminated via agricultural extension, the knowledge (or property) that developed from research was considered public. As a result, the creation and development of agricultural property may be seen to have existed in the public domain.[119]

In many cases involving agriculture, private property has been shown to be regulated by public property belonging to the Federal and/or state governments, as in the case of research and development. As a result of this regulation, what became public knowledge was regulated as an effective by-product of the knowledge handed down from the Extension Services section of the USDA.

With regard to public knowledge, the price of food was a most immediate factor for public consideration. As has been seen, hybridization contributed toward a reduction in the percentage of income spent on food, an increase in the price of food as a tradable stock commodity, as well as an increase in the quality and quantity and apparent diversity of food produced. Due to the development of urban society between 1930 and 1960, the majority of people became alienated from the production side of agriculture, and public concern revolved around the side that most affected them commonly--usually at the retail level. The increase in income available to the consumer was often perceived as being much the same as a decrease in the price of property, in this case food.

To special interest groups, the utility most apparent on the production side of agriculture--the farmer--was that technological innovations provided a means to permit increased production of better food, which may have been seen as a form of property essential to life and prosperity.

Genetic research pursued the goal of increased production and improved quality to achieve lower costs on this level while enabling a reduction in land necessary for increased production. Federal regulations also served this end by creating incentives for land use reduction when coupled with increased production.

The same perception of technological innovations resulting in "better" property was evident in the United States' helping undeveloped and underdeveloped countries to better feed themselves by way of inexpensive imports of food and the ability to better cultivate their own crops internally. Between 1955 and 1960, for example, just over $7.8 billion worth of food and aid was exported to other countries.[120] These exports, which were seen as surplus production (in terms of both food and physical assistance), provided other countries with at least a start toward internal production, and in many cases meant the difference between mass famine and survival.

On this basis, the purpose served by the inexpensive sale or donation of United States property was to provide help for the needy. In addition, these contributions served to create the perception to both the people of the United States and recipient countries that the export of food and technology conveyed the image of Americans as benevolent providers of food to feed the world--a highly valued ideal.

There were, of course, other reasons for providing needy countries with this type of property. One of these was achievement of a broader sense of national security, which in the public realm was also seen as property, or at least property insurance. The United States contributions of food has been described as "one of the marvels of the world [is] that the United States can feed its own population and still export ... its wheat and rice crops ... its soybeans, ... its grain sorghum, and ... its corn."[121] This type of national property, or security, has been considered inexpensive due to the exports of these commodities coming from surplus production.

Despite this description, recipient countries did not necessarily see the relationship between the production incentives provided by the United States Government to United States farmers, and agricultural contributions to other countries, but often United States farmers were aware of the relationship: "However [the farmer] sometimes realizes that man's fate ... depends on decisions and actions which range far beyond the market price of hogs or the price support level for corn."[122] The significance of this realization is that the property created by farming represents a significant contribution toward national security, a fact which although most apparent within the boundaries of the United States was effective throughout the world.

The combination of these and other elements in the public realm were based on using agricultural property to maintain and improve the quality of life while providing insurance and security. In the United States the quality of life was often based on the power, both politically and physically, to maintain agricultural property at a surplus level. This combination served to devaluate agricultural property internally, and to provide other countries with surplus agriculture for the betterment, security and increased quality of life for all concerned. Due to United States incentives to produce agricultural commodities to the level of surplus, the benefits are perceived by a recipient to be more valuable and therefore more important than the actuality of the value to the United States. By this combination, the effects of public knowledge producing property to a level of overabundance led to devaluation, which ultimately served the end of security.

What has been the most predominant as public knowledge during this era have been the factors promoting the uses of genetic technology to achieve this end. This predominance has permitted the steadily increasing use of genetic technology with the chief source of public complaint coming from farmers displaced in part as a by-product of the technology. However, the loss of property and income farmers have suffered has been deemed of less significance than the gain of property and security achieved by virtually all other aspects of society. Meanwhile, the loss of diversity has been all but ignored. Due to this, genetic technology may be seen to have been applied in the realm of public welfare, to serve as a means of increasing food production for the betterment or at least the maintenance of the nation's people. In this sense, genetic technology may also be seen to have served a utilitarian purpose for the betterment of life by providing an immediate cure for a problem that has been facing society from its beginning. For the most part, genetic research has virtually removed the threat of famine, which has recurred throughout the history of civilization. In removing this threat, the interests of the public may be seen to have been served by ensuring the feeding and security of the public through making genetic technology public knowledge.

B. GENETIC DIVERSITY AS NATIONAL PROPERTY

Arising from this perception of a humanitarian utility is the question of what utilities are truly served, and what effects are brought about as a result of utilizing genetics to increase production. The most favorable effects are well known to the public, as are the effects in terms of farmers lost due to the change in technology. As stated above, in the latter case, the loss of farmers was seen as contributing toward public welfare on a larger scale. Genetic technology served to create an increase in food production in terms of both its quality and quantity, though at the cost of genetic diversity. In turn, this helped the increasing urbanization of the United States by allowing more people to pursue non-agricultural activities (and earn other property) while enabling people to feed themselves for substantially less money and time than may have otherwise been possible.

In the realm of public knowledge, it is interesting to note that there was no formal society or journal to indicate or track trends and relationships between increased genetic technology and "biosafety" until 1955.[123] This silence is more interesting in light of the fact that of the three hundred thousand known higher plants, only about 1 percent has been used for the combined food, animal feed, fiber and pharmaceutical needs of society.[124]

Contributing to this silence has been the almost complete lack of mention in popular literature of the relationship between using select cultivars for a given crop, and the resulting effect upon the diversity of the gene pool of that crop. During this era, general fiction was more concerned with human drama and rarely featured themes of scientific lore for entertainment or didactic value.

Science fiction, on the other hand, has made notice of the use of genetics as a panacea or goal of society, but seldom did it elaborate on the consequences. Aldous Huxley's 1932 book, Brave New World, is one example of writing that reflects a culture predominately designed by the use of genetics. Implicit in the portrayal of this society is the homogeneity of society as well as the effects of homogeneity upon society. Brave New World portrays the use of genetics to be well enough developed so that risks regarding "manufactured" (or cultivated) versus "native" life are seen as a nominal concern. In this story genetics is used to control people from inception. The apparent goal of this is to condition people for pre-determined roles. The consequence of this approach is a lack of diversity. It would seem that due to the conditioning, society simply does not apprehended any issue in its loss of diversity.

In an essay entitled "The Double Crisis," Huxley continues upon perspective of obtaining a goal without regarding the consequences of the means:

> ... and we need a new system of ownership that will check the tendency towards monopoly in land and make it impossible for individuals to lay waste to planetary resources which belong to all mankind. But changes in social and economic organization are not enough, of themselves, to solve our problem. Production is inadequate to present population, and population, over large areas, is rapidly rising. A change in the laws governing the ownership of land will not change its quantity or quality. The equitable distribution of too little may satisfy men's desire for justice; it will not stay their hunger. In a world where population is growing at a rate of about fifty-six thousand a day, and where erosion is daily ruining an equal or perhaps greater number of productive acres, our primary concern must be with reducing numbers and producing more food with less damage to the soil.[125]

Huxley's attitude is perhaps best explained later in the same essay where he states: "It does not matter which comes first, the political chicken or the technological egg. What is important is that, in some way or other, we should get both."[126]

These representations serve to indicate perceptions of need. This need is stated without emphasizing the potential consequences. On a larger scale, the apparent silence regarding the consequences of genetic selection for predetermined traits may be seen to represent the predominance of orientation towards short-term goals, or perhaps goals which are merely standardized in their spoken orientation so that the needs of society will seem to the public to be obtained.

What has been obtained by genetic technology has been a great standardization of cultivation techniques coupled with increasing uses of select cultivars for growth in the United States. A 1970's estimate made by the National Academy of Sciences is that at the time there were 51 varieties of cultivars used on 13 primary food types. All of these were imported cultivars and include dry beans, snap beans, corn, millet, peanuts, peas, potatoes, rice, sorghum, soybeans, sugar beets, sweet potatoes, and wheat.[127]

Types of cultivars or agricultural property indigenous to the United States include sunflower, cranberry, blueberry, strawberry, and pecan.[128] As most cultivars used in the United States have been imported, it is possible that any concern with regard to standardization has been minimized. However, the exportation of United States technology to other countries has also served to reduce the number of living cultivars in those countries. A seed is capable of germinating for only so long, depending on the type of seed and the climate in which it naturally exists. By exporting crops, the amount of cultivation of a comparable crop in another country has been reduced, which has caused an attrition in the amount of indigenous diversity for cultivar types in that country.

Additionally, by exporting cultivation techniques for predominantly hybridized seed stock in other countries, the attrition rate of indigenous seed stock has been further accelerated. The countries where this process has taken place were comparatively poor and underdeveloped, and there were little research or attempts to document the quantities of indigenous stock. Due to this combination, a predominance of silence regarding the attrition of cultivars has been perpetual until very recently, despite concern about the trend having been voiced since the 1940's.

Due to lack of concern, at least partly caused by a lack of public knowledge, the utility served by hybridization has been to serve the short-term needs of society by creating a profession which created and developed highly uniform properties along the same guidelines which created the industrial revolution. Nevertheless, the real benefits in terms of public knowledge have been significant:

> With the potential benefits ... come risks. Because genetic changes during the development of new varieties are often cumulative, and because superior varieties are often used extensively, the new technologies could increase both the degree of

> genetic uniformity and the rate at which the improved varieties displace indigenous crop types. Furthermore, it has not been determined how overcoming natural breeding barriers ... will affect a crops susceptibility to pests and diseases.[129]

There have been reductions in cultivar types since the start of cultivation, and the rate was substantially accelerated during this era. Estimates range up to 40,000 lost cultivar types due to the use of hybridization, but "what is not known is how much species disruption can take place before the quality of life is also affected."[130]

Thus, the concern during this era has been to disseminate knowledge for the betterment of public property, which is the equivalent of public welfare. What has been achieved is an abundance of select property. What has been lost is a much greater abundance of diverse property. The sense of security felt during this time was perhaps the reason for the obscureness of potential problems resulting from standardization of cultivars. Most of this loss has occurred outside the boundaries of the United States, and where the United States was able to alleviate hunger in other countries it is interesting that, in the long run, this process may serve to remove the abilities of both the United States and other countries abilities to secure food.

In view of the foregoing, what some people may have interpreted to be a form of social evolution, may just as well have been seen as the enactment of pre-determined social modification.

CHAPTER VII

SUMMARY AND CONCLUSIONS

This paper has covered selected aspects of the development of genetic technology in its application to agriculture. As has been discussed, the development of genetic theory between 1930 and 1960 was significant primarily for increased resolving power. The increases included the confluence of cytological cell mapping with genetics, a furthering of the understanding of genetic linkage and crossing over, an increase in the understanding of the chemical basis for plant nutrient requirements, the realization that DNA was the basic mechanism of heredity, and finally, modeling DNA after the double helical design.

These findings and others permitted a dramatic increase in both the resolving ability of the study of heredity and provided for a means of understanding as well as manipulating inherited characteristics. Additionally, the manipulation of hereditary characteristics occurred during this time without the application of population statistics, introduced early in this era.

Techniques of applied genetics were aided by the above developments and discoveries. However, applied genetics was actually well ahead of theoretical means of explanation. The most predominant form of applied genetics was the double cross technique of hybridization. By means of this crossing technique it was possible to breed cultivars for greater resistance to natural hazards. This included resistance to pests and disease, lodging and other climate caused hazards, as well as inducing cultivars to grow more vigorously and to maturation in less time. The use of double crossing provided an average increase in yield which ranged from about 25 to 50 percent.

The other most predominant technique in applied genetics was the development of artificial insemination and so-called up breeding of livestock. Artificial insemination allowed livestock to be grown by the use of a preferable male animal's semen on greater numbers of a females than would be possible by natural means.

Artificial insemination achieved this end by increasing the productive longevity of a male animal as well as its productive frequency. This method was often applied in combination with up breeding, whereby live stock showing preferable traits were bred through successive generations for high meat to fat ratios as well as preferable growth rates. The combination of these two aspects of animal breeding accounted for about one third of the cattle production in the United States and half the production in Great Britain.

Both theoretical and applied aspects of genetics were taught in educational institutions, primarily the land grant colleges and the experiment stations, which were affiliated with the land grant colleges. Education in genetics expanded with developments in technology and theory. Other educational measures included training in conservation and an increased guided experimentation. Emphasis on agricultural education was aimed primarily toward those aspects of agriculture that most promoted a reduction of cultivar diversity. Training in genetics was focused primarily on double crossing techniques to increase production quantities as well as qualities. This was often applied to land suffering from generations of overuse or neglect.

The techniques developed at the land grant colleges and experiment stations were applied in field experiments in other countries. There, students and instructors utilized the latest United States technology for the combined education and well being of all parties. Support for these field experiments came from both public and private sources.

The administration of genetics in the United States was mainly in the form of Federal regulation. This provided economic emphasis on growth of select crop types and economic discouragement of growth of non-supported crop types. Several agricultural regulations during this era had the effect of greatly increasing the cultivation of select crop types while also reducing the amount of land utilized for production by about 50 million acres. State regulations favoring commerce, industrialization and living accommodations over agriculture were the principal contributors of land reduction. Other significant contributors the decrease in the number of farmers and increased productivity of hybrid crops. This combination of economic support for select crops and land use reduction necessitated the use of hybridized cultivar types to achieve profitable production.

The professionalization of agriculture has been the central factor in the shift toward engineered agriculture in response to government-directed, economic and social perspectives of need. Applied genetics has been the enabling force in this transformation. It has been the factor most responsible for the decreased number of farmers and the increased homogeneity of cultivated species both in the United States and abroad.

Production was increased primarily by the development of professionalism, whose product--improved biotechnology--served to permit increased production and improved quality. In turn, this enabled an economically feasible decrease in land use. The growth of professionalism and the concurrent increase in technology was attributable to the attraction of agricultural genetics, which worked on at least two different ways. The first way was the ability of people, primarily from poor families (many of who earned their living in agriculture), to utilize the educational system to obtain training in genetics, thereby leading to a career in agriculture. This may have been perceived as a form of state patronage that was more intellectually intensive than the labor intensive careers of their parents, as well as permitting a potentially higher income than their parents could have earned. Agricultural genetics also attracted professionals trained in physics, chemistry, biology and several other scientific professions, who switched their professions to focus on genetics. The effect of professionals trained in different disciplines who focused on agricultural genetics served genetic research by rapidly increasing the methodological and technical abilities of genetics. Further, their influence helped to expand observational techniques to include the physical, structural, cellular, and chemical levels of genetics.

Professionalism was enhanced by autonomy, which granted independence to the professional and protected him from outside influence and judgment. As the profession developed from academic traditions rather than through private industry, agricultural professionalism had the added protection of being, in effect, an extension of the government.

Regulation of professionalism was accomplished primarily by providing economic and research incentives, usually in the form of grant writing. Grant writing was made effective by extending and/or adapting previous successful research to new cultivars. In addition, grants for different types of research than were traditionally utilized would be more readily accepted if they included a potential of increased spillover.

Often serving the end of increased technology, productivity, and spillover, was the exporting of agriculture to other countries. Traditionally, this involved sending agricultural professionals and students to poor countries to help increase agricultural output for the recipient country. Production increases were achieved by applying Western cultivation techniques coupled with hybridized cultivars along with western methods of storage and transportation.[131] These cultivars were often, but not always, of indigenous origin. In addition to the benefits provided to the recipient country, the professionals and students benefited from the field excursions by increasing their knowledge (also a form of spillover). By the extensive internal use of professionalism as well as by exporting professional techniques, the importance of the agricultural profession increased dramatically. Consequently, professional agricultural geneticists became the consultants of agriculture. Regulation further contributed to an increase in the status of the profession.

In terms of economics, agricultural genetic research provided the government with a true return on investment. However, this return came at the cost of many farmers and a great amount of diversity in the types of cultivars grown. The product of research--genetically preferable cultivars--was indirectly coupled with agricultural parity. Parity and research were combined to permit an increase in productivity, thereby allowing a greater return by area while economically decreasing the government's cost in terms of parity on the same basis.

The returns on investments in agricultural genetics were substantial. A conservative estimate shows that maize provided a rate of seven dollars returned for every dollar invested. The cost to the farmer of obtaining this return, however, was not accounted for. Primary requirements for the profitable use of hybrid technology were adequate land, fertilizer, storage, and transportation facilities. Central to generating a profitable return was the ability to utilize increased technology. These factors are the basis of the so-called economics of size. These economics determine return on investment by including both the cost and types of hardware and land needed to generate a profitable return.

By the mid 1940's, it became necessary for a farmer to utilize the latest technology to be competitive in a relatively inelastic market place, which is a partial basis for the economics of size. To achieve profitability, it was essential to have enough land to generate a profit plus harvesting equipment capable of processing the land. Harvesting equipment was increasingly designed to accommodate the general growth characteristics of hybridized cultivars, as were fertilizers and pesticides. Therefore, it was commonly necessary for a farmer to accommodate the needs of biotechnology or lose his farm.

Following this trend of the economics of size were the increases in farming cooperatives, partnerships, and corporations with the capital and credit worthiness needed to finance the change in technology. The change brought about by genetic technology was evidenced by the decrease of about 3.8 million farmers in the 30 year period this paper covers.

While government regulation provided the greatest control over the farmer, the production and processing houses were next. As by 1950 one processing plant could utilize the production of up to ten thousand farmers, both the price and required quality of production were regulated by the farmer's principal source of sale.

In short, parity served to regulate support for select agricultural commodities, production plants served to regulate quality and sale price, and research served to modify and regulate what was economically profitable to cultivate. The combination of these tended to promote hybridization to achieve the quality, production, and cost requirements imposed upon agriculture.

To the United States of America, a most significant aspect of national security was concept of property. Public property was most commonly exemplified as public knowledge; that is, knowledge which was accessible to the people of the United States. Public knowledge contributes to national security in part by enhancing the probability of consistency throughout the nation. To the farmer, the most apparent aspect of public knowledge provided by agricultural genetics was the ability to increase production and improve quality by applying techniques developed at the land grant colleges and experiment stations. To the general public, the most apparent results of agricultural genetics were lower costs and better quality of agricultural commodities at the grocery store.

During this period, one was not allowed to patent or claim proprietary rights to a cultivar that was sexually reproducing, even though it was hybridized. Thus, cultivars were perceived as public property, unless the cultivars were purchased as plants or seed stock (for resale or personal consumption). Consequently, most cultivars in the United States were considered public property.

Despite the effective ownership of the diversity of cultivars by the people of the United States, the incentives in agriculture to grow primarily homogeneous, hybridized cultivars, has greatly contributed to the estimated reduction of genetic diversity by 40,000 types during this era.

Literature, a principal means of disseminating knowledge, tended to promote the use of genetic technology, as did scientific journals. Due to this direction of public knowledge, the risks of hybrid technology tended to suffer from silence in publications. This may be seen to have contributed to the reduction of diversity. Due to the knowledge of at least a few professionals of the reduction of cultivar types, and the general lack of public notification, in this instance, a great disservice to public property has been done. In the long run, this could be a disservice to our national security.

As has been seen, approaches utilizing genetic technology are indeed more productive than previous approaches that did not utilize this technology. With the change in approach toward agriculture has come an inherent short sighted outlook on the productivity of select cultivar strains and the effects of not utilizing cultivar diversity. By forming agricultural technology and productivity in the same mold as non-agricultural commodities, the trend toward homogeneity of productive means and types developed quickly. This approach set the stage for the so-called "Green Revolution," which occurred during the 1960's and 1970's and continues today, spreading hybrid technology throughout the world.

The Green Revolution has generated two primary changes: One is the use of desoxyribonucleic acid for the recombination of genetic characteristics (r-DNA) and cultivar cloning. The other is the granting of patents for cultivars so "created," even though genetic material actually is cut and moved rather than created. This allows a corporation, company, or individual to own a cultivar--something whose ancestors were public property--and to have all the rights of private ownership. Further, research in r-DNA has developed seed stock which is capable of germinating and growing only by the use of fertilizers having a specific genetic complement to the seed stock's designed traits.

Although there can be no understating the ability of genetic technology to reduce and help eliminate famine, there can equally be no understating the ability of this technology to both remove genetic diversity from the planet and to place existent gene stock in the hands of very few corporations. This latter trend has been followed by an increased step away from accommodating nature and toward engineering nurture. The result has been an increase in both productivity and genetic homogeneity.

Through this combination of genetically designed seed stock and fertilizers, the tendency of corporations to "collect" patents by utilizing preferable seed stock to create hybrids has accelerated. This has led to acceleration of the use of cloned cultivars, manufactured by a cut and move technique. This technique incorporates refined pre-selected traits distinct from naturally occurring cultivars and previously hybridized cultivars in agriculture to maintain what is perceived to be necessary productivity.

The loss of this type of public property has been accompanied by an increase of private property, although at different rates. The latter is characterized by economic control by a few corporations. To this trend the statement "Give us this day our daily bread, should not be a prayer to Shell Oil Company,"[132] especially when viewed in the light of Huxley's Brave New World, becomes both foretelling and alarming.

The trend of a few corporations producing the majority of cultivars brings up the question of how much homogeneity is considered safe:

> Successful plant breeding is based on the availability of genetically diverse plants for the insertion of new genes into plants.... However, the rate and extent of this trend is unknown; the data simply do not exist. Therefore, it is essential to have an adequate scientific understanding of how much genetic loss has taken place and how much germ plasm (the total genetic variability available to a species) is needed. Neither of these questions can be answered completely at this time.[133]

While it is true that to date, few disasters have resulted from the use of homogeneous crop types--leading to the belief that there is little risk in this approach to agriculture--it is equally true that there neither the Government nor private industry has made an intensive effort to estimate the risks. In light of the seemingly systematic exclusion of statisticians through this era and after to construct "adequate" statistical models to evaluate the risk(s), one wonders why this has been avoided. A lack of knowledge has seldom been the cause of avoiding intensive research on a problem, particularly where Government support is involved.

It is also true that there has been both selection for preferable characteristics in agriculture since man began to cultivate, and there also has been a steady decrease in genetic diversity. This combination and what was perhaps too much bureaucratic pragmatism has served as precedent. The current emphasis is on expanding r-DNA research in the belief that it may provide compensation for both past and current losses. However, current abilities in r-DNA only enable moving known aspects of genes to produce preferable traits, not designing them to reconstruct genetic elements lost to the past.

NOTES

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[4] A. H. Sturtevant, _A History of Genetics_. New York, 1965. p. 74

[5] _Ibid_., p. 76.

[6] Muller, _Ibid_., pp. 220-319.

[7] Harriet S. Creighton & Barbara McClintock, "A Correlation of Cytological and Genetical Crossing-over in Zea mays" [in] James A. Peters, Ed., _Classic Papers in Genetics_. New Jersey, 1959. pp. 155-160.

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[9] G. W. Beadle and E. L. Tatum, "Genetic Control of Biochemical Reactions in Neurospora" [in] James A. Peters, Ed., _Classic Papers in Genetics_. New Jersey, 1959. pp. 166-173.

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[11] _Ibid_., p. 175

[12] _Ibid_., p. 178.

[13] James D. Watson and Francis Crick, "Molecular Structure of Nucleic Acids" [in] James A. Peters, Ed., _Classic Papers in Genetics_. New Jersey, 1959. pp. 241-244.

[14] _Ibid_., p. 242.

[15] Ibid., p. 243.

[16] Sturtevant, "Population Genetics and Evolution [in] Ibid., pp. 107-116.

[17] Ibid., p. 108.

[18] Edward M. East & Donald F. Jones, "Inbreeding and Outbreeding" [in] Wayne D. Rasmussen, Ed., Readings in the History of American Agriculture. Illinois, 1960. p. 215.

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[22] M. H. Arnold, "Plant Breeding" [in] Commonwealth Agricultural Bureaux, Perspectives in World Agriculture. England, 1980. p. 78.

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[24] Ibid., p. 73.

[25] Ibid., p. 75. By the 1960's, seed dressing was incorporated with the gene for gene theory to further protect against blight, parasites and pests.

[26] Ibid., p. 76.

[27] Michael Lerner & H. P. Donald, Modern Developments in Animal Breeding. New York, 1966. pp. 119-120.

[28] Ibid., p. 83.

[29] Paterson, Ibid., pp. 97-108.

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[30] James D. Watson, The Double Helix. New York, 1968. p. 74.

[31] Glenn Z. Stevens, Agricultural Education New York, 1967. p. 32.

[32] Roland R. Robinson, "Resource Allocation in the Land-Grant Universities and Agricultural Experiment Stations" [in] Walter L. Fishel Ed., Resource Allocation in Agricultural Research. Minnesota, 1971. p. 239.

[33] Duane Acker, "Trends in Agricultural Curricula" [in] National Academy of Sciences, Undergraduate Education in the Sciences. Washington, D.C., 1971, p. 14. This resulted in part due to an overabundance of PhD's trained in physics.

[34] Ibid., p. 15.

[35] Ibid., p. 20.

[36] Ibid., p. 20.

[37] Ibid., p. 20.

[38] Due to long term difficulty in determining what constitutes a plant family, this study is still experiencing difficulty today.

[39] Julian D Corrington, "Inclusion of Ecology in the General Biology Course" [in] American Biology Teacher. Pennsylvania, 1945. 8:30-33.

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[43] James H. Connell, Ed., "Life Histories and Ecological Genetics" [in] Ecology and Ecological Genetics. New York, 1970. p. 1.

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[51] Determination of significant agricultural industries to this time vary. See Ingolf Vogeler, Ibid., pp. 109-110, and Pauline Arnold and Percival White, Food: America's Biggest Business. New York, 1959. pp. 113-115; 225.

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[53] Graham Chedd, Ibid., p. 15.

Chapter III

[54] Rasmussen, Ibid., pp. 227-228.

[55] Ibid., p. 259.

[56] Ibid., p. 259.

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76 Gladys L. Baker, Wayne D. Rasmussen, Vivian Wiser & Jane M. Porter, *Century of Service*. Washington, D.C., 1963. p. 238.

77 Roy, *Ibid*., p. 43.

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78 Burton J. Bledstein, *The Culture of Professionalism*. New York, 1978. pp. 80-81.

79 *Ibid*., p. 87.

80 Warren O. Hagstrom, *The Scientific Community*. New York, 1965. p. 108.

81 Bledstein, *Ibid*., p. 88.

82 For information on the distribution of labor used by the USDA, see p. 51.

[83] See pp. 7 and 12.

[84] In many aspects, Agricultural Genetics is a profession that is separate from other genetic professions. Awards, publications and other reward and recognition functions are handled within agriculture were did not generally participate in the recognition programs of other genetic professions.

[85] A brief listing includes Agricultural History, Agricultural Research, Agricultural Science Review, Genetic Engineering, Principals and Methods, Genetica, Genetical Research, Genetics, Genetics Lectures, and Land Use and Environment Law Review.

[86] Hagstrom, Ibid., pp. 13-14.

[87] Office of Technology Assessment, Impacts of Applied Genetics. Washington, D.C., N. D. pp. 237-242.

[88] David F. Noble, America by Design. New York, 1977. p. 84. "...Abraham Lincoln could well say that 'the patent system added the fuel of interest to the power of genius.' Today it would be more correct to say that the patent system adds another instrument of control to the well-stocked arsenal of monopoly interest ... it is the corporations, not the scientists, that are the beneficiaries of patent privileges." To this end, it is interesting to note that today when genetic "inventions" develop from university research, the university, like the corporation, receives the patent.

[89] "Commission on the Organization of The Executive Branch of The Government." [in] Code of Federal Regulations. Washington, D.C., January, 1949. Chart 1. p. 8a.

[90] Walter L. Fishel, Ed., Resource Allocation in Agricultural Research. Minnesota, 1971. p. 242.

[91] Hagstrom, Ibid., p. 141 and Fishel Ibid., p. 242.

[92] For an example of private institutions, see p. 30.

[93] Hagstrom, Ibid., p. 125.

[94] Ibid., p. 127.

[95] Ibid., pp. 138-140

[96] Fishel, Ibid., p. 316.

[97] Ibid., p. 7.

[98] Committee on Institutional Cooperation, Building Institutions to serve Agriculture. Indiana, 1969 pp. 69-91. It is interesting to note that one of the greatest (and well founded) concerns of the "CIC" is: "Staff members who have returned from overseas assignments have little opportunity to use their experiences and increased interest in international work .... Once the assignment has been completed, little effort is make to use the individual's ideas and experiences to improve either the overseas project or on-campus programs." (p. 84.)

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[99] Walter Fishel, Ed., Ibid., p. 97.

[100] Ibid., p. 146. All costs are stated in terms of the dollar value at the time.

[101] See above, Chapter 3.

[102] Peter Timmer, Getting Prices Right. New York, 1986. p. 81.

[103] Timmer, Ibid., p. 34.

[104] Vogeler, Ibid., p. 30.

[105] This is based on a summary of only the cultivars mentioned on pp. 27-28.

[106] Fishel, Ibid., p. 157.

[107] Vogeler, Ibid., pp. 93-95.

[108] With the exception of the drought years of the early 1930's.

[109] Vogeler, Ibid., p. 76.

[110] Ibid., p. 72.

[111] Ibid., p. 75.

[112] Pauline Arnold and Percival White, Food: America's Biggest Business. New York, 1959. pp. 107-08.

[113] Ibid., p. 120.

[114] Ibid., p. 116.

[115] Ibid., p. 112.

[116] Ibid., p. 112. Taken from calculations made by the USDA.

[117] Marion Clawson, Policy Directions for U.S. Agriculture. Maryland, 1968. p. 132.

[118] Peter G. Brown and Henry Shue, Eds., Food Policy. New York, 1977. p. 83.

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[119] Ibid., p. 69.

[120] Ibid., p. 83.

[121] Gary H. Koerselman and Kay E. Dull Eds., Food and Social Policy. Iowa, 1978. p. 104.

[122] Talbot and Hadwiger, Ibid., p. 67.

[123] Office of Technology Assessment, Ibid., p. 205.

[124] Ibid., p. 158.

[125] George A. Panicas Ed., The Politics of Twentieth Century Novelists. New York, 1971. p. 75. Quoted from "The Double Crisis" in Themes and Variations. 1950.

[126] Ibid., p. 77. Also quoted from "The Double Crisis."

[127] Office of Technology Assessment, Ibid., p. 157.

[128] Ibid., p. 156.

[129] Ibid., p. 159.

[130] Ibid., p. 159.

Chapter VII

[131] This combination of technique and technology occasionally tended to not be very useful depending on the ability of a recipient country to support such a system.

[132] Graham Chedd, Ibid., p. 14.

[133] Office of Technology Assessment, Ibid., p. 13.

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