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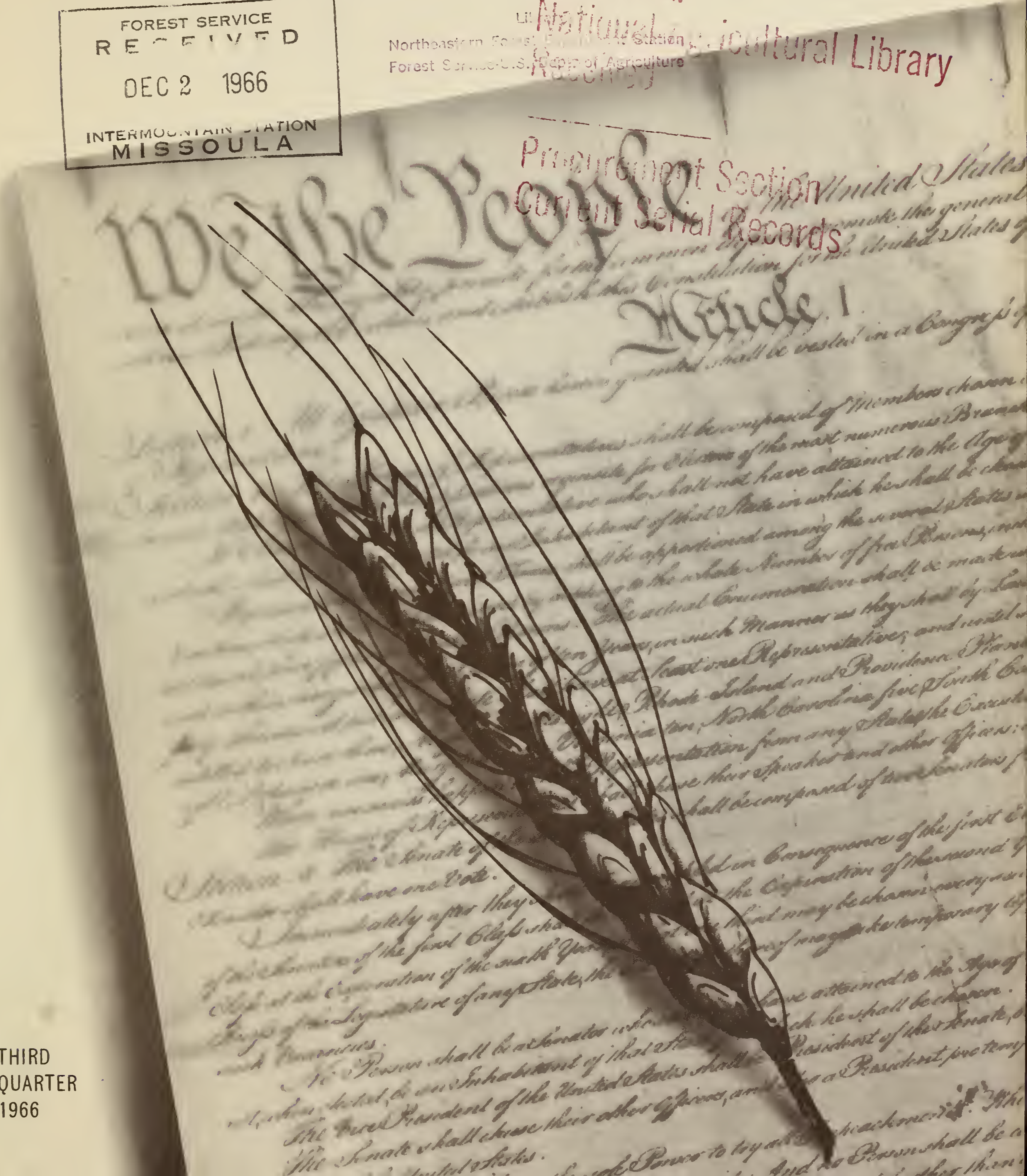

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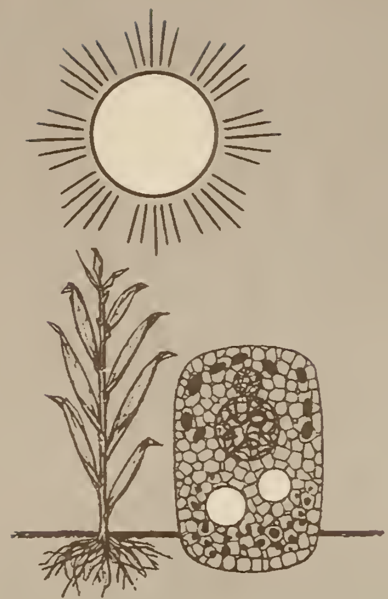

AGRICULTURAL SCIENCE REVIEW

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CONTENTS

The Maturity of Agricultural Science

Some scientists would have us believe that several of the agricultural disciplines have reached a state of maturity and are now entering a long era of minor refinements and position consolidating. Such a philosophy can often be noted among those scientists who are approaching the ebbtide of their careers. Their attitudes may actually betray a feeling of compassion for beginning scientists who, they suspect, lack the exciting horizons that characterized an earlier era.

Although it is true that a state of maturity can logically come to a given science and, thus, represent its final and legitimate phase, one can never be quite sure when it has arrived. Julian Huxley warns that all it takes is one solitary fundamental discovery to remind us that a science is still in its second stage—that of building theory. As a matter of fact, a series of negative findings may even indicate that a discipline has not yet left its first phase—that of amassing knowledge.

Using Huxley's assumptions as a guide, therefore, one need only casually examine the current state of the agricultural sciences to reach the conclusion that not a single one of our disciplines has reached the coveted third phase in its development.

How can we be sure, for example, that we've reached a permanent plateau in whittling down the feed/gain ratio of a farm animal? Or that citrus fruit has to be harvested by hand? Or that we have to live with certain plant diseases?

Exactly what are the desirable and realistic plateaus of achievement in the agricultural sciences? The answer is, of course, that there are none and never will be. Nor in any other branch of science. To admit stagnation presupposes that the human brain has, in turn, reached its last plateau of development. Hopefully, that stage of man's existence is but a figment of idle fancy.

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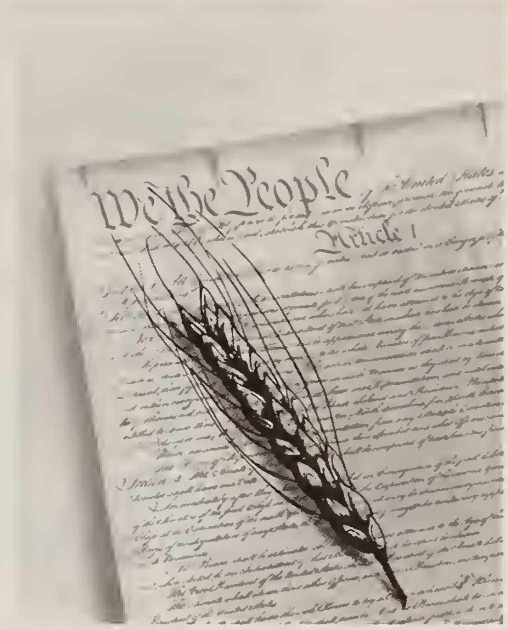


The Problem of Plant Breeders' Rights

S. O. FEJER

LEGISLATION concerning various forms of variety protection, or "plant breeders' rights", is rapidly spreading in Western Europe, since the Convention of Paris for the Protection of New Varieties of Plants of 1961 was signed by eight countries. A few European countries adopted such systems several decades ago, but in the New World there is widespread resistance to these developments, although many think that inevitably they will be adopted due to international pressure.

This paper outlines the most commonly used arguments for and against the introduction of plant breeders' rights, after surveying the historical background. An analysis of these arguments will be attempted and some new ones will be introduced. This is not intended as a plea for or against plant breeders' rights, but it is hoped that a better knowledge of this complex problem will be of help in arriving at an eventual solution. Any solution will have to be in the nature of a compromise between opposing interests and opinions.

The author is indebted to many sources, as documented. These will be freely used, with emphasis on forage crops, with which the author is most familiar. Any views expressed are his own, and do not represent those of this journal or any public body.

Historical Developments

THE Universal Declaration of Human Rights by the United Nations adopted the principle that "everyone has the right to protection of the moral and material interests resulting from any scientific, literary or artistic production of which he is the author". However, a glance into the history of invention and other "spiritual property" shows that their protection in the form of patents, trademarks and copyright developed much less from idealistic concepts, than from the commercial privileges of the Middle Ages. Such monopolies spread from England to the New World and persisted there in some states till the last century. In Western Europe, the monopolies of the craft guilds gave way to industrial development, and the patent system evolved to give incentive for the establishment of new industries (*23*).[1]

The first patent regulation in the modern sense was legislated by the Senate of Venice in 1474. One of the early patents under this law was given to Galileo for a machine for raising water and irrigating land. In Britain, however, agricultural crops were not involved in the early development of pat-

[1] Italic numbers in parentheses refer to Literature Cited, p. 6.

ent law. The Statute of Monopolies of 1623, which served as a model for former colonies, defined the "manner of new manufacture" in a way which was interpreted till recent times to exclude processes making use of the natural functions of plants and animals (*7*). This hardly satisfied the requirements of modern competitive agriculture, especially since in the medical field antibiotics extracted from selected fungi were protected in the United States by patents (*11*). A legal precedent was created in England in 1962 concerning the use of proteolytic enzymes to improve meat tenderness. Extension of this precedent to new varieties of plants and animals was urged (*7*). Legislation was enacted in the United Kingdom in 1964; the Plant Varieties and Seeds Act is now in operation for cereals (*21, 22*).

In the United States, the Patent Acts of 1790 and 1836 were extended in 1930 to cover most asexually propagated plants. Further extension to cover seed plants was advocated (*15*), but many feel that other means, in particular seed certification (*6*), would be more suitable. However, certification systems, unlike plant patents or breeders' rights were not devised to protect the plant breeder and will not be discussed in detail in this review.

In Canada seed certification has long been operative but additional legal protection was also considered. In 1960 a Royal Commission on patents (*14*) refuted the introduction of plant patents in Canada, quoting from a similar report of a U.S. Senate subcommittee (Research Study No. 15, by F. Machlup): "If we did not have a patent system, it would be irresponsible on the basis of our present knowledge of its economic consequences to recommend instituting one."

This point of view conflicts with the arguments used by the United Kingdom committee (*11*) for granting the plant breeder rights in his new varieties as a matter of equity. These rights would give him a means to negotiate a fair return from others benefiting from the products of his hand and brain. This would put him into a similar position to that enjoyed by inventors, authors and artists who are protected against "piracy" of their work. Beside this moral argument recognizing the "art of plant breeding," a real economic necessity was seen in the increasing complexity in plant breeding with the advanced scientific knowledge necessary to further progress. This complexity requires the investment of large resources, and only if the plant breeder is assured that he can recoup these expenditures, can the private sector of the industry be expected to develop any new variety. In the United Kingdom the financial rewards were very modest, and generally, private plant breeding was a part time activity of seedsmen and nurserymen. From the introduction of plant breeders' rights, a stimulation is expected, especially in the breeding of self-pollinated crops—as exemplified by the success of private breeders in continental Europe.

Counter arguments prevail in the United States (*20*). Some public plant breeders question the necessity for private plant breeding in certain crops, and this question is difficult to resolve. However, all plant breeders seem to be afraid of the curtailment of free exchange of germ plasm among breeders and its effects on progress. Expenses for developing distinctive characters, and for testing and verification by some public body are thought to divert funds from more important breeding problems. Release of varieties may be delayed by such tests. Registration fees and the risk of not being accepted may actually discourage the breeding of new private varieties, particularly if compulsory registration were legislated.

For a better understanding of this problem of plant breeders' rights, it will be necessary to review the issues involved in somewhat greater detail. These are difficult to separate, but the main issues around which the discussions on the desirability and nature of legal interference turn are: (a) the present balance of public versus private plant breeding, and (b) the biological nature of the crops involved. Beside those already quoted, discussions took place in Germany (XIII Meeting of the European Confederation of Agriculture) (*16*), in the Netherlands (I.V.R.O., Wageningen (*5*), during the XI International Congress of Genetics), and in the United States (55th annual meeting of the American Society of Agronomy) (*12*). The last meeting was recently critically summarized (*20*), and further commented on (*1, 19*).

Public vs. Private Plant Breeding

THE problem of plant breeders' rights came up at a time when the general tendency in western democratic societies was toward the restriction of any monopolistic rights of one individual against others.

For instance, the difficulty of giving the horticultural breeder legal ownership rights to sports, mutations and variations discovered by the propagator and the grower led to so-called "Breeder-grower" agreements in the United States, but antitrust legislation makes these open to challenge (*20*). On the other hand, communist countries found it necessary to encourage private enterprise in the field of plant breeding by government grants (*11*).

The relative importance of public and private enterprise is much less based on their efficiency in organizing a certain type of activity than on historical development. As an example—in contrast to plant breeding—telephone, telegraph, and railway systems are considered in Europe as *par excellence* public fields to be run by the state, while in the U.S.A. the situation is just the opposite. Any change—and here we are only interested in the plant breeding field—will have to be considered on its own merit, and a review of the present situation in different countries should be of some help.

Competition between public and private varieties was assuring steady increases in wheat yields in the United Kingdom, and the recent introduction of plant breeders' rights in that country is expected to maintain this trend (*21*). Future policy there is toward encouraging the protection of both private and public plant breeding, and sharing the royalty income from public varieties between the tax-payer and future breeding work (*11*).

In countries where the state was doing all the plant breeding, legislation of breeders' rights was pointless, until the recent upsurge of international seed trade and competition with imported private varieties posed a problem. It is hardly a coincidence that two of the major exporting countries, the Netherlands and Germany, protected their plant breeders through a comprehensive statutory system (*11, 12*) passed by legislation more than 20 years ago and that private plant breeding has had a long tradition in both countries, confining the activity of state institutes to basic research. France is in a broadly similar position, with relatively little public plant breeding, but with a largely nonstatutory system, coupled with a unique protection by trademarks. In Denmark, also, private breeding predominates and breeders' protection has been legislated recently, while in Sweden both breeding and protection are cooperative efforts of private industry and state. All these countries, except

Sweden, signed the Paris Convention of New Varieties of Plants of 1961, requiring variety protection for 13 genera.

In the United States, where there is no copyright on governmental publications, there is a similar tendency to extend free availability to the general public of all federally developed patents (*20*). This policy was practiced by the Department of Agriculture in the past—for example, with DDT and penicillin research. In the exceptional case when the use of pollen parents with genes for fertility restoration in crosses with cytoplasmic male-steriles was patented, infringements, although frequent, were left undisputed.[2]

Most public breeders are strongly against the introduction of plant breeders' rights (*12*), and publicly developed plant material is released for the free use of any private breeders—for example, inbred lines for maize hybrids or superior clones for forage synthetics. Under such circumstances, private industry relies heavily on other means of protection, partly by mutual agreements, but mainly by keeping the final combination of parents a trade secret. This, itself, may have disadvantages to the public, but the main handicap is that private breeding is confined to crops suitable for nonstatutory protection. In fact the virtual unanimity in opposing breeders' rights in the United States (*12*) may be partly explained by the missing voice of any private breeders for crops such as cereals and soybeans.

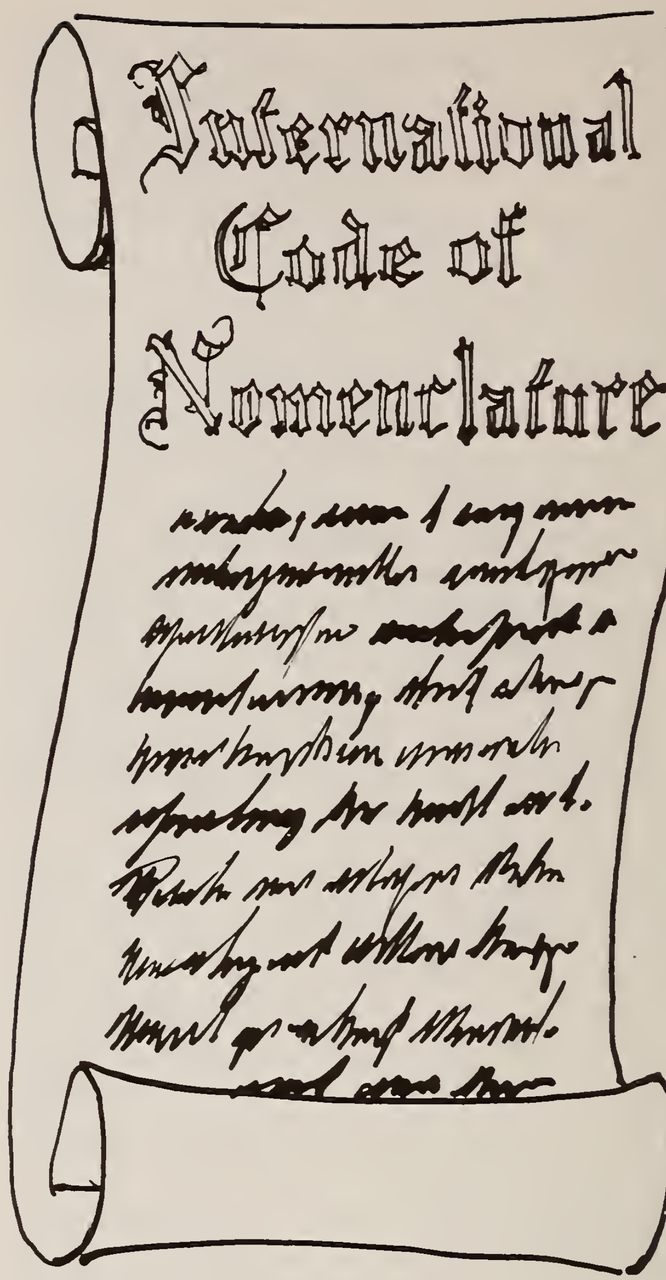
[2] Personal communication from C. S. Garrison.

If international considerations force the introduction of breeders' rights on the United States, it is predictable that governmental institutes will gradually withdraw from breeding such crops, and confine their activity to basic research (*11*).

There is a revealing study from Germany (*16*) touching on many of these problems, and as it uses mainly biological criteria, it serves as a bridge to our next subject. There is a high correlation between the number of private plant breeders working on a particular crop in Germany, and the factors making the breeding of that crop profitable. These factors are frequent reseeding, large amount of seed used, peculiarities of seed production causing high seed price, and little use of homegrown seed (depending on the part of the plants usually harvested for consumption, on disease problems and on the breeding system). Balancing unprofitability in some of these factors is the protection by plant breeders' rights. For example, potatoes and cereals are at the top of the list of the number of private plant breeders, in spite of the use of homegrown seed; some unprotected crops are at the bottom, such as asparagus, marrows, fruit crops, and forest trees. Breeding of forest trees is a state responsibility in Germany, where other public plant breeding activity is regarded as unfair competition to private firms, and a special levy on public varieties or a subsidy to private ones is advocated for countries where public and private breeding coexist (*16*). The income from breeding certain crops is indirectly influenced by the German Federal Republic through price-fixing regulations, but plant breeders employed by private firms or by the state are still regarded as underpaid (*16*) and a levy on all arable acreages, as practiced by the Dutch Government, is recommended.

In any case, whenever the breeding of important crops is for any reason unprofitable, and breeders' rights or public subsidy to private breeders are ruled out for one reason or another, public plant breeding is indispensable. Beside the example of forest trees, and in some countries fruit crops, the extension of the ecological amplitude of a crop into a new area may belong here, such as breeding maize varieties for high latitudes.[3]

[3] Personal communication from L. S. Donovan.



Breeders' Rights and Biological Nature of Crops

THE TERM "variety" was defined by the International Code of Nomenclature for Cultivated Plants as a synonym for the accepted term "cultivar", which "denotes an assemblage of cultivated individuals which is distinguished by any character (morphological, physiological, cytological, chemical, or others) significant for the purpose of agriculture, forestry, or horticulture, and which, when reproduced (sexually or asexually), retains its distinguishing features" (Art. 5). The following subdivision is provided: (a) Clones (vegetatively propagated varieties); (b) lines (self-pollinated varieties); (c) cross-pollinated crops; and (d) first generation hybrids (Art. 11).

The code provides a sound basis for agronomic and legal purposes, and it has been accepted by many nations. However, it is still not strictly followed in practice. Denmark allows a further subdivision of varieties into less typical strains (*18*).

The chief criterion of any protection of invention is novelty or distinctness. Without it, the challenging of any patent infringement would be impossible. Plant varieties have to be new, and also uniform and stable in most countries, and they have to bear a name. All this is in line with the Code of Nomenclature. Utility, on the other hand, is not required by the Paris Convention, and the registration program of the Crop Science Society of America was changed recently to omit this requirement (*20*). The reason for this is that utility is difficult to prove in a court of law, and is best left to an independent certification system.

The proof of novelty depends to a large degree on the requirement of uniformity and it may need a graduated measure. This could be close to 100 percent in clones and other asexually reproduced varieties such as apomictic grasses, and in many self-pollinated varieties. The difficulty of protecting these crops stems from their easy reproducibility. The problem is similar to the protection of copyright from tape recording and xerography. Protection there is confined to propagating material intended for sale, and the same attitude was adopted by the United Kingdom concerning farmers' home-saved seed and other nontrading activities in crops (*11*).

The ownership of sports and other variants discovered by the purchaser is another problem in asexually reproduced crops, and the United Kingdom view is that they should be regarded as new varieties owned by the discoverer if they are sufficiently distinct (*11*). However, some kind of legal exclusion of contractual propagators and growers could be devised if it is deemed necessary to give the breeder rights to sports that arise in his variety.

In cross-fertilized crops, uniformity and stability are the primary considerations of protection, and the problem is particularly difficult with forage crops which offer few prominent characters, and where yield itself depends on the various possible forms of management (*4*). Biological protection may be sought by breeding first generation hybrids, as shown by the classical example of hybrid maize, where seed increase normally leads to deterioration, and uniformity is provided by single-crosses and less perfectly by double-crosses. In forage crops synthetic varieties are predominant, and as far as vigour is concerned, these are not necessarily inferior to first generation hybrids. Even in maize, some geneticists have produced evidence that, due to relatively high general combining abilities, there is a place for synthetic varieties (*13*). However, without plant breeders' rights, biological protection is essential to ensure financial reward. Private breeders of forage synthetics were among the few supporters of protection in the United States (*12*), but in the meantime they are actively interested in developing first generation hybrids. Incidentally in alfalfa, where specific combining ability is claimed to be relatively important (*3*), this approach may lead to higher yields, but because of the polyploid nature of this and many other forage crops, there is reason supported by experimental evidence (*3*) to think that maximum yields may be reached in later generations and consequently the biological protection may be lost.

A practical way of maintaining the identity of synthetic varieties is to have a suitable marker character, but the additional expense and delay caused by searching for such a character is sometimes regarded as prohibitive (*12*). However, in countries with a long history of seed certification, best results in maintaining the identity of varieties were achieved when such characters were located, often with little effort on the breeder's part. In New Zealand, simple biochemical tests were used for perennial ryegrass (fluorescence-test) and white clover (picric acid-test). For red clover, a system based on internode counts was developed (*9*), and the present author found speed of germination in osmotic salt solution a promising method. Light and temperature treatments were found satisfactory to distinguish between established varieties of trefoil in New York State (*10*) and the work was recently extended to the use of growth promoters and inhibitors.[4] In the absence of suitable tests, breeding for the introduction or the loss of a marker gene is a routine procedure as described for two New Zealand experimental varieties of white clover, "HCN-free" and "red-midrib" (*2*). In Canada, the relative absence of leaf marks in Dollard red clover is a measure for detecting shifts in the pedigree generations of the blended variety Lasalle (*8*).

[4] Personal communication from J. Pauksens.

Utility, as mentioned before, is a property very difficult to judge even by expert plant breeders. In some countries, in conjunction with certification systems, lists of recommended varieties are published from time to time, based on agronomic tests. These are generally regarded with suspicion by the seed trade, especially if they are in the nature of restricted lists. Admittedly, with any merchandise, consumer protection is a difficult problem, involving such issues as ethical advertising, and is mostly left to private cooperatives. The example of tobacco shows that different agencies within a government may have conflicting opinions. However, lists excluding obviously useless or harmful varieties—such as the Noxious Weed Acts—may be of public interest in some cases.

Conclusions

NOTHING has been said about the duration of plant breeders' rights. This varies from a few years in some countries and crops up to 25 years in others, as compared to copyright which expires 50 years after the author's death. All patents in the United States, including plant patents, are protected for 17 years. Whether protection is given by some specialized body such as the new Plant Variety Rights Office in the United Kingdom, or by an existing Patent Office as for some asexually propagated plants in the United States, is of secondary importance. However, international agreements for mutual recognition of breeders' rights are necessary at the time of their introduction. These should include the question of official tests required before granting protection, and there is much to be said for the point of view (*15*) that application for protection should be voluntary and that testing for novelty and uniformity should be done by the breeder. Rights could be given then, within reason, on the basis of these tests, and challenged before the courts.

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A Layman's View

Given the world we live in, I've wondered whether the Station could be of more specific assistance, than I am aware it presently is, to local governments and regional planning agencies. This would provide an opportunity to come into direct contact with the consumer where he lives—where he uses air and water and land and products. It is here where he is beset with conflicting desires and ideals and necessities. Is it reasonable to suggest that as a regional plan develops or a community Conservation Commission lays out a course of action that the Station be asked to pass judgment on the ecological effects of the propositions? It occurs to me that if this sort of work were undertaken it could lead to what I believe the research people call "input"; that is, the introduction of new areas for either applied or pure research.

The longer I live the more conscious and alarmed I become about the proliferation and fragmentation of knowledge on the one hand and the interdependence of all of life on the other. Scientific and technological advances are such that the specialist can hardly keep abreast of his own rapidly extending and changing field, much less does he have time to share in other developments. The interdependence and interrelationship of life and living is not always sufficiently considered. Modern society does not develop as a balanced whole nor is it viewed as such. But greater efforts should be made to this end.

I am sure there is some sort of moral which can be applied here in the old couplet which goes this way:

"The crane which waited for the sea to sink
And leave dried fish to feed him, died, I think."

By *Percy Maxim Lee*

Quoted by permission of the author from "A Layman's View," the Samuel W. Johnson Memorial Lecture, which was delivered at the Connecticut Agricultural Experiment Station, New Haven, as a feature of the Station's annual Science At Work program on August 10, 1966.

Engineering Applications of ELECTRO-PHYSIOLOGICAL PROPERTIES OF PLANTS

JOSEPH MOLITORISZ

IN all probability, all forms of biological activities possess characteristic electric signals. Living systems are never in equilibrium; therefore, some energy must be continuously expended. Any change, whether in the external or internal environment, results in some form of response that absorbs energy and this energy must be immediately available. The electric potential of a living system may therefore be assumed as an energy reservoir which can be drained to supply the energy to perform the responsive action. The pattern of the potential differences defines an electrodynamic field which may determine growth and development, or simply the life pattern of that biological system.

Early Research

PLANT scientists have been interested in the possible effect of electric current on the growth of plants for more than 200 years. Earlier studies showed striking increases in growth and yields, despite an apparent lack of exactness in procedure.

In 1870, the Abbe Bertholon in France treated various garden plants by sprinkling them with electrified water (*1*).[1] A gardener, standing on a slab of insulating material, carried the sprinkling can which was electrified by a static machine. The report reads: "By means of this process, strange for the times, the good Abbe Bertholon, who was considered something of a sorcerer, obtained salads of an extraordinary size."

In a 1904 experiment by Stone, a continuous small current was applied in soil-filled greenhouse flats by connecting one electrode to an elevated copper brush, the other to the ground. He reported 28–39 percent increase in the yield of radishes and lettuce (*10*).

Lemstrom's account (*9*) of his findings with garden and field crops indicate approximately 45 percent increase in yields.

In 1927, Koernicke (*8*) published results of his experiments on growing beans in chambers filled with highly ionized air. Treated beans transpired more rapidly and had a larger leaf area.

Several investigators have studied the response of plants subjected to electric current flowing

Editor's comment: There is a very large body of published information on electrophysiology of plants. Are there important opportunities for innovation?

[1] Italic numbers in parentheses refer to Literature Cited, p. 11.

through overhead wire networks, highly charged. Networks were supported on insulated posts so that the discharge could reach the plants and the earth only through the atmosphere. In some studies the responses were favorable; in others, differences in growth and yield were not significant.

Among the later experiments conducted under carefully controlled conditions, the majority of the reports show significant yield increases (*5*).

These works certainly demonstrate an early recognition of the significance of the effect of electric current on plant life.

One of the more recent studies was reported by Burr of Yale University School of Medicine (*2*). He attempted to examine the impact of many environmental forces—both local and universal—on the continued existence of a single living form—a maple tree. He recorded the impact of these environments by using electrometric techniques continuously, day and night. His findings showed evidences of some electrical correlate of the diurnal rhythm of a growing tree. There was no significant relationship between meteorological data and the electrical changes. His data showed, however, evidence of the existence of an unexplainable periodicity. The closest phenomenon associated with the observed electrical functions of plants was the change in the phases of the moon. A few well-authenticated examples of correlation between lunar activity and living things have been documented. Burr pointed out, however, that both lunar cycles and observed periodicities in living things may be the consequence of some still more fundamental cosmic factor acting upon both responding systems.

Conclusions by Khvedelidze (*7*) following studies on the biological potentials of plants point to significant relationships between the life processes of plants and of the occurring potentials. In his judgment, rhythmical fluctuations in bioelectrical potential did indicate both biochemical and physiological processes taking place in the vegetative tissues and may have great importance in electrodiagnostics and dosimetry of stimulating electrophysical agents. He reported an increased electrical activity in plants during springtime when the life process occurs at a faster rate. Rhythmical fluctuations in electrical activity were regular and rather characteristic. A rise in activity in amplitude and frequency was observed daily from about 11 a.m. to 1 p.m. and between 7 p.m. and 1 a.m.

Considerable significance may be attached to the observation by Dainty (*4*) and Fensom (*6*) on the influence of applied electric current on the movement of polar compounds such as growth regulators.

Another paper by Burr (*3*) may deepen our appreciation in this field. "It has been customary, in the past, to look upon all electrical manifestations of living things as byproducts or consequences of chemical processes. The primacy of the forces which are measured by electrical devices throughout the material universe raises the possibility that in living organism these same forces might operate with the same primacy. From this standpoint, then, living beings, like inanimate beings, would depend for their pattern of organization upon electrical forces. If . . . it is assumed that electrical forces are as primacy in living as in nonliving things, then it must follow that protoplasm, the physical basis of life, must exhibit meaningful electrical manifestations. These are as fundamental as those other properties of protoplasm, descriptively designated as irritability or metabolism, or reproduction."

Engineering Applications

WHAT relation does all this have to agricultural engineering? Mechanization or automation is at a rather high level in many fields of engineering. Not so in agriculture. Agriculture is in or is approaching a new industrialization, a revolution when new concepts have to be developed to meet the ever growing demand of increased production. It has to be understood, however, that agricultural mechanization is more than building tractors and plows, it is more than collecting vegetables and fruits in boxes, and it is more than just applying suction to milk a cow. The complexity of the problem may be well appreciated by realizing the biological, physiological and physical characteristics of the animals and vegetation we are working with.

The key to many of the problems in agricultural mechanization is the control over the growth and development of the plant. But the structural configuration and mechanical characteristics of the plants have to be compatible with the machine.

The harvesting of fruits from perennial plants, such as trees, presents another problem. Handpicking is not economical; mass harvesting without selectivity is difficult to justify. What is needed is some practical means to regulate growth, to pro-

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gram ripening and to provide controlled selective separation. Thus, it was decided to study the application of the electro-osmotic concept to citrus.

The principle of electro-osmosis has been known and used by engineers in soil stabilization. It represents an electrochemical process induced by the applied direct current potential causing the movement of ions, and therefore, movement of liquids. If a potential is applied across a saturated, porous medium, the fluid moves through the pores toward the negative terminal. A commonly known expression for the induced fluid velocity is the Helmholtz equation:

$$V_e = \frac{E\epsilon\xi}{4\pi\mu L}$$

where

V_e = Fluid velocity
E = Electrical potential
ϵ = Dielectric constant of the liquid
μ = Fluid viscosity
L = Distance between electrodes
ξ = Electrokinetic potential

Studies With Citrus

We have experimented with the application of external electrical potential to citrus trees. The growth-stimulating effect of the d.c. potential was demonstrated on two young citrus trees. Accelerated growth was observed on branches which were subjected to 58 volts d.c. with about 1.6 milliamperes for 28 days. Moreover, the leaf density of this branch was greater. Some abnormality in the shape of the leaf was observed. The electrified branch dropped nearly all of the ripe fruits but kept the green ones. It should not be assumed, however, that the loosening of fruits by electrical means is solved. The complexity of the changes due to the applied potential makes it very difficult to draw any conclusions. Long years of cooperative work among engineers, physiologists, biologists, and other disciplines will be necessary to find the answers. Electrolytic decomposition of the liquids and electrodes, polarization of the electrodes, and the variation in acidity—these are just a few of the many factors that must be considered.

In another experiment, a normal branch of a citrus tree was cut to a 1-foot length and, before it could dry, was placed between two electrodes surrounded by saturated sponges. The electrode at the lower end of the branch was positive; the saturating liquid was distilled water colored with a neutral dye. The upper electrode was negative and was saturated with pure distilled water. Saturated sponges attached to the electrodes provided the continuity of the branch; when no external electric power was connected to them, chemical potential was nil or negligible. The test was made with 12 branches of the same tree, the only major variable being the diameter of the branches. Six of the 12 units were powered by half-wave rectified 60-cycle live current (58 volt d.c. average) while the other 6 were not connected to receive power. After 18 hours of continuous testing, the specimens were removed and the translocation or displacement of the dyed liquid was measured. For those branches without power, the maximum displacement was less than one-fourth inch. Branches under power clearly showed not only total displacement, but also the channels of the flow. This test may suggest the possibility of applying current to maintain, accelerate, or decelerate the flow of liquids in living trees.

To know more about the possible application of this concept to citrus trees, we have to study the natural electrical potential of the trees and also the current flow pattern. We have to know whether a continuous or periodic application will cause the stimulating effect we desire. Data collected so far indicate a rhythm in the natural potential, which reflects a change in the magnitude of the potential and a periodic reversal of the polarity of the tree. Potential variation was observed daily and for longer intervals.

We have experimented to find the practical possibility of applying a constant electric current to hasten differentiation in the plant. When the natural electropolarity of the plant was preserved, the process of regeneration became considerably accelerated, and then markedly inhibited, following the application of a potential of the opposite sign.

To study the effect of the disturbance of the natural electrical potential on the trees, one full-grown orange tree was short-circuited. The upper branches and the root system were connected with insulated wires, continuously discharging the potential. The measured resistance of the tree between the roots and the upper branches was about 300K ohms. It is therefore valid to assume that the current flow will take place through the good wire conductor, rather than through the high resistance branches. But bypassing the normal conductive elements may affect the normal life of the tree. If natural electrical potential and flow of electrons are important elements of physiology, short circuiting of trees may be one way of proving it.

Future Applications

IT IS not my assignment to make predictions for future developments, but I am inclined to believe in the coming of an era when electrical stimulation of living systems may replace much of the chemical treatments. If the useful consequences of chemical processes in plants can be characterized by electrical manifestations, efforts should be made to examine the reversibility of these phenomena and introduce electrical impulses as physical means to obtain the same consequences. Unknown health hazards due to the extensive use of chemicals may be reduced by this method.

As a consequence of the electro-osmotic process, accurately controlled water management may be assumed in the root zone of plants—providing a means of regulating the liquid and water soluble compound intake of the trees or plants. Applied electric current—by upsetting the natural rhythm of protoplasmic streaming in plants—affects the movement of polar compounds such as growth regulators and a consequent deleterious effect on the growth of plants, thus offering a physical means for weed control. The same concept may be expanded to an application in frost protection by extending the dormant cycle of trees until the frost danger is over and then inducing an accelerated growth.

To close this discussion, it may be proper to quote a few profound thoughts of E. J. Tangerman (*11*):

"The engineer must, in his way, work constantly with the stuff that dreams are made of and must make those dreams into realities. Once . . . Archimedes talked of a fulcrum and a place to stand, so he could move the earth; in his way, he moved it—a little. . . . Other men since then—engineers and others—have had dreams just as big and have had to content themselves with similar 'little' advance."

May this discussion serve as an invitation to a dialogue between the involved disciplines to move the earth—"a little."

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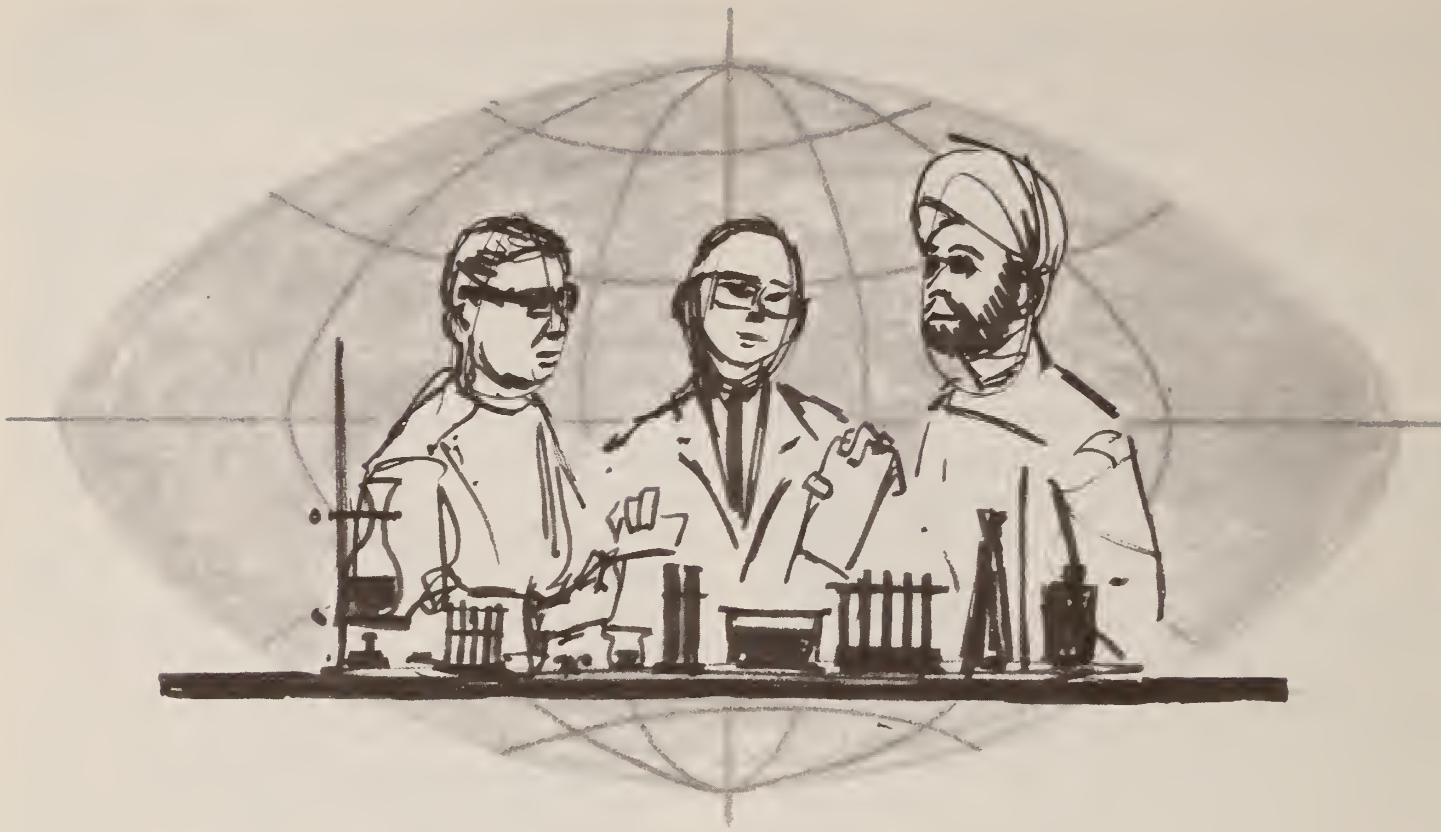


DECIDING THE QUANTITY AND DIRECTION OF SCIENTIFIC RESEARCH

C. F. CARTER

WE have been told very often that the greatest resource of a country is its people. But what is the quality of people which makes them valuable as a natural resource? Occasionally in advanced nations, and frequently in the less advanced, human beings are still wanted as a mobile source of physical work. But the tasks for which manual labor is economical have contracted for many years and are still contracting. The importance of human beings as a natural resource rests increasingly on skill, intellectual power, and creative talent.

A concentration of intellectual power and creative talent on a particular area of scientific research and development can often achieve remarkable results. The handful of cases which we now call a smallpox "epidemic" is a reminder of success in eradicating killing diseases. The electricity which heats my house may come in part from a nuclear power station. The weeds in my garden and in the farmer's field are (some of them) eradicated by selective weedkillers unthought of 20 years ago. The aeroplane is both powered and guided on its course by products of a new technology. With such examples all around us, it is tempting to think that the material problems of the country can be solved if only the resources of science are brought to bear at the right points.

But when one tries to translate this general belief in the virtues of science into a program which says how much scientific effort, and at what points, and how organized and financed, the matter is less clear. The area of human knowledge is constantly expanding; therefore its circumference is becoming longer and is divided into more segments of specialization. Even the largest and wealthiest countries cannot find enough talent to work in all those segments at the same time. A very small country (say, Andorra) may not be able to do significant work in any one of them. A small country must inevitably make a choice of a few points at which to work, and neglect all the rest. How is this choice to be made?

This article was adapted by the author from the Finlay Lecture, University College, Dublin, 1962, expressly for the readers of *Review*.

Transmission of Science

BUT (you will say) what is all this talk about countries? Is not science the great uniter of nations, the builder of an international fellowship of like-minded people to whom distinctions of nation, race and religion are of no account? Surely what matters is the world effort, and a country can expect to partake freely of the benefits of discovery anywhere in the world, even if she contributes little herself? Many of the implications of these questions are valid, but they represent an over-simplified idea of science. A distinction must first be made between the transmission of pure and of applied science. Pure or basic scientific discoveries are transmitted with only moderate efficiency and mainly between specialists in the same sector of scientific effort. The efficiency of transmission is reduced by the barrier of differing language, but also (and increasingly) because the sheer mass of scientific publication has become so great that it has become difficult, even with good abstracting services, to sort out what is relevant. The flow is mainly from specialist to fellow specialist; the amount of transmission across the boundaries of the segments of specialization is much smaller, and transmission to nonscientists is very imperfect and much delayed.

Discoveries in applied science and technology relevant to industry are transmitted quite readily between a firm and its overseas subsidiaries, and between a firm and overseas firms with which it has agreements for the exchange of knowledge. Otherwise the flow is on occasion impeded, not only by the obstacles mentioned in the last paragraph, but also by commercial secrecy. For some purposes, the international flow of applied knowledge runs more freely than that within national boundaries. It is often found, however, that discoveries in applied science cannot be taken directly from one environment to another: they must be adapted or further developed to be of use. Thus, every agricultural country has work to do to find the varieties of crops and the breeds of animals best suited to its particular combination of climate, soils, and production and market conditions.

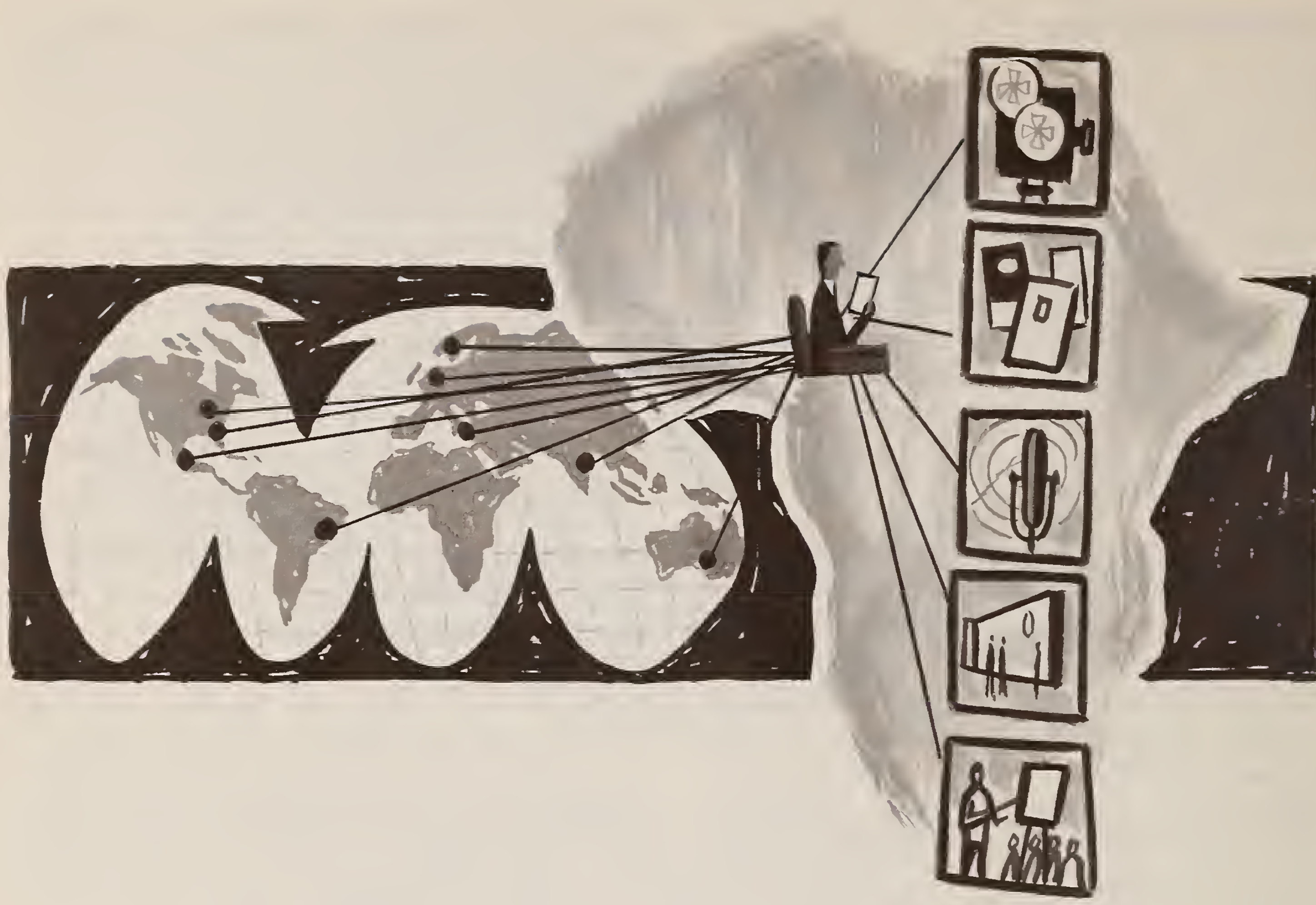
Many discoveries of applied science have to go through a long expensive process of development before the work of the laboratory can have commercial application, and some part of this process may need to be repeated at each point of application. At the very least, it is likely that if a business buys fully developed the machines of a new process, or the method of making a new product, it will find it necessary also to hire technologists capable of understanding and adapting the development, and capable of putting things right when they go wrong.

Receiving Stations

IT thus follows that a country cannot do without scientists and technologists, for they are the essential receiving stations of the world's transmissions of knowledge, and are essential also to adapt and interpret the knowledge which flows in. They will mainly be found in five kinds of places: Universities and other teaching institutions; public research institutes or government research stations; individual enterprises; research stations jointly financed by a group of enterprises; and privately established sponsored research institutes. The distribution between these types of employers depends on the industrial structure of a country and on its past history of private and public initiative, but there are certain facts which limit the choice. A small enterprise cannot usually afford the cost of even the most elementary independent research unit. A small country will have few or no large enterprises. It has little chance of setting up its scientific receiving stations in individual enterprises and must make other arrangements. Agriculture and building in particular must rely on some other form of scientific effort; the individual farmer and builder will seldom be able to afford any research of their own.

The nearest alternative choice is to set up research stations jointly financed by a group of firms; this development has in some countries been encouraged by a government subsidy. But, though joint research stations have considerable achievements to their credit, their further development is impeded by two main obstacles.

The first obstacle is the absence of the will to cooperate: the proportion of turnover which enterprises are willing to devote to cooperative research is often tiny (less than a 20th of 1 percent), even where they have no access to other research facilities. It appears that private owners accept the value of science mainly in the hope of getting a lead over their immediate competitors, and are not greatly interested in discoveries which will be communicated simultaneously to their fellow members.



Scientific Communication

THE second difficulty is the problem of scientific communication in another form. It may be found that the enterprises which make effective use of the services of a cooperative research association are those which also have their own research departments, because ideas then flow quickly between scientists of similar interests. In order to convey the benefits of cooperative research to the small enterprises which really need them, a research association may need to spend heavily on promotional or educational activities—and it is hard to persuade people to contribute to the cost of an education whose value they will not appreciate until the education is complete.

The next possibility is to fill in the gaps of research by setting up government research stations. The example of my own country, Britain, in this is not very helpful as a guide to others. There are many government research stations, covering subjects such as agricultural research, food processing, atomic energy research, building, roads, water pollution. But there is no conscious effort to fill in, by the development of new government research stations, the gaps in the research effort of industry. The official attitude has been, I think, that if private enterprise fails to provide for its own scientific development it must take the consequences. Agriculture, however, is treated as a special case; an elaborate and expensive system of research stations is provided by government as a free service to the industry.

In most countries, an important section of research—mostly pure but including some important "applied" activities—is in the hands of the universities and other institutions of higher education. The size of university staffs and the basic grants available for university running expenses are often related almost entirely to the university's teaching function. The income, therefore, provides an amount for research which is illogicaliy related to the number of students; though, because of the increasing cost of research relative to teaching, a 50-percent increase in undergraduate numbers does not produce a 50-percent increase in real research output. In Britain, the Government, through research councils, supplements university effort by grants to universities to support particular projects. It increasingly tends to provide very expensive pieces of equipment as a joint service to several universities. The situation is confused, however, and Britain, though she has a Council on Scientific Policy, has not got a clear scientific policy. Let us consider what the elements of such a policy, in a country of moderate or small size, should be.

Policy-Creating Body

THE first thing is to have a policy-creating body, well informed on scientific matters and covering as wide a field of scientific effort as possible. It should not, however, be a committee of scientists alone. The problems of scientific policy relate to the best use of scarce resources; they are inevitably economic problems, and in my experience natural scientists do not take kindly to the hardheaded weighing up of costs and rewards involved in an economic assessment. They accept a disproportionately great expenditure on some new, exciting and costly line of inquiry, without asking whether the same money would not buy much greater results somewhere else.

I therefore suggest that a Council on Scientific Policy should contain (say) eight natural scientists, an economist, a statistician, a sociologist, a philosopher, and two businessmen. Its first duty should be to make an inventory of the country's scientific resources, including estimates of (a) where scientists and technologists of various kinds are at present employed within the state, (b) how many scientists and technologists are working abroad, (c) the scale and distribution of the effort in pure scientific research, and (d) the relation of the quantity of applied research and development to the net output of the industries or services to which it is particularly related.

Such an inventory would, of course, reveal serious gaps, even in relation to a country's present economy. But it would be important not to allow policy to be related only to the improvement of existing industries. It would be a poor, thin view of research which judged it only by immediate profit. Even in the applied field, it is necessary to have points of contact with new developments of technology which may yield new industries. This raises a difficult problem of selection, since it is impossible to cover more than a small proportion of the numerous possibilities. In pure research, the problem of selection also exists, and is commonly made almost in a random manner in the process of insuring a diverse and vigorous life in the universities. But there are some forms of applied research—for example food processing—which *prima facie* are fairly likely to be of importance to a country's economy. And there are some forms of pure research whose growth elsewhere will suggest the rightness of their inclusion in the programs of the universities and research institutes.

Filling the Gaps

LET me, therefore, suppose that a Council on Scientific Policy could reach a judgment about the gaps in the country's research and development effort, in relation to the wider needs suggested in the last paragraph. I suggest that its proposals for filling these gaps should be based on its answers to three questions:

1. The communications question: What is the most effective way of making sure that the world's discoveries in science and technology are quickly applied in the relevant places? (The relative importance of the problem of the communication of ideas is the greater, the smaller the area which we consider.)

2. The adaptation question: What effort is required to adapt to local circumstances discoveries made elsewhere?

3. The education question: What basis of research is necessary to effective teaching of science and technology within the country?

In conformity with what I have said earlier, the answer to the communications question will often be that it is necessary to undertake research within a country in order to have a receiving station for a flow of ideas from abroad. Occasionally it may be possible to join in international research programs and these indeed are of growing importance in the very expensive fields of nuclear, space and aeronautical research. But there will seldom be any satisfactory alternative to having a receiving station within the country, in close contact with the final user.

In a small country with a high proportion of agriculture, the most frequent form of organization for applied research must be the state-financed research institute, since the base for a cooperative research association will usually be inadequate. The minimum research activities of such institutes must be such as will attract to their service scientists of sufficient standing. But their task must include not merely the communication of their own research, but also the communication of a flow of ideas from the rest of the world—and not merely the giving of advice on request, but also the active encouragement of a new attitude toward science in people who have not yet realized what it can do for them. This implies a much larger and more active information and propaganda function than is usually found in research organizations.

The answer to the adaptation question is most obviously seen in agriculture; substantial effort is needed to find out what is best done in each of the varied climate regions and soil-type areas of a country. Elsewhere adaptation appears as a development problem in adapting a piece of agricultural machinery to local needs, or in using on a small scale a process which elsewhere has always been used on a large scale. The trouble about development is its expense. Properly undertaken, it may involve a heavy burden for a short time, and the hiring of the services of foreign enterprises and experts. This is where state financial assistance may be needed.

The answer to the education question will vary from country to country. But in many places there is a danger that, in the effort to provide a modern scientific and technological education in the universities and colleges, the available resources will be spread too thinly, so that viable centers of research fail to appear and teaching becomes in consequence out-of-date and pedestrian.

Scale of Expenditure

FINALLY, if a Council on Scientific Policy had made its assessment and had given its proposals to the government, what scale of expenditure would these be likely to involve, both from government and from private sources? In Britain total research and development expenditure is about 2.2 percent of national product and in the United States about 3.1 percent. These figures are considerably inflated by the very great expense of defense research. The absolute level of research and development expenditures is, of course, very much higher in the United States (by a factor of about 10), and (since Americans do not consume 10 times as many kinds of things) this would seem to give the large country a considerable advantage in being able to concentrate large resources on each frontier area of research. There is no doubt that this advantage exists, but it is lessened by the diseconomies of scale. In a big country, overlapping between research organizations is difficult to avoid; its existence has been noted in Russia. It is also probable that in the United States more of what passes as "development" is work associated with technically unnecessary model changes.

But even if we halve the U.S. expenditure to allow for these factors, Britain would need to spend over £3,000 mn. a year to equal the U.S. *absolute* effort. She can avoid this burden only by limiting the range of her effort; and the same is of course true of smaller countries. If population is divided by 10, is the area over which research expenditure is necessary divided by 10? It hardly seems likely. A smaller population will still have a considerable range of consumption, and even the range of types of exports (embodying scientific effort which is directly in competition with the scientific effort of other countries) does not necessarily contract proportionately as we move to a country of lower population.

I would conclude, therefore, that civilian research expenditure in a small country ought to be a larger percentage of national product than in a large country. But there are possibilities of saving on this figure; a small country can, by the exercise of ingenuity, meet its main needs for the communication of scientific knowledge with a low research effort, *provided* it gives its main attention to communication rather than independent discovery. It may thus hope to be parasitic on the large nations, sucking nourishment from their bloodstream.

WATER ACTIVITY IN RELATION TO FOODS

R. G. GARNER

SINCE water comprises from 60 to 95 percent of the total weight of foods and is by far the dominant constituent of foods, the state of water and its distribution in foods is of prime importance. Changes in water content or water distribution lead to significant changes in food products.

Water is so commonplace that it may not seem worthy of attention and, at first glance, may appear to be an uninteresting, simple and inert constituent of foods. The situation is quite the contrary. Most foods are characterized by great complexity and heterogeneity of constituents. Water becomes an ubiquitous and fundamental part of the complex structure of foodstuffs. Thus the behavior of water in a food is intimately related to the ultimate quality of the food, and moisture loss or gain during processing or storage often accounts for major changes in the characteristics of foods.

Properties and Measurements

ACCORDING to Ward (*28*),[1] the structure of the water molecule enables it to form weak but directed bonds with other water molecules and with certain groupings on the major macromolecules present in foodstuffs. In most foodstuffs hydrogen bonding exists between water molecules, between

[1] Italic numbers in parentheses refer to Literature Cited, p. 22.

water and small and large molecules and ions, and as the direct link between these later macromolecules. He points out that there is competition between the components for the available hydrogen bonding sites and states that the rate at which water may break particular intermolecular hydrogen bonds, and the extent to which these bonds are broken, together with the converse process of displacement of water from bonding sites, affects all practical dehydration and rehydration processes.

Fennema and Powrie (*6*) have indicated that change of state, such as freezing, will also modify the normal relationships between water and other food constituents and will likely alter the typical character of the food. Kuprianoff (*12*) has discussed the role of water in foods and the forms in which it may be "bound". Methods for determination of moisture equilibrium and of the water content of dehydrated and other foods have been reviewed extensively by Stitt (*23*) and others (*16, 25*). Detailed discussions of the water molecule, interactions between water molecules, the structure of water and ice, and methodology for moisture determination are outside the scope of this review.

Van Arsdel and Copley (*27*) have pointed out that the changes in foods as affected by moisture content and temperature are related to changes in the water vapor pressure of the substance. In general, a moist food held at constant temperature displays a vapor pressure which approaches a steady equilibrium value reflecting the composition of the material, its moisture content, and the temperature. The experimentally determined relation between water vapor pressure in the atmosphere surrounding the food and the moisture content at equilibrium is sometimes expressed as equilibrium vapor pressure, or equilibrium relative humidity, or equilibrium moisture content. A vapor pressure isotherm shows the quantitative relationship between vapor pressure and moisture content at constant temperature.

The equilibrium moisture content is the moisture the food material retains when it is in equilibrium wth its surroundings. For example, Charm (*4*) has stated that the final moisture content a food material reaches on drying is usually not less than the equilibrium moisture of the dried material when it is in equilibrium with drying air conditions at the end of the drying operation. Vapor pressure isotherms enable one to predict whether the material could be dried successfully under the conditions chosen. Isotherms, which show the relationship between moisture content and percentage relative humidity for a series of temperatures, are much more informative than moisture content alone.

The ratio, p/p_0, where p is the vapor pressure of water in equilibrium with the material and p_0 is the vapor pressure of pure water at the same temperature, gives us the water activity, a_w, or the relative humidity, RH, when expressed as a percentage. By definition, the water activity, a_w, of a solution is the ratio of the vapor pressure of the solution, p, and the vapor pressure of water, p_0, at the same temperature. It is expressed as $a_w = p/p_o$ or $a_w = RH/100$. The relative humidity is defined as the ratio of the partial pressure of water vapor in the air to the vapor pressure of water at the same temperature and is expressed as $RH = p/p_0 x100$. Under equilibrium conditions $RH = a_w x100$. Water activity (a_w) is a fundamental property of aqueous solutions while the term relative humidity refers strictly to the atmosphere surrounding the material. At times this distinction has been overlooked, but it is well to keep it in mind.

Food Constituents

WATER-HOLDING capacity is closely related to taste, tenderness, color and other features of meat quality. It is influenced by conditions which prevail during almost all operations after slaughter—transport, storage, aging, grinding, salting, curing, heating, freezing, thawing, drying and freeze-dehydration. Conversely, almost all treatments affect the interaction between muscle solids and water (*9*). The toughness which sometimes develops during freeze-drying meat always appears to be associated with a loss of the true water-holding capacity of the muscle.

Hamm (*10*) has supplemented his earlier review on the effects on water binding capacity of intermolecular reactions between meat proteins, electrostatic forces and cross-linking by divalent metal ions, and pH and salt concentration with a useful further review of the water-holding and imbibing properties of a range of foods, including meat. He states that the water is immobilized within the meshes of the protein network. Secondary valences, namely hydrogen bonds between the peptide groups, also play a part. With large macromolecules, water adsorption occurs as a result of the interaction between the field of force at the surface of solids and that emanating from the molecule of vapor. The amount adsorbed at a given pressure is, at the low pressure end of the isotherm, proportional to the extent of the solid surface exposed to the vapor, and therefore to the specific surface area. Rhodin (*15*) found that in general at a_w values below 0.25 the adsorbed layer is only a single molecule in thickness, and it forms a multilayer as the saturated vapor is approached.

Starch is a carbohydrate system which is able to imbibe a great amount of water. According to Geddes and Bice (*8*), water associated with starch is believed to exist as bound and free moisture, the bound being held mainly by hydrogen bonding to the hydroxyl groups of the carbohydrate molecule. That moisture is present in two states is indicated by the wide reversible variations in starch gelatinization temperature inducible by drying or soaking. While simple drying out has been ruled out as the cause of bread staling, loss of moisture as such from the bread loaf, may, however, accelerate reactions leading to bread staling and thus moisture relationships within the crumb may well be important (*13*).

Food Processing

DEHYDRATED foods exhibit S-shaped moisture sorption isotherms. The slopes and points of inflection are indicative of the water-binding capacity or of the relative amounts of free and bound water. The isotherms show hysteresis effects which are most pronounced above the point which represents completion of a monomolecular layer of water molecules. The isotherms below that point represent a region of tightly bound water having a high heat of adsorption.

Most freeze-dried products are, after reconstitution and cooking, distinctly tougher and less juicy than untreated cooked controls. One real virtue of drying from the frozen state lies in the increased solubility that results. This is believed to be due to removal of many scattered ice crystals which results in a porous structure with large surface area and good solubility.

In addition to sometimes being tough upon cooking, many reconstituted dehydrated food tissues are incompletely rehydrated. The mechanisms involved in these phenomena are not as yet fully understood. Sterling and Shimazu (*22*) have reported a continual increase in crystallinity in all samples of dehydrated carrots as storage time increased, and no notable differences in crystallinity as a result of different dehydration rates. They suggest that the crystallization in cellulose may occur as an increase in polysaccharide-polysaccharide bonding at the expense of polysaccharide water bonding. They further state that, possibly, crystallization can also explain toughness of dehydrated fish in storage and the poor reconstitution of dehydrated meat.

Food Deterioration

NONENZYMATIC browning reactions often limit the storage life of dried foods. These reactions result in deterioration of color and appearance, darkening and development of off flavors. In addition, the nutritive value of the food may be impaired, especially in regard to loss of ascorbic acid and reduction of available lysine since both of these compounds may be involved in the reactions. The

chief method of preventing nonenzymatic browning is to dry to low moisture content. The moisture levels required for adequate stability vary with the type of product. In the case of dehydrated orange crystals Karel (*11*) found that moisture contents as low as one percent on a dry basis are still too high for complete elimination of browning and ascorbic acid destruction. Other investigators have also concluded that complete inhibition of these reactions requires a complete absence of water. Complete removal of water from foods, however, is not only uneconomical, but has other consequences: extremely low moisture contents, especially where the concentration of water is below the level corresponding to monolayer coverage may accelerate other types of reactions, especially of lipid oxidation. Drying to too low moisture levels, in general, may also initiate nonenzymatic browning reactions according to Stadtman (*21*). Further researches are needed on the reactions involved in nonenzymatic browning, the components of foods that are involved, and the dependence of the reactions on environmental conditions, including moisture relationships.

Acker (*1*) states that in foods which are protected against microbiological deterioration due to their low water content, not only chemical reactions, such as autoxidations of lipids and nonenzymatic reactions, can occur during storage but also enzymatic reactions; provided that the enzymes in these foods are still active and have not been damaged by processing. He has pointed out the remarkable dependence of enzyme reactions on moisture content and that, if not inactivated, enzymes can play an important part in low-moisture foods in the solid state. This dependence of enzymatic reactions on moisture content cannot be explained by the law of mass action but can best be understood in relation to the sorption isotherm of the corresponding food. It would appear to be desirable to study the enzymatic changes in relation to relative humidity. In all foods and model mixtures studied, it has been established that a noticeable enzyme activity was first observed above the inflection point of the sorption isotherm. If this observation were to be further confirmed, it might be possible to predict the occurrence of enzyme reactions from the sorption isotherm, thereby permitting lengthy storage studies to be replaced by the establishment of the sorption isotherm and its interpretation.

Packaging and Storage

ANY food requires packaging adequate to protect it from its environment. Selection of the proper package atmosphere and moisture content requires a knowledge of the desired properties of the product and the storage conditions it will likely encounter. Factors associated with the deterioration of foods which can be influenced by packaging and package material selection are: moisture uptake, oxygen uptake, flavor contamination and deteriorations, mechanical damage and physical protection—that is, protection from insects and filth by the package functioning as a barrier.

Dehydrated foods, in particular, must be protected from moisture uptake. They normally have a good shelf life if the moisture content is maintained within narrow limits. With dried foods the moisture content generally lies in the region of 2–4 percent, which often corresponds with a low relative humidity. Many dried foods are extremely hygroscopic and, in contact with an environment of greater relative humidity, will absorb moisture rapidly. The relationship between equilibrium relative humidity and moisture content is peculiar to each product, and it is important for this relationship to be known. For a given set of storage conditions, knowledge of this relationship enables one to relate the moisture permeability of the packaging material to the transference of water vapor into or out of the product and, thus, to make a prediction of safe shelf life. Tables which provide equilibrium relative humidity data for a number of foods and which contain moisture and oxygen permeability data for a number of typical packaging materials may be found in the following source (*2*). Taylor (*26*) has provided data for a number of freeze-dried foods.

Storage stability is a vital characteristic of foods. Extensive storage and performance studies are often necessary since moisture level affects the rate of reactions that often lead to serious quality loss. Makower and Dehority (*14*) found that the maximum moisture content compatible with storage stability in dried vegetables lies below the inflection point of the sorption isotherm. The monolayer, as calculated by the equation of Brunauer, Emmett and Teller (*3*), also corresponds to a moisture content that lies somewhat below the inflection point of the sorption isotherm.

Salwin (*18*) found that differences in equilibrium relative humidity relationships are responsible for the migration of moisture vapor from one ingredient to another when mixtures of several food ingredients or foods containing several ingredients are packaged. Moisture sorption data gave useful guidance for processing and packaging. In most cases, the monomolecular-layer moisture content proved a good first target when specific stability data were lacking. He felt that the compatibility of items which are to be packaged together could be determined with good reliability (*18, 19*).

Salwin and Slawson (*19*) have presented a method of computing the moisture transfer among two or more dehydrated foods within a package. It is based upon the adsorption theory of Brunauer, Emmett, and Teller (*3*), often termed B.E.T.

The B.E.T. theory is dependent on the observation that for almost every food item the moisture content specified for good stability agreed closely with the amount which represented a statistical monolayer of adsorbed water. The values which correspond to a monolayer of adsorbed water computed by the B.E.T. equation agree closely with analytical moisture contents (Table 1).

Potato flakes are a relatively new form of dehydrated mashed potato. Strolle and Cording (*24*) made moisture sorption studies on flakes from several potato varieties. Regardless of variety or geographical origin, the flakes were found to have similar moisture sorption properties and similar storage stability. According to the B.E.T. equation, the flakes should have an optimum storage value between 5.1 and 5.8 percent moisture. These values agree well with data obtained from storage tests.

Microbial Growth

IN general, the most rapid spoilage in foodstuffs is caused by microbiological changes. Foods with high microbial counts are not of as good quality as comparable foods with low counts. High counts are considered indicative of poor quality raw material, poor manufacturing procedures, or poor handling and packaging procedures.

An effective means of suppressing microbial growth is to remove moisture. Recently Ferrel et al. (*7*) have determined the equilibrium moisture behavior of four different samples of bulgur. Mold appeared in all samples at relative humidity values of 84 percent and above in 4 to 64 days, depending upon temperature and relative humidity. On the basis of mold growth alone, these data point at a hazard to be considered whenever bulgur is shipped or stored under high humidity conditions, particularly when the temperature is high.

It is generally agreed that microbial changes can occur only above a certain atmospheric relative humidity (65 to 75 percent). It is also common knowledge that living processes have a universal requirement for water and that micro-organisms are

TABLE 1.—*B.E.T. monolayer of adsorbed water for various food materials* (*17*)

Food item	B.E.T. monolayer percent water, wet basis	Analytical value
Potato dice	5. 46	5. 84
Small red beans	4. 50	4. 73
Onion powder	3. 58	4. 10
Crackers	4. 23	5. 04
Instant macaroni	5. 87	6. 99
Instant starch	5. 68	6. 28
Dry whole milk	1. 97	1. 87
Cocoa beverage powder	2. 37	2. 92
Shrimp	5. 56	3. 09
Chicken	5. 48	1. 53
Ground beef	6. 19	0. 78

no exceptions. All of us are familiar with the growth of mold on bread and recognize that this deterioration proceeds more rapidly under humid conditions than under very dry conditions.

Scott (*20*) and Christian (*5*) have reviewed the water relations of food spoilage micro-organisms from the point of view of the water requirements for growth. Both conclude that the water requirements for growth of many micro-organisms are best considered in terms of the activity of the water, a_w, in the immediate environment of the organism. Scott uses water activity, $a_w = p/p_o$, to describe the status of water in the atmosphere as well as in the substrate or solution in preference to relative humidity, RH, which applies strictly to the surrounding atmosphere. In practice, the a_w of a given solution varies only slightly with temperature within the range of temperatures permitting microbial growth. Both of these researchers have pointed out that although micro-organisms can grow from close to 1.00 a_w down to values approaching 0.60 a_w, most species are limited to a much smaller range. As a class, bacteria grow at a_w as low as about 0.75, whereas some yeasts and molds grow very slowly at 0.62 a_w. This suggests that some bacteria may yet be found to grow at an a_w below 0.75.

Foods preserved by salting, syruping, or dehydration have in common low levels of a_w. It has been pointed out that the water relations of micro-organisms are important in determining whether they are capable of spoiling foods preserved by dehydration, salting, or syruping. Freezing is another method of food preservation in which the a_w is reduced substantially. Growth of micro-organisms in frozen substrates demonstrates their tolerance not only to low temperature but also to low a_w.

* * *

In summary, water content is a most important factor to be considered in choosing the conditions of processing, storage, and distribution of foods. Furthermore, it is not the absolute water content that plays a decisive role, but the manner in which the water present is available. Research is needed to fill the imperfections in our knowledge of the forms in which water is found in a food and of the interactions between water and other molecules present in various foods.

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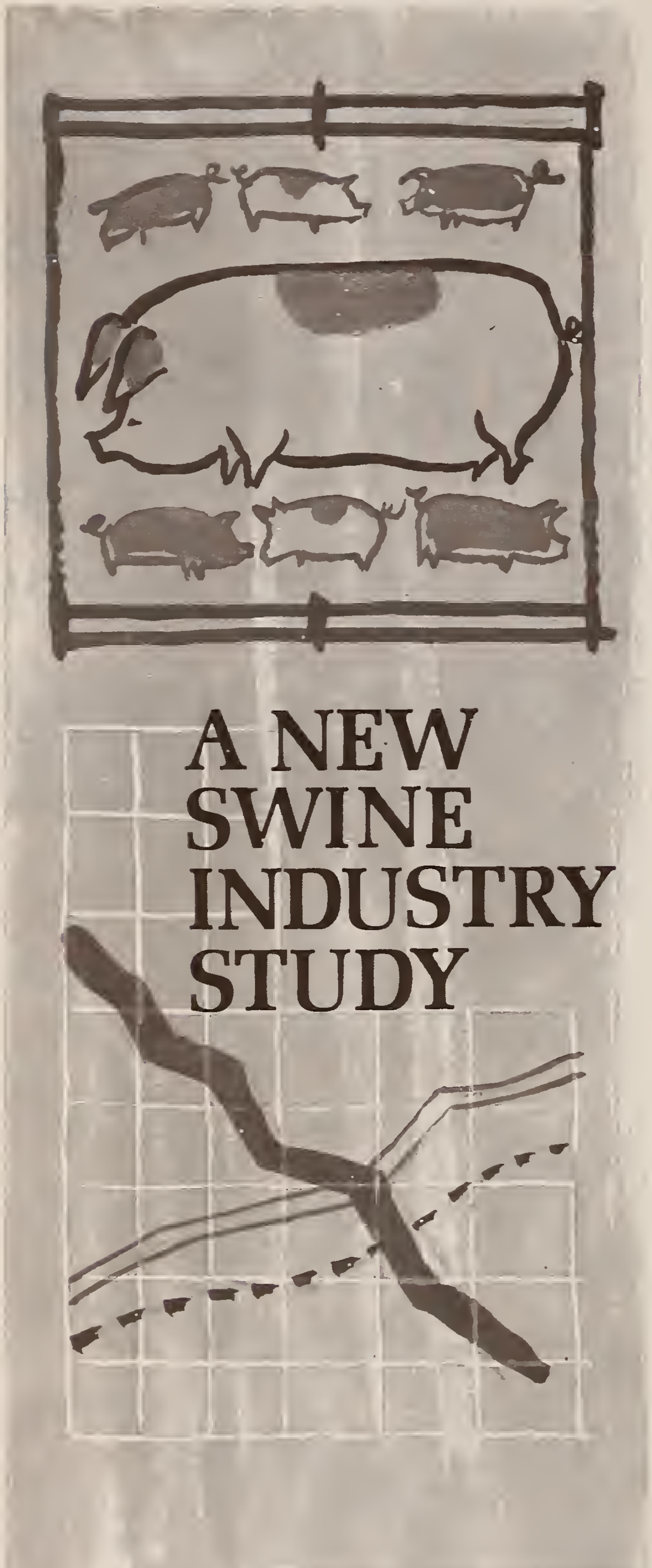

A NEW SWINE INDUSTRY STUDY

On May 27, 1966, 25 industry leaders and research administrators met in Chicago to review current swine industry problems and research needs.

The meeting was arranged as a working group by action of the Committee of Nine, a statutory committee of USDA whose duty is to recommend cooperative regional research projects for approval by the Secretary of Agriculture. This committee is concerned with developing policy and procedures including coordination and support for the long-range regional research programs.

Both Assistant Secretary of Agriculture George L. Mehren and CSRS Administrator T. C. Byerly discussed keynote issues at the meeting. Dr. Mehren called attention to the rapidly decreasing number of farms reporting swine and the increase in herd size. He referred to the shrinking sheep and dairy industries. He asked if the swine industry is really shrinking and if so why and what should be done about it. Dr. Mehren challenged the committee to develop researchable questions.

Dr. Byerly told the committee its task is to determine whether or not there is need to develop and evaluate alternate systems of least cost production of high-quality pork. In order to provide perspective, he asserted the following points of progress and problems subject to challenge.

1. Per capita pork consumption in the United States has been decreasing for the past 20 years.
2. Lard production has diminished about 5 pounds per hog during the same 20 years—largely because of genetic information developed by Federal and State agencies and cooperative action among all segments of the industry.
3. Producers wean about one pig more per litter then they did 20 years ago—mostly because of the use of cross-breeding and antibiotics.
4. Cholera and erysipelas approach eradication.
5. In spite of major laboratory advances in swine nutrition, there has been no apparent improvement in realized feed efficiency in the national herd.
6. Although individual herds have increased in size while the number of farms keeping hogs has decreased, there is no evidence of realized economy of scale or mechanization reflected in decreased swine production costs.

7. Too many sows fail to conceive, too many embryos die, too many neonates die. Pertinent research is indicated, therefore, on behavior, environmental physiology, artificial insemination, endocrinology, and SPF.
8. Diseases, materials handling, feed efficiency, marketing, quality, and systems development—these are also some of the research problem areas.

At the conclusion of the meeting participants agreed on the following points:

1. The swine industry faces real problems in its competition for the consumer dollar.
2. The ratio of funds supporting swine research to the value of pork produced is not as favorable as in other major commodities.
3. An interdisciplinary research approach to swine industry problems should be increased.

At the suggestion of Dean Elmer Kiehl, University of Missouri, a subcommittee was appointed to develop a priority list of researchable questions and to make other recommendations for consideration by research administrators.

To give readers an overview of the swine situation as seen through the eyes of the committee, *Review* presents here selected excerpts of three of the presentations.

TRENDS IN THE SWINE INDUSTRY

THE swine industry has been in turmoil, ferment, and controversy for the better part of two decades. Recognition of declining rates of consumption in the early 1950's brought to the surface some of the problems and concerns. Per capita consumption declined from 80 pounds per person in 1945 to 59 pounds per person in 1960. Many people have attributed this decline to a rejection of excess fat and unacceptable pork quality. The reason for the decline is not that simple. In addition to quality problems, the very rapid changes in our society since 1945 contributed to the change in the consumption patterns of the population. The continuing shift from farm to urban living, the changes in living patterns that accompany higher incomes and more leisure time, and the increased availability of competing meats such as chicken, turkey, and beef—all contributed to the decline in per capita consumption of pork. Recent analysis indicates that we may be at the lower level of per capita consumption of pork and we could conceivably see a slight increase in per capita demand for pork during the next 5 to 10 years.

During the past decade, research and application of that research have taught us that we can produce pork with larger hams and loins. The goal of a carcass with 40 percent of the carcass weight represented in hams and loins is within reach. For the outstanding producers, the goal is 50 percent. Today, some pork loins are as large or larger than beef loins. The advances in pork quality during the past decade are impressive. However, it will be increasingly difficult to achieve the same level of improvement as we move forward.

Generally, the changes in the technology of hog production have contributed to the intensification of the hog enterprise on U.S. farms and have enabled producers to substitute capital and technology for labor, thereby making larger hog operations feasible for the individual producer.

Concentration of hogs in the North Central States rose from 75.2 percent in 1940–42 to 82.1 percent in 1964. Increases in production have been largest in Iowa and Illinois. We fully expect an increasing concentration of hog production in the major feed grain producing areas.

Increased uniformity of farrowing throughout the year is another shift taking place in hog production. Variations of marketing during late fall and early winter markets as compared to the summer months have been reduced substantially.

Along with the changes in production and farrowing patterns, marketing trends and patterns have also changed. Iowa has marketed high proportions of its hog output directly to plants since the 1940's. At present over 85 percent of Iowa hogs are marketed direct rather than through terminal markets. The shifts in marketing patterns coupled with the rapid rate of expansion of new interior plants have resulted in increased decentralization of the hog market, which has made marketing more complex for individual producers. As the number of market choices available to producers has increased, the alternative methods of marketing have also increased. Carcass grade and yield selling, forward selling through contract and the hog futures market—all increase the complexity of market decision-making for producers.

The sale of hogs on a carcass basis has contributed to more accurate pricing of hogs for the individual producer and has also provided many producers with valuable information as to carcass quality. Each company has developed its own systems of carcass evaluation and pricing—a situation which sometimes makes it rather difficult for a producer to compare returns from different lots of hogs if he has sold at different times to different packers. Increased uniformity of carcass evaluation methods and pricing methods would be desirable from the producer's standpoint.

Following are some of the future research needs in our industry:

1. Swine breeding. Thirty-five percent No. 1's is not good enough. Well-designed breeding research could speed up this process. Also, we need to know if less backfat changes the physiological makeup of the pig.
2. Management requirements, in the broad sense, of high-intensity confinement systems.
3. Effect of feeding on reproductive physiology (sow nutrition).
4. Effect of disease, stress and environment on young pigs; 75 percent death loss occurs first 2 to 3 weeks of life.
5. The implications of forward-selling, price-incentive contracts and other marketing devices for hog producers.
6. Feasibility of new hog slaughter facilities locations in major producing areas.
7. Better and more uniform techniques of carcass evaluation.
8. Merchandising and new product development for pork.
9. Quality improvement and quality control for wholesale and retail pork products.
10. Feasibility of producers hiring specialized production and marketing services on a group basis.
11. The possibilities of more effectively using communications technology such as radio, telephone auctions, and television in marketing hogs.
12. Possibilities of developing computer technology to assist producers in determining cost of production, time of marketing and the quality and value of hogs. Also, possibilities of using computer technology in developing in-plant systems of identification and measurement which will increase the pricing accuracy and make quality differentials systems more precise.

One important contribution research personnel could make to the swine industry at the present time would be a systematic and thorough collection, evaluation, and publication in popular form of significant research relating to the swine industry. Much research has been done which has not come into the hands of Extension personnel, plant personnel, producers, and others in the industry. There is need for a collection, evaluation, reconciliation of results and the publication of these results if we are to systematically approach the need for additional research. In addition to providing better sources of information, it would point up research gaps and suggest some priorities for future allocations of research funds.

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SWINE PRODUCTION RESEARCH PROBLEMS

AN EXPANDED research program on problems in swine production will result in substantial improvement in the efficiency of pork production. The following summary of some of the major problems reveals the potential for improvement.

1. Reproductive inefficiency and embryonic mortality—

Only about 80 percent of bred females conceive. In addition only 65 percent of the eggs ovulated result in live pigs farrowed. Therefore the approximate reproductive efficiency from breeding to farrowing is about 50 percent.

2. Postnatal mortality—

About 30 percent of live pigs farrowed die before weaning. At least two-thirds of this loss occurs during the first three days after farrowing. The combined effect of failure to conceive, embryonic mortality, and postnatal mortality results in only about 35 percent of the actual potential in the number of pigs produced to weaning age.

3. Efficiency of feed utilization—

Feed costs represent about $2 out of every $3 of the cost of producing pork. More precise knowledge of nutrient requirements for growth, reproduction, lactation, nutrient availability from feedstuffs, selection for improved feed efficiency, influence of environment and management systems, and effects of disease and parasites will permit substantial reductions in feed costs.

4. Disease and parasite losses—

Swine diseases and parasites have a major impact on the efficiency of pork production through their influence on conception rates, prenatal and postnatal mortality, and on feed utilization. In addition, drug, vaccine, and treatment expenses are added costs of diseases and parasites in swine production.

5. Swine production systems—

Factors of major importance are the development of efficient and economical systems for waste removal and disposal, for maximum efficiency in labor utilization (a growing concern in swine production) of housing and equipment, for necessary environmental control, and for protection against disease and parasite infestation. Oestrus control and artificial insemination offer interesting possibilities in improving the efficiency of swine production. Swine behavior as influenced by environment and production systems is worthy of study.

6. Pork quality—

The production of high-quality pork having strong consumer acceptance is essential for expanding pork consumption. Improved criteria for identifying swine of superior quality, increasing effectiveness of selection and breeding systems, and developing nutritional and management methods for producing desired quality are all necessary components for the solution of this problem.

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THE PROCESSOR'S VIEWPOINT

AS PACKERS, we see two main issues involved in the relative position of pork:

1. Costs of producing pork have not been reduced anywhere near as spectacularly as the close substitute—poultry.
2. Consumer demand for pork has not kept pace with another close substitute—beef.

We need to acquire a perspective of where the greatest potential savings in costs may be. In 1964 the proportion of the consumer's pork dollar going to various levels was about as follows:

	Cost per live cwt.	Percentage
Farm	16.00	51
Packer (fresh pork)	2.29	7
Packer (processed pork)	2.95	9
All transportation	1.60	5
Retailing	8.50	27

At the Producer Level.—The big areas for potential cost reduction are obvious:

1. A 10-percent reduction in the investment in the physical plant for producing hogs could run from $100 to $200 million.

2. A 10-percent improvement in feed conversion would amount to $200 million a year.

3. If we could raise the efficiency of all hog producers to the level of the most efficient one-third, costs would be reduced about $450 million a year (based on an Ohio study which showed that the

difference between the lowest costing one-third and the highest costing one-third was about $5 per cwt. in 1962). The probable reason for this wide variation is that many small producers are willing to subsidize hog production by taking a very small return for their labor, or because hogs are produced as only one of several enterprises and the producer does not keep records which clearly indicate what his returns are on hogs.

4. Control of disease could possibly mean even greater direct savings. In addition, control or substantial improvement in this area would have important indirect effects on the image of pork, the rate of gain in feed conversion, and the ability to put together big units which would reduce costs.

At the Packing Level.—Potential for saving at the packer level is not as great because the packer adds less value than the producer does. Furthermore, competition is keener at the packer level than at the production level. Most packers have to pay competitive wage scales, so there can be no subsidization at this level. The bulk of the hogs are handled by packers whose major enterprise is the processing of meat; thus, most packers are required by economic circumstances to know with reasonable accuracy what their returns are on pork. There are, of course, variations in costs between the most efficient and the least efficient. If we compared the top third with the low third, however, the variation would probably be on the order of 50¢ per cwt., or less, as contrasted with the $5 at the producer level.

At the Retailer Level.—The available data (the McKinsey Meat Study, 1964, and USDA studies) indicate retail margins on pork are much wider than on beef. It is likely that a substantial proportion of this is labor which cannot be readily reduced within the present technology.

Trends Associated With Reduced Production Costs

A REDUCTION in the incidence of disease and a general lowering of costs through improved feed conversions would provide an incentive for hogs to be produced in larger units. It would probably also lead to increased specialization and possibly a further division between the production and the feeding of hogs.

A few cattle feeding units are now handling tens of thousands of head of cattle. If the average hog producer were to grow and market 10,000 head of hogs, we could produce our present requirements with about 8,000 producers as contrasted with the near 1 million different producers we now have.

If production units should grow to large size and be much more specialized than at the present time, producers will want to shift part of the risk of price change to packers or to others. This, we believe, will lead to contracting of hogs for future delivery. If the futures in live hogs should continue to develop,

there would be a tendency for producers or packers to shift some of the economic risk to professional risktakers.

Although only spotty statistics are available, the evidence indicates that the large hog producers of today are tending to produce somewhat better than average quality hogs. We, thus, would assume that as units get larger we may speed up the trend toward better quality hogs.

Demand

THE demand for pork has held up better than the demand for many other foods such as milk, eggs, lamb, most cereal products, potatoes. It has not, however, maintained the pace of beef. In 1947–49, 43 percent of the meat and poultry dollar was spent on pork. By 1964, this had dropped to 32 percent. If the proportion had remained the same, the amount spent on pork would have been $2¼ billion higher than it actually was in 1964. The stagnant demand for pork has frequently been attributed to fat. Undoubtedly this is one of the major causes but evidence would indicate that it is not the only factor.

Differences in Value

THE packing industry has frequently been cited for contributing to the loss of consumer interest in pork because, it is claimed, it has not induced producers to develop a better hog. It has been stated that if packers would pay a differential for the better hogs or conversely discount the poorer hogs, this would result in upgrading hogs at the farm level and stimulate consumer demand.

Studies made at Oscar Mayer & Co. in 1964 indicate that the variation in value between the average No. 1 hog and the average No. 3 hog is not as large as has frequently been assumed. The wide differences that come out of some studies appear to be based on the difference between very high quality No. 1 hogs and very poor No. 3's rather than on average quality. Using fiscal 1964 average prices for wholesale cuts, the Oscar Mayer study showed that on a green primal cut basis, the average No. 1 hog was worth about 33 cents per live cwt. more than the average No. 3 for the 210–220 weight range.

It is not frequently recognized that almost any farmer in the Corn Belt has ready access to a packing plant or a packer buying station that will buy his hogs on a grade and yield basis, wherein the differences in value to the packer are reflected to the producer. Packers buying on a live basis also pay a differential for the better hogs, but frequently the prices are averaged so that the difference in value between grades is not called to the attention of the producer as forcefully as when he sells on a grade and yield basis. Also, because it is difficult to estimate yield in buying live (a factor which is automatically taken care of in grade and yield buying), some packer buyers may be a little more conservative in quoting differentials on a live basis. No data on this point, however, are readily available.

Suggested Areas of Research

IN addition to the suggested areas of research previously mentioned, there are other areas we feel would also be beneficial.

What happens in the hog cycle? Who expands? Who cuts back?

What are the changes in farm management system which are affecting hog production?

What are the economic losses from cycles?

What steps could be taken to help avoid major cycle swings?

What are the facts on the value of pork in the diet relative to competing products?

How can we improve cooking methods and provide the ease in using pork which pertains to other meats?

How can we develop incentives to encourage hotels and restaurants to feature pork more often?

Work also needs to continue on controlling the incidence of pale, watery pork.

We also feel that attention needs to be given to the changes which would be brought about by successful research which might alter the production, marketing and processing of pork. Who would be the beneficiaries? Who might be injured by the changes? And what would be the effects on competing products?

Pork should not be sold short; its demand has held up relatively well and a real breakthrough in the cost of producing pork is not only possible but attainable if we copied the best techniques already known. To increase the consumption of pork, we feel the biggest payoff would come through the cost route.

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Advances in DOCUMENTATION RESEARCH

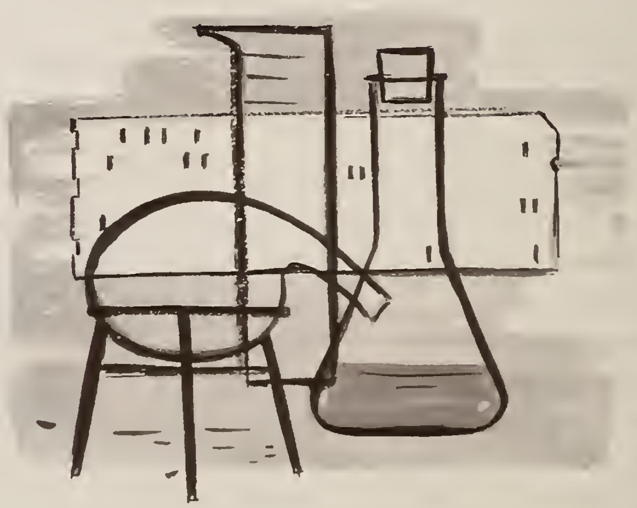
MOST agricultural scientists, no doubt, are well aware of the revolutionary changes taking place in the documentation, storage, and retrieval of science information. An earlier issue of *Review* discussed computer handling of the burgeoning data in the agricultural sciences ("Computer Applications to Agricultural Science," Vol. 3 No. 2, 1965). Another issue reviewed the Federal facilities being established to provide better communication and coordination of science knowledge ("Communicating and Coordinating Agricultural Research: A Review of Federal Facilities," Vol. 3 No. 3, 1965).

Not so well known, we suspect, is the vast scope of research activity on all aspects of science information handling. A realization of how broad the panorama is became apparent to those outside documentation research recently when the National Science Foundation published a 400-page volume titled, "Current Research and Development in Scientific Documentation No. 12" (CRDSD No. 12).

Review believes this volume deserves more than casual commentary on our pages—not only to enlighten those readers who might nor hear about it otherwise, but also to relate the impact of this rapidly growing discipline to the agri-related fields of interest. One need be only slightly aware of the "Babel of words" pouring into libraries to reach the sobering realization that science is facing problems never before dreamed of. Even the most modern giant computer complex—impressive though it may be—represents only a modest beginning in digging ourselves out. For there is much we need to know about science documentation before we can truly escape from the card file-bookshelf era. In the meantime, researchers in this field are making a good start—as CRDSD No. 12 shows so well.

Essentially, CRDSD No. 12 is a cumulative bibliography listing nearly 3,000 publications and reports of research in scientific documentation. It was compiled by the Office of Science Information, National Science Foundation. One of the commendable features of the volume is that practically every item contains information on where the cited document may be obtained. Furthermore, the Foundation made a special effort to make as many documents as possible available from the Clearinghouse for Scientific and Technical Information, U.S. Department of Commerce, Springfield, Va. In most cases, hard copies are available.

Classification of the documents as to subject matter and an actual count of the cited documents will indicate how far this discipline has gone in just about a decade of existence.



1. *Information Needs and Uses*—221 documents. These include studies and analyses of the information needs of scientists, the uses made of scientific and technical information, and communication problems in science.

2. *Information Storage and Retrieval*—933 documents. This category covers studies of methods and systems for analyzing, organizing, encoding, storing, and searching subject matter.

3. *Mechanical Translation*—476 documents. These deal with research on problems of automatic translation from one natural language to another.

4. *Equipment*—129 documents. These include reports on the development of devices for the processing of scientific information.

5. *Related Research*—1,010 documents. These reports cover research on problems not immediately connected with scientific documentation, but whose solution is likely to have an impact on the future of documentation—for example, character and pattern recognition, speech analysis, artificial intelligence, and others.

Many of the documents reflect an awareness by researchers of the information and communication problems facing the science community today. For example, consider the following titles: *The Flow of Information Among Scientists: Problems, Opportunities, and Research Questions; Style and Speed in Publishing Abstracts; The Library of Tomorrow—Today; How to Design an Information Center;* and *Augmenting Human Intelligence.*

As might be expected, hundreds of the documents are closely related to the use of electronic data processing in handling science documentation, as the following sample titles show: *Communication Engineering Approach to Microforms, A Device for Feeding Graphs into Digital Computers,* and *A Method of Voice Communication with Digital Computer.*

Like other disciplines, this one has its own distinctive vocabulary—many words of which would be utterly meaningless to those outside the discipline as these titles show: *A General Convergence Theorem for the Four-Layer Series-Coupled Perceptron, An Adaptive Adaline Neuron Using Chemical Memistors, Transition and Release as Perpetual Cues for Final Plosives.*

Closer scanning of CRDSD No. 12 reveals some areas of research that seem to be only remotely associated with documentation. For example, a California researcher made a study to observe how humans make mistakes in order to discover how to get computers to do likewise. In a Harvard study, a computer system was used to analyze some characteristics of genuine vs. simulated suicide notes. At least four studies are cited that deal with chess playing and the complexity of problem solving.

Most of the research cited is being conducted in the United States, although projects are reported from nearly a score of other countries. The heaviest concentrations abroad are in England and Russia.

What are the implications of all this activity to the agricultural sciences? That is difficult to say at the moment. The situation might be likened to that of a foot traveler who needs to climb another hill or two before he can properly assess the nature of the terrain around him. Of course there are those visionaries who hopefully look for the day when it will be possible for a researcher to push a button and have a machine spew out to him a listing of all the research being conducted on a particular problem. To some extent we are already entering this stage—as attested to by the Science Information Exchange, the Clearinghouse for Federal Scientific and Technical Information, and others. And of course, within the Department of Agriculture, the new organization, Current Research Information System (CRIS), is charged with developing compatible information storage and retrieval procedures for research conducted in the USDA and State agricultural experiment stations.

Despite the rapid advances being made in machine storage and retrieval, some agricultural scientists take a skeptical view of such methods. This is understandingly so, because the new system invades the traditional person-to-person lines of communication that have served them so well. For example, the first announcement of the establishment of Science Information Exchange (SIE) drew the expected comments from scoffers who said they couldn't foresee any need to take any advantage from the new service SIE would offer. Yet today, inquiries for data on current research are pouring in from many of this same group. Indeed, a member of the *Review* staff has listened to quite a number of confessions from agricultural scientists within the past year acknowledging that they find it impossible to keep up-to-date under the old system.

Let us suppose, for a moment, that eventually the documentalists will be able to announce the storage and retrievability of all existing knowledge pertaining to the agricultural sciences. Let us further suppose that a need arose to determine the extent of our knowledge on, say, swine nutrition. Would we have the courage to push the button? Bentley Glass once said if all man's knowledge of molecular biology were computer-stored and available to him at the touch of a button, he doubted if he would care to expose himself to the deluge.

It is precisely because of such predictable problems as these that researchers in documentation are addressing themselves to the wide panorama of study cited by National Science Foundation in its CRDSD No. 12. To an obscure nematologist carefully studying his specimens in a laboratory, word of a documentation project on, say, "the theory of clumps" may well bring a reaction of mild amusement from him. Yet the documentalist some day may be able to tell the nematologist he is wasting his time. His research problem has already been solved by another nematologist in another State, another country. The computer says so.

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