The Influence of Research on Efficiency of Sugar Beet Production

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It is a pleasure for me to attend the Twelfth General Meeting of the American Society of Sugar Beet Technologists and discuss the influence of research on your industry. Too frequently we are inclined to forget research accomplishments that contribute to developing, maintaining, and assuring the future of a sound industry. Some of these high lights will be briefly reviewed in order to bring some of our current problems into sharper focus. In addition, I am certain that you will be interested in a few examples of our current basic research programs which benefit sugar beet production as well as other crops.

The sugar beet industry, including production, has grown in importance in our agricultural economy at a pace commensurate with the increase in sugar quota and acreage allotments. These yearly manifestations of vigor and responsiveness to increase production demands may be attributed to several factors such as improved economic environment, new developments in technology, and more efficient management in industry and on the farm. But agricultural research can justly claim credit for the remarkable improvement in acreable yields of roots and sugar: increased efficiency in sugar production, including a reduction of labor requirements; and, above all, for protective measures against certain disease hazards that once seriously threatened continuance of growing sugar beets in several major districts.

The sugar beet, as other crops, has been through periods of discouragement. Many of you can recall the low yields and erratic productions of the twenties and early thirties when recurrent epidemics of diseases, such as curly top in the West and leaf spot and black root in the eastern sugar-beet regions, resulted in low quality of roots for the processor and in unsatisfactory returns to the grower. These diseases adversely influenced the economy of beet sugar production for several years.

Relief from these disease hazards was not the result of some benevolent act of Mother Nature or a change in the weather. Actually the diseases are still present, but protection has been accomplished through the development of resistant varieties and the application of improved field practices.

These advances have been the product of well-organized research programs conducted by groups of devoted scientists em-

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ployed by the beet sugar industry and by Federal and State agencies. The financial support, as well as cooperative assistance, received from the beet sugar industry for our joint research activities has been remarkable. It stands as one of the best examples of government and industry working together toward a common objective.

An early significant accomplishment in sugar-beet breeding was the development of curly-top-resistant varieties that gave new life to the beet sugar industry in most of the districts west of the Rocky Mountains. The havoc caused by curly top in the varieties available in the twenties was an appalling sight. Probably no research assignment appeared more difficult than the control of curly top through breeding of resistant varieties. For this reason, the accomplishments have been most gratifying.

The level of curly-top resistance that has been attained in commercial varieties such as US 22 and its improved releases is remarkable and may have given rise to a feeling of unconcern for the disease. Not only is the disease still brought into irrigated districts from rangelands each spring by the leafhopper, as in the past, but new and more virulent strains of the virus have been found and other new ones may be expected to occur. These new strains of curly-top are capable of causing severe damage to US 22 and other varieties that gave protection in the past. Therefore, research on curly top is still important and must be included in our over-all program of sugar beet research.

Breeding for resistance to leaf spot and black root for the districts east of the Rocky Mountains has resulted in benefits comparable to those derived from curly-top-resistant varieties for the western region. With the introduction of American varieties in the Great Lakes region, the acreable yields of roots have shown a steady increase, and some districts in this region are now well above the national average in productivity.

Sugar beet crops are now threatened by virus yellows or a complex of viruses that bring about yellowing of foliage and strikingly influence the yield and quality of the sugar beet. No doubt this disease will be a factor of increasing concern in the economy of beet sugar production in this country, as has been true for Europe where the disease has been under investigation since the thirties. Virus yellows was first identified in the United States in 1951 from plants collected in Michigan. Since that time, the disease has been found in all major sugar beet districts where surveys have been conducted. The disease has reached epidemic proportions in California and in areas where sugar beets or other susceptible plants are growing most of the year. The damage depends upon the age of the plants when infected and on the virulence of the strains of the virus involved. Damage appraisal tests conducted in California have indicated reduction in root yields from 2 to 47 percent and in sucrose content ranging up to 3 percentage units.

The immediate relief from damage caused by virus yellows must come from measures directed at the vectors or at field practices and cropping systems. The ultimate goal is protection through the development of resistant varieties. Progress has been made in the breeding of basic lines that do not react to the virus by the yellowing of the foliage, while the development of productive varieties that are more tolerant or immune to virus yellows is a goal of the future.

Nematodes have long plagued the sugar-beet producer. As research advances are made, the complexity of the nematode problem is revealed through a multiplicity of alternate host relationships and an increasing knowledge in the number of different kinds of nematodes. Some empirical control has been obtained with soil fumigants at a high cost, and by more practical control through cropping practices including fallow or crop rotations without alternate hosts. For ultimate control of the sugar beet nematode, the most promising project is breeding for resistance or tolerance by using the wild *Beta* species. In the meantime, information on the biology of the sugar beet nematode and its relation to alternate hosts, as the tomato, gives some basis for guidance in modified cropping practices until more suitable varieties are developed. Several species of the root-knot nematodes well known in other crops, particularly in California, contribute to production hazards and most economical and efficient production of sugar beets. Also, gall-forming nematodes, sometimes confused with the root-knot nematode, add to the complexity in Colorado, Wyoming, Montana, Kansas and Nebraska. These gall-forming nematodes are known to have a definite effect on the efficiency of beet production along with a nematode complex involving root lesion nematodes, spiral nematodes, and pin nematodes, commonly found in the association with sugar beets. The significance of each will not be clear until the whole biological relationship can be established with one another and with the crop.

The establishment of a sugar-beet-seed production enterprise in the United States was a direct result of the accomplishments of our sugar-beet geneticists and breeders. Various segments of the industry joined forces in this endeavor to insure a dependable source of seed with maximum disease resistance, and agronomic characteristics suitable to regional environments. This industry has in turn provided a wealth of material for the plant breeders to continue their work on improving the crop. Our current sugar-beet economy would be quite different today if industry had not provided wise management of seed stocks, maintenance of reserves, and facilities to permit an orderly and rapid change-over to new varieties.

Hybrid sugar-beet varieties have shown roughly 15 percent increase in yield over the open-pollinated varieties. The discovery of cytoplasmic male sterility in the sugar beet and the utilization of this character as a tool in the production of hybrid seed have had a measurable influence on the economy of beet-sugar production. Of special significance is the recent discovery that certain combinations of inbred lines show heterosis for sucrose percentage as well as for root yield. If future combining ability tests with inbred lines should reveal the general occurrence of this phenomenon in sugar-beet-breeding material, one should be able to push forward with higher root yields and with improved quality through one breeding procedure. Obviously such a development would have a profound effect on the efficiency of beet-sugar production.

One of the most elusive factors that we have to deal with in all crops research is quality of the finished product. This is due to the fact that our agriculture products must meet the requirements and standards of diverse end-use. Sugar beets having only one principal end-use simplify the problem to a degree, however, quality is conditioned by several factors, such as disease, nutrition, environment, and genetic components. No doubt the processor, as well as the grower, has the impression that quality is a temperamental condition that can be upset by many factors. Actually the physiologist must admit that he does not have all the answers. Certainly nutritional and climatic environments are known to be associated with low quality, but it is also true that these same factors favor disease. Therefore, it is difficult to separate the causes into their component parts. It has been clearly established that imbalance of nutrients, especially heavy and untimely applications of nitrogen, results in low sucrose percentage without bringing about an increase in root yield. There are several papers on this subject in the technical sessions that should help in developing the proper fertilizer practices.

The ability to completely mechanize all field operations in sugar-beet production must be attained in order to insure the grower of maximum production potential. Monogerm varieties of sugar beets that are now available or in advanced stages of development for all regions, will have a far-reaching effect on this goal when we learn to use them in proper field practices.

Weeds are among the last remaining obstacles to complete mechanization of many crops, and excellent progress has been made in the development of herbicides for weed control in sugar beets. Complete mechanization of sugar-beet production can only be accomplished when more effective and selective herbicides become available to the sugar beet growers in all areas of production.

Progress in the development of herbicides for weed control in sugar beets through the combined effort of federal, state, and sugar company employees has been most significant during the past decade. Within this period, trichloroacetic acid (TCA); 3,6-endoxohexahydrophthalic acid (endothal); isopropIy N-phenylcarbamate (IPC); 2,2-dichloropropionic acid (dalapon); ethyl N,N-di-*n*-propylthiolcarbamate (EPTC); propyl ethyl *n*-butylthiolcarbamate (PEBC); 4-chloro-2-butynyl N-(3-chlorophenyl) carbamate (barban); and 2,3-dichloroallyl diisopropylthiolcarbamate (DATC) have been developed for the control of broadleaved weeds and grasses in sugar beets.

Even with all of these advances more effective herbicides for the control of broadleaved weeds in sugar beets are needed. The recent development of pre-planting soil-incorporated treatments with EPTC and PEBC for the control of both grasses and broadleaved weeds represents a significant improvement in chemical methods of controlling weeds in this crop.

Barban and dalapon have proved highly useful for the control of wild oats after they emerge in sugar beets. The development of these two chemicals for wild oat control in sugar beets represents a significant accomplishment because TCA, endothal, and other herbicides used as pre-emergence treatments are not effective in controlling wild oats in this crop.

Progress has also been made in fundamental research on the selective action of herbicides. Basic research on the differential effects of dalapon on sugar beets and weed grasses has yielded valuable information. Fundamental research on the mechanisms of action of herbicides, the basis for their selective action, the behavior of herbicides in soils, and the effects of environmental factors on their efficiency has been of great value in the synthesis and development of new herbicides for weed control in sugar beets. Basic research has also provided guidelines for more effective use of herbicides presently available for weed control in this crop.

New herbicides are being developed at a rapid rate and each new one must be evaluated to determine its usefulness for weed control in sugar beets. Promising new herbicides, including such additives as surfactants, must be thoroughly evaluated as pre-planting soil-incorporated, pre-emergence, and post-emergence treatments, including their behavior in soils, effects on crops grown in the rotation, and the effects of environmental factors on their efficiency in controlling weeds without injury to the crop.

The Agricultural Research Service has established 16 pioneering research laboratories since 1957. These laboratories operate on broad charters with the primary objective of exploring the unknown in order to discover basic principles that will be useful to agriculture in future years. The Crops Research Division has two such laboratories. One is concerned with plant physiology and the other with plant virology. Actually our research in the physiology laboratory started in 1936 with work on photoperiodism. In 1957, the charter for this group as a Pioneering Laboratory was broadened to cover effect of light on plant growth and development.

Very important advances in our understanding of the physiology of plants have resulted from studies of their responses to light. Flowering and growth responses of plants to different lengths of day indicate an internal regulation for measuring time. The controlling factor is found to be the length of the uninterrupted night. Sugar beets flower when days are long and nights are short. Interruption of the nights by dim incandescent lights to make two short nights out of each long one promotes flowering of beets and other long day plants, thus showing that duration of darkness, not light, is the controlling factor.

Detailed experiments have shown that red light is more effective in controlling flowering than any other color. The light energy required to induce flowering is extremely low. The effectiveness of light applied in the night results from absorption, and since red light is the most effective in controlling flowering, the responsible pigment must be blue. The concentration of this pigment is too low for visual detection.

The minimum light energy for a particular response as a function of color or wave length has been identified for flowering of short and long day plants; stem and leaf growth; germination of many seeds; and pigment formation. Responses to light of different colors, or action spectra, are remarkably similar, suggesting that all of these different phenomena are regulated by the same receiver in the plant. Maximum effectiveness was at about 650 mμ, which is in the center of the red region of the spectrum.

Seed germination can be either promoted or inhibited by red light, and the process is reversible. Radiation at 730 mμ or far red which is at the visual limit is inhibitory; while that at 650 mμ is promotive. The level of germination is independent of the number of alternations between 650 mμ, (promotion) and 730 mμ, (inhibition). It is completely dependent upon the wave length of the last radiation given in a series.

Re-examination of the flowering and stem elongation responses previously known proved that they were also reversible by exactly the same wave lengths that control germination of seeds.

These various responses led to the conclusion that they are all controlled by a single photoreversible reaction and implies that the photoreceptor must undergo reversible changes from one form to another—one form absorbs red light (650 mμ) and the other far-red (730 mμ). The length of the night is measured by the change in darkness of the far red to the red absorbing form.

Physiological experimentation developed these facts. Now biochemists have isolated phytochrome from 20 or 30 plant species including sugar beet leaves. The action compound is a protein that denatures at temperatures about 50°C when isolated from the leaf and permanently loses its reversibility.

The far red absorbing form of phytochrome is an enzyme, but the reaction it controls in the plant is unknown. That this reaction is a very basic one of plants is shown by its control of numerous widely different plant responses. Its point of control is evidently a very primitive one in the reaction sequences that lead to display of these various responses.

This has been a very abbreviated summary of the development of knowledge in this field in the last 10 or 15 years, initiated 40 years ago by Garner and Allard. A study designed to investigate the light control of flowering led step-by-step to eventual awareness that the controlling mechanism is not peculiar to flowering but is exhibited in innumerable phenomena of plant development. A few decades ago most of us looked upon photoperiodism as a biological curiosity of casual interest but no immediate general concern. Today, we look upon it as a key response of plants to a fundamental reaction that has most diverse and far-reaching consequences.

Where will these investigations lead in the future? Prediction is unsafe. Ten years ago we surely could not have predicted that studies of photoperiodic response of soybeans might lead to understanding why tomatoes in a grocery store are often pinkish instead of orange-red, why one should not cultivate after applying a pre-emergence herbicide, or why pieces of green apple skin floating on sugar quickly smell like stored apples in darkness but not in light. These are only a few of the phenomena one finds himself contemplating with at least partial understanding as a result of logical step-by-step study of the influence of light on flowering.

In our Pioneering Research Laboratory in Plant Virology the study of developmental forms of plant viruses may be possible as a result of recent research findings. An infectious material distinct from tobacco mosaic virus has been isolated from infected tobacco leaves. This infectious material can be broken down by the plant enzyme ribonuclease which indicates that the material is ribonucleic acid (RNA), the chemical building blocks in living cells.

Tobacco mosaic virus particles are rods consisting of a core of RNA surrounded by protein. It is believed that during tobacco mosaic virus multiplication in infected leaves, nucleic acid exists free as an early form of the virus. Until now this free RNA could not be isolated from infected leaves (except by methods which also extract the RNA from complete virus), because the ribonuclease in the plant material destroyed the RNA before isolation could be accomplished.

It has been found possible to purify and separate viruses by a system involving diffusion- -filtration through glass columns packed with a buffered suspension of agar gel chips. Spherical virus particles diffuse into the agar chips and particles of different sizes move down through the column at different speeds depending upon their diffusion coefficients. Long particles such as those of tobacco mosaic virus, cannot move into the gel and pass through the column quite rapidly. This method is useful for the separation of very small contaminants from virus suspensions and for the sorting of viruses which differ by as little as 3 or 4 mμ in particle diameter. Preliminary work with enzymes and other large protein molecules suggest this method of purification and separation will be extremely useful for the purification and separation of many biological components in addition to the virus work for which it is currently being used.

Experiments are under way to purify the curly-top virus of sugar beets and to determine its size by diffusion-filtration. In

February 1956, Dr. Steere reported at the San Francisco meeting of the American Society of Sugar Beet Technologists, the isolation of an infectious component from curly-top infected sugar beets which had a particle diameter of 16 mμ but was not willing to publish a paper on the infectious particles he isolated, because his final product was unstable and he feared that the 16 mμ particles might be a breakdown product of the virus resulting from the purification procedure employed. The diffusion-filtration procedure is both rapid and extremely gentle on the virus particles and we expect to have some interesting results with curly-top virus in the near future.

Basic research on plant growth regulators provides a background for more applied research on many of our crops. Some rather recent examples have a direct application or at least contribute toward a better understanding for the development of practices in sugar-beet production or applied research contributing to advances through production research. Three chemicals—Ammo 1618, phosphon, and CCC -found to retard plant stem growth in our laboratories and later adapted to limited commercial use, have been found to prevent salt damage to soybean plants growing in highly saline soils. Soybean plants growing in pots with a fertilizer application equivalent to 7,800 lb. per acre, with plants treated with 38 milligrams of the chemical growth retardant, grew to maturity and produced viable seed. Untreated plants in this high fertilizer concentration wilted within 24 hours and died within 3 weeks. While this specific finding cannot be applied directly to sugar beets in a field practice, it offers a very significant lead which should be investigated for crops like sugar beets often grown on soils of high salinity.

A new antibiotic, phleomycin, previously known to be effective against organisms causing human and livestock diseases, has been found to be effective in preventing or curing rust disease of snap beans under greenhouse conditions. Our scientists at Beltsville have demonstrated that an exceptionally low concentration of phleomycin -one part of the antibiotic per million of water - sprayed on the leaf surfaces, will control bean rust. This lead has opened the way to further experiments to determine the effectiveness of phleomycin against other rusts and against downy mildew and anthracnose diseases.

Another chemical known as PAC (penacridane chloride), developed originally for medical purposes, is promising as a foliar and seed treatment fungicide. In laboratory tests at Beltsville, PAC killed both fungal and bacterial disease organisms carried on seed surfaces and it did not seem to slow seed germination. It has been applied to seeds as a soak, dip, or spray with equal success, and is bound to the surface even better than some chemicals accepted for commercial seed treatments. Even repeated washings of treated tomato seeds left enough of the PAC on the surface to prevent the growth of bacteria. The material may have an added advantage for practical use in its apparent absence of toxic properties to humans and animals. This development for a new use of a chemical to control seed-borne diseases is promising for any crop propagated by seed, and should not be overlooked for its possibilities in sugar-beet disease control.

In another area of work, our Federal-State scientists have recently found concrete evidence of substances in plants that make them physiologically resistant or susceptible to disease. A protein of the globulin type found in a particular race of flax rust fungus, was found to occur also in flax plants susceptible to the same race of the fungus. Plants resistant to the particular race do not contain the protein. This discovery is a basic one in plant science, and may prove especially important to plant breeders searching for disease-resistant plant materials. In principle, it offers a new tool to our scientists for almost all crops including sugar beets. This principle of physiological disease resistance in plants serves as an example of the results and need for the close working relationship between our scientists in the different disciplines—specifically the geneticists and physiologists in this case. Here specific information on the globulins from each of four lines of flax and four races of rust of the fungus *Melampsora linii* were used in serological analysis, which tests show a clear basic relationship between susceptibility to particular fungus races and plant varieties, thereby opening the door to a new approach in disease control.

These are only a few examples of our current research program. If time permitted I would like to tell you about our work on the Biological Control of Root Disease where we are attempting to develop "bugs to fight bugs"; of our work on translocation of large molecules from leaves to roots; of our plant exploration work to provide new germ plasm - - - - etc.

This year we are commemorating the 100th Anniversary of the U. S. Department of Agriculture and the approval of the Morrill Act, which created the national system of land-grant universities and colleges. In all of these institutions and in the U. S. Department of Agriculture, dedicated scientists have provided the knowledge that has enabled American agriculture to be the most productive that the World has ever known. We must keep our research program strong to insure a constant flow of new knowledge that will be required in the future. Continued progress demands dynamic action. The graduate students of today must be convinced that Biological sciences have as many challenges and rewards as the Physical sciences, otherwise the next generation will not have the trained manpower to cope with problems ahead. The general public should be better informed as to our aims and objectives in agricultural research. We should never take our minds from the primary objective—to provide the most wholesome food supply in the most efficient and economical manner possible.