A VIEWPOINT FOR PLANT PHYSIOLOGY

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Notable as has been the growth of plant physiology and great as have been its contributions to agriculture, horticulture, forestry, and other fields, it may be questioned whether it is making as substantial contributions to plant science as it can and should make. There is considerable evidence that it is not. There are still too few courses in plant physiology offered in our colleges and some of those offered are not taught so effectively as would be possible and desirable. As a result many professional botanists and workers in applied fields of plant science have had little or no training in plant physiology. It is particularly unfortunate to find men going into agriculture and forestry lacking such training, because without it they can never really understand the growth processes of plants. There are also few plant physiologists employed in research projects by allied fields. While plant physiologists have been widely employed in horticulture for many years, few are in agronomy, and until very recently almost none in forestry. Many agricultural experiment stations do not even list plant physiologists as staff members. Likewise, few plant physiologists have entered industrial research. Although industrial laboratories such as those of food-processing companies and fertilizer manufacturers employ agronomists, chemists, plant pathologists, plant breeders, and soils specialists, they seldom have plant physiologists on their staffs. While considerable physiological research is being done in industrial laboratories, most of it is carried on under conditions such that our field receives no credit.

If it be true that plant physiology is not making so large a contribution to plant science as it is capable of making, we should search for the reasons and attempt to find remedies. One reason may be that administrators in charge of teaching and research programs do not sufficiently appreciate the usefulness of plant physiology in training students and solving problems. This seems to be largely our own fault; we have been too modest to advertise the contributions we can make and we have often failed to see or to take advantage of our opportunities.

If we are earnest in our desire for plant physiology to attain its widest possible usefulness, we must educate scientists in other fields to appreciate its possibilities. Before we start a campaign to sell plant physiology to others, however, it might be wise to consider what we have to offer. First we, ourselves, must know what plant physiology can contribute to workers in other fields of plant science. It is probable that our aims and objectives have received too little attention. Each year hundreds of papers are published in the field of plant physiology, but almost nothing is published about

1 Delivered as the address of the retiring president of the American Society of Plant Physiologists for 1945-46, at Boston, Massachusetts, December 27, 1946.

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the field. This is unfortunate; more consideration should be given to the objectives of our field and its proper relationship to other fields of plant science. We must develop a clearer understanding of our aims and objectives—a sort of professional viewpoint or philosophy. We need to develop a clearer understanding of the scope of our field and its relationship to other fields of plant science; this is essential to the planning of both successful teaching and productive research programs. We must know for what we are training our students if we are to know how to train them, and we must imbue them with a broad viewpoint and stimulate their imagination if they are to render maximum service.

It is difficult to define the field of plant physiology in terms of content because it is so extensive. Papers published in the area of plant physiology deal with such diverse subjects as the vitamin content of vegetables, the moisture content of leaves, the mechanism of respiration and of photosynthesis, plant hormones, weed killers, and methods of determining the permanent wilting percentage of soils. Originally the interests of plant physiologists were confined to the field of botany in its narrow sense, but in recent years they have extended to agronomy, forestry, horticulture, plant pathology, soils, biochemistry, and biophysics. Furthermore, topics once of interest solely to botanists are now important to other scientific workers. Thus the chemical composition of tobacco leaves may be as important to agronomists, soils technologists and chemists as to plant physiologists; and measurements of respiration and of photosynthesis may be as essential to the explanation of problems in forestry and horticulture as in botany. The field of plant physiology therefore can no longer be clearly distinguished from other fields by content alone; it can be better distinguished in terms of its viewpoint and relation to other fields of plant science. This is illustrated by the following diagram showing the interrelations among various factors determining the growth of plants.

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Hereditary potentialities of the plant.

The field of genetics and plant breeding.

Internal physiological processes and conditions of the plant.

The field of plant physiology.

Environment of the plant.

The field of ecology and soils technology.

The field of applied plant science, including agronomy, forestry, and horticulture.
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The behavior of plants, like that of other organisms, is determined by two interacting groups of factors. These are the genetic factors, determined by the heredity of the plant, and the environmental factors, determined by the conditions of soil and climate under which the plant is grown. Study of genetic factors obviously is the field of the geneticist and plant breeder, while study of the factors of the environment is primarily the field of ecologists and soils technologists.

Plant behavior, as measured in terms of quality and quantity of yield, whether corn, cotton, lumber, apples, or flowers, is primarily the concern of workers in applied fields such as agriculture, forestry, and horticulture. These men are concerned principally with the problem of how to grow larger crops of higher quality. They think and experiment chiefly in terms of crops, not of individual plants. No matter how much investigators in the applied fields learn about the effects of such specific treatments as fertilizers, irrigation, tillage, or cutting practices, on quantity and quality of growth as measured by crop yield, a very fundamental question is left unanswered. This question is: "How do variations in hereditary and environmental conditions produce differences in quantity and quality of plant growth?" The answer is, of course, that the growth behavior of an organism can only be affected through changes in its internal physiological processes and conditions. Here lies the field of activity of plant physiology. The aims of plant physiologists are to observe and measure these internal processes and conditions, to study their physicochemical mechanisms and the effect on them of variations in environmental factors, and to use the information so obtained in explaining the behavior of plants.

Plant physiologists have been effectively observing and measuring plant processes, but they have been somewhat negligent about interpreting and applying the results of their observations. Too often the interpretation and application of physiological findings have been left to workers in other fields. As a result, even though fundamental research has been done in plant physiology, full credit is seldom given for its discoveries. If plant physiology is to make its maximum contribution to plant science, plant physiologists must give more attention to the significance of their research, and especially to its usefulness in explaining plant behavior. Mere accumulation of data is not enough, no matter how carefully the data are obtained. Any industrious person can learn a technique, accumulate data, and publish a paper, but only a well-oriented investigator can interpret his results and publish a paper which makes a valuable contribution to our knowledge of plants.

Much time, money, and energy are wasted on research projects from which no worth-while results are obtained simply because the investigators do not agree on a definite objective. Funds are available for research, a certain problem seems interesting, or there is pressure to publish something; so a piece of work is done without adequate consideration of its ultimate contribution. With a little more foresight and imagination a valuable contribution might result instead of another "So what?" paper. Such a waste
of time and money is all the more unfortunate because of the tremendous amount of fundamental research so clearly needed.

There is not a single crop plant for which we have all the needed physiological data. Although much work has been done on a few species such as apples, corn, and tomatoes, there is no comprehensive, well-integrated survey of the physiological processes of any species under field conditions. Careful, and preferably simultaneous measurements of growth, photosynthesis, respiration, transpiration, stomatal opening, and other processes are needed. Such studies would make known the causes of variations in quantity and quality of yield and thereby aid in the control of the yield of crop plants. Some possibilities for worth-while physiological research in fields which have not been adequately investigated can be indicated by a few examples.

Foresters have long debated the relative importance of shading versus root competition for water and minerals. They have attempted to solve the problem by various types of field experiments, particularly the use of trenched plots. Their experiments were not entirely satisfactory, however, because the results could be interpreted according to the bias of the observer. Actually the relative importance of water and light in the survival of tree seedlings depends on the physiological characteristics of the competing species, hence laboratory studies of these species are essential to determine the more important factor in survival. Foresters have learned from experience that certain silvicultural practices are better than others, but they seldom know why; plant physiology should help explain in terms of physiological processes why certain practices are successful and others unsuccessful.

Plant physiologists, working for several decades in the mineral nutrition of plants, have acquired much information about the absorption mechanism and the manner in which some of these elements are used in the plant. Agronomists and horticulturists have performed numerous field experiments to study the effects of mineral elements on quantity and quality of the crop. Nevertheless, it is still not fully understood why specific fertilizer treatments produce certain results in terms of yield. This is because there is inadequate information concerning the effect of fertilizer treatments on various physiological processes. Since fertilizer treatments can affect plant growth only by changing internal physiological processes, the need for such studies seems obvious, yet little fundamental work of this sort has been done. Plant physiologists must bridge the gap between field and laboratory experimentation in order to explain plant behavior more completely.

As another example, a certain tobacco research laboratory has a remarkably complete set of chemical analyses of tobacco, showing the differences in composition of leaves grown on various soil types, with different fertilizer treatments, and in different seasons. Unfortunately, reasons for the differences in composition can only be surmised because there are no measurements of the physiological processes of tobacco plants grown under these conditions. Only after studying the water relations, the rate of photosynthesis, respiration, stomatal opening, and other processes as they vary with season, soil, and fertilization can the differences in yield and quality be explained.
and only when the causes for these differences can be explained can a rational, scientifically sound cultural program be developed for tobacco. The same is true of many other crops. These are clearly tasks for plant physiologists—tasks well worthy of their best efforts.

The field of plant pathology offers many opportunities for physiological research. The physiological condition of a plant has important effects on its resistance or susceptibility to disease. Furthermore, many of the abnormal conditions termed diseases are physiological in nature and could be worked on more efficiently by physiologists than by pathologists. Progress in the control of human diseases has been greatly advanced by a physiological approach, and it is probable that plant physiology can make equally worth-while contributions to the control of plant diseases. More attention should also be paid to the physiology of fungi. Mycologists have given most of their attention to the morphology and taxonomy of fungi and physiologists have concentrated on seed plants, so the physiology of fungi has not received the attention it deserves. There are scores of such opportunities to contribute to the knowledge of fundamental physiological processes and at the same time to obtain information valuable to workers in the various applied fields; the only requisite is the imagination to recognize opportunities and the training and persistence to approach them scientifically.

Two general approaches to physiological research are apparent. One is to concentrate on the details of particular processes without regard to the role of these processes in the life of the plant as a whole. Examples can be found in the investigations of the mechanisms of photosynthesis, respiration, and mineral absorption where the emphasis is on the chemical and physical processes involved rather than on their importance to the organism. The other approach might be termed "interpretative" in viewpoint because it stresses the plant as a unit and emphasizes the study of plant processes in order not merely to understand the processes but to explain the growth behavior of plants.

Greater emphasis has been placed on the interpretative or applied approach for several reasons. In the first place it seems intrinsically important to our understanding of plants, and hence for plant science as a whole, that this aspect of physiology be energetically investigated. Secondly, plant physiology as a field will flourish only to the extent that it can prove the value of its work. Under present economic and social conditions it is relatively easy to obtain funds for research projects which promise to yield results capable of practical application, while it is extremely difficult to justify large expenditures on research of purely theoretical interest. If plant physiologists insist on working chiefly on projects of theoretical importance with complete disregard for their applications, the field is apt to suffer from lack of financial support. Thirdly, development of practical applications of fundamental research usually stimulates interest in and support for the related fundamental research. Only by demonstrating that our research yields information with worth-while applications can we expect to obtain funds and support with which to continue.
For example, twenty years ago the study of photoperiodism in plants was largely of academic interest, but it was soon discovered that a knowledge of the photoperiod requirements of various crops was useful to agriculture. Appreciation of the practical importance of photoperiod has stimulated more fundamental research in this field than would ever have been possible if its practical applications had not been demonstrated. Another example of the impetus than can be given to fundamental research by practical needs is in studies of dormancy and retention of viability in seeds. Funds can often be obtained for work on species of economic importance although financial support is not usually available for work on species of no economic importance. The work on plant hormones was originally of only theoretical interest, but since it has been demonstrated that hormones and related substances have important practical applications in growing plants, research in this field has been greatly stimulated.

While emphasizing the interpretative or applied approach, the contributions which come from specialized research on the mechanisms of various physiological processes should not be minimized. More investigators with training, inclination, and equipment for work in these specialized fields are needed. Nevertheless, it seems likely that most of the support for such specialized research will come because of the need to explain problems in the applied field. Of course there is no real distinction between fundamental and applied research; there is merely a difference in viewpoint. It has often and truly been said that the more fundamental the research the wider its possible practical applications. The importance of fundamental research is widely appreciated, but more attention should be given to its application to practical problems.

This emphasis on the necessity of understanding and cooperating in the solution of problems attending the growth of economic plants does not mean that short-time applied projects of the so-called practical type are desirable; far from it. No greater disservice could be done to the applied plant sciences than for plant physiologists to forsake fundamental research on plant processes and turn to investigations of the best methods of growing corn, cotton, tobacco, or forest trees. It is important, however, that there is a tremendous amount of basic research on plant processes which should be done, because eventually this work will have important applications in growing better crops of corn, cotton, and forest trees.

Another way of expressing this viewpoint is to state that more attention should be directed to the relevancy of research and teaching to the environment of the workers. President Conant of Harvard University has been quoted as saying "To my mind a scholar's activities should have relevance to the immediate future of our civilization." The same can be said of a scientist’s activities; his work should be related to the general scientific problems of his environment. Financial support can hardly be expected if the researcher insists on following his own personal interests, without regard to the rest of the world. It is possible that problems which now seem irrelevant may later become very important, but this is no excuse for neglecting
or avoiding work on problems which if successfully solved would have immediate applications.

It is obvious that this viewpoint requires a high degree of cooperation with colleagues in other fields. We must become familiar with problems in other fields of plant science and in industrial research. We need better cooperation between those workers who are principally interested in basic research and those who are chiefly concerned with applications. An exchange of ideas will stimulate imagination and broaden understanding. Many problems will be too complex to be solved by one worker or by workers in one field, hence investigators from several fields may cooperate. It will be necessary to call in chemists and physicists to aid in using the new research tools being developed in their fields.

Development of a broad viewpoint must also be taken into account in the training of students. They must learn not only of the physiological processes of plants, but also the contributions of these processes to the growth of the plant. Proper training of graduate students is of the greatest importance, for the future of plant physiology depends on our success in training future teachers and investigators.

More and more of our problems are becoming too complex for individual scientists to deal with effectively. This increases both the responsibilities and the opportunities for service of such organizations as The American Society of Plant Physiologists. The greatest service of our Society has been the publication of Plant Physiology, but certain other functions are likely to become increasingly important in the future. Society committees can be very helpful because they are able to collect and evaluate information on a scale impossible to individuals.

The Society committees on chemical and physical methods have given us useful reports, and they should continue to keep us informed concerning new research methods. New committees have been authorized to study such problems as the professional status of plant physiologists, the training of students, and the relation of plant physiology to industrial research. The Society must now consider how to cooperate effectively with the other plant science societies and what its relation will be to an organization representing all the biological sciences. There is need for greater cooperation among individuals in supporting our Society and among societies in promoting objectives common to all workers in the plant sciences. Such cooperation will help us as individual scientists to work more efficiently and will enable our societies to work more effectively for us.

To be successful our officers and committees need active support. Obtaining new members and paying dues are important, but that alone is not enough to make our Society successful. All of us must study our problems and help the officers and committees solve them. Just as the success of our field depends on the value of our scientific contributions, so the success of our Society depends on the extent of our contributions as members to its activities.

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