THE
NEW YORK BOTANICAL GARDEN

A REPORT ON
SCIENTIFIC RESEARCH

BY

THE SCIENTIFIC DIRECTORS

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Rise of Botanical Gardens

The original conception of a botanical garden, dating from the sixteenth century, seems to have been that of a place in which there might be collected living plants, especially medicinal plants. As a matter of fact these earliest gardens were repositories of all that was known about plants at the time, including even the methods of propagation and the various horticultural practices of the time. Once the idea was formed it spread rapidly, and during the next three centuries there were established in Europe, it is said, some 1600 botanical gardens. These were usually private enterprises, or gardens connected with monastic institutions, or gardens under the auspices of universities. The earliest gardens brought together living plants, but it was only natural that in time these were supplemented by herbaria. While some collections were confined to medicinal plants, others covered wider fields of more general botanical and especially of foreign interest. In more recent years, with the growth of botanical science, the scope and purposes of certain notable botanical gardens have been much extended, and there is perhaps a tendency for them to become again repositories of all our knowledge of plants. That this was the thought of the founders of the New York Botanical Garden is indicated by the statement of its purposes in the Act of Incorporation.

This statement included among the purposes of the institution "the advancement of botanical science and knowledge, and the prosecution of original researches therein and in kindred subjects." The founders of the Garden thus early decided that it should be not merely a static, but a progressive, institution. The wisdom of this decision cannot be questioned. In these days, when science permeates and is indispensable to all human activities, no institution that is avowedly scientific can long continue to justify its existence unless it engages in research. The question, therefore, that is here presented for consideration is not whether the Garden shall engage in research, but along what lines its research shall be pursued.

Research a Duty of Garden

Botany, as is true of all natural sciences, was at first descriptive and concerned itself with collecting, describing, naming and classifying the different kinds of plants, especially those supposed to be of medicinal value. This has developed into the great field of systematic botany. Such studies are embodied in the innumerable, more or less comprehensive, studies of the regional floras of the earth's surface. Floristic studies represent the pioneer work of botanical science. While their immediate object is the securing of information concerning the geographical distribution and the genetic relationships of plants, they are often of great value to the botanist in other lines of research, to the pharmacologist and pharmacist in their investigations of the medicinal uses of plants, and to those who are interested in the commercial and economic utilization of plant materials. Such work should be continued, for, notwithstanding that botanical exploration and the systematic study of plants have been going on for centuries, comparatively few regions of

Systematic Botany

the earth's surface have yet been combed exhaustively for botanical material. To yield its full value exploration should furnish information on the kind of habitat in which the different plants occur.

Just as the collection of plants may be said to be the traditional object of botanical gardens, so systematic botany is the traditional, time-honored form of their scientific research. From the first, systematic botany has been the chief feature of investigation that has been carried on by the New York Garden, and in this field the institution has acquired a leading position in this country. One of the most ambitious and most notable of its enterprises of this kind is that of making and publishing a very complete descriptive treatment of all species of plants occurring within the boundaries of North America, including Central America and the West Indies. This has required much exploration and much study of other collections than those of the New York Garden. The published work, entitled "North American Flora," was inaugurated in 1905. Fifty-three parts have now appeared under the authorship of members of the Garden staff and others. Its completion will be a work of many future years. A highly important investigation recently begun is the study of the flora and plant products of northern South America, in cooperation with the United States National Museum and with the Gray Herbarium of Harvard University. A member of the staff of the New York Garden, with the staff-members of the cooperating institutions, is making progress in the reduction of the vast collections from the Guianas, Venezuela, Colombia and Ecuador, and has effected important alliances with the Royal Botanic Gardens at Kew and the Jardin des Plantes at Paris. Research in systematic botany may be either one of two kinds: either a study of all the plants of a

given geographical area, irrespective of their botanical relationships to one another (floristics); or a study of a given group of related plants, irrespective of their geographical distribution (taxonomy). While the Garden's contributions have been mainly of the first kind, a notable example of the second type is that of "The Cactaceae; Descriptions and Illustrations of Plants of the Cactus Family," a work of four volumes, the joint research of the New York Garden, the Smithsonian Institution, and the Carnegie Institution of Washington.

At present the scientific staff of the Garden includes thirteen members, and of these ten are systematic botanists engaged in the kind of research above described during such portions of their time as their other duties permit. Among these the different groups of plants are partly represented, some are receiving adequate attention, and the work in these goes on at a satisfactory pace. It should be added, however, that with the relatively considerable staff of experienced specialists at the top there is a serious lack of assistants below.

Paleobotany

Modern plants are the descendants of those which lived and, in largest part, developed, culminated, and disappeared in the geological past. To understand fully the botanical life of today and its local distribution, we must often study and reproduce both the life of the past and the geological history of the particular region. In the early development of the Garden, the importance of these researches was appreciated; and to forward and strengthen them, the Trustees of Columbia University deposited in the Museum of the Garden its very extensive collections of fossil plants, which were among the best in America. To them, from time to time, the expeditions of the Garden have added accessions. The interest and importance of this branch have always been realized

by the Scientific Directors, and for years they have wished that the Garden might be able to carry on collecting in localities of special interest and to support subsequent study and publication. Today most promising grounds for investigation are known in the West Indies and in Alaska.

Economic Collections

Although the purposes of the Economic Museum are largely educational, much research work is required in the classification and arrangement of its materials. The botanical sources of many economic plant products are as yet unknown or poorly known. In many cases such knowledge is confused, owing to mixed origin or to commercial substitution or adulteration. The methods necessary to be employed in the identification and differentiation of these fragmentary materials are quite different from those involved in the study of the complete specimens of the Garden or herbarium. Not only minute microscopical examinations, but chemical tests, must often be employed, and long and patient investigations are often necessary in the determination of differential characteristics. Besides these questions of identity, there are others, often of greater moment, which relate to the determination of relative values, and which call for quantitative methods of estimate. In the case of drugs these requirements have resulted in the development of the distinct branch of science known as pharmacognosy, offering broad fields of research. The requirements are no less urgent in the department of foods, fibres and other products represented in our Museum.

Experimental Botany

While the Garden's growth up to the present has provided more or less adequately for research in systematic botany, paleobotany and economic botany, research in other fields has had to remain relatively undeveloped. Yet

it is in these other fields where lie many pregnant problems of the science of plants. These are the problems which lie at the basis of a broad science of biology; these are the problems in which there is widespread interest; these are the problems on the solution of which the future welfare of the world is in large part dependent. It is in the solving of these problems that the Garden can perform a most important and timely service to mankind. The study of these problems requires the use of the experimental method, the method which, more than any other, has been instrumental in the phenomenal advance of science that has characterized recent years.

All of these problems have to do with the plant as a living organism and, while covering a vast and varied field, they lie, in general, within the scope of four divisions of botany, namely: physiology, which deals with the internal life processes of the normal, healthy plant; ecology, which deals with the relation of the plant to the environmental forces acting upon it and with the distribution of plants and plant communities; pathology, which deals with the disease processes of plants; and genetics, which deals with the processes of inheritance in plants and the production, by hybridization, mutation and selection, of new and often better types. Many of these problems are of immediate and obvious practical importance; many relate to the more fundamental features of plant life, the application of which for the benefit of mankind is not always immediately manifest. A broadly conceived scientific institution of the present day ought to be so organized and equipped as to be able to turn its attention to all aspects of a problem before it. In this particular the Garden, if properly endowed, would afford an unusually favorable environment for research. For example, the wide range of

varieties of plants here available would constitute an especially valuable material for experimental investigation of the widest scope.

Relations of State and Endowed Institutions

It is coming to be generally agreed that, while government agencies, such as the Department of Agriculture at Washington and the State Agricultural Colleges and Experiment Stations, have fully proven their value and justified invoking the taxing power of the state for their support, they can by no means meet the needs of the situation as it now exists. Governmental institutions must, from the nature of their sources of support, aim to meet immediate exigencies in agriculture from year to year, and especially must devote themselves to the work of directly aiding the farmer and nurseryman in the application of known methods of culture, crop-feeding and the prevention of disease. Their service in the control of plant diseases is rather that of practising physicians than of research pathologists. But we have now reached a period in plant science, where further advance demands the experimental investigation of fundamental problems, extending over long periods of time and requiring in many cases costly apparatus. It is difficult to pursue such work in laboratories that are under more or less changeable political control; the endowed institution with its more stable organization and greater freedom is practically indispensable.

There are enumerated below a few of the innumerable problems that are attracting the attention of experimental botanists and the study of which might profitably be undertaken by the New York Garden.

Dendrology

Trees are of supreme importance to our general welfare. It is coming to be recognized that the practice of forestry and reforestation is a state, as well as an individual, undertaking and accordingly the state is undertaking, more and more, to regulate the utilization of our forests and to promote reforestation. Yet those who attempt to interest legislators in this service are continually hampered by the ignorance to which plant scientists must confess as to many of the commonplace phases of tree growth and reproduction. A rational system of forestry can only be developed by replacing this ignorance by exact knowledge. Dendrological problems are difficult and require prolonged experimentation, and it is increasingly evident that the state must depend to a large extent upon private initiative to solve them.

Root Growth

The Garden could render a very important service by undertaking a series of intensive experiments on the root requirements of a large series of our most important trees. These would involve the use of large permanent root cages which would make possible the direct observation of the growth of roots under experimentally controlled conditions. Such a method would yield data concerning the water and food requirements of trees and the rate of growth to be expected with varying conditions of moisture and temperature, and the composition of the soil and atmosphere.

Many, if not most, of our common forest trees bear upon their roots certain peculiar fungi, the expanded growth of which is called "mycorhiza." These seem to have highly specific and indispensable relations to the growth and nutrition of their tree hosts. The subject is very much in need of study; we know just enough about it to indicate its great importance in all plans for reforestation and the maintenance of soil conditions favorable to forest growth. Such large collections of the higher fungi as are already in the Garden herbarium are an essential part of the equipment necessary for the study of these root-inhabiting forms.

Root Fungi

Tree production in nature is ordinarily a matter of decades and even centuries, hence greater rapidity of growth, combined with other good qualities, deserves attention. The already well established fact that hybridization is a means of vastly accelerating growth is of fundamental importance here. This is the subject of the researches on the growing of pulp wood, in which a member of the Garden staff is now acting as consulting expert. The fact that many trees may be propagated by non-sexual means, makes possible the immediate utilization of rapidly growing hybrids as soon as they are secured, without waiting for the establishment of varieties which will come true to seed. Experiments in hybridizing and selection for rapid growth should be extended to all types of forest trees. The old problem of hybridizing the conifers should be attacked from the standpoint of modern methods. The peculiar forms obtained by graft hybridizing should be further studied for the light they may throw on our conceptions of plant organization and relationships. Further work is much needed on the standardization of stocks for the propagation of fruit trees.

Breeding and Selection

One of the most important lines of experiment, both for the Garden and all park and street planting, lies in the possibility of tree feeding, as a substitute for soil deficiencies, and of various soil treatments as a corrective for abnormal soil conditions. We know that under certain circumstances beneficial results can be obtained by tree feeding, but the time, method, and amount of various possible soil applications are in need of careful and protracted experimental study of a wide range of species of shade and ornamental trees.

Tree Feeding

Another tree problem of vital significance is that of atmospheric pollution and its effect on tree life. It is known that minute amounts of many gases which are natural by-products of the industrial and other activities of great cities may have profound physiological and sometimes deleterious effects on plants. We share with our own and all other city park authorities the duty of investigating fully the matter of atmospheric pollution in its relation to trees and other plant growth and must reach practical solutions if we are to be able to safeguard the natural beauties of parks under the conditions found in modern commercially developed cities. We have advanced far enough to know that the pollution of the atmosphere by industrial establishments can frequently be controlled with financial advantage to their owners, and it remains for us to show specifically just what gases and what degrees of their concentration are injurious to tree growth, and the measures that can be applied most effectively for the prevention of their occurrence in the air in dangerous quantities.

Atmospheric Pollution

The solving of the problems of the food, soil, water, and atmospheric and climatic requirements of trees, and of determining their rate of growth and longevity

under city conditions, rests as an especial duty upon a botanic garden located in a great metropolitan center like New York. Not only must we solve these problems if we are to maintain our Garden plantations, but, in view of our relations to the city as a municipal institution, the park department and all those interested in beautifying the city by street planting have a right to look to us for authoritative advice on such matters. The study we are beginning on the growth requirements of the hemlock is directed to the solution of one of our own most immediate problems, and should be extended to cover the basic physiological and ecological experiments outlined above.

Tree Problems and Botanical Garden

It might here be added that much that is said above concerning the problems of trees applies equally well to many other plants.

Some Problems of Soils

The soil in which plants grow offers many fruitful problems for investigation, other than those mentioned above in connection with trees. These relate especially to the two material constituents of the soil: its chemical substances and its living micro-organisms.

It is well established that the mere demonstration by chemical analysis that any particular chemical element is present in the soil does not imply that it is available to the plant. One of the most important problems in maintaining soil fertility concerns the potash supply. Potassium may be present in abundance in soils and yet not be available to crop plants. There is some evidence that so-called green manures are an effective means of increasing the availability of potash,

Chemical Constituents of Soils

but the chemistry of the processes involved is quite unknown. In view of the limited supplies of potassium salts which are commercially available at prices within the limits of their profitable use in agriculture, studies along this line are especially timely. This is particularly true in our own country, since at present we are dependent almost wholly on imported potassium salts for agricultural use.

Micro-organisms of Soils

The discovery that the availability of chemical constituents of the soil may be dependent on the activities of soil micro-organisms, has emphasized the necessity for making extensive studies of the floras and faunas of the soil, including bacteria, fungi, algae and protozoa. The discovery of the nitrifying and the nitrogen-fixing bacteria and their relations with soil protozoa which may prey upon them, have quite changed our points of view as to the maintenance of soil fertility. We are already carrying on at the Garden well-organized studies on the identification and classification of the ordinary decay-producing and parasitic fungi and of marine and fresh-water algae. These could very profitably be extended to include the similar organisms of the soil, a work that has not yet been adequately provided for in this country.

Plants as Sources of Food

Perhaps the most fundamental process in all physiology, both plant and animal, is the production of carbohydrates, that is, starches and sugars, by green plants in sunlight. This is the ultimate source of all food supplies, both for men and animals, and may well become the limiting factor in determining the population which the earth can ultimately support. Many phases of both the chemical and biological processes involved

have been studied from very early times and by many investigators; but the very important matter of the rate at which these carbohydrate materials may be produced in crop plants under standardized conditions of atmosphere and soil has never been determined. And yet knowledge of such data for each of our major crop plants would seem to be a fundamental prerequisite for any really rational system of agriculture. The value of any crop plant as a food producer is practically a question of its capacity to use sunlight in assimilation under any given set of conditions.

The Adjustment of the Plant to Its Environment

The importance of a knowledge of the requirements of different trees and other plants as to different qualities of soil and atmosphere, as emphasized above, can be stated in more general terms, namely: the successful culture of plants of whatever kind and for whatever purpose depends upon having at one's command very complete information on the influence of all the various factors of the environment upon the individual plant species and plant community. Most of the knowledge which we possess along these lines has been gained by the accumulation of the results of empirical methods of trial and failure. But science is now beginning to develop more exact quantitative methods under the general head of "ecology." Problems of distribution—the reasons why a certain plant grows in one place and not in another—are also ecological. The Garden possesses a great deal of material for fruitful studies on the requirements and the distribution of different species and on the fundamental laws of the ecology of all plants. To utilize this material effectively there are lacking only the needed personnel and the needed laboratory facilities.

The Problems of Disease in Plants

The diseases of plants offer many analogies to the diseases of human beings. Some, the so-called physiological diseases, are of internal origin; others are caused by other living organisms, such as bacteria, fungi, and insects, entering into the plant from outside. While it is becoming customary to control the infectious diseases of human beings by the use of serums and vaccines, this method has so far proved impracticable with plants; and the common procedure with them is to apply poisons by spraying, dusting, or treating the seed. This entails a permanent cost on the grower, which in the case of food plants is added to the cost of the human food supply. If, however, races could be produced which were immune to disease, the cost of food production would be by so much reduced. It is now, indeed, generally agreed by plant pathologists that it is in the study of racial and inherited immunity and in breeding for disease resistance, rather than in prophylactic measures with existing races, that the solution of the great problem of reducing the enormous losses to agriculture and horticulture due to diseases of both physiological and infectious origin is to be sought.

The vast importance of such considerations as these has led the state and national governments to expend large sums in research along the lines of disease control. But the immediately pressing problems have as yet hardly been touched, either for our major agricultural crop plants or for ornamental and decorative horticultural types. Such conditions as the leaf scald of the maples, and gummosis in many of the fruit trees and flowering shrubs of the apple family, are examples of widespread diseases whose causes are as yet unknown. The breeding of types resistant to the rusts, smuts and

mildews, of our great agricultural crop plants, is only beginning. Such problems as these can only be attacked successfully by the cooperative efforts of both breeders and pathologists.

As illustrating the great importance to farmers and consumers alike of the diseases of our great cereal crops, we may note that the U. S. Department of Agriculture estimates that wheat rust alone in the United States caused a loss of over $20,000,000 in a single year. The losses from dry-rot of corn, which have attracted little attention until recently, are estimated at over $5,000,000 for a single year in the state of Illinois.

Besides the production of immunity, there are other phenomena of disease in plants that will well repay investigation. There are, indeed, reasons for believing that many of the fundamental phenomena of disease processes applicable to all living beings may be studied in plants as readily as, if not more readily than, in human beings. With New York gradually becoming the leading medical center of this country and with the opportunity for medical contributions from the side of botany, it would seem most appropriate for the Botanical Garden to offer the facilities of its unusually large collections for fundamental researches into the problems of disease.

The extent of our collections offers another reason why the Garden ought to have a pathological staff and equipment and become a center of research on pathological problems—it needs to protect itself. In this particular the Garden is confronted with a necessity which is no less an opportunity. Already various of our collections have suffered seriously from disease. To give specific illustrations: Our Rose Garden suffers from black spot; in our dahlia collection each year a number of varieties show disease, due perhaps to the

attacks of leaf-hoppers carrying mosaic; our hemlock grove has been recently threatened with bark borers. These and other ravages have happened within our own borders, with no persons on our staff having either the time or the special training to deal with them, and there is every reason to believe that similar things will continue to happen. The Board of Managers of the Garden is now planning to make great advances in the esthetic improvement of its grounds and collections, but this would be a short-sighted policy if we have no provision for coping with the problems of disease which may arise.

The solutions of the problems with which we ourselves are confronted and will continue to be confronted would constitute a contribution of the highest value to those who are concerned with the care of decoratively planted estates—among whom many of our own members are included—and to those who are concerned with the maintenance of public parks and planting for city decoration. They would thus be a direct return for both our municipal and privately contributed support. But these problems are in no sense sharply separated from those of general plant pathology, and research on our material would, beyond question, yield very valuable data bearing on the whole subject of the diseases of cultivated plants.

Horticultural Collections as Material for Fundamental Scientific Research

The Garden has opened up in recent years a new and important field of activity in connection with the display of floricultural types and especially of floral novelties as they appear. Here, besides the general esthetic value of the plantations, a useful service is performed

both to that part of the public which desires to keep informed on, or to purchase, the newest developments in these plants, and to the professional growers, who are given an opportunity to exhibit their products. With the increasing interest of the people in decorative gardening and the expansion of the business of bulb growers, seedsmen and nurserymen, there is great need of standard floricultural plantations. The immediately practical objects of such plantations, which should be grown under standardized conditions, are the comparison of old and new types, the identification of new types, the detection of carelessness or fraud in presenting, as new, types already known, and the determination of the hardiness, artistic value, immunity to disease, and the requirements as to soil, light, moisture and food, of the plants under observation. The increase in the number of garden clubs and of societies devoted to special groups of floricultural plants, such as roses, peonies, dahlias and iris, indicates the practical importance of such work, and many of these societies would probably be found willing to aid in it. Work of this kind, indeed, is already started by the Garden in connection with the Iris Society of America, and it was included in the original plan of our Rose Garden that it should be one of a world-wide series of gardens which were to maintain test plantations for determining the qualities of all new offerings in the rose trade. Such work would require specially trained gardeners for each group of plants, who are experts and specialists both as to gardening practice and the work of breeding. But, in addition, there would be needed also the supervision and advice of scientific physiologists, ecologists, geneticists and pathologists. While achieving these practical results the Garden would be amply repaid on the scientific side, for its staff would find in collections sufficiently large to give reliable practical results

material of unique value for the intensive study of the problems of heredity, variation, the origin of new types, and of many other fundamental questions of plant growth and nutrition.

The Garden and Columbia University

It is provided in the Act of Incorporation of the Garden that its Scientific Directors shall include the president, and the professors of botany, geology and chemistry of Columbia University, *ex officio*. In accordance with an agreement made in 1896, the Garden and Columbia cooperate in matters of graduate instruction and research in plant science. Under the terms of the agreement the herbarium and much of the botanical library of Columbia are deposited at the Garden, and it is provided that the research equipment and materials of the Garden shall be made, as far as practicable, available for the research work of the graduate students and staff of the Department of Botany of Columbia. This arrangement has worked as satisfactorily as has been possible with the limited funds available, and under the conditions proposed for the extension of experimental work at the Garden it is assumed that the Department of Botany of Columbia will participate in the work of pushing forward research in the special lines of interest of its members and thus broaden still further the scope of the work as outlined above.

This cooperative relation between the Garden and Columbia University affords also a very effective basis on which to bring to the support of the new research work at the Garden the assistance of specialists whose aid may be needed in particular fields of chemistry and physics, and other sciences. While the first essential in research is still undoubtedly the initiative of the

individual investigator, there is no question that many basic problems in experimental botany demand the combined efforts of a group of experts representing different aspects of any specific problem. It is thus obvious that the close association of the experimental research workers, such as it is proposed to bring together at the Garden, with the specialists in the basic sciences represented in the faculties of a great university, will be a factor of very considerable importance in determining the success of the work undertaken.

The Research Staff and General Questions of Personnel

For the successful prosecution of research on some of the additional problems outlined, there should be added to the existing staff of the Garden a physiologist, a pathologist, and a chemist; and for each such major position a subordinate associate, who also is a trained specialist in the field to be covered, and assistants who, in part, are still in training.

A word might here be added regarding the need of a chemical staff. The study of the chemistry of life processes has proven itself one of the most fruitful methods of attack on a great series of biological problems. Physiological research, especially in the lines of plant growth and nutrition, involves, and is in large degree based upon, research in chemistry. Many problems in pathology too, especially those concerned with the fundamental nature of immunity, require the use of chemical methods. The chemistry of soils is also a fertile field of investigation. The chemical equipment provided should by no means be limited to provision for routine matters of chemical analysis, but should be adequate for research in all phases of physical and col-

loidal chemistry, in so far as they are related to biological material and processes.

The method by which men of unusual ability may be recruited for research positions like those already existing, as well as those under consideration, involves some of the most difficult problems with which universities and research institutions are confronted. It is of course obvious that the question of personnel is one of the most vital to the successful development of the Garden's work along the existing and proposed lines. An important aid in maintaining the efficiency of the scientific staff at its highest possible level would be some provision for supplying continuously a considerable group of young research workers who have the status of assistants in training, rather than that of permanent members of the research staff. From such a group, as men of unusual research ability appear in it, the more permanent staff might be recruited.

Housing and Equipment for the Additional Research of the Garden

Additional space for the existing scientific work of the Garden has long been needed. The rooms that now house the library, the herbarium, and the museum collections are overcrowded, and additional workrooms for the present staff are essential in the interests of efficiency. The construction of the proposed west wing of the Museum Building would adequately meet these needs and allow for further growth for some time.

For the proposed experimental research a further laboratory building would be needed. It should be of relatively simple construction, with readily adjustable distribution of space, abundant light, and ample provision for the modern essentials of biological and chemi-

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cal experimentation. It should be equipped with the customary apparatus that is required in general for the kind of research proposed, and additional special equipment should be provided from time to time as the needs of special researches require. In addition to laboratories for the proposed physiological, ecological, pathological and chemical work, the building should also include provision for the work in genetics, which is at present very inadequately provided for in the Museum building and the propagating houses. The building should be located so as to be readily accessible to experimental plots adequate in area, and it should be capable of enlargement as new fields for investigation become apparent in the future. A very considerable increase in the present experimental greenhouse space would also be needed.

The cost of such additions to the research staff of the Garden, with the necessary laboratory building and equipment, would be at least $1,000,000. The expansion of investigations already in progress would require additional funds.