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ECONOMIC TOXICOLOGY

CALIFORNIA annually spends more than a million dollars in the control of insects and fungi infesting citrus trees, and possibly a million more for a like purpose on deciduous trees. To these startling figures may be added no small amount expended in the control of the pests of garden and field crops, stored grain and seeds, and a large sum in the preservation of timber against the attack of wood-destroying fungi. The vineyards need protection from the ravages of mildew. Nor does this conclude the list. There must be added a considerable sum for the control of the parasites of man and beast. Tons of poisoned barley and quantities of expensive chemicals are used to rid the fields of vertebrate pests. The customary way of holding in check this formidable array of pests is by the use of chemicals of various sorts. Of recent years, chemicals have also come to be used to some extent for the control of weeds, and no little interest is being taken at the present time in possible developments in this connection under California conditions. It is said that California is the largest consumer of insecticides and fungicides of any state in the union. The state at least makes use of the greatest variety of these and other economic poisons on account of the great diversity of its agriculture.

These facts, from an economic standpoint alone, justify not only an intensive study of the proper use of the materials, but also a comprehensive study of the materials themselves. This station early recognized the need of the special knowledge of the chemist in the solution of the vexing problems that often confront the investigator who has to deal with the control of pests. Through the publication of Morse in 1887, the utility of hydrocyanic acid as a fumigant for the control of scale insects on citrus trees was first made public.

Under the direction of Professor Woodworth, the activity of the Division of Entomolgy in the investigation of insecticides dates back many years. The early publications of the insecticide laboratory by Woodworth and Colby were among the first to call attention to the need of legislation to protect the consumer against the unscrupulous or careless manufacturer of insecticides. The development by Volck and Luther of a new type of lead arsenate which could be used with safety in the humid coast regions is to the credit of the Division. The later studies by the head of the Division on the complex problems arising in the practical application of fumigation methods are probably the most exhaustive of any similar effort made elsewhere.

The scope of the activities of the insecticide laboratory was enlarged in 1911 to include a study of fungicides. The state insecticide and fungicide law came into operation that year and the chemical work incidental to its administration was assigned to the laboratory. The administration of the law was placed in the hands of the director of this station, although the immediate supervision of the work was assigned to the head of the division of Entomology. The writer became identified with the work at this time.

The most pressing need for chemical study appeared to be the origination and perfection of methods of examination of insecticides and fungicides which were on the market in endless variety and were of such complex composition as to defy ordinary analytical procedure. An intelligent study of analytical methods presupposed some slight knowledge at least of the nature and source of the raw materials and of manufacturing methods in order to know what impurities to look for and to fairly judge their permissible limits in commercial samples.

The reorganized laboratory began work along the lines indicated above, but it soon became evident that it could be of more use to the state than to merely inform the public of the composition of the materials which came to its notice. The greater need seemed to be a more complete knowledge of the toxicology of the materials; a better knowledge of which constituents of the various preparations are active and which inert; the constituents injurious to foliage, and to what extent; the most suitable remedies to choose in order to meet the varied and exacting requirements for the control of pests; and which materials could be mixed with safety and applied in combination.

As opportunity was afforded, the solution of some of these problems was also attacked. It soon became evident that the accumulation of laboratory data alone was wholly inadequate for the solution of many of the problems encountered. A definite effort was made to interpret the results of the laboratory by means of field observations whenever possible.

As a result of these studies, the laboratory has made contributions to agricultural literature from time to time. In this manner and through correspondence and by occasional talks by members of the staff before agricultural audiences, it is felt that the work of the laboratory has been of greater usefulness to both manufacturer and consumer than if the work had been confined more largely to the carrying out of the routine police work of the law.

Another activity of the laboratory has been that of instruction. When the writer first began to collect material suitable for the presentation of a course entitled "Insecticides and Fungicides," it was soon discovered that the great mass of literature on the subject was on the *practical use* of these materials rather than on their composition and properties. Such courses offered at other universities were being given by horticulturists, entomologists, plant pathologists or botanists and the subject was, therefore, discussed from their standpoints. Furthermore, it was found that the students of this college of agriculture were already being well supplied with adequate instruction along these lines by the several divisions. It was clear that it would be inadvisable to offer a course of lectures patterned after the usual lines—largely a reflection of the information already supplied by other courses. There did seem to be a need, however, of a course pre-

sented from the standpoint of the chemist—a discussion of the *composition, properties,* and *toxicology* of the remedies used for the control of agricultural pests. An effort was made to accumulate all available information from this viewpoint; the materials were classified according to active ingredient or derivation rather than according to use as had been heretofore done; and the subject presented accordingly as a three-unit course of lectures.

A one-unit laboratory course was also offered by Mr. Miller, taking up in a practical way the most approved methods of preparation of pest remedies and demonstrating the significance of the simpler tests. The students were divided into groups and each required to prepare the commoner preparations which may be made on the farm, and were given an insight into the underlying principles of commercial manufacturing methods. The use of elaborate apparatus was consistently avoided, only such utensils and measuring devices being used as would be found on the average California ranch. It was thought that if the students were taught the fundamentals of the various processes without any unusual equipment, they would be better able to make use of whatever equipment, simple or elaborate, would be provided them in later years of actual work.

That this sort of instruction filled a want is evidenced by the fact that the enrollment increased from seven the first year to forty the fourth year that the courses were offered.

In the fall of 1915, the laboratory was instructed to undertake an investigation of chemical means for the control of noxious weeds. Sets of experiments have been conducted in five localities, some of which have been under observation for more than two years. These investigations have furnished some very interesting data, both from the practical as well as from the scientific standpoint, the results of which are to be soon published as a progress report.

At first thought, it may seem strange that a study of herbicides was assigned to a chemical laboratory heretofore devoted to the study of insecticides and fungicides. A careful analysis, however, of the toxicological problems encountered in either case discloses a very close correlation of certain phases of the work.

The accumulation, classification, and otherwise making available of an accurate and complete knowledge of the source, manufacture, composition, and properties of the poisons used for the control of insects, fungi, weeds and other pests is work for which the chemist has been trained. When any of these poisons are to be used upon vegetation for the control of insects or fungi, it is fully as important to know their action on plant tissues as their action on the pest, in order to avoid the use of any remedy which may seriously injure the plant. Certain of these poisons can be used at certain times of the year only, or upon certain plants only; others are suitable for use under restricted climatic conditions. Some of these facts are directly applicable to the problem of weed control by means of chemicals. The materials to avoid in the first case may be just the ones to use in the latter case. These observations may be well illustrated by referring to some of the results of this laboratory's herbicide investigations. It is a well-known fact that soluble arsenic (except in very small amounts) is not permissible in any spray which is to be applied to cultivated plants on account of the danger of foliage injury; a completely soluble compound of arsenic was found to be the most effective of any chemical tried for the destruction of weeds. Unpublished experiments by Mr. E. R. de Ong and the writer, testing the action of petroleum oils on foliage, indicated that the constituents of petroleum distillates which are capable of removal by refining with sulfuric acid are very much more toxic to foliage than other constituents; a by-product of oil refineries, containing these highly toxic constituents, was found to be a very effective herbicide.

Quite recently this laboratory has been called upon to analyze a number of squirrel, gopher and rat poisons and to pass on their respective merits, and to answer letters on this subject which were referred from other departments.

It is thus seen that the scope of activities

of the laboratory has steadily (perhaps unconsciously at times) enlarged from a most creditable beginning in the study of insecticides, so that its work included the study of fungicides, then herbicides, and lastly, poisons for the destruction of vertebrate pests. Shall we call the latter "rodenticides" or "zooicides" in order to complete the nomenclature of the list?

The question may be asked: Should not insecticides be studied by the economic entomologist, fungicides by the plant pathologist, herbicides by the economic botanist, and rodent poisons by the economic zoologist? Most certainly they should be. In fact, they have been, and, as a result, the most important contributions to the literature have come from these sources. The questions involved are so complex as to require the application of the special knowledge of all of these scientists. The specially trained chemist may also contribute his share toward the solution of their common problems, a more intimate knowledge of the poisons which may be to a certain degree lacking in the others.

In an organization as large as our experiment station, it is sometimes difficult to avoid duplication of work by the various divisions. One way of avoiding duplication is for each man or group of men to have a very clear and well-defined conception of their respective functions in the machinery of the organization, whether it be a cog, a crank, a governor, or a safety valve, and then to confine their activity to the efficient performance of these functions. A study has been made of what should be the functions of this laboratory and it appears that it will serve the state well if it acquires and disseminates as complete a knowledge as possible of the poisons which are used for the control of insects, fungi, weeds and rodents; insecticides, fungicides, herbicides and "rodenticides."

It has often seemed desirable to make use of a collective term in referring to the materials which are under study by the laboratory. Various names have been suggested, the most appropriate of which appears to be "economic poisons."[1] The qualifying word "economic" serves to distinguish between the poisons which are made to serve a useful purpose in the control of pests and the more popular conception of the meaning of "poisons" as being substances harmful to man. The use of the former is strictly of an economic character and anticipates either direct financial returns, or an improvement of the general welfare of the public. The expenditure of a dollar in the control of crop-destroying pests is not usually justified unless more than a dollar is thereby added to the net returns from the harvest. On the other hand, the poisoning of mosquitoes, flies, rodents, etc., in the interest of public health, does not necessarily involve the question of direct financial return. From both standpoints, the term "economic poisons" seems appropriate as referring to the materials under discussion.

The work of the laboratory has been thus described as having developed into a study of the various poisons, beneficial use of which has been made by society. Toxicology is the science which treats of poisons, their effects, antidotes and recognition. This science, however, has been developed largely among men of the medical profession and deals with the poisons in respect to their harmfulness to man and their use with criminal intent. As undertaken by this laboratory, poisons are studied for an altogether different purpose. Clearly, then, the unqualified word "toxicology" can not be used in this connection without confusion. Inasmuch as the study of poisons in respect to their harmful use has been given the name "toxicology" the term "economic toxicology" will serve to differentiate the study of poisons in relation to the control of pests detrimental to agriculture and to the public health, and may be used to describe the activities of this laboratory.

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[1] The terms "economic poisons" and "economic toxicology" were suggested by the writer's associate, Mr. M. R. Miller. See this journal, Vol. XLIV., No. 1185, page 264.