Contributions of Botany to Military Efficiency.

R. M. Holman, Wabash College.

Certainly no science seems, at first thought, to be more remotely related to military pursuits than does the science which deals with plants. In chemistry we recognize at once one of Mars' chief servitors; for even in the days before men fought with deadly gases, the products of chemical research, leaders in military affairs were indebted to the science of chemistry for the development of more and more destructive explosives and for a great number of other essential though minor war materials. In physics, too, we recognize a science whose contributions to the business of warfare are scarcely to be enumerated. But so many and varied are the factors which play their part in the successful pursuit of modern warfare, and so extensive are the applications of the sciences today to practical problems, that every science has been called upon to make its contributions to military efficiency. Thus the science of botany has come to play a by no means inconsiderable part in the organization, equipment and operation of an army. In the time allotted to me it would not be possible to consider all the particulars in which this science has aided directly or indirectly in the pursuit of war, but I shall call to your attention two or three phases of botanical work which have been of rather direct assistance.

The very considerable shortage of cotton which existed during the greater part of the war period, and the great demand for this material for civilian and military clothing and for the manufacture of explosives, suggested late in 1914 a search for a suitable substitute for the cotton so extensively used in surgical dressings. The material which proved best fitted to this use was sphagnum moss, which grows so abundantly in peat bogs and by its accumulation has built up very largely the great deposits of peat which are utilized as sources of fuel in some parts of the world. This moss, which was in fact employed to a limited extent for surgical dressings in the Russo-Japanese War, has the two great virtues of being very abundant and of possessing a remarkable power of absorbing liquids. In this latter respect it is many times as efficient as cotton. By no means all species of the genus *Sphagnum* are suitable for use in the preparation of surgical dressings. The species which can be used for this purpose, and which are found in the United States, are: *Sphagnum imbricatum*, *S. palustre*, *S. papillosum*, and *S. magillanicum*. These species are not found in the numerous bogs in the region of the Great Lakes, but are restricted to the bogs of the North Pacific and North Atlantic coastal regions. The recognition of the numerous species of the genus *Sphagnum* is by no means easy, and on that account there has fallen to the few botanists of this country who are familiar with the genus the task of supervising the collection of suitable material for the use of the Red Cross. The British War Office, the Canadian Red Cross, and the American Red Cross have used large quantities of sphagnum moss for the making of dressings, and so satisfactory has it proven that it seems likely that, even in times of peace, it will continue to be extensively used for this purpose.[1]

In a symposium on War Problems in Botany at the meeting of the American Association for the Advancement of Science at Pittsburgh in December, 1917, an appeal was made by Dr. G. R. Lyman, pathologist in charge of the plant disease survey of the United States Department of Agriculture, for effective organization of botanists and correlation of their efforts toward the increase in food production and conservation of food so essential to the military success of ourselves and our allies. The principal practical outgrowth of this appeal was the organization at Pittsburgh of the War Board of American Pathologists by the members of the American Phytopathological Society there present. The War Board had as its object the increase of the product of land already under cultivation by means of emergency plant disease research, and by a more extensive application of the measures known to plant pathologists for the reduction of crop diseases; and the reduction of the losses by disease of fruits, vegetables and other plant products in transit or storage.

In the pursuit of these objects a number of measures were carried out by the War Board. A man-power survey was undertaken to determine what botanists, not already engaged in plant pathology, were prepared and willing to do emergency work on plant diseases. This survey was made necessary not only by the extensive program of work planned by the War Board but also by the large number of trained pathologists which had been lost for the time being to the science by reason of enlistment and conscription.

Estimates were prepared, showing more accurately than any previous estimates had shown, the losses due to diseases of the staple crops in the year 1917. These figures revealed that, in spite of the absence of any serious epidemic during that year, the loss in cereals alone, due to plant diseases largely preventable by already known methods, was over four hundred million bushels; and that the control of two diseases of wheat—

[1] For the facts in this paragraph the author is indebted to the article entitled, "Sphagnum as a Surgical Dressing," by J. W. Hotson, Science, N. S. Vol. XLVII, No. 1235.

loose smut and bunt—during that year would have resulted in saving thirty-three million bushels of that grain. This might have been added to the quantity furnished to our allies in Europe, and might well have been an important factor in the military situation. It is clear that these loss estimates were important in the execution of the plans of the War Board to reduce these losses in the interest of the armies and the civilian populations of the United States and her allies.

Early in 1918 conferences were held in the six districts into which the country had been divided for the organization of the emergency plant disease work. At these conferences the plant pathologists of each district met together with one or more of the commissioners of the War Emergency Board to discuss fully and informally the plant disease problems of the district. Leaders were elected for the work on each special problem, and co-operation for the earliest possible solution of such problems was arranged among the workers specially interested.

In addition to the man-power survey, the crop loss estimates and the emergency research organized at the district conferences, the War Emergency Board, through one of its commissioners, carried on a publicity campaign through all available channels for the wider dissemination of information as to the importance and methods of plant disease control. Provision was also made for the prompt exchange among pathologists of emergency information on methods of control. Thus it was sought, by means of mimeographed sheets mailed frequently to all workers, to make available at the earliest date important new facts which could be utilized in an intensive campaign against crop diseases. The delay which would have attended publication through the usual channels was thus avoided.

Another department of the work was concerned with the gathering and distribution of information as to supplies and prices of the important fungicides and spraying machinery. The production and marketing of these most important agencies of plant control had been greatly interfered with by war conditions in the industries and in transportation.

The early and unexpected termination of the war prevented the activities of the War Emergency Board from bearing the fruit in increased food supply for the allied nations which might have been expected in the second and subsequent years of its existence. Ten months from the conception of the plan the war was over, and the possibility of its making further contribution to military efficiency through adding to the food supply had ceased. This fact, and the impossibility of estimating the results secured after so short a period of operation, should not prevent us from recognizing the value of this unprecedented movement for co-operation in increasing knowledge in what is probably the most important field of applied botany, and for the effective application of this knowledge to the problems of the farmer, the fruit grower, the gardener, and the shipper.

Forestry is another branch of applied botany which has contributed to the successful prosecution of the war. Its contributions have been more direct in their bearing upon purely military affairs than have those of plant pathology.

Two regiments of engineers (forest) were organized during the year following our entry into the war. Trained foresters largely officered the first of these regiments, and the second drew about 25 per cent of its officers from the ranks of professional foresters. The companies making up these regiments were employed in the forests of France in the felling of trees, in the sawing of timbers and boards for military construction, in hewing ties for army railroads, and poles and props for use in the trenches and elsewhere. The forester officers found abundant opportunity to utilize their experience in supervising this work, for the French forests have in the past been managed with the highest skill and efficiency. It was necessary that the work of the forest engineer regiments be carried on with the least possible waste, and with due regard to the future of the forests worked.

The entry of the United States into the world war and the initiation of our ambitious aircraft construction program offered a great opportunity for service to that branch of forestry which is concerned with the study of forest products. On account of its virtues of lightness, strength and elasticity, wood is very largely employed in airplane construction. Different parts of the airplane in the construction of which wood is used call for lightness, strength and elasticity in varying degree. In the building up of the framework much more consideration may be given to the matter of lightness than in the case of a part such as the front of the fuselage, which, by reason of the weight of the motor, is subject to great shock in landing. Lightness must also be sacrificed to strength and resilience in choosing suitable wood for the tail skids and for the landing skids on the lower planes. Special demands are also made upon the material employed for the engine bed.[2]

The careful tests upon which was based the choice of the best woods for the purposes mentioned and for others in connection with airplane construction were made largely by or under the supervision of foresters trained in the study of forest products. A large part of this work and of other work on forest products connected with the airplane program was carried out at the Forest Products Laboratory, Madison, Wisconsin,

[2] The facts in this paragraph and many others used here were secured from an article entitled, "Our Air Fleet in the Making," by Samuel J. Record, Yale Forestry School News, July 1, 1918.

which is administered by the Forest Service of the Department of Agriculture in co-operation with the University of Wisconsin. How extensive was this work may be judged by the fact that on September 1, 1918, all or part of ten buildings were being utilized by the Forest Products Laboratory and approximately 400 persons were engaged in its work. At that time 75 per cent of the work of the laboratory was concerned directly with the airplane problems.[3]

The great demand for airplane woods rendered it impossible to depend upon the slow method of air drying and necessitated tests of different types of kilns, various kilning procedures, their suitability for different species, and the effect of kilning on strength. Satisfactory kiln drying methods were determined, and these were introduced into commercial kiln drying establishments engaged in the curing of airplane stock. Research was also undertaken upon the factors which determine the suitability of certain species for steaming and bending into the various bent wood parts employed in airplane construction, as well as upon the best conditions for bending and the effects of bending on the strength of the wood.

A particularly interesting feature of the work was that relating to the utilization of thin plywood for fuselage walls, the pontoons of flying boats, and eventually for the covering of the wings themselves. Since these were entirely new uses for laminated wood, tests were necessary for the best species and for the best combinations. It was also necessary to test the efficiency of various joints and splices, and the effect of vibration on plywood strength, and to determine the best methods for stamping and molding the new construction material. By September, 1918, tests on the strength of plywoods had been carried out with 56 series of panels, each series consisting of 40 panels and requiring 240 tests. Twenty-five species of wood were represented in these 56 series. Plywood was also found to be an excellent material for different parts of the airplane framework. For such uses a core of yellow poplar with thin layers of birch, mahogany or black walnut was shown to be satisfactory.

Laminated construction is also used in the airplane propeller, although here the laminations are of much greater thickness than in plywood. Six to ten layers of something less than one inch thickness each are used in building up the propellers. At the Forest Products Laboratory extended studies were made to determine what wood species are most suitable for this very exacting use, what types of construction are best, and what conditions of manufacture and what finish are most effec-

[3] For these and other statements relative to the aircraft work of the Forest Products Laboratory the writer is indebted to the "Aircraft Research Program" and other reports of the laboratory furnished through the kindness of the Acting Director.

tive in preventing loss of balance or change of shape under the strains of service and in varying humidities.

The species which proved to best combine the properties desirable in a propeller wood—i. e., relative freedom from checking, warping and splitting; good glueing qualities; moderate hardness; and ability to be pierced by a bullet without being split or shattered—are the Central American and African mahoganies and the black walnut. These are used on combat planes, where motors of great power are employed and the demands upon the propeller are particularly heavy. For training planes, however, white oak (quartered), cherry, birch, and the various species known in the trade as Philippine mahogany were found suitable.

There fell also to the Forest Products Laboratory the task of training many of the inspectors essential in the carrying out of the airplane program. It was necessary for these men to inspect material and parts after various steps in manufacture, such as kilning, glueing and finishing. Some of them must also identify wood species and discern defects in the wood, often very difficult to detect, but, if overlooked, sufficient to cause the destruction of a costly machine or even the loss of an aviator's life. Decay, knots and brittleness or brashiness are relatively easy to detect; but pitch pockets well below the surface are very difficult to make out, as are also the so-called heart breaks. The origin of the latter defect is still somewhat obscure, but it is probably due to injuries to the tree by high winds while still standing, or to damage in felling. In planing, the fibers are sometimes broken in such a way as to closely simulate a heart break, and thus it becomes more difficult for the inspector to detect this source of weakness. Diagonal and spiral grain are important sources of weakness in airplane stock. Spiral grain is due to a peculiar development of the tree itself, but diagonal grain is due to mistakes in sawing, a tapering log being cut not parallel to its outer surface but to the center line. In some woods the direction of the grain is easily detected, but in others it can be made out only with difficulty. For some purposes wood with a greater divergence than one inch in thirty must be rejected.

The extensive research carried out by the Forest Products Laboratory in connection with the airplane program which has been briefly summarized above does not constitute the only war work of the laboratory. Investigations undertaken in co-operation with the Chemical Warfare Section of the War Department had important results, the confidential nature of which prevent their publication. Work was also conducted bearing on wooden ship building, gun stock manufacture, and the construction of artillery wheels and various military vehicles. Thus the laboratory was called upon to investigate the seasoning of the treenails or wooden spikes employed in large numbers in fastening parts of wooden ships. For the turning of these treenails black locust is the preferred material, but the supply of this wood became so limited in certain districts that it was necessary to substitute live oak for it. The Emergency Fleet Corporation's specifications called for thoroughly air-seasoned treenails. Stocks of air-seasoned live oak were soon exhausted, and in a number of the shipbuilding districts green or incompletely cured material was used. As a result serious defects in the ships developed through shrinkage of the treenails and loosening of joints. On that account the services of the Forest Products Laboratory was sought and the whole situation was investigated by the experts of the laboratory. It was decided that the long time necessary for air drying of live oak made it impracticable to insist upon the Emergency Fleet Corporation's specifications as to curing of treenail stock. Recommendations were made for the kiln drying of such stock at central points in each producing region and for the best kiln drying procedure.

Difficulties encountered in the bending of heavy oak for the rims of artillery wheels were made the subject of experiments by the laboratory, which resulted in the development of satisfactory methods. These were introduced into the factories engaged in this work. A schedule prepared by the laboratory for the curing of walnut blanks for rifle stocks came to be widely used by the manufacturers.

The molding of stock for the construction of army vehicles of many sorts called for investigation of the fungi concerned and of the methods by which mold development might be prevented. Mold which developed during the period between the felling and the arrival at the factory was particularly troublesome in the case of wood for the manufacture of spokes. As a result of extensive experiments, one series of which involved the testing of forty-three different antiseptics, means were found which were largely effective in removing this trouble.

Not all the cases have been here mentioned in which experts in forest products gave direct aid in the solution of problems arising in the industries engaged in the production of equipment, munitions and ships. Other branches of applied botany than those touched upon here might be cited which have contributed no less truly, although less directly, perhaps, to that great complex of factors which made for the success of our army. Sufficient has been said, however, to indicate that a by no means unimportant place among the sciences in the matter of contributions to military efficiency belongs to the science of botany.