voting his time to what was formally an official work of the government of a foreign country.

This attempt to set forth in a few words the scope and significance of twenty-five years unremitting labor on the part of one who would have made his mettle felt in any sphere of activity he might have chosen to enter may well appear to others, as it does to us, extremely inadequate. The work of Gill may fairly be called epoch-making in a sense even better than that in which the term is commonly used. If we find in it no brilliant discovery to attract the attention of the public, it offers us what is yet better; improved instruments and methods of research applied with such tireless industry, conscientious care, sound judgment, and accurate knowledge of every related subject as not only to expand our intellectual horizon, but to supply the astronomer of the coming generation a pattern which he can study with profit to himself and advantage to his science.

S. Newcomb.

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*EXPERIENCE NOTES UPON PLOT EXPERIMENTS.**

Field experiments are not easy to plan and very difficult in execution. Uncertainty attends every step from the soil to the seed —the cultivation to the harvesting of the crop.

During the past six years the writer has had two acres under experimentation, and no lesson has been more impressive than that of the lack of uniformity of the soil. An apparently even plot will vary in the composition and texture of the soil, almost from one foot to another. This may be due to many causes, not the least important being the rock strata, gravel beds, etc., that underlie the soil. The surface is usually far from level and the shaving down and filling in to bring the surface to a grade only emphasized the differences that already existed, as results upon the experiment grounds before mentioned abundantly prove.

The field itself should be laid off with exactness, and this means the aid of the surveyor or his instruments. The corner stakes should be set deeply and never removed, and those of each plot should be established once for all. Unless this is so the plots will move and the subdivisions will vary, and shortly the whole area is unsatisfactory, if not in confusion.

Ideal experiment grounds should have the same exposure. There are objections to perfectly flat land, and there are more to a rolling surface. The grounds under the charge of the writer are upon a slight incline, nearly uniform throughout the two acres; but even there a wash of the soil is always troublesome during heavy rains, and introduces an element of uncertainty when soil treatment obtains upon the plots.

There should be no tree, bush or other tall object upon or close to the trial grounds. The shade of a single tree may do more to disturb the course of an experiment with sun-loving crops than the sapping of the soil of plant food by the roots of the same tree.

This matter of the influence of shade has been tested by means of lath by the writer; it is very great, and incidentally it should play no part in the experiment grounds. It is not safe to grow corn or any like tall crop within many feet of any small crops, as lettuce or spinach. The scheme needs to be so planned that the question of shade is reduced to a minimum. This is one reason why the outside plants are not comparable with these in the interior of the plot.

A single back furrow or a dead furrow

* Presidential address before the Society for the Promotion of Agricultural Science, Columbus, Ohio, August 19th.

running through a plot will so change the capacity of the area as either to vitiate the results or render them exceedingly unsatisfactory. To avoid this and prevent the mixing of treated soil the writer has resorted to the spade.

He has experienced great difficulty in manuring the plots evenly. This is a practical difficulty, not appreciated by the average workman, and if the dung is drawn directly from the barnyard there may be a great variation according to the amount and character of the bedding used. The manure should be made by only one class of animals, as cattle or horses, or mixed with the greatest care. Instead of being spread upon the plots in winter it is better to place it in piles and when well rotted and forked add by weight or measure, preferably the latter, to the plots. With commercial fertilizers the above difficulty is eliminated.

During last winter a test was made of placing the piles of manure upon some of the plots for the purpose of determining the influence of the same upon the soil and crops. In every case the growth was much retarded and in some instances the seed did not produce more than a small fraction of the full quota of plants. The results of an experiment would have been worthless for any plot where a manure heap had been upon a portion of the ground.

It is not the purpose here to discuss the cause of the failure where the enriching was excessive, but the fact remains and any one who would follow plot experimentation must not fail to manure his land evenly with the greatest care and prohibit the piling of dung upon the plots.

Previous Crops.—One could have all the points in common save that of the previous crop and the results might be worthless. This the writer knows to his sorrow. The influence of a crop is more lasting than one might suppose. Of course the wide difference between sod ground and cultivated land goes without saying; but let both previous crops be tilled ones, as for example, beans and corn, or potatoes and onions and there is enough of the personal equation to make the land unsuited for plot experiments unless the plots are confined to some one crop. When a crop is successive no portion of that experiment should grow upon old land. The marked influence of any leguminous crop is a case in hand. The soil from an old pea, bean or clover field when added even in small quantities to land new to such crops may double the yield. Turnips after turnips may be so diseased as to neutralize results of cultural treatment when compared with the same crop upon new land.

All prospective ground for a plot experiment ought to be uniformly in the same crop or succession of crops for a term of at least five years and fallow for the last season.

That the quality of the seed has an influence upon the results goes without further saying. In the early days of the writer's experiments the supply of seed would sometimes fail and that of another lot, but of the same variety would be used to finish the area. With bush beans, for example, it is very difficult to get the same strain of a variety from different dealers. The same is true of potatoes and nearly all sorts of truck crops. It is of considerable importance, therefore to purchase so liberally that there is no chance of one plot not receiving from the same lot of seed as all the others.

As it is our practice to grow two and even three crops as of peas and beans, during a season, it is imperative that enough seed be purchased in the spring to supply the needs of all the sowings and plantings of the growing season.

In planting and sowing there is a possible element of variation. After the seed bed has been made as uniform as possible throughout the whole area, the sowing or

planting should be done by one man only and all upon the same day. One man may make the drills for the peas, turnips, beans or onions, but only one should do it for any given experiment. Another man may drop the seeds, but he should drop it all, unassisted by a second person anywhere. A third person may do the covering, but no one should help him. So important is this matter that it is the writer's plan to have the sowing or planting of a plot begun at such a time that it will be finished the same day. Some experiments have been ruined by beginning late one day and a shower at night prevents the finishing upon the next. He remembers well noting the untimely appearing of the beans upon one plot when a portion had been covered by one man and the remaining portion by another. Some will cover a little deeper than another and firm the soil excessively. There is in mind an instance where one row of onion seed was accidentally trodden upon and it soon became conspicuous for the good stand of vigorous plants. Another instance is with beans in which the writer was the guilty party. He was doing the covering, and at the call of the dinner bell, left a row and a half of the dropped seed to lie in the open row and exposed to the hot May sun. That row and a half was covered an hour later, and many others were planted in freshly-opened rows during the afternoon. When the young plants appeared two weeks or so later the row and a half made a very poor stand that was evident to every one who passed that way. The moisture of the open row was dried out and a highly heated and dried soil was placed upon the seeds instead of the cool moist soil of a freshly-opened row, and in this there seems to be the great difference in the plants. If I had not covered all the seed and knew it was all out of the same sack it would have been difficult to convince me that the cause was in the delay in covering the seed.

If it is so essential that the seed be covered by but one person through a whole plot, it goes without saying that plants should be set with even greater care. The writer has seen rows of cabbage, tomato and even strawberry plants that differed greatly from each other and the only point of variation was the person with the dibble.

Not more than one person is permitted to set the egg plants, for example, in an experiment plot at the New Jersey Experiment grounds. A second person may assist, but the ideal in all this work is when the same individual has brought the plants through all their vicissitudes of the seed bed, the potted plant and placed them in the field.

The Importance of Surplus.—There are so many contingencies that the experienced experimenter will have a large surplus in store in many ways. He should have some plots or portions of plots at hand in case land is needed at any time. There needs to be a surplus of any given seed for emergency. A crop may fail and a reseeding is advisable or the stand is so poor that a portion of the plot is made the basis of a new test, and the same old stock of seed is desired.

There should be a surplus of plants in the row so that they may be thinned to the desired distance after the chances are that there will be no further losses. Some unforeseen cut worm may take the corn or a bad smelling bug the squash vine and the need of surplus plants is evident.

Nowhere else does the old saying hold so strongly as in the plot experiment. "One for the cut worm, one for the crow; five to plant and three to grow." The writer has had too many plots prove failures from a lack of a stand of plants that might have been avoided by greater liberality of seed to let this point go by without more than a passing notice.

In the case of plants that are set out the rule is still more important. There should

be a stock of eggplant or tomato plants far in excess of the number to be set, that the selection may be made in such a way as to give a uniform stand, fulfilling the requirements of the experiment. Such plants should be raised from the seed by, or under the eye, of the experimenter that he may feel sure of the kind and character of his plants. One would scarcely trust to ordinary commercial plants for use in a plot experiment. The seed might be mixed at the outset and an over stimulus might make the plants unusually tender.

In cultivation and all those processes which find a place under the term 'care of crop' one cannot be too serious. By a little carelessness here an element may be introduced that will spoil all the previous work. It is as essential, for example, that the whole plot be treated alike in the cultivation as in the sowing or planting. It is a good rule to never cultivate one row or plant unless the watch, and the clouds as well, indicate that there will be time that day for the same treatment of all in the experiment. If a half of a plot is hoed one day and the job finished the next, there are substantial reasons for inferring that the harvest of results will be scattered and scarcely worth the gathering together. There is a chance in all this work of being faithless to the ideals of the genuine experimenter who is constantly striving to eliminate all but the one point of variation in the test. For example, the wheel cultivator may be used twice in the row for a half of the plot and only once for the remaining portion and, while saving time it is robbing the experiment of its full value. A person who could permit such a thing is entirely unfit to occupy, much less fill, a position in a center of research, which we call in this country an Experiment Station. Far better to clean up the paths in the late afternoon than to make a beginning only upon a plot with hoe or cultivator.

It seems almost unnecessary to add any remark here concerning the necessity of keeping experiment grounds clean of weeds until the time is past when they can interfere with the results. Each plant in the crop should have its full soil and air space, and if weeds are permitted to contend for these essentials, the test, whether it be of fertilizer or distance or depth or any other thing, fails. Pigweeds and purslain and the whole list of weeds must be kept out of a plot experiment, and all results should read between the lines—these are with clean culture always understood. This is the cheapest as well as the only way.

There is a watchfulness demanded by the superintendent of field experiments that savors of the wisdom of the owl. He must also love truth beyond all else. Pardon me if I mention one of the elements in plot experiments that has been a great source of annoyance. It is the end plants and the outside rows. There ought not to be any, but it is not easy to get rid of them.

Their terrors came to me very forcibly last year in the old plot of eggplants, where the end plants, that is the outside row, all around the plot, was vastly better than those within, and demanded a separate record; but it was not made. With beans, an extra row has sometimes been planted upon the outside and rejected in the final results.

This problem of the end of side row only emphasizes what has gone before, namely the importance of placing each and every plant under precisely the same conditions as all the others. This is not done in case of the end plants and the results may be considered accordingly.

Troubles not to be Avoided.—There are dangers which all crop plants run. Stray animals may break in and destroy. Pigeons may get the first sowing of peas before germination. Moles may burrow under a plot and introduce a source of error. The hole thus made will turn the flow of an ir-

rigating stream away from where it seems to go. The winds may blow down and destroy the branches and their fruit, and frosts sometimes bring an untimely end to a vigorous stand of plants. Thieves may break through and steal.

Weather we cannot control, but long-season crops should be started early. The enemies of the street need to be fenced out as securely as possible, but it is not easy to put a pad-lock upon a field experiment. Poison for the vermin, insecticides for the insects and fungicides for the diseases should be used with a judicious hand. One needs to guard his experiment area with infinitely more care than an ordinary orchard, farm or garden crop, for the fruits are an in-gathering of truth, as nearly as it can be obtained.

The Keeping of the Record.—This is the most difficult of all the operations connected with the successful issue of a field experiment. The conscientious superintendent will not trust to his memory for the details, nor write up the results from the information that is only in mind at the close of the experiment. He must keep a record of the stages of the crop from the time the ground is broken until the end of the harvest. This means during the more rapidly growing season the taking of almost daily notes as to growth of plants, etc., associated with rainfall and soil and air temperatures. The character of the notes will vary with the crop, but they, in any case, need to be full.

Many plans of note-taking have been devised, but of them all there is nothing better than a day-book for all the crops, from which the items are transferred upon rainy days and odd hours to the separate books for each particular crop. There is a journal, so to speak, for the beans, or each class of beans, as bush, dwarf lima and pole sorts, those of the peas, potatoes, tomatoes and cucumbers, etc. A set of small pigeon-holes placed upon the wall above the desk holds the crop-books close at hand. Note paper in pads has been tested, but the loose pages, while convenient for some things, are easily lost. Form-sheets with spaces for certain entries, and upon set dates with various schedules prove cumbersome, and from all the methods the writer has accepted the books as the most satisfactory.

Statement of Results.—The statement of results of plot experiments should of course be clear and comprehensive. The precise point to be held up to view will vary with the crop and the reason for the trial. In general it should be in percentage of increase, or of decrease, over the control plot where the single feature of the test did not obtain. For example, if the experiment is with a remedy for the pod spot of the beans the results admit of several methods of expression. They may be in terms of total weight of plants, of weight of marketable pods, or matured sound seed, or in percentage of diseases as compared with the control area. It seems to the writer that the chief point is the relative amount of marketable pods of the check plot. In other words, place in concise form the increase of the salable product, for this is the crucial test of the value of the fungicides. To this may be added the cost of the gain that the practicability of the spraying may be shown. As secondary matters the effect upon the whole plant and sundry other matters may be given.

But the end is not yet; to return to the increase of salable product. Shall it be shown in pounds or quarts or in number of pods. Snap beans are sold by the quart and it might seem the most natural method to state it in terms of quarts. In getting the results upon a plot it is easier to weigh the pods, and to assort out the spotted from the diseased pods it is simpler to count them. All these methods have been tested and experience suggests the counting as the

best method. It is less subject to error in the harvest, there is no difficulty with fractions, the unit is a natural one, and shows upon the face of the results that each pod has been inspected. Neither weight nor measure do full justice to the disease for the spotted pods average much smaller than the healthy ones. Finally from the numbers the percentages are made up and the gain or loss is instantly applied to whatever unit of quantity that is in vogue.

The results must be calculated to a full stand of plants for both the trial and check plots. The absurdity of anything otherwise is evident with such crops as tomatoes or eggplants, but it is equally rational with bush beans or turnips. Sow the seed thickly and thin the crop to a given distance in the row, say six inches; count the plants at harvest for each row and if there are any missing allow for them.

Let the following serve as an illustration: A plot of ground is limed at the rate of 300 bushels per acre for the club-root in turnips. The adjoining plot has everything in common excepting the lime. The plants stand six inches apart and those upon the limed land flourish to the harvest time. Those upon the check plot languish and die from week to week and at the time the record is made only one-third are to be found. The roots are pulled and weighed, the roots weighed separately, assorted into those with and those without club-root and each lot counted and weighed. From the counts the percentages are made up, while the weights also go on record. One large unclubbed root will outweigh a dozen clubbed ones and the unfairness of weights as a basis for the final per cents. is apparent.

With the writer the results of his field experiments square usually to the line of disease, and the number of units of the plant product is the one that best conforms to the requirement of the case. With vegetable fruits as cucumbers, tomatoes, peppers, eggplants, it is the fruit and whether it is marketable or diseased. Tests have been made with the fruits left upon the plants until a single harvest day, as with cucumbers. The results may then become very striking to the eye; but the writer thinks the better way is to pick at the same intervals as for market and keep the record in the book. The results of the spraying may here be perhaps better estimated by counting the healthy and the diseased leaves and getting the percentage from these. The gain in marketable product is also given.

In root crops the writer has not always followed the plan herein advocated. Thus with sweet potatoes the series of experiments for checking the soil rot, started out five years ago with the pound as the unit and the plan has not been changed. It is not as easy and probably is not as accurate, owing to the fact that diseased roots are on the average smaller than healthy ones, because they are diseased.

In like manner in estimating the scab upon the round potato very scabby potatoes kept in a glass jar for the purpose and taken as one hundred per cent., have served for estimating the amount of disease of each pile at harvest time regardless of size or number, the crop being recorded in total yield in pounds and percentage of scab. For example weight of tubers 75 pounds, per cent. of scab 60; weight 84 pounds, percentage of scab 15.

The value of pictures is not to be overlooked as when the relative yields are placed in baskets, boxes or heaps. The superiority of the one treatment, whether of fertilizer, culture, pruning or spraying over another, in this way appeals to the eye in a vivid manner. Squares or circles upon the printed page will aid in the same way. There is, taken all in all, perhaps no better method of indicating the relative results than by the parallel bars, and they admit of many features in very small space. Thus three or

more grades of product may be shown by different shadings or the relative amount of healthy and diseased fruit or vegetable. Like all similar devices, they admit of errors of statement and need to be constructed with great care and then should always form an adjunct of the text.

The personal equation needs to be reduced to the lowest terms and the experimenter should test this at frequent intervals by calling to his aid the judgment of the disinterested person, who is competent to arbitrate. A person with his eye fixed upon some point to be reached may be oblivious to side lights that play an important part.

The born experimenter we may expect in the next generation, but the present station workers needed to be made and that quite quickly. When the ideal truth searcher comes we shall be shown how best to work for the truth, the whole truth, and nothing but the truth.

Byron D. Halsted.
College Experiment Station,
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*MODERN PROBLEMS IN ACOUSTICS.**

The subject of acoustics appeals in one or more of its phases to a wide range of people:

To the mathematician, for the laws of vibrating bodies furnish countless problems that tax his science to the uttermost;

To the physicist, to whom primarily the field belongs;

To the architect, whose business it is to design auditoriums fitted for hearers as well as for spectators;

To the anatomist and physiologist, who finds in the organ of hearing a wonderfully complex structure that is incomprehensible without the aid of acoustical principles;

To the psychologist, who investigates the operations of the mind concerned in the hearing of sound;

To the instrument-maker, who must furnish the musician the means of expression and help him develop them;

To the musician, who cares to know the historical development and the foundations of his present art;

To the ethnologist, who recognizes music as one of the most important expressions of the life of a people; and lastly,

To all intelligent men who find with the Roman 'nothing of human interest alien to them,' and realize that a subject of such world-wide, time-long, interest as music may be studied profitably even by those who are not numbered among musical performers. For they appreciate the fact that here, as everywhere, the ability to learn *why* the alien does what he does, to enter sympathetically into his thought and see through his eyes, is the subtle power which distinguishes culture from mere knowledge.

In accordance with the custom of these Reports we are to take a bird's-eye view of recent progress in the science of acoustics.

I. In the history of acoustics two names are pre-eminent: Chladni, the text-book writer, who united to wide knowledge of the subject great ingenuity and experimental skill; and Helmholtz in whom there was a unique combination of mathematician, physiologist, physical experimenter and musician. His *Sensations of Tone as a Physical Basis for Music* published (in German) in 1863, and his monographs summed up in it, contained enough in each of these four lines to make one famous. The book has for nearly forty years dominated the thoughts of most people who believe that the science of acoustics has anything to teach musicians. Still it is significant that musicians have largely refused to recognize its sway, some showing crass ignorance in their comments, others making it clear that there is something in

* A Report from the Committee on Physical Science presented to the Washington Philosophical Society by Charles K. Wead.