conditions had been ideal for the production of corn the digit value would have been 10.

Since $U^d = A^d \times P^d$, $\therefore U^d = 6 \times 8 = 48$; that is, the present degree of utilization of said field has a digit value of 48.

The next step in the determination of the geographical index number is to consider the digit value of the maximum degree of utilization. It may be repeated for the purpose of clearness that the most efficient utilization of a given area is recognized as the maximum utilization or geographical relationship. Again, referring to the above illustration, let us suppose that (A) activity has a digit value of 10 if cotton is grown, while the digit value for corn as stated above is 6. Thus the (A^m) maximum activity has a digit value of 10. It is also assumed the component (P) has a digit value of 10 for cotton and only 8 for corn. Thus, the (P^m) maximum productivity has a digit value of 10.

Since $U^m = A^m \times P^m$, $\therefore U^m = 10 \times 10 = 100$. In other words, it is much more advisable so far as the geographical relationship is concerned to grow cotton than corn because the digit value for corn is 48 as compared to 100 for cotton.

In completing the formula, G. I. N. $= \frac{U^d \times 100}{U^m}$, or $= \frac{48 \times 100}{100} = 48$. Thus the geographical index number for the given field is 48. (It should be kept in mind that the digit value of the maximum utilization is always equal to 100 per cent and that a maximum geographical relationship is 100.)

The question undoubtedly comes to the reader as to how the digit values are determined. Are they largely personal estimates? However, after a careful consideration of maps, statistics, field work and consultation with specialists in the respective sciences the problem assumes a tone of encouragement. The satisfaction reaches the point where the results are above estimates, at least, more than personal opinions. As previously stated the attempt to place on a quantitative basis the factors involved is a worthy step towards the establishment of geography as a true science.

Another query about geographical index numbers pertains to the difficulty of determining what shall be recognized as the most efficient use of the land. Shall it be considered from the interests of an individual, a community, a state, a nation or society as the human race? With the tendency to consider geography as chorography, or a study of regions, it may be safe to say that the degree of utilization should be considered from the point of view of the occupants of the accepted region. There may be reasons at times to consider the problem from the interests of the individual or even nations. It all depends upon the objective.

In conclusion it may be said that geographical index numbers are intended to show the intensity of man's utilization of the environment or the geographical relationship. A low geographical index number suggests inefficient use of the environment. It may be the reader's interest to determine why a given region or area is not more effectively utilized. Areas of low geographical index numbers should disclose the future lands for human occupancy if the index numbers fulfil their purpose. Indeed, it is not assumed that it is always advisable for man to use his environs most efficiently. In other words, there are factors other than those classified as geographic that enter into the activities of man. Geography is not a science of determinism.

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OVERWINTERING OF THE FIRE BLIGHT PATHOGEN, BACILLUS AMYLOVORUS, WITHIN THE BEEHIVE[1]

IN a former article[2] the writer discussed the pioneer work of Merton B. Waite, who showed that the honey-bee is capable of acting as a carrier for the fire blight germ. Waite, as is well known, produced artificial epidemics of blossom blight by inoculating pear blossoms with pure cultures and then noting the relationship of bees in disseminating the pathogen from inoculated or diseased blooms to healthy ones.

Following Waite's work it has been commonly assumed that under natural conditions bees and other insects obtain the inoculum from drops of ooze or exudate that are extruded in the early spring from blight cankers located on diseased trees. In other words, while Waite had presented no evidence to show that under field conditions the insects obtain the inoculum from bacterial exudate originating in overwintered cankers, his findings of bacterial dissemination by bees from artificial infections has been used as a basis for the assumption that bees and other insects obtain the inoculum from oozing cankers. And, notwithstanding the fact that Waite[3] in his later articles makes no mention of bees as visitors or disseminators of primary inoculum from exuding cankers, though mentioning wasps and flies as acting in this capacity in one of his articles (a theory of Waite's for which no proof has been presented), it has been almost universally assumed up until recently

[1] Research paper No. 209, Journal series, University of Arkansas.

[2] SCIENCE, 70: 355, 1929.

[3] *Trans.* N. Y. State Agr. Soc., 1897: 779–790, 1898. Thirty-first Fruit Growers Conv. State Cal., 1905: 137–155, 1906. *Proc.* W. Va. State Hort. Soc., 1911: 66–73, 1912.

that bees and other insects, chiefly pollinating and nectar-seeking ones, obtain infectious material from "holdover" blight and spread it to the newly developed bloom. In accordance with this assumption the removal of blighted limbs from infected trees has been the main recommendation, often the only one, for controlling this disease.

Beginning with the observations of Stevens and his associates[4] in 1918 on the dissemination of the blight-producing pathogen by wind, there have been a number of investigators who have questioned the rôle of insects either in disseminating the blight producer after the disease started[5] or as agents of initial dissemination,[6] and some excellent evidence has been presented to show that rain falling over exuding cankers may readily act as a disseminating agent. But so far as the writer knows no concerted effort has been made by these investigators to explain the fact that, with relatively few exceptions, the first signs of blight in bearing orchards are to be found usually in the blossom clusters. Inasmuch as several investigators have presented rather conclusive evidence showing that young pear and apple leaves may readily be infected through natural openings by means of water suspensions of the pathogen, why then are the foliar shoots relatively free from disease in an orchard where they develop simultaneously with the bloom and where the latter may show a high percentage of infection?

It is this question plus one other consideration which has made it appear worth while to investigate the source of inoculum which may be involved in the first spring infections. The other consideration arose from the fact that no infectious exudate from overwintered cankers has been found to occur in the Ozarks of Arkansas prior to the first signs of blight, as reported in a previous publication.[7]

Aside from the overwintering of fire blight bacteria within twigs and limbs which were diseased the previous year, there are several other possible sources of overwintered inoculum. Among these are, first, bacterial masses freed as exudate during the previous growing season and remaining alive over winter, or bacteria freed by the disintegration of formerly diseased material, including leaves, succulent and woody shoots, flowers and fruits; second, the carrying over winter of the germ within the living quarters of insects which had previously come in contact with diseased material, or the adherence of the bacteria directly on the insect bodies. Indicative of the first possibility, evidence has been obtained which suggests that this may be true but which at this time is considered to be inconclusive. For the present it may suffice to note that certain strains of bacteria of proved pathogenicity have been isolated in the early spring from diseased material, strains which morphologically and physiologically are markedly different from the ordinary ones of *Bacillus amylovorus*.

Considering the second possibility, the writer has successfully isolated the fire blight pathogen from bee-hive material gathered throughout the summer, winter and early spring and from the bees themselves obtained from the hives in the early spring prior to the development of blight. The details of this work will be reported elsewhere. It may be stated that technique of isolation is extremely important in this instance. There remains to be determined, however, whether these findings are applicable to various sections of the country, and under diverse climatic conditions.

In the meantime it appears likely that we now have an explanation for the common occurrence of blossom blight in the absence of twig blight and in the absence of early spring oozing from blighted twigs and limbs. It is also probable that an explanation is at hand for the failures to control blight in orchards where painstaking, current remedial methods have been used, including the removal of blighted wood.

As a matter of caution it should be noted that even if the present findings will be duplicated in different parts of the country this does not mean that bees can be dispensed with. As long as self-sterile pears and apples are grown, these insects seem essential for proper pollination. The problem of control involves, among other things, the maintenance of uninfested beehives, and the failure to recognize this must at least in part account for the gradual extinction of the pear industry in America.

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[4] Science, 48: 449–450, 1918.

[5] *Ohio Agr. Exp. Sta. Bul.*, 357: 83–126, 1922; *Mich. Agr. Exp. Sta. Tech. Bul.*, 97, 32 pp., 1929.

[6] *Jour. Agr. Res.*, 39: 579–621, 1929.

[7] *Ark. Agr. Exp. Sta. Bul.*, 244, 96 pp., 1929.

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