

PRESENT KNOWLEDGE OF MOSAIC DISEASES

By MELVILLE T. COOK, Pathologist, Insular Experiment Station

The mosaic diseases of plants have become very prominent within the past few years. No doubt these diseases have existed for many years but they may not have been so widely distributed or so destructive as within recent years. Certainly no group of plant diseases known to modern science have proved so mysterious or so difficult to control as these "mosaic" diseases. In fact the causes are as yet unknown unless the recent studies to which I shall refer prove to be an open door to this phase of the subject.

A number of terms have been used to designate the disease which is now so generally known as "mosaic". This term has come into very general use because it is in itself descriptive of the diseased plants. Another type of disease which appears to be of the same general character but which does not show the markings is known as "yellows". However, this term is not so descriptive because diseased plants are not always yellow and because the term "yellows" is applied to some diseases which are caused by fungi. "Curly leaf" of beet, "leaf roll" of potato and some other diseases are probably similar in character to the mosaic disease.

Although these diseases did not attract much attention until within the last quarter of a century, they have no doubt been important factors in plant production for a very long time. Unfortunately, some of the early descriptions are of such character as to leave us in doubt as to the disease in question. However, some of them are sufficiently definite to lead us to believe that "peach yellows" was known to the growers as early as 1797. Swieten mentions a disease of tobacco which was probably "mosaic" in 1857 and which was known for some time as "rost" or "Fleckenkrankheit". This appears to be the first definite record of a mosaic disease on any plant. The "mosaic" disease of tobacco was studied by Adolf Mayer in 1885 and he gave it the name of "mosaic". For many years, tobacco mosaic occupied the centre of the stage, but the discoveries of mosaic in other plants and its recognition as a very severe disease on many crops, such as sugar cane, potatoes and tomatoes, have directed our studies along broader lines.

The "mosaic" of sugar cane was reported from Java in 1890 under the name of "*gele strepenziekte*" or "yellow Stripe". In 1909 it was reported from Egypt on cane imported from Java. In

1910 it was reported from Hawaii. It was first reported from Porto Rico in 1916 and its spread and destructive characters are so well known that it is not necessary for me to discuss them at this time.

In fact it is the purpose of this paper to give a review of our knowledge of mosaic diseases in general, with special attention to the cane mosaic. A paper by Commissioner Carlos E. Chardón on this same general subject was published in *Revista de Agricultura de Puerto Rico* in October 1922, but it was considered advisable by both Mr. Chardón and the speaker to present the subject again at this time.

The cause of the disease is the question which is uppermost in the minds of all observers. We will give a brief discussion of the theories which have been advanced from time to time.

1. *Bud variation theory.*—It is well known that many species of plants are subject to very great variations, both through the seeds and through the buds. In fact it is through the selection of the most desirable variations that we have obtained many of our most valuable cultivated plants. Sugar cane is very generally known as a plant subject to many variations. The Dutch scientific workers in Java who were the first to report mosaic of the sugar cane, having failed to transmit the disease by means of artificial inoculation, came to the conclusion that it was not a disease in the usual sense of the term but a bud variation. However, they recognized that these supposed bud variations, which were in reality cases of mosaic, were undesirable. Therefore, they made an effort to get rid of them and unconsciously practiced elimination of the diseased or undesirable plants and the selection of the resistant varieties.

2. *The soil theory.*—The influence of the different kinds of soil and fertilizers on plant growth is so very generally recognized that many people very naturally took in that direction for the explanation of both good and evil. The results of studies on this line have been such that it is now very generally recognized that the causal agency does not lie in the soil or in the use of fertilizers.

3. *The bacterial theory.*—The rise of bacteriology by which so many diseases were explained very naturally led many to believe that this important science would give us the key to this disease. The idea that bacteria were the cause of the mosaic of tobacco was first advanced by Mayer (1886). This theory was supported by Iwanowski (1892) (1901) (1903); Prillieux and Delacroix (1894); by Marchal (1897); by Koning (1899, 1900); by Breda van Haan

1899); by Behrens (1896); by Hunger and others. Some of these workers obtained and described what they believe to be the causal organism. Unfortunately, no definite proof was obtained.

4. *Protozoa theory*.—Although the bacterial theory has not been proven there are many who believed that these diseases might be due to an organism with a life cycle somewhat similar to that of the organisms causing the yellow and malarial fevers.

In 1903 Iwanowski found bodies which he thought might be the cause of the mosaic in tobacco, but no proof was forthcoming and his work did not attract much attention until recently. In 1919, Matz found what he at first claimed to be an organism in mosaic sugar cane in Porto Rico, but he later found reason for doubting his first claims. In 1921 Kunkel reported the finding of protozoan-like bodies in corn mosaic and later in cane mosaic. It was thought that these bodies might possibly be the cause of the disease but as yet there is no definite proof. In 1922(?) Nelson reported the finding of protozoan-like or trypanosomelike bodies in tomato and other plants infected with mosaic. Later studies show that similar bodies are to be found in apparently healthy tissues.

In 1923, McKinney, Eckerson and Webb reported the finding of bodies in wheat rosette and mottled wheat. The speaker has been making studies on sugar cane in Porto Rico along similar lines as the studies of Iwanowski, Kunkel, Nelson, McKinley, Eckerson and Webb. Bodies similar to those reported by these workers have been found. There are also certain other very pronounced differences between the cells from normal and diseased cane. Whether these bodies which have been reported are the causes of disease or the results of the disease is a problem which is as yet unsolved.

5. *The physiological theory*.—This was at one time more generally accepted than any other theory. It was developed in connection with the study of the tobacco mosaic. Sturgis in 1899 expressed the belief that the disease might be due to injuries or to soil and atmospheric agencies. Hunger (1903, 1905) stated that it was due to a disturbed metabolism which might be the result of meteorological or soil conditions. Westerdijk (1910) called attention to certain data indicating that it might be due to intensity of light.

While it is very doubtful if the cause is to be found in the soil, temperature, light or moisture, the study of these factors must not be neglected. Even though they may not be the causal agents they may influence the severity of the disease.

The causes of wheat rosette and wheat mottle, whatever they may be, are said to persist in the soil. Temperature is an influential factor in potato mosaic and there is evidence to indicate that moisture is an influential factor in cane mosaic. All of these factors must be studied in connection with cane mosaic.

6. *The enzyme theory.*—This theory was adhered to by Woods and others and was closely associated with the physiological theory. This theory as briefly stated by Woods is: "The disease is not due to parasites of any kind, but is the result of defective nutrition of the young dividing and rapidly growing cells, due to a lack of elaborated nitrogenous reserve food accompanied by an abnormal increase in activity of oxidizing enzyme in the diseased cells." Woods also found an excessive accumulation of starch in the diseased plants and a defective translocation of same. He believed that the excessive amount of oxidases inhibited the diastatic action on the starch and thus resulted in its excessive accumulation. The excessive accumulation of starch and reduced translocation was demonstrated for "peach yellows" by the speaker and the results published in the *Botanical Gazette*, but this does not prove that the enzyme theory is correct. The speaker is now making similar studies on the sugar cane. The studies up to this time indicate some very interesting physiological disturbances, especially in connection with the photo-synthetic and metabolic activities of the plant. In brief, I may say that from the physiologic standpoint cane mosaic is "starvation" due to disturbed photosynthetic and metabolic activities. The cause of these disturbances are problems for further investigation.

7. *The virus theory.*—This theory was advanced by Beijerinck (1898), who had previously held to the bacterial theory. It explained the mosaic as due to a "*contagium vivium fluidum*" or contagious living fluid which was soluble, diffusible, living and capable of increasing in amount. This theory has been accepted by many and has been the basis of a considerable amount of research. This is still a fruitful line of study which is being followed in some places.

Regardless of cause it is very evident that the mosaic diseases can be transmitted from plant to plant. In the case of some plants, of which the tobacco is a notable example, the disease can be transmitted by contact or even by the handling of diseased and then healthy plants. In some cases it can be transmitted by pruning and in some cases by inoculation. In a number of cases it has been demonstrated that the mosaic diseases are carried from diseased to healthy plants

by insects. In the case of the sugar-cane mosaic successful work on this line has been carried on by Brandes, Ledebøer, Bruner, Kunkel, Chardón and Veve. In some few cases there is evidence to indicate that the disease can be transmitted between plants of different species. It has also been demonstrated that the mosaic disease of some plants may be carried by plants of an entirely different species without showing it.

PRESENT STATUS

Our knowledge of mosaic diseases in general may be summarized as follows:

1. Mosaic is a term applied to diseases of plants which cause a mottling or striping of the foliage.
2. This disease also frequently causes a dwarfing of the plant and sometimes reduction of certain parts.
3. Some of the diseases known as "yellows", "curly leaf", "leaf roll", etc., are very similar in nature to the mosaics.
4. The disease in many plants is transmitted by insects.
5. The disease on cane spreads most readily during wet weather.
6. The cause of the disease is not definitely known.
7. Recent studies by Kunkel indicate that diseased plants may recover.
8. The disease may be carried on apparently healthy plants and sometimes in plants of entirely different species.
9. There is some evidence to indicate that the disease may be due to an organism.

Future lines of work are as follows:

1. More extensive and exact field studies to determine susceptibility, of varieties, spread, effects of soil, cultivation, character of seed, etc. These studies will require a long period of time.
2. Histological studies to determine possible cause and effects on the plants.
3. Physiological studies to determine the effects of soil, fertilizers, temperature, light, moisture and other factors on the disease.
4. Studies on transmission to determine the insect carriers and their life histories. Also the extent to which the disease is carried in other species of plants. Also to determine the possibility of its being carried in supposedly immune varieties.
5. There is no evidence that any of the mosaic diseases are caused by soil conditions or can be transmitted through the soil, although the mottle disease of wheat is said to persist in the soil.