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SOME PHYSIOLOGICAL DISORDERS OF COFFEE

DIE - BACK

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I - DIE - BACK

The term die-back refers to the death of twigs starting from the apex and progressing downwards. It should not be used to identify a disease but rather to describe a symptom. There are various types of die-back just as a chlorosis or wilting may be caused by a series of different factors. It is possible to try to establish distinctions between a die-back of principally physilogical origin and one of a more pathological nature. However, there may be such an interaction of these two types of factors that often it is practically impossible to ascertain which are the most important ones. The die-back which will be discussed here in greater detail may be considered as a physio-pathological complex. This disorder occurs especially on bearing trees and seems to be related to a lack of balance between the crop produced and the available food supply. One of its main symptoms is the die-back of branches which explains the name usually given to the disease. Some Spanish speaking authors use the term "paloteo" (5,26) which permits one to distinguish between this well defined disorder and the general symptom of terminal death of the twig. Without forgetting the role that a pathogen may play in this disease there is no doubt that the physiological conditions of the plant seem to control its development. This die-back is bound to so many aspects of coffee physiology that it seems worthwhile to cover the subject in detail. Also, from the practical point of view, it is a very common coffee disease which may become even more important with the present trend towards growing coffee more often in full sun.

I - CONDITIONS WHICH FAVOR THE OCCURRENCE OF DIE-BACK

After the occurrence of die-back or "paloteo" the fungus Colletotrichum coffeanum Noack (Glomerella cingulata (Ston.) Sp. and V.) can be usually isolated from the dry twigs. This fungus is however considered as a weak parasite able to cause damage only to plants or plant parts debilitated by other causes (5), Castaño (3)

observed that Colletotrichum brings a latent infection with characters of hectoparasitism when conditions are not favorable for its fructification. He mentions also that in the case of certain coffee districts of Cauca (Colombia) the fungus shows greater parasitic effects due to the fact that the ecological conditions are more favorable for its development (humidity temperature, higher altitude).

Small (27) found other organisms besides Colletotrichum in dead branches of diseased trees (Periconia byssoides, Phoma sp., Fusarium sp., Tubercularia sp. It was also shown that the conidia of Colletotrichum coffeanum are often present in the atmosphere and may invade coffee trees but that Colletotrichum is not an agressive parasite and does not necessarily cause die-back if the conditions are not favorable to its development (27). The fact that it has been possible to reproduce the symptoms of the disease by special treatment of the branches but without inoculation of the fungus (32) also seems to indicate that physiological factors are of first importance in this type of die-back. We will subsequently discuss some of the conditions which seem to favor the occurrence of the disease.

1 - Overbearing.-

It is often stated that an excess of production leads to die-back. We should however agree on what the expression "excess of production" or "overbearing" means. As explained by Duque (5) a normal tree in good health, with enough foliage (good capacity for food production) may bear an abundant crop without exhausting itself. The yield of a normal tree must be in proportion to the foliage. For a vigorous tree a crop of several pounds may be normal while for a debilitated tree a small crop, half a pound for instance, may be excessive (5).

Therefore we may consider "overbearing" as the production of a crop higher than the capacity of the plant to sustain growth and fructification of this intensity. This generally depends upon the relation between the number of leaves (or preferably the leaf area) and the number of fruits. This relation of fruit/leaf ratio has been studied in an almost mathematical way for various trees. Garner and his collaborators mention for instance that studies carried out in the state of Washington (U.S.A.) have indicated that, in the most common apple varieties 10 good leaves were not enough for the development of a fruit of a size commercially satisfactory, 20 to 30 leaves were adequate, the size of the fruits being then increased but not in proportion with the number of leaves. They also quote results obtained in the Philippines according to which at least 10 leaves were necessary to produce a mature mango fruit of medium size (7).

Similar studies have not been made yet on coffee. However in the course of an investigation carried out in Turrialba on the effects of complete and repeated defoliation of branches after fruit set, it was found that the treatment did not seem to result in a higher rate

of fruit fall nor in a significant decrease in the dry weight of the fruits. Nevertheless nine tenths of the defoliated branches and only one tenth of the untreated controls showed die-back symptoms in later weeks (30). This suggested that the developping coffee fruit may have the ability of drawing food from the main stem and other branches but at the end of the period of fruit maturation the bearing branches show exhaustion when they are deprived of leaves. The deficiency of carbohydrates has been mentioned as conductive to die-back (20, 33) a fact which is of course related to overbearing.

2 - Deficiency of Nitrogen or other Essential Elements.-

Nitrogen deficiency may act directly causing a distinct type of die-back which has been well studied in East Africa (33), or indirectly by a reduction in growth and leaf resulting later in a deficiency of carbohydrates.

Symptoms of death of the terminal bud resulting from Boron (4, 19, 23) or Calcium (4, 6) deficiency have been reported in the literature. However, it seems that in the case of Boron, there is not always a true die-back but often a cessation of growth of the terminal bud resulting in the development of lateral buds giving a witch broom aspect to the branches. According to Cibes and Sammuel (4), terminal buds of the stem and branches die, following calcium deficiency but it seems that the necrosis does not extend much as these investigators mention that new shoots develop from axillary buds below the terminal bud.

3 - Other Factors.-

In general any factor which may have a detrimental effect upon growth may lead to die-back. Ripperton and his collaborators state, that, in Hawaii, die-back is always more severe during a dry summer and especially if the preceding winter and spring were humid, giving origin to a vigorous and succulent growth. From the edaphic point of view, they indicate that certain soils which have a low power of water retention and which limit the development in depth of the root system are more conducive to die-back than the soils of deep ash or ash with gravels (25).

Other conditions leading to die-back mentioned in the literature include inadequate drainage (15) soil erosion (1,5) growth of weeds (1, 22) and the action of wind (1).

II - INVESTIGATIONS CARRIED OUT IN EAST AFRICA

Various investigators have studied die-back in East Africa (20,29, 33). The work of Beckley is especially interesting (32). This author mentions that, according to Saunders and Wakefield, the die-back which occurs in the Northern Province of Tanganyika is due to an

insufficient supply of nitrates at the time of greatest need while Nutman attributes the disorder to a lack of carbohydrates at a critical time. After three years of investigations, Beckley concluded that there are in East Africa at least two main types of chlorosis and die-back due to physiological disorders. One is directly caused by nitrogen deficiency and can be mitigated by the application of rapidly available nitrogen fertilizers. The other type comes from a deficiency in the carbohydrate supply when the fruits are in most active development. This die-back can be lessened by fruit removal in case of excess of production. The two types have distinct symptoms which permit one to diagnose the cause of the disorder and are described in detail in the article. It is mentioned that both types may occur simultaneously.

In the first type caused by nitrogen deficiency the leaves show a lemon yellow color, the apical leaves die together with the growing point and these leaves usually drop off as they die. The death of the bud is followed by a progressive die-back which may involve the whole branch. The fruits are abnormal and the outturn (yield of green bean obtained from cherries) may be very low. In a certain case an outturn of only 2% was obtained instead of the usual 22.5%. The majority of the cherries were empty or contained fragmentary beans. The root system of plants suffering from this type of die-back is normal. It was found that the application of ready available nitrogen fertilizers control this disorder. In a case when a tree was in an advanced condition of die-back the application of 500 gms. of ammonium nitrate in solution stopped the disorder and the ripened crop from the treated tree gave a good outturn of coffee.

In the die-back caused by inadequate carbohydrate supply the color of the leaves is more of a buff yellow than lemon yellow, death of the twigs does not begin from the terminal bud but from the place where green immature word starts. Dead apical leaves may be retained several weeks before they fall. The twig dies back as in the preceding case. The fruits are generally normal and there is no decrease in the output of green coffee. Concurrently with the die-back of branches the lateral roots show a similar condition and may die-back to the main root-stock. After examining many trees suffering from this type of die-back, in no case was a positive test for starch obtained. The application of nitrogen fertilizers to the diseased trees does not control the disorder, but the same fertilization at the time of fruit formation or of the first signs of chlorosis may prevent it or lessen its damage by increasing leaf growth. This type of die-back seems to be similar to what Latin American authors call "paloteo" and will be discussed later in more detail.

Sturdy (29) investigated in Tanganyika the effect of shade upon the intensity of chlorosis and die-back. He considers die-back as a more serious form of the same physilogical disorder as leaf yellowing (chlorosis). Thirty two, two-year old trees located in two rows

were shaded with bamboo laths and two rows with the same number of trees were left in full sun as controls. Table No. 1 shows the difference between the incidence of die-back or yellowing according to treatment.

Table No. 1+

Number of Trees Showing Severe Yellowing or Die-Back During four years

32 Trees	1931	1932	1933	1934
In full sun	6	6	21	13
Shaded	1	2	3	2

Sturdy concluded that artificial shade controls almost completely the yellowing and die-back. These results do not seem to be related to overbearing as in this case the plants in the sun did not produce more than those in the shade.

III - INVESTIGATIONS CARRIED OUT IN INDIA

Mayne carried out a series of investigations on die-back at the Mysore State Coffee Experiment Station (11, 12, 13, 14). He found a relation between the incidence of die-back and premature leaf fall resulting from disease or drought (13, 14). However, a complete defoliation was not always necessary to lead to the disease. In 1933 many branches which still retained a number of pairs of healthy leaves, were found with a beginning of decay (12). On the other hand, defoliation does not always result in die-back. Observations were made of 100 branches defoliated by the rust (Hemileia vastatrix B. and Br.) 48 of them later died while 52 recuperated and formed one or two more pairs of leaves (11). Nevertheless there are good indications that a relation generally exists between the occurrence of Hemileia and die-back. It may be concluded that often the following cycle occurs:

1) Conditions favoring the development of Hemileia
2) Leaf fall resulting from this disease.
3) Physilogical conditions resulting from leaf fall favoring die-back.
4) Die-back

+ Taken from Sturdy (29).

Leaf fall may be caused by other factors than the Hemileia without altering the cycle. In the Western Hemisphere where there is no coffee rust, other disease like the American leaf spot caused by Mycena citricolor (Berk and Curt.) Sacc. or the brown eyespot caused by Cercospora coffeicola Berck and Cke. may play the same role in the cycle. Mayne considers that any factor which helps in leaf retention may reduce the severity of die-back (13). Two year data are available upon the decrease in die-back intensity following sprays used to control the Hemileia rust (12).

Table No. 2 +

Effect of Spraying upon the Percentage of die-back in September 1932 and 1933

Treatment	1932	1933
Spraying before and after the Monsoon	3.1	8.7
Controls (no spraying)	8.8	23.5

The data show that in both years spraying to control Hemileia reduced the die-back incidence to about a third.

Mayne made also careful observations about the development of the disease beginning with the first symptoms (13, 14). According to him the first signs of blackening begin at a node, almost always, the second or third node from the apex. In some cases the decay extends, accompanied by a yellowing of the green internodes which progressively blacken, until the twig dies. These investigations included also the isolation of the fungus Colletotrichum coffeanum, in various parts of the plant. The fungus was always found in diseased tissues and was often present in the nodes but not in the internodes of branches which did not show symptoms of the disease (13).

IV - INVESTIGATIONS CARRIED OUT AT THE TURRIALBA INSTITUTE, COSTA RICA

I - Studies of the Symptoms.

To determine the succession of symptoms related with die-back

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+ Taken from Mayne (12).

of the "paloteo" type, it was attempted to artificially induce the disease. Considering the fact that, according to the literature, carbohydrate exhaustion results in die-back a method of ringing and defoliation of branches bearing immature fruits was adopted (32).

As the supply of carbohydrates was thus cut off and the consumption remained high, a carbohydrate deficiency of the treated branches should result. Chemical analyses of branches collected 35 days after the treatment of control branches taken from the same trees revealed that the controls had a percentage of reducing sugars and of starches and dextrins almost twice as high and a percentage of non reducing sugars five times as high as in the case of the treated branches.

Frequent observations showed that the succession of symptoms occurred in the following order:

1st.- The first observed change was a blackening of the stipules. However, although in this investigation this symptom always preceded the others, it may happen that the stipules blacken without being later followed by die-back of the twigs. It is not therefore a sure indication of the beginning of the complete disorder.

2nd.- Later a blackening of the nodes occurred beginning usually two or three nodes from the apex.

3d.- From the nodes the blackening reached the internodes.

4th.- The necrosis of the apical bud sometimes occurred at this moment. In various cases the apical bud remained green or yellow when some of the internodes were completely black.

Table No. 3 +

Effect of Ringing and Defoliation upon the Incidence of Die-back Symptoms in 23 Branches of Coffea arabica

Days after treatment	Branches without visible symptoms	Branches with black stipules	Branches with blackening of the internodes	Branches with necrosis of the apical buds
12	3	20	6	3
14	2	21	7	4
22	1	22	17	14
32	0	23	22	19

+ Taken from P.G. Sylvain (32).

Table No. 3 shows the number of days needed after treatment for the occurrence of the various symptoms.

These noted symptoms parallel the observations of Mayne about the development of the disease under natural conditions. It may be inferred that in both cases the causes are similar and that the studied disorders are of the same type.

Inoculation experiments with cultures of Colletotrichum coffeanum were made by Hastings de Gutierrez (8) using branches of coffee trees with different treatments. The die-back symptoms developped only in the case of branches which had been ringed and defoliated at the time of inoculation. 80 per cent of these branches died within a week (8) while it required 32 days for the death of almost the same number of branches submitted to the same treatment but without the fungus inoculation (30). These results indicate that although the pathogen seems to play a role in the disease, a specific physiological condition must exist before the occurrence of the typical symptoms.

In another experiment involving bearing branches submitted to repeated defoliation 38 of the 40 treated branches showed apical necrosis after 6 months while this occurred in only three of the untreated controls (30, 31).

2 - Effect of Soil Fertilization and Fruit Removal upon Die-back Incidence

In investigations carried out by Boss (2) and McFarlane (16) on the growth cycle of coffee, a number of branches coming from trees under various treatments were observed and the die-back incidence was noted. It may be seen in Table 4, that fertilization with Sodium nitrate did not affect appreciably the incidence of the disorder while fruit removal decreased the percentage by about a third.

Table No. 4 +

Summary of the Effect of Different Treatments upon the percentage of Die-back

Replications	Fertilized Twice (1)	Fertilized Four times (2)	Defruited	Controls
I	36.7	56.7	46.7	46.7
II	42.7	45.8	23.3	58.3
III	63.3	50.0	33.3	51.7
Average	47.6	50.0	33.3	51.7

+ Taken from P.G. Sylvain (32)

1) With 479 grams of Sodium Nitrate on May 20, 1949 and May 2, 1950.
2) With 160 grams of Sodium Nitrate on May 20, July 20 October 1 and May 20, 1950.

The same investigation revealed also the seasonal effect upon the incidence of the disease from June 14, 1949 to May 20, 1950.

It was found that 50.6% of the observed cases occurred during the months of November and December. Although there were some minor differences according to treatments the greater incidence of die-back occurred always at the time of minimum growth. After the new flushing, during the second part of January, the percentage dropped to 1.9% of all cases observed during the year. It must be noted that, in spite of the absence of crop, the defruited trees showed the greater incidence of die-back almost at the same time as the controls, in fact 70% of the cases occurred in the two months of November and December.

These factors may have had some influence on the incidence of the disease. It is interesting to mention that there seems to be a negative correlation between growth and die-back, the months of relative dormancy showed a high incidence of the trouble which decreased when growth started again and disappeared almost completely at the time of the peak in growth in March (31).

V - MEANS OF CONTROL

From the preceding statements it seems clear that the control of die-back of the "paloteo" type should consist in maintaining or establishing conditions favorable to a good balance between production and consumption of carbohydrates. This balance depends greatly upon the fruit/leaf ratio. This ratio is very important as it constitutes also the basis of the maintenance of trees in good production during a number of years. It may be obtained by a high production of carbohydrates or by a reduction in the crop. As the goal of cultivation is to obtain maximum yields without impairing the good development of the plants, it seems more convenient to try to maintain this balance without decreasing fruit production. An exaggerated fear of the possible harmful effect of heavy crops may result in yields so low that they are not economically profitable. In general, one should therefore consider first the methods which control the excess of production by increasing the vitality of the plant. Among them we will consider those which prevent premature leaf fall and those which lead to a good general development of the trees.

I - Control Measures which Prevent Premature Leaf Fall.

The effect of spraying against Hemileia upon the incidence of die-back has already been shown in Table 2. Although we do not have precise data as to the effect of control of other leaf diseases upon this disorder it may be assumed that similar results would be obtained.

Some time ago Rayner (24) noted in Kenya that copper sprays used as a protective measure against Hemileia resulted in apparently healthier plants which showed a lesser leaf fall than untreated neighboring trees although the presence of rust was not observed in the whole field. As there were no visible signs of other disease, it was thought at the beginning that the beneficial effect of copper might be of a nutritive order in case that the plants had difficulty getting this element from the soil. The name of "tonic spraying" was thus applied to this treatment. However copper injections made in the trunk of trees did not reduce premature leaf fall. Later it was found that other fungicides without copper could increase leaf retention. This suggests that there must have been some fungal infections which affected the leaves and were controlled by the treatment.

A recent publication from the same area reveals that an effective control of premature leaf fall together with an increase in yield of the order of 40 to 67% may be obtained using various fungicide treatments in form of spray or dust. Fernide (an organic iron compound) and Perenox (a copper oxide) spray gave the best results. They also tried the use of a growth substance, (naphtalene acetic acid) to control premature leaf fall. This treatment resulted in small increase in yield but the leaf fall was almost the same as in the controls (9). A similar investigation carried out by Molina in Turrialba with four growth substances did not give positive results (18). The possibility still exists however that other substances or the same substances at different concentrations might reduce significantly premature leaf fall as it has been found in California in the case of lemon trees (28).

2 - Control Methods which Lead to a Good General Development.

Some of the methods in this category could be included in the preceding one but they are discussed here as in addition to their effects upon leaf fall they also directly influence other aspects of the plant welfare. For instance better water relations in time of prolonged drought will have a beneficial effect upon leaf retention but also upon the various phases of general development of the tree.

a) Soil Fertilization

Pereira and Jones (21) have published interesting data on the effect of various fertilizers upon the incidence of die-back.

Table No. 5+

Effect of Fertilizers upon the Number of Branches with die-back per tree

Years	Amonium Sulphate 4 cwts/acre		Double superphosphate 2 cwt/acre		Manure 14 tons/acre		least significant difference	
	No N	N	No P	P	No C	C	P=0,05	P=0.01
1950	10.7	7.8	9.3	9.3	10.6	8.0	1.9	2.9
1951	48.5	33.4	42.1	39.8	42.4	39.5	10.4	15.3
1952	15.6	8.6	13.1	11.2	13.7	10.6	3.9	5.8
Totals 3 years	74.8	49.8	64.5	60.3	66.7	58.1	13.5	20.0

+ Taken from Pereira and Jones (21).

Table No. 5 shows that the application of 4 cwts/acre of Ammonium sulphate reduced significantly, every year, the incidence of die-back while the double superphosphate (2 cwts/acre) practically did not affect it. The manure at a rate of 14 ton/acre had a significant effect only the first year. We have already seen in Table No. 5 that at Turrialba fertilization with sodium nitrate did not diminish appreciably the total number of branches with die-back but besides the differences in soil and climate of the two localities it should be mentionned that in this case only six branches per tree were observed.

In Hawaii it is considered that, to diminish the incidence of die-back, the fertilizers must be well balanced in such a way that there is an ample supply of potassium and no excess of nitrogen (25). Ripperton et al give results of a fertilizer experiment of several years duration including 5 differents treatments, N, NP, NPK and control. The quantities used were of 160 lbs.Nitrogen, Phosphoric acid and potash. Great effects of the treatments upon die-back incidence could be noticed after two years. All the plots without potassium (N, NP and controls) suffered excessive die-back while the others (NK and NPK) showed practically no signs of the disease (25).

Results on an interesting experiment on the effect of soil fertilization upon the incidence of die-back have been published last year in Brazil by Malavolta et al (10). 8 treatments N, P, K, NP, PK, NPK and control were used on randomized blocks with 6 replications. The fertilizers consisted of 150 grms. of chilean nitrate, 300 grms of single superphosphate and 180 grms of potassium chloride per "cova" of 4 trees (A "cova" consists of several trees planted in the same hole). These quantities correspond to 27 kilos of Nitrogen, 69 kilos of Phosphoric acid and 123 kilos of Potash per

acre. The fertilizers were applied in two applications one at the beginning and the other at the end of the rainy season. The first application was made when the trees had been in the field for about a year.

At the time of the second harvest a count was made of the dead branches of 4 "covas" in every treatment to obtain die-back figures. The following table gives a summary of the results:

Table No. 6+

Average Number of Dead Branches on 4 "covas" (16 trees) According to Treatment

Treatment	Average number of Dead Branches
Control	69.1
N	28.0
P	75.3
K	41.7
NP	36.2
NK	6.2
PK	33.8
NPK	6.7

The statistical analysis revealed that the application of either Nitrogen or Potassium resulted in a highly significant decrease in the intensity of die-back. However the decrease was still much greater when the two fertilizers were used conjointly.

Phosphorus did not seem to have any influence in this respect.

b) Control of Soil Moisture

Drought may lead to die-back by its effect upon leaf fall and growth. In this case any treatment which increases or conserves the available water in the soil will help to control the disease. The use of irrigation and mulch may be considered under this heading. The mulch of course has other advantages besides its beneficial effect upon water relations.

c) Good Cultural Practices.

In general all the cultural practices necessary to good plant development should be adopted. For instance the harmful effect of an excess of weeds (1) and of soil erosion (5) upon die-back has been reported in the literature.

+ Summarized from Malavolta et al (10).

Pereira and Jones (22) give valuable information upon the effect of various weed treatments during the rainy season upon the incidence of die-back. In all the plots the weeds were turned in at the beginning of each dry season. As indicated in Table No. 6, the presence of weeds even during the rainy season when there were no problems of soil moisture competition increased greatly the incidence of die-back in relation to the crop.

Table No. 7+

Number of Branches with Die-back per Pound of Cherries Harvested

Treatment	Year	
	1950	1951
Clean cultivation	3.8	7.1
Weeds slashed during the rains	7.9	9.3
Weeds not controlled during the rains	12.4	14.2

3 - Control Measures which Reduce the Crop.

It is obvious that in the case of a debilitated tree a reduction in the crop may maintain the balance between production and consumption of carbohydrates and in consequence reduce the incidence of die-back. Although it may be practiced by fruit thinning this method is not used under field conditions, except sometimes in the case of the first crop of very young plants.

Adequate pruning systems have been recommended instead to reduce what is considered as excessive production. The technicians of Hawaii think that with the non-topped system of pruning the incidence of die-back could be lessened by using a moderate pruning every year instead of very heavy pruning followed by one or two years of light pruning. In theory, th systems in which a great portion of the tree is permanent should result in less die-back than those in which most of the tree is young wood. Some growers reduce the bearing surface of the trees by removing a whole vertical or by cutting off part of the laterals if it becomes evident early in the season that die-back will be severe (25).

The use of shade recommended to reduce the intensity of the disease generally acts also by its effects upon the crop. However

+ Taken from Pereira and Jones (22).

other factors may play a role in this case such as the effect of light and temperature upon the development of a pathogenic agent.

4 - Use of Resistant Types.

There seems to be differences between various types as to their susceptibility to die-back. Investigations carried out in Brazil (17) and Belgian Congo (31) show that even within the same variety progenies may be found with distinct grades of susceptibility to the disease. The selection of resistant types, may therefore be of great help for die-back control.

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