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Integrated Control Methods

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Definition

The need to control cocoa black pod, due to *Phytophthora palmivora*, depends on the magnitude of attack and loss, both of which must be quite high to justify the expense and effort entailed by treatments. The methods used in applying the treatments must, for their part, be deduced from the observed epidemiological scheme.

In a given location the extent of attack and the epidemiological scheme depend on a complex set of factors made up as follows:

the virulence of local strains of the parasite;
the sources of inoculum and their ability to liberate this inoculum;
the susceptibility of the varieties of cocoa cultivated;
the arrangement of vulnerable organs on the plant, their density and distance from effective sources of contamination;
the potential influence of vectors such as insects;
climatic conditions favouring more or less intense activity of the parasite.

A plant pathologist concerned with ensuring maximum yield from the cocoa plantation by controlling the disease both effectively and as inexpensively as possible, while studying the possibility of direct disease control by applying fungicides, must also as a matter of course consider taking action on the largest number of factors which determine the extent of the attack and the modes of dissemination of the parasite.

It is the body of interventions as a whole, of all kinds and in all directions, whether or not associated with direct chemical control, which we refer to here as *integrated pest control methods*, since there is no doubt that these interventions must be viewed as integral parts of standard agricultural practice which are applicable now, within the present context of cocoa growing, or of more elaborate agricultural techniques which it may be assumed will be applied in the more or less near future within the framework of production modernization.

It should be noted that among the factors conditioning the disease some will always be beyond the reach of control measures:

for example, the virulence of the strain of the parasite involved, and which must be accepted as inevitable;

pod density on the tree can also be mentioned: it is certain that because of the process of contagion high yield favours infection; it is self-evident that no action can be considered on this point – on the contrary in this respect high yield is a sort of desirable evil.

On the other hand, action may be considered *a priori* in regard to some of the other factors listed above. We shall try to explain what advantages can be expected from them in the light of experiments already carried out, or more speculatively what advantages could be derived from them in the future.

Use of resistant cocoa trees

Direct resistance

The susceptibility of varieties growing in plantations at the present time is one of the factors on which it is not possible to take immediate – or at least any significant – action. It should be noted, however, that recent work (Tarjot, 1971 b) tends to show that the susceptibility of a given variety of cocoa tree varies to a certain extent according to the relative humidity of the air: certain agricultural practices, especially adjustment of shade to the lower limit tolerated by the variety of tree under consideration, might have some effect in this respect.

Whatever this possibility has to offer – and this is undoubtedly quite limited, at least in those areas where the disease in other respects finds optimum conditions for development as in Cameroon – the best use must be made of the characteristics of what planting material is to hand, so long as immune varieties are not available. Cultivation of immune varieties would of course offer the most radical solution to the problem, provided that these varieties combined high yield and suitable market qualities with immunity to *P. palmivora*. The search for such varieties tops the list of objectives of selection work. Until such varieties are forthcoming, which would perhaps be a utopian panacea for those places where the disease is particularly serious, varieties possessing a certain degree of resistance, which are easier to find among existing planting material or which can be created by hybridization, constitute a real advance, and their cultivation is one of the agricultural measures whose application, associated with others, will lead to the most convenient solution of the problem.

Indirect resistance

But besides cocoa varieties showing this 'true resistance' or 'direct resistance' in varying degree which amounts, for the parasite, either to the impossibility of penetrating the fruit or to the impossibility of developing inside the cortex, since the trophic elements which it requires may be lacking or antagonistic substances might be synthesized therein and prevent its penetration and development, a place must be allowed for what may be termed 'false resistance' or 'indirect resistance'.

Unlike direct resistance, this indirect resistance is not the result of anatomical, physiological or biochemical characteristics which prevent or counteract parasitic aggression, but is the result of phenological characteristics of the tree whose fruits, although intrinsically susceptible, generally escape infection. Presumably agronomic treatments might reinforce natural tendencies of these varieties and make it possible for them to manifest indirect resistance.

Duration of the fruiting cycle

Among the simplest phenomena which might act in this direction, the duration of the fruiting cycle, which is the period between flowering and maturation, is the first to come to mind. In Cameroon, cultivated varieties, which for the most part are Trinitario hybrids, have long cycles which may last up to approximately 7 months. Under conditions prevailing in the south-centre area of the country, flowering starts in earnest in early February and ends in June, after reaching maximum intensity during March–April, corresponding to the rainfall peak of the first rainy season; picking takes place between September and January, the peak period being in October–November. The seriousness of the attacks is a result of the coexistence, required by the very nature of cocoa cultivation, of the rainy seasons, which favour the development of *Phytophthora palmivora*, and the pods, which are vulnerable at all stages of their development: the disease, starting from zero reaches a first – modest – peak during the first rainy season and its highest point during the main rainy season, during which the pods are largest and most numerous, thus favouring contagion.

It is obvious that if the pods ripened earlier, i.e. if their cycle of development were shorter, the effect of the attack would be less severe. This, moreover, is what is observed in years in which, for reasons which elude analysis, maturation occurs earlier. The cultivation of varieties with a short cycle can therefore only be beneficial. These varieties exist, particularly in the high Amazonian group, with cycles lasting for approximately 5½ months only, under conditions prevailing in Cameroon. This we believe is one of the orientations to be given to the work on selection.

Use of varieties providing an overall early flowering

From what is known of factors determining flowering (J. Boyer, unpublished), it seems to depend partly on a direct relation with rainfall, partly on the amount of insolation and temperature, and in third place on still incompletely known internal factors.

If flowering ranges over a long period, it may be supposed that this is due to the fact that certain natural factors, rainfall in particular, exert their effect in a gradual manner only. A hypothesis can therefore be advanced at this point –

would not irrigation, applied at the beginning of the flowering period, be a means of accelerating the flowering process? Concentrating flowering at the beginning of the season might make it possible to obtain early maturity, thus outstripping infection so that a substantial number of pods escape attack by *Phytophthora palmivora.*

Selection and cultivation of cocoa trees with a displaced fruiting cycle is perhaps the surest means of escaping a large part of the infection.

In Cameroon in 1970 we observed that certain cocoa cultivars flower out of season as it were: clone UPA 134 bloomed abundantly in the middle of the dry season in December, January and February. Certain other clones that year showed a less displaced flowering compared with normal flowering, but were still very early to a varying degree, for example, clones SNK 459, ICS 39, ICS 40, ICS 43, ICS 46, SNK 213, SNK 10, ICS 84, SNK 136, SNK 16, SNK 12, ICS 61, etc.

Logically, pods from such flowers, if they can develop at all, should escape infection. Now under natural conditions such flowers are rarely successful because dry conditions do not allow the fruits to develop as they form. Further, with clone UPA 134, which is self incompatible and with no other flowers forming at the time among other clones in its vicinity, no fruit-setting whatever occurred. But it may be possible to avoid these 'natural' failures by taking measures of an agricultural nature:

fertilization might be provided by setting up polyclonal fields comprising early-flowering clones; and possibly by enhancing fertilization through manual intervention (i.e. application of a brush by Soria's technique);

the retention of young fruits might be ensured through irrigation.

Climatic factors

Shifting of production zones

Climatic characteristics favouring *P. palmivora* also favour cocoa varieties cultivated hitherto: in Cameroon, where Trinitario hybrids are planted, we have found a correlation between the amount of yield and the extent of attack; this correlation of course points first to the contagion phenomenon, but also shows that conditions under which the host yields well are also conditions good for the development of the parasite.

Consequently, shifting cocoa cultivation to climatic zones which, *a priori*, are less favourable to the parasite and therefore relatively dry, should only be envisaged with caution. Such a shift is to be envisaged if accompanied by thorough studies necessary to choose planting material and growing techniques (i.e. shading, irrigation, manuring) which can ensure suitable growth under such conditions.

Action on climatic effects

Although it is not possible to act directly on climatic factors it is nevertheless reasonable to consider the modification of climatic effects on the cocoa plantation. The fungus by its very nature has strong aquatic affinities: its reproductive organs, the ciliated zoospores, must find water to emerge. Their possible activity can be limited by good aeration of the plantations and a certain amount of exposure to sunlight. By lowering the humidity in the plantations, conditions in which pods remain damp for a long time will be avoided – a matter of prime importance.

The thinning out of shade, up to the limit tolerated in the locality by the variety of cocoa cultivated, can be recommended as a suitable means to this end. This is quite an old practice referred to in the most authoritative works (Roger, 1951–4), a practice whose justification is evident to those who have lived for long in cocoa-growing areas, especially where the disease occurs with a high rate of incidence. Tarjot (1971 b) studied this matter explicitly, giving figures showing that substantial differences exist between relative humidities in plantations with no shade, light shade or dense shade. Shade trees could be grown in the same way as Erythrinas in arabica coffee plantations in Costa Rica or as we have done in Cameroon at the Nkolbisson Research Centre with *Cassia spectabilis*: in this method the shade trees are thoroughly trimmed in the rainy season so that practically only the trunks remain; they progressively reconstitute their foliage during this period and can again provide adequate shade by the beginning of the dry season.

As an extreme measure total removal of shade could be considered, so far as (contrary to what has been accepted up to now) the cocoa tree can adapt itself to such conditions. It is undoubtedly necessary to envisage research into varieties which are better adapted to direct insolation, as well as the use of cultural methods, particularly the use of mineral fertilizers. Under such conditions consideration should be given to the possibility of insect attack, especially by psyllids which thrive in sunny areas.

To sum up, the general thinning of shade, its seasonal adjustment, or even its total suppression or the shifting of cocoa plantations away from their traditional home if we have available planting material adapted to direct insolation with cultural methods which allow it to tolerate such conditions, are to be included among those cultural practices which can diminish the gravity of attack by *P. palmivora* by creating a climatic environment which is unfavourable to the parasite.

Action on sources of inoculum: prophylaxis

We have shown at length (Chapter 18) that it is possible to act directly on certain sources of inoculum (and on the most efficient of them, considered as sources of contamination) in order to modify dissemination of the parasite quantitatively and qualitatively. We shall deal here with certain of these points more fully and precisely.

Destruction of pod shells in heaps or scattered over the ground

It was seen earlier that pod fragments scattered over the ground, or heaps of pods abandoned in places used for pod breaking, were particularly effective sources for vertical as well as for horizontal dissemination of the infection. One of the first actions to be recommended, therefore, is the application of strict prophylaxis by carefully destroying these fragments, all of which constitute sources of infection, in this way reducing the amount of inoculum in the plantation.

Destruction of mummified pods on trees

We have also seen that diseased pods, withered and left on trees, which are all primary and permanent sources of infection, play a substantial role in East Cameroon by qualitatively modifying the epidemiological scheme of the disease: the vertical ascending development of contamination which we described for this area appears only if these old pods have been removed before the beginning of the season. This observation is of considerable importance, for this epidemiological scheme makes it possible to reduce the efforts and expenses necessitated by chemical pest control to a considerable extent: it may then be sufficient in fact to treat only the low pods growing between the ground and a height of 2 m, during half the season only, which at least halves the quantities of fungicide required.

This second prophylactic measure, as applied in East Cameroon, seems to us to be of primary importance, and we consider it to be absolutely inseparable from the indispensable chemical treatments in that area. There can be no doubt in any case, even in those areas where the incidence of the infection is not so obvious, for various reasons as we have seen elsewhere, that this measure has a quantitative effect on the infection by eliminating the sources of contamination.

Destruction of diseased pods during the season

We have also studied the role of diseased pods during the season as secondary but nevertheless permanent sources of contamination, and have emphasized their importance: their systematic destruction every week, thus limiting the production of inoculum and its presence during the season, contributes to a reduction in the rate of attack. It is of course true that this reduction in rate of attack varies according to the plantation, and the particular year. We have noted in a series of repeated observations in East Cameroon that it could vary from 6 per cent to close to 40 per cent, with an average of approximately 20 per cent.

It cannot therefore be considered as sufficient to control the disease in regions with high rates of infection such as Cameroon, or in a year which is particularly favourable to the disease. But it is far from being negligible: tests have shown that it is possible in Cameroon to attribute to it, out of a total additional yield of 385 kg of dry cocoa per hectare obtained by chemical pest control methods with which it is associated, a share amounting to 85 kg.

It is logical to assume that its efficiency would be even greater in areas where the disease is less serious. As far as we are concerned we consider it to be an indispensable auxiliary to chemical treatments: it is indeed common experience to note that chemical treatments do not prevent veritable outbreaks of black pod when growers leave the diseased pods on the tree.

Destruction of epiphytes

We shall include within the context of prophylactic measures the destruction of mosses and other epiphytes which sometimes grow abundantly on the trees. It was recently shown in Brazil, particularly in the state of Bahia, where these epiphytes are extremely abundant, that they harbour *P. palmivora*, and therefore constitute a source of infection all the more effective in that they remain impregnated with water for a long time and therefore maintain at their level conditions which are favourable to contamination. Besides the fact that they interfere with fruiting it is therefore necessary for sanitary reasons to eliminate them from plantations before they become a serious handicap.

To conclude this section let us emphasize therefore that prophylactic measures are first and foremost indispensable in plantations. Apart from the fact that they reduce the proportion of inoculum through eliminating its reserves formed by heaps of shells in pod breaking sites, by shells scattered over the ground, dead pods on trees, mosses and other epiphytes, and the fact that they prevent the intense production of reproductive organs on diseased pods, these prophylactic measures are simple cultivation practices which may be applied by anyone and require neither expensive working equipment nor considerable labour:

care should be taken to break cocoa pods outside the plantations or in places which have not been planted if the plantations extend over a large area, so as to avoid the formation of heaps of shells near the trees;
in between seasons careful sanitary cleaning operations should be carried out in plantations at the same time as general maintenance operations;
diseased pods should be eliminated during the season when carrying out weekly visits necessitated by normal maintenance of the plantations, pruning suckers, trimming trees and insecticidal and fungicidal treatments.

It may therefore be said without exaggeration that these prophylactic measures do not require any special interventions and are simply part of the normal care to be given to the plantations.

As factors which are indispensable to the success of chemical treatments in areas where these treatments are necessary, prophylactic measures integrated with routine cultivations practices are perhaps sufficient in areas with a low rate of attack to ensure satisfactory control of the disease.

In Cameroon it is noteworthy that the sources of *P. palmivora* with which we are faced fructify very abundantly on diseased pods, forming a veritable whitish crust with a soapy consistency on the surface of the spots. We therefore believe that the role of these pods as particularly effective sources of contamination is strikingly demonstrated. It is possible, in other regions where the parasite does not fructify so abundantly, that the importance of diseased pods is not realized; this is undoubtedly an error, for if it may be conceived that various degrees exist these are in proportion to the overall phenomenon observed.

Action on vectors

In Chapter 18 we described the role, sometimes obvious and sometimes insidious, of insects and other invertebrates in spreading the disease. It naturally occurs to one to try to limit the action of these vectors through direct intervention.

Certain authors (Okaisabor, 1971 b) have shown that application of insecticides make it possible effectively to decrease the rates of attack of *P. palmivora*, but before recommending this the practice requires careful thought. For there can be no doubt that systematic application of insecticides aimed, as it were, against the fauna as a whole and not only against species harmful to the cocoa tree at special periods, may considerably disturb the natural cocoa plantation fauna and create serious imbalances in this biosphere. It is particularly important not to lose sight of the fact that, on the one hand, pollination of the cocoa tree is due to insects, and that on the other hand, numerous examples show that abuse of insecticides is often followed by a fresh outbreak of parasitism, due to the destruction of natural enemies of certain harmful species. Consequently, as far as we are concerned, it is only with a great deal of reservation that we accept the idea of systematic application of insecticides, and we believe that any intervention on the fauna must be strictly reserved to special actions, oriented towards well defined objectives at specific points of time.

However, we shall describe one experiment in Cameroon which forms a special case where action may be envisaged, although in an indirect manner, to avoid a temporary rapid multiplication of insects which are accidental but effective vectors of *P. palmivora*. We often observed that certain fruit trees (mangoes, guavas, citrus) used in the plantations as shade trees fruit abundantly at certain seasons and shed a substantial part of their fruit which falls to the ground, forming a medium for proliferation of certain insects, in particular *Drosophila*, which then rapidly multiply and fly in clouds, settle on diseased pods and then on healthy pods which they contaminate. Veritable outbreaks of black pod on cocoa trees growing under such shade trees are then observed.

The easy way to avoid this temporary but effective proliferation of parasite vectors is to avoid planting fruit trees in the plantations.

Conclusion

Referring back to the definition given above of the expression 'integrated pest control methods', by which we mean all kinds of agricultural treatments which, in addition to their strictly agricultural value, exert an action on the disease at whatever level this may be, we have seen that there exists a whole range of possible actions.

1. Some of these actions have already stood the test of experience, particularly in Cameroon, where they must be associated with chemical treatments which are obligatory because of the high level of attack encountered in this country:

These are *prophylactic measures*: some of them through elimination of locations favourable to parasite conservation (heaps of shells, pod fragments abandoned on the ground, dead pods on trees) decrease the amount of inoculum and provide a particular epidemiological scheme whose economic consequences are quite substantial; others, by decreasing the parasites ability to multiply (weekly destruction of diseased pods during the season) constitute a quite significant factor for direct control of the infection and an indispensable auxiliary to chemical treatments, ensuring maximum efficiency of the latter.

They include also those measures which are calculated to create a micro-climatic environment less favourable to the parasite by lowering the relative humidity in plantations. These measures consist either of thinning out the existing forest shade to a certain degree not unfavourable to the cocoa tree, or of adjusting the microclimatic environment depending on the season by seasonal cutting of certain shade tree species which are sufficiently plastic to withstand this treatment.

2. Other actions may be contemplated in the future and undoubtedly require work of a varying nature, the results of which may be felt in the more or less distant future:

Cultivation of immune varieties will be the ideal solution. However, cultivation of varieties having a certain degree of resistance will provide a partial short-term solution to the problem, facilitating direct pest control where this action is unavoidable, and perhaps making it possible to reduce attacks to a negligible level in regions where, although troublesome, they are not of such intensity that chemical treatments on economically feasible lines can be envisaged.

It is also possible to consider cultivating varieties with phenological cycles such that their fruits, although intrinsically susceptible, will escape infection because their fruiting periods do not coincide with periods of possible activity of the parasite. We believe that such varieties already exist, but special cultivation techniques will be undoubtedly required to make them entirely useful because they will be required to fruit out of season.

Cultivation of varieties adapted to a completely exposed environment or, as a limit, to drier climate, is also a future possibility, provided adequate growing techniques permit this type of culture, and if entomological problems peculiar to this environment (Psyllids, for example) do not arise too acutely.

We shall finally mention interventions on the fauna which can only be advised with extreme caution, but which can of course constitute auxiliaries to anti-cryptogamic treatments in places where such treatments are required.

To sum up, we believe it is with a whole range of methods of an agricultural nature, associated with the cultivation of new varieties showing a more or less confirmed degree of resistance, and wherever necessary with the application of fungicides, that one can hope to find the best solution of the problem of black pod due to *Phytophthora palmivora.*