SOME CONSIDERATIONS ON SILT-PITTING.*

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Considered as a planting topic the subject of silt pitting is marked by the number of points it presents which have not yet got beyond the controversial stage. This is but the reflection of the fact that it is a comparatively short time since soil conservation work of this kind was introduced into rubber estate practice. So many variations are presented by the different soils and situations and by the different ways in which silt-pitting may be devised, that it is little wonder that a settled practice does not immediately emerge. Even the limits under which the different schemes may be regarded as applicable have never been properly defined. Practices which have been found to work well under a given set of conditions may want examination and modification before equally good results may be expected under changed conditions. It is the purpose of this paper to deal with some of the more fundamental points which must be considered in evolving from the stage of conflicting opinion towards that of a standard practice, though much remains to be done before the details of such standards can be firmly laid down.

In some respects the term "silt-pit" as applied to most of the soil conservation work to-day is not too well chosen, although it has probably come to stay. It is apt to carry with it the idea of silt-collecting pits rather than that of silt-prevention pits. Silt being the product of soil erosion it is plain that an ideal system for preventing erosion will put silt out of the question. It is certainly the less of two evils to collect silt rather than to lose it, but it must be quite clear that to prevent any silt formation at all is the vital aim of all remedial measures.

This criticism does not bear the same weight in cases where the pitting may be regarded as a temporary expedient, and this question as to the permanency of the pits is one that we must deal with at the outset. The most natural way in which wash can be prevented is by the growth of low-growing cover. Where such is feasible silt-pitting may be introduced as a merely temporary measure to protect freshly cleared land until a cover can be established. In such a case it is not objectionable if the pits do fill up

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in a short time. But in the main we are speaking of systems which it is desired to maintain permanently. A good stand of rubber may be expected ultimately to carry such a heavy canopy of leaves that an adequate ground cover is likely to prove an impossibility on account of shading. In such a case earthworks must be relied on to stop wash, since a tree canopy is not of such a type as to simulate the protective action of a ground cover. We may say then that, although the ideal prevention of soil erosion is provided by the natural conditions of a ground cover, yet this must often be reinforced and sometimes replaced by a system of silt pits under the conditions which apply to rubber plantations.

The soil erosion with which we are dealing is that produced by excessive rainfall—excessive in its rate of fall rather than in total quantity over a long period of time. The eroding action is of two distinct kinds, one a disintegration produced by shear impact of large drops and the other and most important the wash produced by cumulative surface-flow of water. The first action is most noticeable where soil has been loosened, as on a bund, and gives rise to those little pillars of soil which one so often sees. Fitting exactly on the top of each one will be found a stick, a leaf or some small object which has protected the soil immediately beneath it, while all round the soil has been cut away in the vertical line of impact of the falling drops. In other circumstances, as on a level clay soil, an opposite effect may be produced, the falling drops in that case puddling the soil surface by their impact and producing a state of unhealthy consolidation, or deflocculation as it is called.

The most important action that we have to combat, then, is the surface flow produced by rain falling at a rate in excess of that at which the soil can absorb it. The pit is a simple expedient to increase effectively this capacity of the soil to take up the water. Water movements in soil which govern the question of absorption take place as the result of a difference in pressure between two locations, and such differences may result from two quite distinct causes. In the first place there is the universal hydro-static head produced by gravitation and secondly there is the effect of capillary suction. One tends to increase the pressure while the other decreases it, but both cause movement. In certain cases the capillary effect may be the largest factor producing water movement, and it may also act either in conjunction with or against the gravitational effect according to circumstances. Consider the course of events when rain falls upon a dry soil surface. At first it is quickly absorbed, mainly by capillary attraction, since the capillary suction is generally high for dry soil. As the saturated surface layer extends, however, the water front reaches moister soil and the capillary suction diminishes; also the resistance to water movement is proportional to the depth to be traversed, so that for two reasons the rate of water absorption rapidly diminishes as the depth of penetration increases. In addition to this there is a very important effect which comes in to bring water penetration to a standstill, and that is the trapping of air in the soil pores. It is self-evident that water can only enter the soil if the displaced air can escape, and this escape may be prevented if the rain is of such intensity as to saturate completely the surface layer of soil and leave no open pores. If the underlying layer contains much air, that is, is fairly dry, the water above sits on a pneumatic cushion, as it were, and cannot penetrate farther. In ordinary cultivation the practice of ridging helps to get over the difficulty, and in rubber estate practice there is little doubt that silt-pits also help by providing subterranean outlets for the displaced soil air. All such movements, of course, benefit the soil. These considerations apply to the rapidly changing conditions of a rain storm. The slow water movement which goes on by which the soil drains under gravity is of equal importance because it is incessant. The soil holds a certain proportion of water by capillarity and the rest tends to drain always lower at a rate depending upon the openness of the soil texture. This continued subterranean flow is well evidenced by the way our rivers continue to be fed even after rainless periods.

A large part of the rainfall in Malaya is of that intense type which no soil, however porous, can keep pace with by absorption. In Fig. 1 some of the rainfall records taken at the Rubber Research Institute are so presented as to show this characteristic. The values have been plotted to show the *rate* of rainfall at any given moment. Taking the curve in broken line we have an ordinary steady rain presented. The average rate of fall over several hours is about ¼″ per hour and the greatest intensity reached is about one inch per hour. The total is 1½″ and the period would be reckoned an exceptionally heavy rain in the temperate zone. Yet the comparison with the curve in continuous line, which shows a more typical local downpour is very striking. The rain comes in bursts which reach an intensity of 6″ per hour. The last burst would certainly fall upon a soil already saturated and it represents over *an inch of rain deposited in fifteen minutes*. This alone would be one hundred tons of water per acre to work havoc by surface flow unless silt-pit accommodation is provided for it.

The great secondary advantage of silt-pitting is that the moisture is conserved as well as the soil. The sites which stand in greatest need of the one, namely hilly land, are also in greatest need of the other, since on a hill the trees are much less likely to

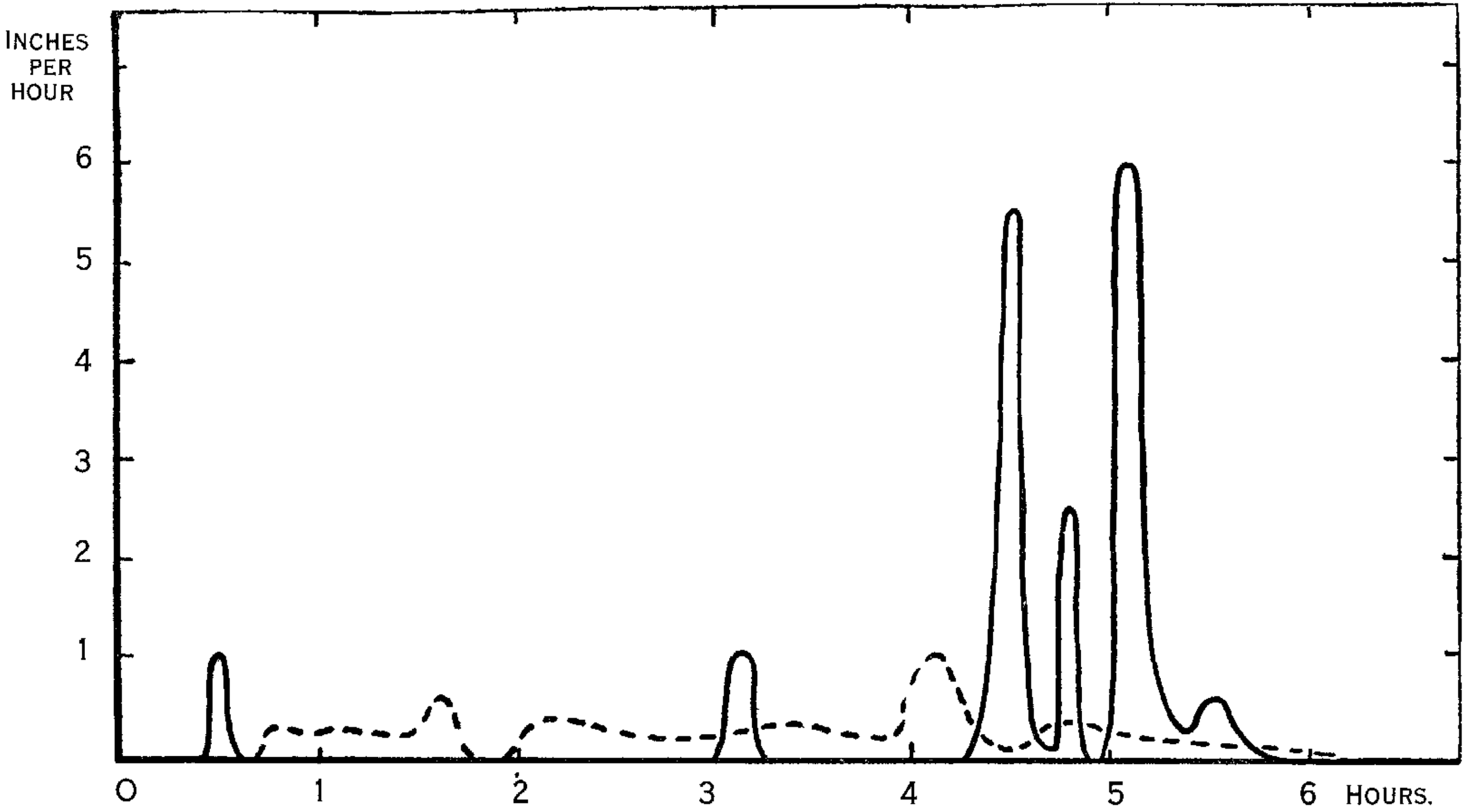

FIG. 1.

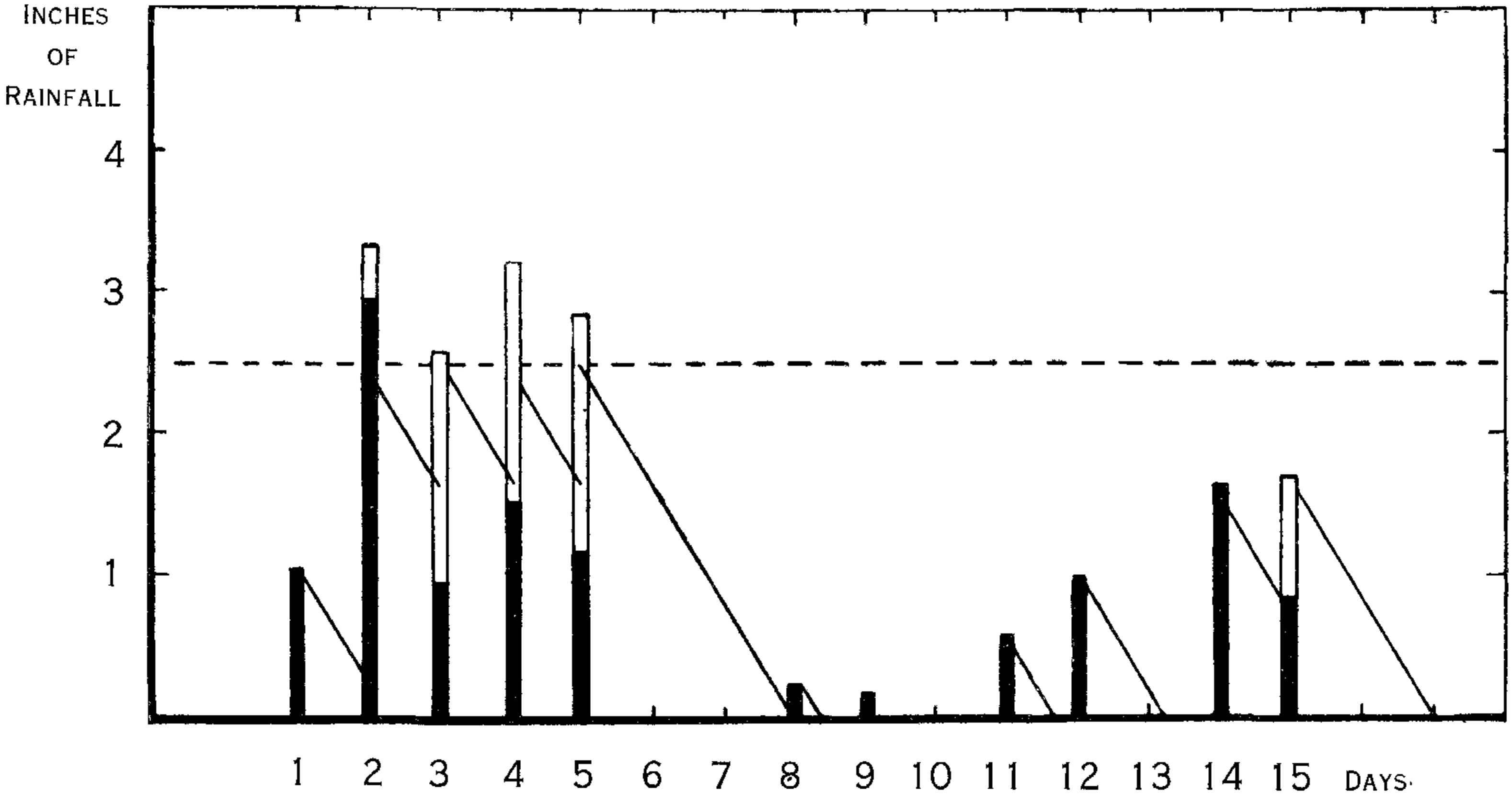

FIG. 2.

be within reach of permanent ground waters than on the flat. Silt-pitting causes much greater quantities of water to percolate naturally into the soil of a hillside. In this way the trees not only get a more adequate moisture supply, but they may get a more extended root range which is of the greatest value. This is analogous to the beneficial effects of drainage on flat land. Although in the one case we are draining water into the soil while in the other case we are draining it out, yet the effect of water movement and consequent aeration is the same in replacing stagnant conditions with healthy ones. It is sometimes assumed that aeration is effected merely because a hole is dug and the soil exposed to the air, but this is by no means the important aspect of the case. Indeed, it is important to remember that added exposure means added evaporation, which has its disadvantages under certain circumstances.

In making the calculations necessary for scheming a system of silt-pitting the most difficult point to deal with is to decide what quantity of excess rain is normally to be dealt with. The term normally is used because it is probably impossible or at least uneconomic to devise the system to meet the very exceptional cases of excessive and continuous rain.

The pits must have a capacity to hold the excess water of a normal rain with an additional reserve to cover the contingency of further rain falling before the pits have had time to empty. The last factor becomes so great on some heavy soils owing to the extreme slowness of percolation, that it sets a very serious limit to the utility of pits on such sites. Thus we require data both as regards rainfall and as regards soil permeability before we have a basis for laying down a sound scheme. One method of roughly examining the data is shown in Fig. 2. Along a line divided into intervals to represent days blocked in, columns are erected of heights to correspond to each days rain. The case shown is the most rainy period during a year's records at Kuala Lumpur. For the purpose of the examination we will suppose that it is proposed to dig pits to have a capacity of 2½ inches rain, which would correspond to a system of pits 24″ x 24″ section placed continuously on contours about 19 ft. apart. We will further suppose that percolation out of the pits is at the rate of 1″ per day, so that full pits would take 2½ days to empty. Most soils on hill sites would take less time than this, but it must be remembered that the rate will fluctuate greatly according to the degree of soil and subsoil saturation. Imagine now that the height of the columns represents the degree to which the pits are filled each day. Starting at the first day we allow a small proportion of rain taken up by the soil and draw a sloping line at the requisite angle to show the rate at which the pit will empty. The amount cut off by this line on the next column may be taken as the amount of water left in the pit when the second day's rain falls and the column is extended by this amount. This procedure is carried on, so giving a rough idea of the state of the pits at any time during the rainy period. When the extended column rises higher than 2½ inches this indicates overflow and consequent damage due to inadequacy of pits. It will be seen that this occurs on the second day and the three subsequent days, the total wash corresponding to about 2 inches of rain. It is easily seen, however, that if the pit capacity were increased to 3 inches the wash would be stopped. It would also be considerably reduced if the percolation rate into the soil could be taken as more rapid. By means of such diagrams based on their own material estates may usefully examine the adequacy of any proposed scheme. The records for a complete year at Kuala Lumpur were examined in the way described and there were four occasions when the conditions assumed would have proved inadequate and led to overflow. Three of these would have been prevented by an increase of capacity from 2½″ to 3″ of rain, but the fourth would have required pits of 4″ capacity. *It should not be difficult to judge the point at which* the risk of overflow is so small that it is economic to neglect it.

The calculation of capacity is very easily made on a cross-sectional basis if the pits are placed continuously on the contour. By way of example it is easy to see that a pit 2′ wide by 1½′ deep will have a cross section equal to that of 2″ of rain over 18 ft. of ground (432 sq. inches in each case). Hence continuous lines of pits of those dimensions placed at 18 ft. intervals would hold up 2″ of excess rain. It is easy to adapt the calculation to the planting distances and other factors affecting a particular case. On the same basis the capacity of a terrace may be estimated in terms of its width and inward slope, remembering that in this case the cross section is triangular instead of rectangular. When the line of pits *is not continuous the calculations must* be based *upon* cubic contents. As already stated a distinct limit is set to the usefulness of silt-pitting if the pits do not empty themselves by natural percolation in a reasonable length of time. Fortunately it is unusual to find heavy impervious soils on the hill sites which stand most in need of silt-pitting. Under ordinary circumstances pits should drain clear in two or three days. If they do not normally dry up between one period of rain and the next the sodden conditions themselves produce an impervious state. For the action of the surface soil of the pit is that of a filter and its pores tend to become clogged with a fine slime extracted from the water. This clogged state of the lining of the pit will become permanent unless intervening dry conditions occur. The advantage of dry conditions is that this lining shrinks and cracks and this helps very much to keep the pit functioning properly.

Apart from the uselessness of water lying stagnating in the pits there is the positive objection on health grounds of providing such breeding places for mosquitoes. It is clear that a pit which is always half-full of water has no distinct advantage over one that is half full of soil, so that it can be laid down that, at any rate in areas where health considerations are important, sluggish silt pits should be filled in until their capacity is such that they empty themselves in a safe period and modified methods adopted. The safe period from this point of view might be set at a week. Hard and fast rules are hard to lay down because of the varied distribution of the rainfall, but the man on the spot can easily judge from frequent observation how far his pits are proving a health menace and deal with them accordingly. The type of diagram already discussed can be used to examine the periods during which the pits are never empty and the possibility noted of these being longer than the safe period. During the year examined the analysis indicated two periods only during which pits would hold standing water for longer periods than a week and these were very little in excess. During very wet periods water lies about under any conditions, so that the pits do not constitute a new problem though they may much aggravate an old one. Oiling may be resorted to if necessary, but this does not constitute a full solution for the whole problem owing to the great number of pits and the big chance of overlooking some of them. Vigilance is the first requirement, and it may call to its aid both oiling and the partial filling in of pits.

While on the subject of health there is another aspect of the matter which has been raised. The increased percolation into the hill sides produced by silt pitting may cause unexpected seepage at the base, and so provide new breeding places for mosquitoes. Since forewarned is forearmed, this need be no menace if provided for by drainage. It may simply be looked upon as a possible slight increase in the total cost of carrying out the complete scheme. Seepage appearing sporadically in the neighbourhood of particular pits is in the same class as pits which retain water too long.

The next point which comes up for consideration is that of pit maintenance. Where the work of the pits is strongly reinforced by a ground cover the question is not urgent, but it becomes so in many cases where the system must be regarded as permanent.

It has already been emphasised that a properly devised system should not silt up quickly, but the action is not always entirely avoidable. The advice has often been given to let one system of pits fill up and then cut others in fresh situations. The main reason for this seems to be to avoid disturbing the feeding roots which come to the old pit on account of the richer, moister and better aerated soil conditions there. I cannot find myself in agreement with this course of action in rubber. The two main objections are, first, that a considerable period of inefficiency must intervene when the old system is disappearing and the new system is not yet dug and, second, that by the time that several new sites have been dug over a severe breaking up of the main root system of the trees must be effected. A regular plan of cleaning pits, on the other hand, maintains them at their best and involves only a disturbance of young feeding rootlets. It also tends to obviate that clogging up of the pit already referred to. The decaying material which is apt to collect at the bottom of a pit is not lost as food for the tree just because it is removed and spread on the surface.

Probably the most debated point of any that comes within my province is the question as to which side of a silt pit the spoil should be placed. A bund immediately above a pit stops the surface water from finding its way in naturally, while when the bund is placed below it reinforces the pit both as to strength and capacity. Hence the common practice of placing the bund below has common sense to commend it. But there are further points to be considered. It is equally good sense to contend that, since silt pitting has as its main object the combating of the natural tendency of the soil to reach the bottom of the slope, the spoil should therefore be thrown out up the slope. This applies particularly to the spoil obtained from cleaning. But the main advantage which advocates of this method have in view is that of using the bund itself to form a water catchment. Indeed some people so emphasise this aspect as to look upon the pit merely as the best means of winning the soil to form a bund. This is in the generality of cases an exaggerated view to take. A bund holds up the water in a large shallow puddle. This certainly gives the maximum surface for the water to drain into the soil and to that extent disposes of it quickly and naturally. When the soil is pervious enough to do this there can be no objection. But it must be very strongly emphasised that on the heavier types of soil when the puddles stand about for some time they produce a very deleterious effect on the physical conditions of the soil surface. The ideal to aim at is to utilise both bund and pit to their fullest extent, which means that they must be separated in some way or another. That seems to be the central fact of the case with its accompanying increase in the expense. There are many ways of planning the utilisation of the spoil in the form of a separate bund. The best way is a continuous bund on the contour between the rows of pits, or where this is not possible separate portions may be given a horse-shoe form, the ends carried up and away from the pit below. In all cases everything must be done to avoid standing puddles round the base of the trees.

The secondary advantage of placing the bund on the upward side of the pit is that on steeper slopes an ultimate terrace formation may be attained, or it may aid when a combination of pit and terraces is being cut*. Such cases require considerable care in consolidating the bund against attrition and may depend for success on direct methods of consolidation. Such cases are in a class to be considered on their individual merits, since any method which begins with one form with the intention of evolving into another brings in too many local factors for successful generalising.

Many different forms can be devised for the cutting of silt-pits, each of which may have its special advantages. No doubt the narrow ditch form along a contour is the best. But owing to the fact that pitting is always done in separated sections, there is a very large number of ways in which they may be disposed. Where planting is not on the contour and pits are dug between each group of trees, there is a natural tendency to an echelon formation such as is required to break up surface flow. The narrow pit gives the larger surface for percolation and also the least possibility of losses by evaporation. The depth of the pit is quite a local matter, depending upon subsoil permeability. Frequently a much less pervious condition of soil exists at the depth of 18″ or 24″, and there is not much advantage to be gained by cutting into this. If in special cases there is prospect of cutting through a stiff layer into a more pervious sub-stratum, this should be favourably considered.

The combination of some form of modified silt pit in conjunction with terracing on the steeper slopes has much to commend it. Terrace maintenance is improved and the functioning simplified, by shallow pits dug at the back, the spoil from which is dragged forward and spread on the edge. In this case surface water reaches the pit from both sides, since the terrace slopes inward. The capacity of the terrace to hold water is much increased in this way, and the tendency for water to lie in puddles is also diminished.

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*Compare the combination described by R. P. Hunter in "The Planter" for September 1928.

The main features which emerge from these considerations may be summed up as follows:

1. In the first place a low-growing ground cover must be looked upon as the main line of defence in regard to soil erosion. It protects the soil from direct impact of the rain as nothing else can do; increases the absorptive capacity of the soil while at the same time binding it together; and maintains healthy conditions in the soil surface.

2. Silt-pitting may be very useful in conjunction with a cover, in which case it may be either temporary or permanent and only in the last resort should it stand alone as the sole means of protection.

3. Unless the silt-pitting system is definitely intended only as a temporary measure it is best to maintain the original system by periodic cleaning.

4. Since it is very problematical whether a pit which retains water for a period of many days has any advantages, it is advisable for health reasons to fill up such pits till their capacity is reduced to the required extent.

5. Simple bunding at the side of the pit is best done on the downward side in most cases: but where the bund can be moved away from the pit a variety of improved arrangements can be made to utilise the catchment value of the bund.