EXAMINATION OF SOILS AND CROPS AFTER THE INUNDATIONS OF 1st FEBRUARY, 1953 [1])

III. SENSITIVITY TO SALT OF INUNDATED FRUIT CROPS

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Summary and conclusions

The following conclusions on the subject can be drawn from the information given in the literature and the results of the investigation.

1. Assessment of the relative sensitivity to salt of species of fruit resulted in a sequence (Table 3) which largely corresponds with that of Dorsman and Wattel (1951). Only the small fruit crops required to be classified as rather more sensitive than the above authorities had considered them to be. On the whole, the sequence of salt sensitivity described by American investigators also agrees with the arrangement arrived at here, in so far as the species concerned are common to the different studies.

2. Owing to the great variability in the damage picture, it is only possible to study the sensitivity of apple and pear varieties by comparing them on a broad scale. Just as in the case of comparing species of fruit, it is easy for investigators to reach incorrect conclusions if they allow themselves to be influenced by incidental observations. A distinct difference in sensitivity between the varieties has been ascertained (Tables 4 and 5; Figs. 1 and 2). This difference in sensitivity cannot account for differences in the condition of the principal varieties under various environmental conditions.

3. Comparison of the sensitivity to salt of apple rootstocks shows that, contrary to the assertion of Dorsman and Wattel (1951), this sensitivity does not run parallel with growth vigour. Just as was the case with the fruit varieties, the difference in sensitivity to salt is due, in the first place, to variations in the genotype. The depth of the root system – which is also determined by many properties of the soil – can, however, certainly play a part, the nature of which is determined by the environmental conditions. A superficial root system means, not only quicker admission of air, but also that the roots all lie in what were initially the saltest layers of soil.

4. The deterioration in the condition of apples and pears during the growing season is shown in Fig. 3. The fact that the pear is much less sensitive than the apple can be seen not only from the fact that its curve lies higher than that of the apple, but also from the slope of the lines.

5. The salt content of the soil moisture is far and away the most important determining factor in the case of apple and pear (Figs. 4 and 5). Under flood conditions commencing on 1st February, a salt content of the soil of 7–8 for apples, and 11–12 for pears, in the end of June 1953, must be regarded as the limit beyond which, in general, it will be impossible to save the trees for cultivation. In this connection, it is necessary that the trees should be well cared for after the flood, and that no exceptionally bad circumstances should be encountered.

6. The influence of duration of flooding only makes itself felt on apple and pear after 8 or 9 weeks (for pear see Fig. 6).

7. The age of apple and pear trees has been found to have no clearly discernible influence. Apple trees 25 years old and more would seem, judging by practical experience, to possess less power of resistance. But the care previously bestowed on the crop also has an effect here.

8. The height of the flood water does not affect the stand of unpruned apples and pears. As a rule, unpruned trees exhibit a better condition than pruned trees, although this does not appear from the data collected. Incidental observations make it reasonable to suppose that deep tillage before flooding, exhaustion ("sickness") of the soil, and general lack of care and attention, have a detrimental effect on the condition of the trees.

9. In various cases, it has been proved that effective cultivation measures may save an orchard, under certain circumstances. The chance of saving the trees is especially great

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where "borderline cases" are concerned. In carrying out such measures, the fruit grower must try not to lose heart.

10. If we compare the results of this investigation with the data in the literature of the subject from regions which are more or less permanently salt, it will be seen that fruit crops can tolerate more salt after inundation than results from constantly salt regions would indicate. This renders very feasible the supposition that low concentrations of salt have a cumulative effect in the course of years.

11. It is highly probable that, under other circumstances, relations between the condition of the trees and the environmental factors will be modified. Results are especially liable to differ from the above in cases in which flooding takes place later than the beginning of February.

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CONTENTS

1. Introduction

As a result of high tides on 1st February, 1953, many polders were flooded in the southwestern Netherlands. The havoc was especially great in Zeeland, the islands of South Holland, and the western part of North Brabant. At first it was only possible to conjecture the extent to which fruit cultivation in these regions had been affected by the disaster, owing to the fact that not enough data were available concerning the sensitivity of fruit crops to inundation by water with varying contents of salt.

The lack of such data was keenly felt by the Dutch Rijkstuinbouwvoorlichtingsdienst (Government Horticultural Advisory Service). The latter had the task of determining at short notice which orchards and plantations of small fruits had to be given up for lost, and which could still be expected to yield a crop worth the grower's while. In this connection the orchards which presented the greatest difficulties were those whose reaction to flooding was not immediately apparent. In these cases the Advisory Service took the view that an orchard forms a homogeneous unit in a farm, so that damage observed in one part of it, if serious enough, was in itself sufficient to warrant writing off the whole orchard. The greatest problem, however, consisted in ascertaining the extent of the damage and the prospects of recovery, in which connection the following circumstances played a part:

1 Experiences after the inundations during World War II had been generally disappointing, and consequently many people were inclined to be pessimistic this time as well.
2 In many instances the poisoning process suffered by the fruit trees took its course very slowly at first – a fact which tended to cause errors in judging the condition of the plants.
3 The time course of the condition of fruit crops depends on a combination of factors, each of which may vary more or less considerably. The effect of many of these factors on the condition of the crops was insufficiently known, and so the causal connection between the above-mentioned factors was very often imperfectly understood. Furthermore, the mutual interaction of the factors made it especially difficult to obtain a clear understanding of concrete cases.

A second task of the Government Horticultural Advisory Service was the provision of advice regarding effective cultivation operations for the purpose of limiting damage in fruit plantations to a minimum. Various instances have proved that such measures can be of great importance. Good advice in this sphere may produce admirable results, the more so because the psychological attitude of the fruit grower has a great influence on the care he bestows on his flooded property.

These problems led to the initiation in 1953 of an investigation into the sensitivity of fruit crops to salt.

2. Review of the literature

2.1. *Fruit-growing in regions naturally salt or rendered salt by irrigation*

Both in the Netherlands and in other countries, examples are known of symptoms of poisoning in fruit as a result of salts in the soil. The salts may be present for one of two reasons:

2.1.1. The salts are deposited in situ during formation of the soil. In the Netherlands, in some places in the province of Zeeland, salt ground water is encountered at a shallow depth in the profile, which ground water, owing to the presence of a high water table, has never been washed out. Butijn (1954) has said in a recent article, that in these cases the growth of apples will certainly be adversely affected in dry years when the salt index in the root zone rises to a value higher than 2. Pears are much less sensitive to salt, and can tolerate salt concentrations of as high as 7. Butijn was struck by the fact that chlorine poisoning was most serious in the driest and warmest years. In cool, wet summers, it is possible for crops to tolerate higher salt indexes than those which cause symptoms of poisoning in dry, warm years. (The salt index is the number of grams of salt, calculated as NaCl, per litre of soil moisture).

2.1.2. In arid climates, salts remain behind in the top layers of soil, owing to the upward movement of water in the soil. Unless the supply of water by irrigation exceeds the loss of water by evaporation from soil and plants, the salts present in the irrigation water only help to increase the content of salt in the soil. In glasshouses a similar process often takes place (Slits, 1945).

A great deal of attention has been paid to this salinization problem in the U.S.A. There, agriculture is concerned with salinization by chlorides, sulphates, and carbonates. We shall confine our attention to the first of these. LOUGHRIDGE (1901) investigated the resistance of fruit trees to salt, and expressed his results in terms of the greatest quantity of salt to which the plant can be exposed without being affected by it. Details of those crops which are of importance to us are given in Table 1.

Table 1. Greatest amount of chlorides in the presence of which fruit trees remain unaffected (after LOUGHRIDGE).

1 Species	2 Kg/ha	3 % of weight in dry soil	1 Species	2 Kg/ha	3 % of weight in dry soil
Grape	10845	0.06025	Prune	1350	0.00750
Almond	2700	0.01500	Peach	1125	0.00625
Mulberry	2520	0.01400	Apricot	1080	0.00600
Pear	1530	0.00837	Fig	900	0.00500
Apple	1395	0.00775			

The Figures in columns 2 and 3 have been calculated in respect of the 0–1.20 m layer of soil.

In view of the fact that salt accumulates in the top layers of the soil, these figures must not be regarded as a measure of the highest permissible quantities of salt. The table does, however, give an impression of the relative resistance of the individual crops.

KEARNEY and SCOFIELD (1936) state that pears and figs are fairly resistant to salt, as far as the growth of the trees is concerned. The quality of the fruit, however, begins to decline as soon as more than very small quantities of salts are present in the soil. Stone fruits are all sensitive to salt; European grapes (Vitis vinifera) can generally produce fruit of good quality.

In contrast to their predecessors, MAGISTAD and CHRISTIANSEN (1944) based their calculations on the concentration of the soil solution. In their opinion, apples and pears are sensitive and will not grow well in soils containing more than 2,000 parts per million of salts. (2,000 parts per million correspond to a C index of 2). HAYWARD, LONG and UHVITS (1946) instituted extensive investigations into the influence of chlorides and sulphates on the growth and yield of peaches in sand cultures. They found that the total salt concentration in the nutrients solution is an important factor in growth of the crop. Irrespective of the chemical composition of the salt, increase of the salt concentration in the nutrients solution will cause a decline in growth, or even death, when the osmotic value of the solution exceeds 3 at. (= salt index of approximately 4). Furthermore, the effect of salt substrata may be cumulative, and, over a period of years, even lower concentrations may result in a slow, but steadily increasing, decline in the growth and yield of the trees.

As regards peaches, this can be the case with a salt index as low as approximately 2. The influence of the salt is also dependent on chemical composition. Thus, under conditions of equal osmotic pressure on the part of the soil solution, chlorides proved to be more toxic than sulphates.

In conclusion, HAYWARD and WADLEIGH (1949) and RICHARDS (1954) published studies summarizing the literature on the growth of agricultural and horticultural crops on salt soils. Most of the above-mentioned American results are quoted in this.

2.2. *Fruit-growing after inundation by salt water*

Reports describing horticultural experiences in connection with flood conditions in the Netherlands in the twentieth century pay more and more attention to the behaviour of fruit crops. In the case of floods in Zeeland in March, 1906 (ANONYMOUS, 1916), it was observed that stone fruits are more sensitive than are pomes. As regards the last-mentioned group, it was found that apples are more easily affected than pears. NOBEL (1921), who described the reactions of horticultural crops after the floods of January, 1916, in North Holland, reached the same conclusion, and added the following information:

1 In general, young apple trees stood the floods better than the older trees. This was attributed to the shallow root system of the young trees.
2 Peaches, plums, cherries, medlars, walnuts and hazelnuts were more sensitive than apples, and nearly all died. The cherry plum, used as rootstock for peaches, proved to be stronger than the scions themselves.
3 Grapes, figs and apricots exhibited fairly good resistance to the effects of inundation.
4 Gooseberries and raspberries almost all died. Black currants and red currants were stronger than gooseberries. Red currants were more sensitive than black currants.

During World War II various polders in the Netherlands were inundated with water of varying salt content. BURGMANS (1945) was the first to make remarks and observations regarding the damage done by this. Later on, a more detailed report was published by DORSMAN and WATTEL (1951). The latter writers describe the symptoms of poisoning on the leaves and branches of fruit crops, and then go on to discuss the factors influencing the occurrence of these symptoms. Finally, they report some results of replanting soil not entirely freed from salt. We shall give a summary of these results.

The symptoms of poisoning described correspond exactly with those observed in 1953; accordingly, reference may be made to the descriptions given under 4.1.

DORSMAN and WATTEL distinguish nine factors which affect the general damage done. We can best divide these nine into environmental factors and factors concerning the fruit itself.

The Fruit

The species. The individual species of fruit exhibit great differences as regards sensitivity to inundation with salt water. The present writer has given an idea of this in Table 2 by allotting the figure 100 to the most sensitive species, and the figure 0 to the least sensitive species.

Table 2. Sensitivity of fruit crops to inundation with salt water. 100 = the most sensitive, 0 = insensitive.

Gooseberry	100	Red currant (Fay's Prolific)	60
Peach, sweet and sour cherries	95	Black currant	40
Raspberry, blackberry	90	Pear	20
Plum	85–90	Mulberry and vineyard grape	10
Red currant (Duitse Zure)	80	(Tamarisk)	(0)
Apple	75		

In the case of casualties to the most sensitive species, asphyxiation of the roots also plays an important part. Gooseberry, cherry, peach and plum, in particular, are very liable to suffer from this. In other species, the salt content is more important. The two factors are difficult to separate.

The variety. Differences in sensitivity between varieties have been ascertained in the case of many species of fruit (apple, pear, plum and red currant). It was, however, difficult to establish these with any certainty, because it is possible for the behaviour of specific trees to be strongly modified by apparently insignificant differences in environment.

Of the apple varieties, Transparente de Croncels and Cox's Orange Pippin, in particular, seemed to be highly sensitive, while Manks Codlin appeared to be rather more resistant. As regards pears, some varieties were distinctly stronger than the others, i.e., Clapp's Favourite, Précoce de Trévoux, Conference, Noord-Hollandse Suikerpeer, and probably Beurré Alexandre Lucas as well. Of the plums, Reine Claude Verte was found to be one of the strongest; Victoria, on the other hand, was very weak. The red currant variety Duitse Zure was markedly more sensitive than Fay's Prolific.

The rootstock. Trees on vigorous rootstocks managed to last longest. By comparison with other plum stocks, Myrobalan B proved to be especially strong. In places where the soil remained sodden for a long time, the reaction was exactly the opposite: there, the trees on weak stocks – which therefore possessed a superficial root system – remained alive longer.

DORSMAN and WATTEL sought the explanation for this in the fact that the superficial roots were less quickly killed by asphyxiation. Furthermore, they considered that the rain water was capable of reducing substantially the salt concentration in the top layers of soil in the marshy fields and orchards.

Age. Younger trees had a greater capacity for resistance than older trees – likewise owing to the difference in depth of the root system.

Environmental factors

The time of occurrence of the flood. A flood in the autumn (1944) proved to have a worse effect on the fruit crops than a flood in spring (1940), of the same duration and by water with the same content of salt.

Duration of the flooding. Plums, apples and pears are capable of surviving a flood in the spring lasting one month. In general, a flood lasting from six weeks to two months will result in the death of all fruit trees, with the exception of some varieties of pear.

The height of the flood water. The height of the flood water above the surface of the ground had no appreciable influence on the effect of the flooding. On the other hand, a difference was clearly noticeable between the effect of complete inundation and of flooding to a point just sufficient to render the soil waterlogged. In the latter case, the trees with a superficial root system – i.e., young trees and trees bred on weak stocks – proved to be more resistant than deeply rooting trees.

The salt content of the flood water. The water need not necessarily possess a high content of salt in order to kill fruit crops. Even when the salt content is low, the trees may ultimately die of asphyxiation anyway if the inundation lasts a long time.

The soil profile. The more permeable the profile is, the quicker drainage and salinization of deeper soil layers take place. The presence of beds of heavy clay can seriously hinder the movement of water.

According to DORSMAN and WATTEL, practical experience with newly planted trees in the years 1946 and 1947 (after the inundation) can be summarized as follows.

1. After desalting for one winter, well drained soil profiles can be planted without difficulty. Even in very dry summers the rise of the salt is not such as to cause damage to the trees. In cool years with an abundance of rain,

apples, pears and plums can tolerate a salt content of 7 g per litre of soil moisture in the 20–50 cm layer.

2. All measures should be taken to render growing conditions for the fruit trees as favourable as possible:

The trees should be carefully planted and not pruned until one year after planting.

Deterioration of soil structure should be prevented as far as possible by supply of gypsum, shallow cultivation, correct choice of intercrop, quick removal of superfluous rain water, and protection of the soil against drought, for example by application of organic fertilizer round the trees and by watering.

Protection of the plantation against wind by an effective windbreak is essential, especially in treeless flooded areas. It is also necessary to tie the trees firmly to stakes, especially apples on M type IX. Small fruit, especially black currant, is also sensitive to wind.

It is not considered advisable to plant gooseberries before the structure of the soil has recovered.

2.3. *Physiological consequences of inundation for the plant*

In a study of the influence of assimilated salts on the growth and production of field crops in flooded soils, VAN DEN BERG (1952) reaches the conclusion that it is not possible to give a generally applicable reply to the question as to what physiological factor plays the greatest part in causing symptoms of poisoning in crops on salt substrata. Chemical examination of various field crops gave strong grounds for assuming that the following factors are in general responsible for the disturbance in metabolism.

1 Deficiency of water in the plant, owing to high osmotic pressure in the soil.
2 Accumulation of salts in the plant.
3 Disturbed (cat-)ion balance in the plant.
4 Deficiency of a particular ion in the plant.

The properties of the plant determine which factor is of greatest importance. Furthermore, the factors can never be entirely separated from each other, so that quantitative assessment of the share of each of them in the physiological process of a plant is sure to come up against great difficulties.

2.4. *Summary*

Conformity exists between the results obtained by Dutch and American investigators concerning the sensitivity to salt of fruit trees in regions which have been salt for years. In general, they are agreed that, as regards apples, the salt content of the soil moisture must not exceed 2. In America, it has been found impossible to grow peaches without ill effects even at this limit. No agreement has been reached as to the sensitivity of pears. In America, these appear to be as sensitive as apples; but BUTIJN (1954) considered that pears could tolerate a salt concentration of as high as 7.

An observation of importance is that the presence of low concentrations of salt has a cumulative effect, over a number of years, on the decline in growth and yield of the peach. Accordingly, when salt is temporarily present in the soil, as is the case after floods, fruit crops will probably be able to tolerate more salt than observations in permanently salt areas would lead one to suppose. The reaction of fruit crops after inundation with salt water, the factors affecting symptoms of poisoning, and the conditions necessary for replanting, have been described in most detail by DORSMAN and WATTEL (1951). Their results are, however, based too much on incidental observations to guarantee general validity. Nevertheless, in themselves they provide valuable indications of the direction research should take.

Lastly, VAN DEN BERG (1952) gives an impression of the complicated nature of the influence of a salt environment on the physiological process in the plant by stating what physiological factors may upset the balance of its metabolism.

3. METHOD OF INVESTIGATION

The sensitivity of fruit crops to inundation with salt water was investigated in two ways.

By the first method – according to which purely relative values were obtained – the relative sensitivity of species of fruit, and of certain varieties of apple and pear in comparison with each other, was examined. As regards the fruit species, it was possible to apply the method by replicate comparison in small plots of ground as much like each other as possible. In classifying the apple and pear varieties according to sensitivity to salt, use was made of the estimates of damage by salt which were made for the purpose of applying the second method. In this connection, reactions to differences in environmental conditions were not investigated (see 4.2., 4.3. and 4.4.).

The object of the second method was to correlate the condition of the fruit crops with the main environmental conditions which had arisen as a result of the inundation. The type of investigation carried out was the survey type with records being collected of many factors on a number of sites. The advantage of this is that it enables an idea to be obtained within a short time of the effect of the factors influencing the crop. A disadvantage of it is that influences may be present which the method of investigation does not take into account.

The latter method is so extensive that it was necessary this time to restrict it to apple and pear. In the course of 1953 83 sampling plots were prepared, the size of which varied from about 10 to 60 ares. Of these, 42 plots with apples, and 33 with pears were suitable for including in the analysis. The symptoms of damage by salt were assessed between 1 and 5 times per tree, and expressed in a "growing condition index". For this purpose, a scale of values ranging from 0 to 10 was used. The significance of some of the indexes is given below.

10 = no symptoms of damage by salt; growth normal,
7 = moderate damage by salt; growth distinctly subnormal,
5 = serious damage by salt; growth poor, here and there a dead branch,
3 = very serious damage by salt; growth very poor, fairly large number of dead branches,
0 = quite dead.

The mean growing condition index for the varieties and species was calculated in respect of each sampling plot.

Correlation of the investigation of influential factors with the results of DORSMAN and WATTEL (1951) was obviously indicated. The following factors were therefore determined per sampling plot:

1 Salt content of the soil moisture (salt index) in the 5–40 cm layer.
2 Salt content of the soil moisture (salt index) in the 40–80 cm layer.
3 Duration of the flood.
4 Maximum height of the flood water.
5 Age of the trees.

The salt content of the soil samples was measured in the manner mentioned by VAN BEEKOM et al. (1953). The salt content of the flood water was not considered in the investigation, because it is reflected in the salt content of the soil moisture and in the duration of flooding. It was no less than 15 parts per thousant, and consequently varied too little as well. The survey is discussed in 4.5.

4. RESULTS OF THE INVESTIGATION

4.1. *The damage picture*

Just as was observed in previous inundations, the overground parts of the fruit crops exhibited specific characteristic symptoms.

4.1.1. Apple and pear. Buds came out rather later than usual, except in cases in which the flood lasted only a few days. When pear tree branches had hung in the water for a long time, the buds often remained partially static in all stages of development. The leaflets and flower buds went brown, and symptoms of decay appeared. It must be assumed that it was possible for the salt water to penetrate into some of the buds, and thus exert a destructive effect on the young tissues. In the spring, it was frequently possible, by reference to the quantity of undeveloped buds, to ascertain the height reached by the water, and sometimes even the difference in height of the tides. In this case, ice formation on the water might also have been the cause of the behaviour of the buds.

When damage due to salt was moderate, the shoots were not shorter, or not *much* shorter, than usual. In view of the fact that few if any of the buds failed to open, the amount of foliage on the trees was also approximately normal. Parts of branches died off only in the immediate vicinity of wounds into which flood water had penetrated: the bark loosened, and the cambium layer exhibited symptoms of decay. The leaves showed the first signs of poisoning in the neighbourhood of these wounds: chlorosis (in pears more than in apples), sometimes an abnormally dark green colour (especially as regards apples), and frequently a reddish brown to blackish brown discoloration of the edges, generally starting at the tip of the leaf. In the case of the apple this discoloration of the edges of the leaves was reddish brown (Belle de Boskoop, Manks Codlin, Golden Delicious) to brown, and, in the case of the pear, blackish brown to dark silver grey (the latter sometimes in Bonne Louise d'Avranches). The greater the damage done by salt, the broader was this dark, sharply defined, frequently necrotic edge, and so, in the long run, it was possible for the whole leaf to turn brown to black. On warm days, many such leaves fell off. On these occasions, pears often shed green leaves as well.

Serious damage by salt manifested itself in scanty growth of shoots, which might even remain absent altogether, and in death of the branches, starting from the tips. Under these conditions, the bark acquired a curious reddish brown to silver grey colour, and came loose. In the vicinity of wounds, these symptoms of necrosis soon increased to a formidable extent.

Blossoming and the formation of fruit were hardly affected by floods of short duration. At the worst, the fruit remained a little smaller than usual. When damage by salt was serious, pears hung on the trees longer than did apples. On the whole, the fruit remained small, was shrivelled and tough, and had an abnormal taste owing to lack of aroma.

In serious cases, the taste was slightly salty. Sometimes small red patches appeared on the skin of apples, resembling a spot disease, and gave them an unsightly appearance.

During the ripening period of apples and pears, the brown discoloration of the edges of the leaves, and the shedding of the leaves, sometimes increased considerably. These phenomena were even more in evidence in the case of other fruit crops.

4.1.2. Plum. In the case of the plum, chlorosis was not so prevalent (it was prevalent, however, in cherry plums). As a rule, the leaf was dark green in colour, so that the brown discoloration at the edges was less conspicuous. Occasionally, the leaves were also somewhat leathery. The symptoms of poisoning usually increased greatly towards the ripening time, and consequently the trees soon became almost entirely leafless, and carried nothing but the fruit.

The growth condition of the tree was found to be closely correlatable with the taste of the fruits. Trees, and even single branches, on which almost all the leaves still hung, bore fruit which tasted fairly good. The flavour of fruit from trees from which the leaves had all, or nearly all, fallen when it was picked was, as a rule, bad; aroma was lacking, and the fruit had a salty to bitter aftertaste.

4.1.3. Cherry. In the present case cherry orchards were only found in districts which had been under water for no more than two or three weeks. At first, the condition of the trees was good when the buds opened. Very soon, however, a very narrow strip round the edges of the leaves turned reddish brown to purple, commencing on the southwest side of the tree. This discoloration spread rapidly over the whole tree, and over the entire leaf, especially towards the time at which the fruit became ripe. In serious cases, the trees were entirely leafless when the ripening period came, just as had been observed in the case of plums.

The taste of the fruit was correlated with the condition of the trees in the same manner as with plums. Fruit which tasted good, was however, seldom found. Little aroma was present in fruit even from trees on which the condition of the foliage was still reasonable. In serious cases the taste was salty to bitter. Sour cherries shed their leaves quickly, sometimes before they exhibited any brown edges whatever. The fruit remained hanging a long time; its flavour was bad. Trees of the variety Klerk retained their leaves for a long while, generally even when they had become quite brown. All flooded cherry orchards had to be grubbed, owing to the very serious damage done by the salt.

4.1.4. Black, red and white currant. The symptoms of poisoning in these fruit crops also consisted in the development of brown edges round the leaves. The discoloration was, however, not so sharply defined as in the case of the species previously discussed. Chlorosis did not occur.

The black currant retained its leaves for a long time, even in examples of serious salt poisoning, in which some of the buds failed to come out, and the tips of the shoots died off.

The red and white currant shed their leaves earlier than the black, while the leaves also became entirely brown earlier. Defoliation frequently took place before or during the ripening of the fruit. The fruit remained hanging normally, but was withered in many cases. Leafless bushes bore ill-tasting fruit – no aroma, watery to salt flavour.

4.1.5. Gooseberry. The damage done by salt to gooseberries was grave in nearly every case. The leaves were small, thick, leathery, and dark green in colour. Chlorosis did not occur. In many instances no shoots were formed. Parts of the bushes usually died off. The fruit was small, sometimes ill-tasting.

4.1.6. Walnut. Here, too, the brown edges to the leaves were first visible on the southwest side of the tree. The leaflets generally dropped off one by one, so that, in many places on the tree, only the leaf stalks were left. In localities where the flood lasted a long time, few or no leaves developed.

4.1.7. Grape and mulberry. Only a few examples of outdoor grapes were present in the flooded region. In serious cases greenhouse grapes produced few shoots, and the leaves soon developed brown edges and fell off. Damage by salt was most in evidence on the sunny side of greenhouses.

The mulberry proved to be very insensitive. No damage to the leaves by salt was found. When flooding lasted for a very long time the trees died, probably owing to asphyxiation of the roots.

In general, the fruit crops showed symptoms of drying out, indicative of an incapacity to assimilate enough water. In the spring, the buds and cambium were drier than was normal. Furthermore, wrinkled bark was frequently observed. The leaves were usually dry, sometimes leathery. Except in serious cases, the fruit was sufficiently juicy which indicates that it has a strong capacity for drawing the water to itself.

It is remarkable that damage by salt strongly resembles potassium deficiency as regards its effect on the leaves. This makes it reasonable to suppose that the cation balance in the plant is disturbed too (see 2.3.).

4.2. *Comparison of the species of fruit*

It was found impracticable to carry out a more accurate assessment of the sensitivity to salt of the fruit species in relation to each other than had been carried out by Dorsman and Wattel (1951). By comparing the condition of species of fruit growing close to each other, it was possible to allot to each species an evaluation figure in a centesimal scale, according to which the most sensitive species was given the figure 100, and the figure 0 stood for "completely salt-tolerant" (Table 3). The data of Dorsman and Wattel have also been included in Table 3, for purposes of comparison.

The order of species in both series roughly agrees. The small fruits blackberry, raspberry, red and black currant are now classified as rather more sensitive. Peaches seemed rather stronger in the 1953 results, as also did mulberries compared with outdoor grapes. Little evidence was available, however,

Table 3. Sensitivity of fruit species to inundation by salt water.
100 = most sensitive 0 = insensitive

According to DORSMAN and WATTEL (1951)		According to the 1953 investigation	
Gooseberry	100	Blackberry	100
Sweet cherry	95	Raspberry	95
Peach	95	Gooseberry	90
Sour cherry	95	Red currant	85
Raspberry	90	Sweet cherry	85
Blackberry	90	Sour cherry	80
Plum	85–90	Walnut	70–75
Red currant (Duitse Zure)	80	Peach	70–75
Apple	75	Plum	70–75
Red currant (Fay's Prolific)	60	Black currant	65–70
Black currant	40	Apple	55–65
Pear	20	Pear	25–30
Outdoor grape	10	Outdoor grape	20
Mulberry	10	Mulberry	5

regarding peaches and outdoor grapes, and the above figures are therefore given with due reservations.

In this table, it is the *order* of sensitivity which is of greatest importance. The evaluation figures as such are not unaffected by the subjectivity of judgment of the investigators. They serve only to give concrete expression to the order of sensitivity.

4.3. *Comparison of varieties of apple and pear*

The fact has already repeatedly been established that the individual varieties of a crop plant react to flooding in differing degrees. Within the context of the 1953 investigation it was possible to investigate these differences further, as regards apple and pear, by means of the sampling plots.

From the outset it was noticeable that, even in these relatively small plots, the condition of the individual trees of one variety could differ fairly considerably. Furthermore, the condition of the varieties in relation to each other proved to be subject to rather large variations, between one plot and another.

This phenomenon, the great variability in the damage picture, must be attributed to differences in the environmental circumstances and in the vigour of the trees themselves. For example, VERHOEVEN (1953) gives various reasons for variations in the salt concentration in the soil moisture. According to him, in addition to the variability of the granulometric composition, the speed of drying and the withdrawal of moisture by plant roots, the main causes of the variations in salt concentration are the great differences in desalting and salinization over very short distances, brought about by the lack of uniformity in the soil's capacity for permitting the passage of water. It is therefore possible that the roots of one plant find themselves entirely or partially in soil, the moisture in which is more salt than the moisture in the soil in which a neighbouring plant has its roots.

Furthermore, state of health and physiological constitution can differ very greatly between the trees in a sampling plot, and especially between one farm and another. In this connection, particular mention may be made of attacks by diseases in previous years and after the 1953 flood, both above ground (e.g., by red spider, woolly aphis and canker) and underground (exhaustion of the soil, "sickness"), the trees' state of nutrition and the origin of the trees, all of which factors may play a part.

Thanks to the large number of sampling plots it was possible to compile a table showing the approximate sensitivity to salt of the principal varieties, notwithstanding this variability in the constitution of the trees. The order of sensitivity of certain varieties of apple is given in Table 4, and of pear in Table 5, irrespective of root stocks. If the number of times in which variety A exhibited a more favourable condition in a trial plot than variety B was greater than the number of times in which the reverse was the case, the fact is indicated in the table by a + sign. In the opposite case a — sign has been inserted, while a o shows that no differences were found in the final result.

Table 4. Order of sensitivity to inundation of some varieties of apples.

Explanation of the signs : + = A more resistant than B
— = A more sensitive than B
o = no difference in sensitivity

A \ B	1	2	3	4	5	6	7	8	9	10	11	12
1	×	+	+	+	+	+	+	+	+	+	+	+
2	—	×	+	+	—	+	+	+	o	—	+	+
3	—	—	×	+	+	—	+	+	+	+	+	+
4	—	—	—	×	+	o	+	+	+	+	+	+
5	—	+	—	—	×	+	+	+	+	+	+	+
6	—	—	+	o	—	×	+	+	+	—		+
7	—	—	—	—	—	—	×	+	+	o	—	+
8	—	—	—	—	—	—	—	×	+	+	—	+
9	—	o	—	—	—	—	—	—	×	+	+	+
10	—	+	—	—	—	+	—	—	—	×	+	o
11	—	—	—	—	—		+	+	—	—	×	o
12	—	—	—	—	—	—	—	—	—	o	o	×

1 = Glorie van Holland
2 = Yellow Transparent
3 = Belle de Boskoop
4 = James Grieve
5 = Laxton's Superb
6 = Lombarts Calville
7 = Jonathan
8 = Cox's Orange Pippin
9 = Golden Delicious
10 = Zigeunerin
11 = Ellison's Orange
12 = Manks Codlin

Table 5. Order of sensitivity to inundation of some varieties of pear.

Explanation of the signs : + = A more resistant than B
— = A more sensitive than B
o = no difference in sensitivity

A \ B	1	2	3	4	5	6	7	8	9	10	11
1	×	+	o	+	+	+	+	+	+	+	+
2	—	×	+	+	+	+	o	+	+	+	+
3	o	—	×	o	o	+	o	+	—	+	+
4	—	—	o	×	+	+		+	+		+
5	—	—	o	—	×			o	+	+	+
6	—	—	—	—		×	o	+			+
7	—	o	o			o	×	+	—	—	+
8	—	—	—	—	o	—	—	×	+	o	+
9	—	—	+	—	—		+	—	×	+	o
10	—	—	—		—		+	o	—	×	o
11	—	—	—	—	—	—	—	—	o	o	×

1 = Beurré Alexandre Lucas
2 = Conference
3 = Comtesse de Paris
4 = Triomphe de Vienne
5 = Doyenné du Comice
6 = Saint Rémy
7 = Clapp's Favourite
8 = Précoce de Trévoux
9 = Beurré Hardy
10 = Légipont
11 = Bonne Louise d'Avranches

On the basis of these tables, we might classify the varieties of apple and pear in three groups:

Apple 1 not very sensitive: Glorie van Holland, Yellow Transparent, Belle de Boskoop and James Grieve;
2 moderately sensitive: Laxton's Superb, Lombarts Calville, Jonathan, Cox's Orange Pippin and Golden Delicious;
3 rather sensitive: Zigeunerin, Ellison's Orange and Manks Codlin.

Pear 1 not very sensitive: Beurré Alexandre Lucas, Conference, Comtesse de Paris, Triomphe de Vienne and Doyenné du Comice;
2 moderately sensitive: Saint Rémy, Précoce de Trévoux and Beurré Hardy;
3 rather sensitive: Légipont and Bonne Louise d'Avranches.

The degree of sensitivity to salt differs more between the varieties of apple than between the varieties of pear. Figures 1 and 2 illustrate this further. In Fig. 1, the estimated condition of some varieties of apple has been plotted against the condition of Belle de Boskoop.

If a line lies above the 45° line, the variety concerned is stronger than Belle de Boskoop; if it lies below the 45° line, the variety is weaker than Belle de Boskoop. As regards the apple varieties, the graph shows that the worse the growing condition, the greater the spread of salt sensitivity.

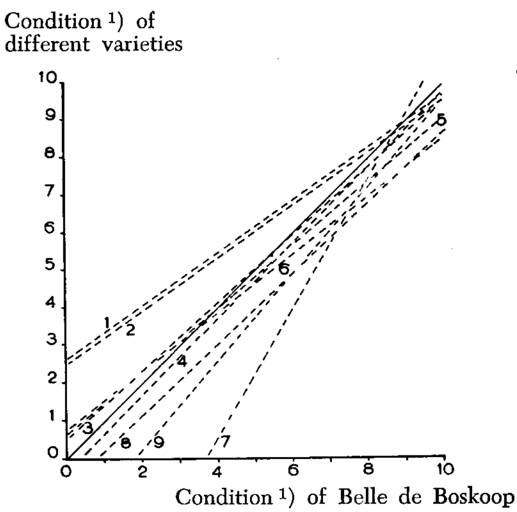


FIG. 1. RELATION BETWEEN THE GROWTH CONDITION OF SOME VARIETIES OF APPLE AND THE CONDITION OF BELLE DE BOSKOOP.

1 = Glorie van Holland
2 = Yellow Transparent
3 = James Grieve
4 = Jonathan
5 = Cox's Orange Pippin
6 = Golden Delicious
7 = Zigeunerin
8 = Ellison's Orange
9 = Manks Codlin.

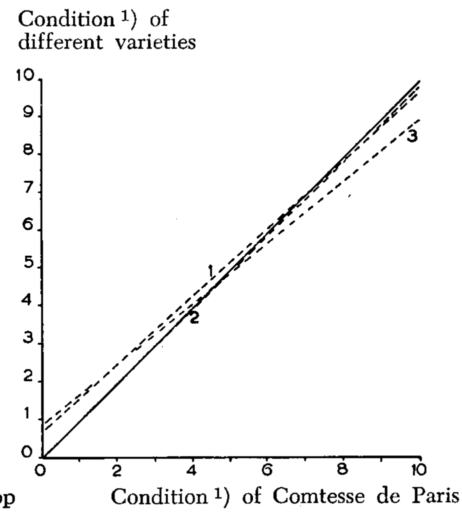


FIG. 2. RELATION BETWEEN THE GROWTH CONDITION OF SOME VARIETIES OF PEAR AND THE CONDITION OF COMTESSE DE PARIS.

1 = Conference
2 = Précoce de Trévoux
3 = Bonne Louise d'Avranches.

1) Scale 0–10 (0 = dead, 10 = normal growth, with no damage whatever).

In the same way, Fig. 2 demonstrates the connection between the estimated condition of some varieties of pear on the one hand, as compared with Comtesse de Paris on the other.

4.4. *Comparison of apple stocks*

By means of the data from the sampling plots, it was also possible to ascertain on a modest scale the sensitivity to inundation of the chief E.M. apple stocks with regard to each other, in the same way as was done in the case of the varieties of apple and pear. This comparison was carried out in respect of various varieties, but in such a manner that stocks repeatedly compared in one trial plot always bore the same variety. Table 6 gives the result of the counts.

Table 6. Order of sensitivity to inundation of E.M. apple stocks.
Explanation of the signs: + = A more resistant than B
— = A more sensitive than B
o = no difference in sensitivity

A/B	IV	XI	II	IX	XIII	I	XVI
IV	×			+	+		+
XI		×	+	o		+	
II		—	×	+			
IX	—	o	—	×	+	+	+
XIII	—			—	×	+	
I		—		—	—	×	
XVI	—			—			×

It is immediately noticeable that quite a large number of combinations were not encountered in the trial plots. This made the order of sensitivity more difficult to establish. For instance, it is not clear whether IV or XI must be regarded as the strongest stock. Nor can the position of XVI be determined with certainty, for it *may* come before XIII. Imperfections are implicit in this table, the more so because it was not always possible to compare stocks bearing the same variety; but nevertheless I think that the following conclusions can be drawn. In the first place, the sensitivity of the stocks does not run parallel with their growth vigour. The depth of the root system is highly dependent on the soil profile and the water table, and is very probably not the primary cause of the differences in sensitivity to inundation.

Like the varieties, the stocks show differences which, at bottom, are caused by variations in the genotype. In that connection, sensitivity to inundation need not necessarily run parallel with the growth vigour of the root system. On the other hand, the depth of the root system may certainly play a part. The nature of this part depends on the environmental conditions, especially the salt content in the various soil layers, and the duration of flooding. But, besides permitting speedier access of air, a superficial root system also means that the roots are all located in what were at first the saltest layers of soil.

4.5. *Effect of some environmental factors on apples and pears*

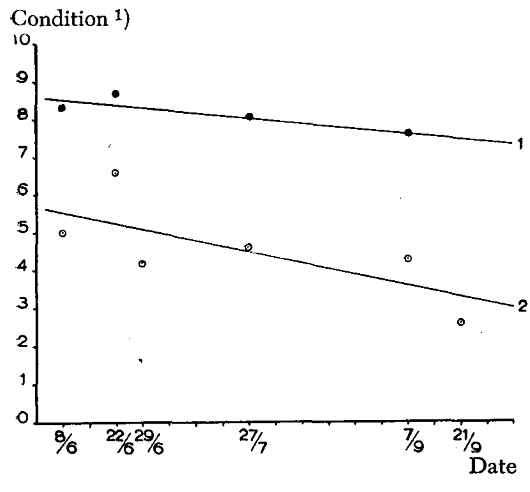
The average assessments per variety, calculated in respect of each sampling plot, are not suitable for representation in graph form as they stand. To begin with, the same varieties were not grown in every plot. Moreover, the assessments were made at different times of the year.

Elimination of differences in sensitivity to salt of the varieties can be effected in two ways. The simplest way is to subject only one variety to graphic treatment. The other way is to apply a correction to the average assessments which restricts to a minimum variability due to varietal differences. This second method was thought to possess the disadvantage that the correction might smooth away certain influences, but it has the advantage of enabling all plots to be used. After application of both methods, it was found that the disadvantage connected with the second method was non-existent, and consequently this method was chosen.

The variability between the varieties as regards sensitivity to salt is already conspicuous in the spread of the curves in Figs. 1 and 2. By moving these curves, with their relevent points, in such a way that they coincide with the 45° line, the variability is reduced to a minimum, and is based on Belle de Boskoop and Comtesse de Paris, respectively.

It was possible to carry out correction of the time factor by means of 13 sampling plots in which damage due to salt had been assessed several times in the course of the growing season.

Fig. 3 shows the trend in the case of apple and pear. The points are averages of 13 and 10 assessments, respectively.



1) Scale 0–10 (0 = dead, 10 = normal growth, with no damage whatever).

FIG. 3. THE COURSE OF THE CONDITION OF PEAR (1) AND APPLE (2) DURING THE GROWING SEASON.

The fact that apple is *more sensitive* than pear can be seen not only from the location of the curves, but also from their slope. For the symptoms of damage by salt increase more strongly in the case of apple than in the case of pear. With the help of these curves, the average assessments of the varieties of apple and pear have been corrected to the level of 1st July.

Accordingly, by means of these corrections, we arrive at a standardized assessment of apple and pear per trial plot, in which assessment both the effect of time and the differences in sensitivity to salt of the individual varieties have very largely been eliminated.

As was mentioned in describing the method of investigation (see 3), the salt content of the soil moisture (salt index) in the 5–40 and 40–80 cm layers, the duration of flooding, the maximum height of the flood water, and the age of the trees, were determined in respect of all plots.

4.5.1. The s a l t c o n t e n t o f t h e s o i l m o i s t u r e was found to be by far the most important factor – a result which was in conformity with what is said in the literature of the subject. In the material collected, the effect of the salt in the soil moisture ran entirely parallel in the 5–40 and 40–80 cm zones. In the latter case, the spread of the points is greater. Accordingly, only the effect of the salt content of the 5–40 cm layer is shown here (Figs. 4 and 5).

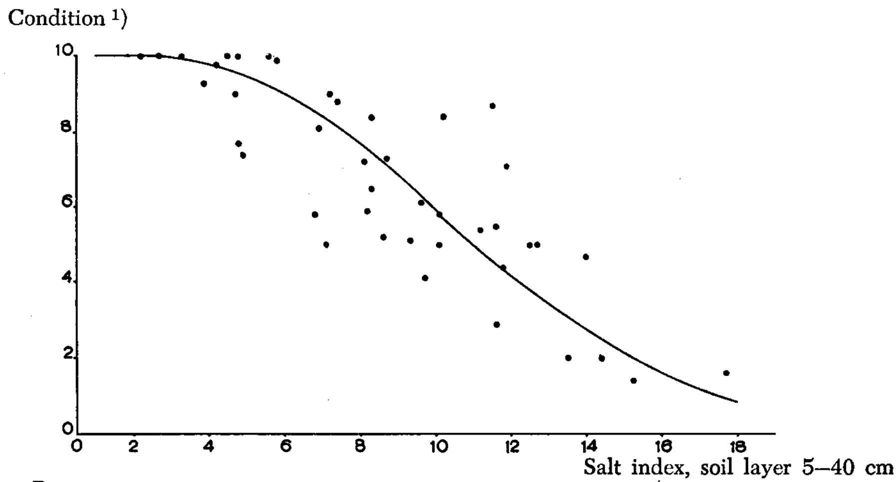
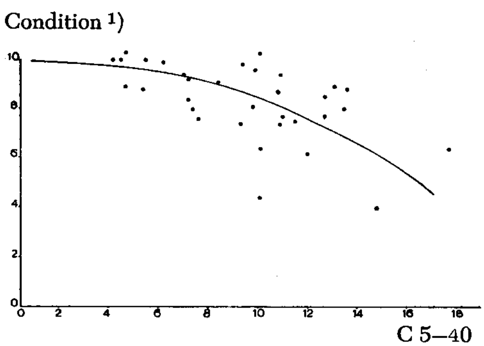


FIG. 4. RELATION BETWEEN THE SALT CONTENT OF THE SOIL MOISTURE (SALT INDEX, SOIL LAYER 5–40 CM) AND THE CONDITION OF APPLES.



1) Scale 0–10 (0 = dead, 10 = normal growth, with no damage whatever).

FIG. 5. RELATION BETWEEN THE SALT CONTENT OF THE SOIL MOISTURE (C 5–40) AND THE CONDITION OF PEARS.

The course of the condition of apples and pears when the content of salt increases is clearly expressed here in a fairly narrow concentration of points. The fact that this concentration of points is situated rather closely round the projected line is in itself a strong indication that other environmental factors must exert only a very limited influence. On further treatment, it was found that this actually was so. Only in the case of pears is the influence of duration of flooding clearly discernible, thanks to the fact that some plots show very high values for this factor. In Fig. 5 this influence has been eliminated by correction.

On the basis of assessments in 1954 of sampling plots which had survived we come to the conclusion that trees with a condition of about 8 can be preserved for cultivation, provided they are well tended. It therefore follows from the graphs that apples can tolerate a salt content of from 7 to 8, and pears a salt content of 11 to 12, in the soil moisture, unless other conditions are exceptionally bad.

4.5.2. In Fig. 6 the relation is shown between duration of flooding and the condition of pears, the influence of the salt content of the soil moisture having been eliminated by correction.

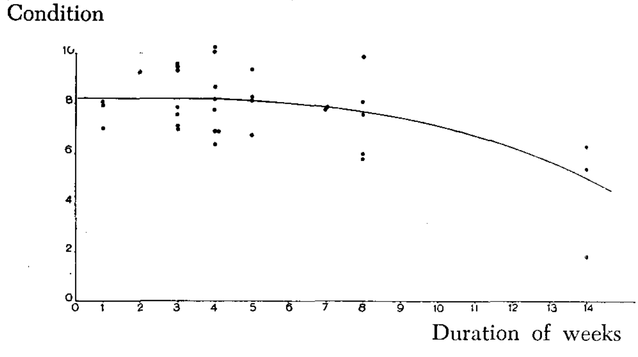


FIG. 6. RELATION BETWEEN DURATION OF FLOODING (IN WEEKS), AND THE CONDITION OF PEARS.

Just as was the case with apples, even 8 weeks of flooding had next to no influence on the growth condition. Accordingly, if the salt content of the soil moisture remains low enough (owing to low salt content of the flood water), apples and pears can endure an inundation lasting 8 or 9 weeks. This has actually been found to be the case in practice — for instance, in the Reigersberger Polder in Zuid-Beveland, which was flooded for 8 weeks, and in which the salt index did not exceed 6. The duration of flooding of one month (see page 20) quoted by DORSMAN and WATTEL (1951) constitutes no standard, because no distinction has been made between the salt content of the soil moisture and the duration of flooding.

4.5.3. Any influence of the height of the flood water on the condition of the trees could not be ascertained from the material available — which is in conformity with the observations of DORSMAN and WATTEL (1951). However, there was certainly a difference between the condition of pruned trees which had stood under water, and that of trees which had not. The reaction in the first case was decay under the pruning wounds, and, in serious instances, damage by salt to the leaves. There was therefore a marked disparity between the condition of pruned and of unpruned trees in an orchard where the water had risen to a point above the wounds.

4.5.4. Age of the trees. It is not possible to ascertain the influence of the age of the trees from the evidence collected. In practice, the impression was certainly made that apple trees 20—25 years old and more showed less power of resistance. Frequently, however, the amount of care given to the trees is also not all it might be, and consequently it is not possible to make a clear-cut evaluation of this factor as regards apples.

Under otherwise equal conditions, young plantations of pears occasionally exhibited a poorer stand than older ones; but in 1954 it was found that they possess great powers of recovery. Youth is associated with small dimensions, and consequently young trees, as a rule, were totally submerged under water. It must be assumed that the water not only did damage by penetrating into wounds due to pruning and other causes, but also harmed the buds, which were already active to a certain extent. Provided it is not too serious, this damage may have only a temporary effect.

4.5.5. The effect of some other factors. From incidental observations it was also found that deep tillage before the flood greatly promoted penetration of the salty water into the soil. In contrast to the situation in untilled orchards, the subsoil can, in such cases, be very salt, a circumstance which has a detrimental effect on the condition of the trees, via the roots in that subsoil. On land exhibiting signs of exhaustion of the soil ("sickness") the condition of apples and red currants was considerably less good than on land planted for the first time. This phenomenon was not observed in the case of pears. As a rule, bad soil conditions are detrimental to the resistivity of the trees. There are indications that in certain cases a superficial, small root system is more disadvantageous than a deep one. Furthermore, in general, badly kept orchards were more hard hit than well kept ones. In that connection, a great part was played by exhaustion of the crop through diseases and attacks by animals.

In addition, the proportion in which the nutritive elements in the soil are available also seems capable of determining the resistance of the trees.

It is perhaps unnecessary to remind the reader that the results described here refer to an inundation with salt water which started on 1st February. It is highly probable that floods at another time of year would cause other reactions in trees. DORSMAN and WATTEL (1951) have already pointed this out (see p. 20).

4.6. *Influence of cultivation operations after the flood*

If there is a possibility of saving an orchard for cultivation, it is very important that effective measures be taken to make the environmental conditions as favourable as possible. In borderline cases, in particular, application of such measures may determine whether or not the trees can be preserved. Accordingly, it is usually necessary to start at once, and not wait until the trees begin to decline. To do this, the fruit grower needs a certain amount of optimism, which it is not always easy for him to muster.

The cultivation measures to be taken can be summarized in the following points :

1 As the waters recede, the flood water should be helped to run away as much as possible by the provision of ditches.
2 After the ground has become dry, and the ground water has subsided to a sufficient depth, fresh water should be supplied to the trees. If it is possible to spray or irrigate, this will be the most favourable time for doing so.
3 No tilling, or at most, very superficial tilling, should be carried out. Gypsum should be scattered according to the requirements of the soil ; for the rest, the soil should be left alone.
4 As far as possible, dead and damaged parts of trees should be removed.
5 Pruning and disease control should be carried out normally, as far as is possible. It will be advisable to use mild disease control preparations.

Some orchards have been sprayed or irrigated with fresh water in the province of Zeeland and in the islands of South Holland (NOTENBOOM, 1953). In these cases, it was clearly seen that spraying yielded better results than irrigation. Irrigation water seems to have a tendency to sink into the soil via cracks and channels, to the detriment of the desalting effect.

Although practically no difference could be observed between the condition of the trees on the irrigated terrain and that on the unirrigated terrain, it should not therefore be concluded that irrigation is useless. In the first place, it commenced late, in these particular cases; and, furthermore, a distinct difference could nevertheless be established between the sodium and chlorine contents of soil and leaf samples from irrigated and unirrigated orchards and plantations.

Comparison of results from various farms showed that spraying was very effective. The objection that it started late also applies here. It is of very great importance to begin spraying or irrigation as soon as possible after the floods have gone down and the water table has regained its old level.

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