29. Chemical studies on the leaf and root (wilt) diseases of coconuts in Travancore-Cochin

III. Reduction products formed under waterlogged conditions: Preliminary investigations

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INTRODUCTION

WATERLOGGING induces many undesirable soil conditions which adversely affect healthy plant growth. Toxic reduction products formed under waterlogged conditions have been reported to cause disease incidence in many agricultural crops.

With regard to the coconut, diseased conditions of the palms brought about by waterlogging have been reported from most of the coconut growing countries. Thus Briton Jones (1928, 1929, 1940) found a very definite correlation between lack of drainage in coconut soils and the wilt disease of coconut palms in Trinidad. Huggins (1930) reporting on wilting of coconuts in British Guiana stated that waterlogging is a contributory factor while Alston (1925) found that the areas affected by the disease were those situated either in lowlying badly drained, heavy clay front lands or on 'pegass' soils which suffer from similar disabilities. Sheppard (1927) was of the view that diseases of coconut palms in Mauritius were due to waterlogging. Muller (1934) has given definite instances of extensive areas of coconut gardens in Western Borneo where the water-table was too high and the palms subject to diseases. Briton Jones (1928, 1940) and Park (1932) reported that the Ceylon root disease was caused by physical or physiological drought. Cooke (1950) and Cooke *et al.* (1950) found waterlogging to cause the tapering disease of coconuts in Ceylon. Leather (1959) is of the view that the 'Cape St. Paul Wilt' of coconuts at Keta, Ghana, is caused by unsuitable ground water conditions. Furtado (1923) found tapering of coconut palms in Akyab in Burma to be associated with lack of drainage. Martin (1945) has described foliar yellowing of coconut palms in Jamaica as due to waterlogging in permanently wet sites. Similar findings have been reported by many workers.

Menon and Nair (1949, 1950, 1951) have carried out extensive surveys of the Leaf and Root (Wilt) diseases of coconuts in Travancore-Cochin. Their observations and those of Menon *et al.* (1950, 1952), Verghese (1934), Verghese (1959) and others go to show that these diseases made themselves significantly manifest after the floods of 1882 when the land was under water and remained waterlogged for a considerable period. The surveys also disclosed the fact that palms growing on the banks of rivers which remained flooded for some days every year during the monsoons generally showed diseased symptoms in a severe form. Menon *et al.* (1952) found root infection caused by *Rhizoctonia solani*, *Rhizoctonia bataticola* and *Botryodiplodia theobromae* on coconut seedlings to be worse under waterlogged conditions. Menon and Pandalai (1958) have reported that a large proportion of the diseased localities has water-table near the surface. It is not definitely known to what extent waterlogging is responsible for the disease, but waterlogging or swampy soil conditions seem to favour the development of the diseases in a severe form.

The chemistry of waterlogged or submerged soils has been studied by several workers - *vide* Subramanyan (1927, 1929), Robinson (1930), De and Sarkar (1936), Peech and Boynton (1937), Ponnamperuma (1955), and others. Pandalai *et al.* (1954) have reported a striking case of sudden wilting of coconut palms, as a result of dumping dredged subsoil and water into a healthy coconut garden. The wilting of the palms was due to root injury caused by (i) the shift in pH due to the percolation of the subsoil water on the surface of the soil during the process of dumping the dredged subsoil on it; (ii) the presence in the water of readily oxidisable agents such as sulphides, ferrous iron etc., (iii) the presence of toxic factors such as soluble aluminium; (iv) the potential capacity of the dredged subsoil for the formation of mineral acids by hydrolytic changes and (v) complete anaerobic condition in the root rhizosphere causing intense root suffocation. The biochemistry of waterlogged coconut soils has been reviewed and discussed by Menon *et al.* (1952). Sufficient data, however, are not yet available on the chemistry of coconut soils subject to waterlogging or high water-table during fairly long periods. The authors have planned detailed investigations on several aspects of the problem. The results of preliminary trials are reported in the present paper.

MATERIALS AND METHODS

Samples of soils and subsoil water collected from a diseased lowlying area of Blocks V, VI, VII and VIII of the Central Coconut

Research Station, Kayangulam, 2,500 ft. long and 200 ft. wide, subject to high water-table during the South-West monsoon (June to August) and water extracts and leachates prepared from the soil were used in the present study.

The seasonal variations in the water-table of the area were recorded and the pH of the subsoil water samples were determined for a period of two years. Subsequently, four other soil profile pits were dug at equal distances along the 2,500 ft. long belt, up to the water-table. Soil samples were collected from the profiles. Samples of subsoil water were also taken. The collection of samples was repeated periodically as and when the water-table receded. The depth of the water-table was also recorded. Immediately after collection the soil samples were shaken with double distilled water (soil to water ratio, 1:5) for one hour and rapidly filtered.

Another soil profile pit was dug in the interspace of three badly diseased palms. Soil samples were collected from the pit horizonwar and air-dried. Five sets of samples from five horizons of the pit were thus obtained. 7,500 gm. of the air-dried soil from each horizon was taken in quadruplicate in bitumen coated clay pots containing a layer of washed sand one inch thick, over a similar layer of washed granite jelly. The pots were provided with drainage tubes closed with glass wool as recommended by Hewitt (1952) so as to get the drainage water quite clear. 5000 cc. of distilled water was added to each pot so that the water level in the pots was five to six inches above the surface of the soil. The water level was maintained throughout. Drainage waters were collected from all the pots after thus waterlogging the soil for eight weeks. Subsequently they were drawn after further periods of waterlogging as shown in Table 5. Special care was taken to see that the level of water in the pots was well above the surface of the soil when collecting the leachates so that anaerobic conditions were maintained throughout the duration of the experiment.

The water extracts prepared from the soil samples, the subsoil waters and the drainage water collected from the pots periodically were anlysed for (i) iron and manganous salts, (ii) sulphates, sulphites and sulphides, (iii) nitrate, ammonical and nitrite nitrogen, (iv) pH, (v) total solids, (vi) conductivity and (vii) oxygen requirements. The pH was determined in a Radiometer pH meter using glass electrode, the conductivity in Mullard Conductivity Bridge and the total solids by evaporating 100 cc. of the samples to dryness in a weighed basin. The oxygen requirement was determined by oxidation with potassium permanganate and the nitrite nitrogen calorimetrically by adding alpha-naphthylamine hydrochloride and sulphanilic acid as described in the "Official and Tentative Methods" of A.O.A.C. A.O.A.C. methods were followed for the other estimations also.

RESULTS AND DISCUSSION

Water-table

The seasonal variations in depth and in the pH of the ground water for the two years beginning with 20-5-1954 are recorded in Table 1. The salient features are summarised below:

Observation	Pit I		Pit II		Pit III	
	1954	1955	1954	1955	1954	1955
Maximum depth of water-table reached	8′ 6″	10′ 3″	8′ 1″	6′ 8″	13′ 1″	6′ 9″
pH on the above date	5.2	5.3	6.0	5.1	5.0	5.6
Depth of water-table when high	3′ 8″–4′ 0″	3′ 4″–3′ 10″	2′ 11″–3′ 5″	0′ 4″–3′ 9″	2′ 2″–3′ 9″	0′ 7″–4′ 0″
Duration of the above	2½ months	1 month	3½ months	7 months	6 months	7 months
pH range	5.4–6.1	5.9–6.0	5.2–5.8	4.8–6.1	4.4–5.8	4.9–5.6

It may be seen that the variations in the level of ground water are appreciably different in the two years. Further, there are seasons of high and low water-table, ranging from 3′4″ to 10′3″ in pit I, 0′4″ to 8′1″ in pit II and 0.7″ to 13′1″ in Pit. III. It is also interesting to note that there is considerable difference in the level of water, duration of high water-table etc. in the pits even though these pits were dug in a small area, 2,500 ft. long, of more or less the same elevation.

Since the water-table recedes in summer to a depth of 8 ft. to 13 ft., it is doubtful whether conditions existing in waterlogged or submerged soils would apply to the area under investigation. It may, however, be noted that the area has high water-table for a considerable period, at about four feet for one to two months in pit I, at four inches to four feet for three and a half to seven months in pit II and at four feet for six to seven months in pit III.

The observations of Menon *et al.* (1950, 1952) and others that area in situations subject to high water-table for some period every year is subject to severe disease infection, is pertinent in this connection. The area now under study which is fairly representative of large tracts of diseased coconut area is seen to have more or less static ground water at a high level for the greater part of the year. Root decay is a distinct possibility as the water-table is quite high, even up to four inches, for a fairly long time. When the water-table recedes down to 8 ft. to 13 ft., the new roots, if any formed, may not reach this level for the necessary water. Being a sandy soil, capillary rise of water will also be at a minimum. The conditions are thus ideal for physiological drought for prolonged periods. Further, the rotting of the roots may also lead to a state of auto-intoxication and make the conditions still worse. Prolonged waterlogging may also favour greater infection by parasitic organisms as noted by Menon *et al.* (1952). The vertical movement of the ground water may itself cause the diseases as in the case of the "Cape St. Paul Wilt" of coconuts in Keta, Ghana, reported by Leather (1959).

The pH of the water is low. But there is no consistant rise in pH when waterlogged conditions prevail, as would happen if decomposition of organic matter were taking place under anaerobic conditions with consequent production of ammonia.

DETAILED INVESTIGATIONS

The results of detailed investigations are presented in Tables 2 to 5. Table 2 gives the profile characters of the soil used for the pot-culture study, Table 3 shows the results of analysis of water extracts prepared from soils of the four profile pits, Table 4 those of the water samples collected from the latter and Table 5 those of drainage waters (average values) collected from pots with soil from diseased area kept waterlogged for different periods.

Profile characters

The profile characters of the soil used for the pot-culture study which are typical of the area under investigation are given in Table 2. The soil is coarse sandy in texture, structureless, nonsticky, non-plastic, loose, acidic and free from carbonates, mottlings or concretion. Coconut roots were present even up to the fourth horizon, though the majority of the roots were in the first four feet of soil. The A horizon contained 0.21 per cent of organic carbon and the B_1, B_2, B_3 and B_4 horizons contained 0.16, 0.07, 0.04 and 0.03 per cent respectively. The nitrogen content of the soil is very low being 0,02 per cent. Appreciable changes in carbon and nitrogen transformations cannot therefore be expected.

Ferrous iron and manganese

The ferrous iron concentration in a soil solution is usually small because of precipitation of the iron as hydroxide, carbonate or sulphide. However, a waterlogged soil may hold in solution quantities of ferrous iron far in excess of the amounts permitted by the ionic equilibrium involving hydrogen ion concentration, partial pressure of carbon-di-oxide and hydrogen sulphide and even oxygen tension. The case of manganese is also similar. In the present study, however, no trace of iron or manganese salts was obtained in any of the three series of samples collected, viz., water extracts of soils, subsoil water samples and percolates from the pots. Obviously injurious effects of ferrous and manganous salts may not be the cause of the disease.

Sulphur compounds

Sulphates, sulphites and sulphides were also absent in the three series of water samples. Hydrogen sulphide is the ultimate product of sulphate reduction. According to Baars (1930) the reduction of sulphate proceeds in the following stages:

$$H_2SO_4 \rightarrow H_2SO_3 \rightarrow H_2SO_2 \rightarrow H_2SO \rightarrow H_2S$$

The intermediate products are extremely transitory. The hydrogen sulphide formed is completely removed by precipitation chiefly as ferrous sulphide in submerged soils, but in soils very low in iron, hydrogen sulphide can accumulate in toxic amounts. The presence of hydrogen sulphide was not detected in the present study. It may also be remembered that the pH is low and the activity of the sulphate reducing bacteria may be at a minimum. In fact, controlling the pH at 5 to 5.5 is one of the common methods recommended for remedying hydrogen sulphide toxicity. Further, the area under study has not so far received any sulphur containing chemical fertilizers. The organic matter content of the soil is also very low.

Nitrogen compounds

The water tested did not contain nitrate and ammoniacal nitrogen. They, however, contained nitrite though the quantities were very small: from trace to 0.1 ppm. in soil extracts (Table 3), trace 0. 2 ppm. in subsoil water (Table 4) and trace to 0.3 ppm. (Table 5). Such amounts are rarely toxic. According to Bonner (1950) though nitrite irons are toxic to plants at high concentrations they are utilized by plants if applied in concentrations less than 50 ppm. Duisberg and Puehrer (1954) noted that even at a concentration of 26 ppm. barley suffered no injury. Thus it may be concluded that the presence of traces to 0.3 ppm. of nitrite nitrogen cannot be toxic enough to cause root injury resulting in the Leaf and Root (Wilt) diseases.

Total solids

The total solid content of the samples is also very low, the highest value recorded being 0.05 per cent. This is supported by the conductivity values.

Oxygen requirement

The oxygen requirement values for the water extracts (Table 3) and subsoil waters (Table 4) are also very low. The percolates from the pots, however, gave higher values, particularly of the water-logged soil of the first two horizons (Table 5). **The effect of this on the diseases requires further studies.**

pH

The fact that the pH of a soil increases on submergence has now been accepted by most workers though there is no unanimity of opinion on the physico-chemical reasons underlying this change. Additional data in support of the above was obtained in the present investigation. The trend of results obtained in records of pH for two years shown in Talbe 1 show a general increase in pH with water logging. Results of detailed study adduce further evidence in support of this. Thus the water extracts of soil (Table 3) and subsoil water samples (Table 4) very clearly show consistant increase in pH values as the water table rises and water-logged conditions prevail. Waterlogging for a period of 22 weeks raises the pH of the leachate of soil of the A horizon from 6.2 to 7.1. The change is not appreciable in the soils of the other horizons; but it may be stated that these soils contain only very small amounts of carbon, nitrogen, manganese etc. transformations of which under anaerobic conditions may cause the pH changes.

The low pH may also reduce the supply of available nitrogen for the needs of the crop. From the foregoing it may be seen that none of the factors studied so far can be the cause of the Leaf and Root (Wilt) diseases.

The most striking difference between the aerobic and anaerobic decomposition of organic matter lies in the nature of the end products. The products of organic matter decomposition in a submerged soil are chiefly carbondioxide, methane and hydrogen and organic acids. Further, in the waterlogged environment, some of the products of the anaerobic decomposition of proteins, particularly products of deamination and decarboxylation of the amino acids, may accumulate. Among these are the carboxylic acids — acetic, propionic, butyric valeric and caproic acids. A low pH favours the accumulation of the organic acids; Butyric acid particularly is known to be highly injurious to plant roots even when present in very small quantities. In fact, the indications of the presence of these acids in subsoil waters in a lowlying area of the Research Station, subject to high water-table, were obtained by Menon *et al.*, (1951-1956). This aspect of the problem is now under investigation. The water samples collected from the three series of experiments were concentrated to a small bulk after the addition of 0.1 N potassium hydroxide to convert the organic acids to their potassium salts as recommended by Mueller *et al.*, (1958) and efforts are being made to detect and estimate the acids by chromatographic methods. In this connection it is worthwhile to note the striking case of wilting of palms reported by Pandalai *et al.*, (1954). These authors found toxic amounts of soluble aluminium as one of the major factors responsible for the wilting. The low pH obtained throughout in the present investigation is a pointer in this direction. Work on the above lines has been taken up and will be reported in a future communication.

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TABLE 1

Seasonal variation in water-table and pH of subsoil water

Date of collection	Pit No. I			Pit No. II			Pit No. III		
	Depth		pH value	Depth		pH value	Depth		pH value
	Ft.	In.		Ft.	In.		Ft.	In.	
26—5—54	8	6	5.2	8	1	6.0	13	1	5.0
31—5—54	7	6	5.4	6	0	5.5	—		—
15—6—54	4	9	5.3	3	5	5.0	2	6	5.2
1—7—54	4	11	5.5	3	2	5.5	3	0	5.4
15—7—54	4	0	5.5	3	1	5.6	2	0	5.4
5—8—54	4	0	5.5	2	3	3.2	2	2	5.2
3—9—54	4	0	6.1	3	0	5.8	2	3	5.6
30—9—34	3	8	5.4	2	11	5 3	2	10	4.5
15-10—54	4	6	6.0	4	0	0.0	3	2	5.8
15-11—54	3	10	5.0	2	11	4.9	3	1	4.7
25-11—54	4	6	4.95	3	5	5.1	3	4	4.4
6-12—54	4	10	4.6	3	7	4.75	3	9	5.0
14-12—54	—		4.9	—		5.0	—		4.5
21-12—54	5	3	4.9	4	3	4.7	4	2	4.4
29-12—54	5	8	5.1	4	0	5.1	4	6	4.8
5—1—55	4	3	5.3	3	11	5.65	4	2	4.75
12—1—55	5	4	5.15	4	4	5.35	4	6	4.5
21—1—55	5	6	5.1	4	9	5.15	4	8	4.15
28—1—55	6	2	5.5	4	10	5.45	4	8	4.6
4—2—55	—		5.4	—		5.25	—		4.15
14—2—55	6	2	4.85	5	0	5.2	5	6	4.25
10—3—55	7	9	4.8	—		—	6	2	4.25
8—6—55	3	4	6.0	0	4	6.0	1	2	5.5
20—6—55	3	10	5.9	0	6	6.1	0	7	5.6
27—6—55	4	4	6.0	0	4	6.0	0	7	5.5
2—7—55	4	2	5.9	1	1	5.9	1	5	5.4
9—7—55	5	4	5.8	0	9	5.6	1	0	5.2
18—7—55	4	8	0.2	1	0	6.0	1	7	5.6
4—8—55	4	2	5.6	2	3	5.2	1	2	5.2
21—8—55	6	6	4.8	2	3	5.9	2	6	5.4
5—9—55	6	3	5.6	2	10	5.3	3	0	5.6
23—9—55	6	11	5.6	2	11	5.0	3	1	5.2
3-10—55	4	7	5.6	2	8	5.3	1	2	5.2
28-10—55	1	0	5.8	1	2	5.2	1	8	5.0
10-11—55	4	11	5.9	2	3	5.2	1	7	5.3
18-11—55	5	3	6.0	1	4	5.4	2	2	5.0
24-11—55	5	8	5.5	2	2	5.2	2	4	5 0
1-12—55	5	3	5.8	2	1	4.8	1	11	5.0
9-12—55	5	10	6.1	2	5	5.2	2	1	5.1
16-12—55	5	11	5.8	2	6	5.2	2	10	4.9
23-12—55	6	6	5.9	3	0	5.4	3	1	5.4
29-12—55	7	2	5.2	3	2	5.1	3	3	5.1
5—1—56	6	2	5.2	2	10	5.1	3	3	5.4
12—1—56	6	10	5.6	3	9	5.2	4	0	5.4

TABLE 1 (*contd.*)

Date of collection	Pit No. I		Pit No. II		Pit No. III	
	Depth	pH value	Depth	pH value	Depth	pH value
19—1—56	7 1	5.4	4 2	5.1	4 0	5.5
27—1—56	8 8	4.8	4 0	4.8	4 2	5.0
2—2—56	7 10	5.2	4 6	5.2	4 3	5.0
9—2—56	9 4	5.2	3 8	5.2	4 2	5.4
16—2—56	7 9	5.3	4 2	4.9	4 10	5.5
1—3—56	9 0	5.3	4 8	5.0	5 2	5.5
8—3—56	9 7	5.2	5 4	4.8	5 5	4.6
16—3—56	9 0	5.2	5 0	4.8	5 6	5.2
22—3—56	9 5	4.9	6 3	5.0	5 6	5.0
30—3—56	10 0	5.4	5 6	5.4	5 0	5.3
5—4—56	9 6	5.3	6 0	5.3	6 0	5.2
19—4—56	—	5.3	—	5.0	—	5.2
26—4—56	9 6	5.3	6 8	5.1	6 4	5.1
3—5—56	9 8	5.5	6 0	5.2	6 2	5 3
10—5—56	9 8	5.8	6 5	5.7	6 7	5.3
16—5—56	10 3	5.3	6 6	5.2	6 9	5.6
1—6—56	7 3	5.4	4 5	5.1	4 6	5.1

TABLE 2.

Showing the profile characters

Horizon	A	B_1	B_2	B_3	B_4
Depth	0-1′ 2″	1′ 2″-4′ 6″	4′ 6″-7′ 6″	7′ 6″-8′ 6″	8′ 6″-9′ 10″
Thickness	1′ 2″	3′ 4″	3′ 0″	1′ 0″	1′ 4″
Boundary	Clear	Gradual	Gradual	Gradual	Gradual
Colour	2.5 Y.R. 5/2	10 Y.R 6/4	10 Y.R 7/4	2.5. Y.R 7/2	2.5 Y.R 7/4
Moisture	Moist	Moist	Moist	Moist	More moist
Colour of mottling	Nil	Nil	Nil	Nil	Nil
Structure	Str. less	Str. less	Str. less	Str. less	Str. less
Texture	Sandy loam	Sandy loam	Sandy loam	Sandy loam	Sandy loam
Consistence	Loose	Loose	Loose	Loose	Loose
Concentration	Nil	Nil	Nil	Nil	Nil
Root distribution	Few	Few	Very few	Few dead roots	Nil
Reaction (pH)	5.6	5.4	6.1	5.3	5.4
Carbonate	Nil	Nil	Nil	Nil	Nil
Special features	,,	,,	,,	,,	,,
Permeability	Moderate	Moderate	Moderate	Moderately slow	Slow

TABLE 3

Showing the results of analysis of water extracts of soils

Block No.	Date of collection	Depth	pH value	Conductivity in micro mho.	Total solid %	Oxygen requirement in p.p.m.	Nitrite nitrogen in p.p.m.
V	11—7—58	0" - 22"	6.0	33.44	0.0102	6.4	0.001
	19—9—58	22" - 53½"	5.8	9.12	0.0078	1.30	Trace
	13—12—58	53½" - 85"	5.2	18.24	0.0060	1.24	,,
	21—3—59	85" - 115"	5.0	21.28	0.0090	1.02	,,
VI	11—7—58	0" - 31"	5.1	16.72	0.0050	1.08	0.104
	19—9—58	30" - 41½"	5.3	25 24	0.0069	0.50	Trace
	13—12-58	41½" - 54"	5.0	27 36	0.0086	2.00	,,
	21—3—59	54" - 87"	4.8	30.40	0.0126	2.20	,,
VII	11—7—58	0 - 19"	6.0	18.24	0.0066	3.2	0.016
	19—9—58	19" - 36"	5.5	11.4	0.0068	0.40	0.008
	13—12-58	36" - 59"	5.4	27.36	0.0080	0.60	0.002
	21—3—58	59" - 96"	5.2	36.48	0.0086	0.20	Trace
VIII	11—7—58	0 - 14"	5.6	11.4	0.0050	2.6	0.001
	2—8—58	14" - 25"	6.9	27.36	0.0020	3.05	0.021
	13—12-58	25" - 50	5.5	36.48	0.0100	2.6	0.020
	21—3—59	50" - 82"	4.8	41.04	0.0102	2.0	Trace

TABLE 4

Results of analysis of subsoil water collected from soil profile pits

Block V						
Date of collection	Depth	pH value	Conductivity in micro mho	Total solid %	Oxygen requirement in p.p.m.	Nitrite nitrogen in p.p.m.
11—7—58	22"	6.3	36.5	0.0056	1.2	0.012
19—7—58	25"	5.5	28.9	0.0040	1.15	0.035
26—7—58	34"	5.0	36.48	0 0032	0.95	0.050
9—8—58	28½"	5.4	50.28	0.0120	0.85	0.004
21—8—58	26"	5.7	28.88	0.0018	1.35	Trace
5—9—58	38½"	5.5	27.36	0.0014	0.50	0.006
19—9—58	53½"	5.5	45.6	0.0041	0.35	Trace
3-10—58	75½"	5.9	62.32	0.0074	0.30	Trace
17-10—58	61"	5.7	44.08	0.0120	0.25	0.044
1-11—58	70"	5.8	21.28	0.0052	0.12	Trace
15-11—58	75"	5.9	33.44	0.0038	0.24	0.014
29-11—58	75"	6.1	56.24	0.0080	0.16	Trace
13-12—56	85"	5.4	27.36	0.0048	0.24	,,
27-12—58	88"	5.0	41.04	0.0032	0.24	,,

TABLE 4 (*contd.*)

Date of collection	Depth	pH value	Conductivity in micro mho	Total solid %	Oxygen requirement in p.p.m.	Nitrite nitrogen in p.p.m.
10—1—59	96″	5.4	31.92	0.0024	0.12	"
7—2—59	101″	5.3	63.84	0.0038	0.15	"
21—2—59	109″	5.5	53.20	0.0036	0.24	"
7—3—50	112″	5.4	42.56	0.0032	0.28	"
21—3—59	115″	5.3	28.88	0.0028	0.20	"
			Block VI			
11—7—58	31″	5.5	21.3	0.0038	0.3	Trace
19—7—58	34″	5.3	30.4	0.0046	0.15	0.003
26—7—58	36″	5.0	30.4	0.0050	0.40	0.041
9—8—58	31″	5.0	21.28	0.0068	0.30	Trace
21—8—58	30″	5.9	16.72	0.0018	0.15	0.004
5—9—58	33″	5.3	18.24	0.0010	0.20	Trace
19—9—58	41½″	4.5	349.5	0.0143	0.50	0.005
3-10—58	54″	4.5	205.2	0.0256	0.15	Trace
17-10—58	41″	5.2	77.52	0.0126	0.15	"
1-11—58	43½″	5.1	83.60	0.0134	0.16	"
15-11—58	44½″	4.9	54.72	0.0066	0.20	"
29-11—58	45″	5.3	33.44	0.0082	0.20	"
13-12—58	54″	5.0	30.40	0.0050	0.20	"
27-12—59	58″	5.0	42.55	0.0052	0.12	0.023
10—1—59	65″	4.9	42.56	0.0028	0.16	0.015
7—2—59	62″	4.9	69.92	0.0037	0.12	0.014
21—2—59	77″	4.9	77.52	0.0080	0.16	Trace
7—3—59	82″	5.0	72.96	0.0074	0.24	"
21—3—59	87″	4.8	77.52	0.0070	0.20	"
			Block VII			
11—7—58	19″	5.9	25.8	0.0052	1.0	Trace
19—7—58	22″	5.0	25.8	0.0010	0.35	"
26—7—58	27″	5.2	27.36	0.0046	0.35	"
9—8—58	20″	5.4	25.84	0.0122	0.10	0.003
21—8—58	20″	5.4	22.80	0.0026	0.45	Trace
5—9—58	27½″	5.4	36.48	0.0022	0.30	"
19—9—58	36″	5.5	28.88	0.0017	0.40	0.024
3-10—58	56½″	5.0	25.84	0.0054	0.15	0.01
17-10—58	42″	5.4	51.68	0.0062	0.30	Trace
1-11—58	48½″	5.8	42.56	0.0072	0.20	0.014
15-11—58	53″	5.4	21.28	0.0028	0.15	Trace
29-11—58	47″	5.3	47.12	0.0074	0.24	0.024
13-12—58	59″	5.5	30.40	0.0049	0.15	0.007
27-12—58	62″	5.1	34.96	0.0042	0.20	Trace
10—1—59	74″	5.5	33.44	0.0024	0.12	"
7—2—59	73″	5.2	31.92	0.0019	0.24	"
21—2—59	84″	5.3	25.84	0.0018	0.20	"
7—3—59	88″	5.2	48.64	0.0024	0.24	"
21—3—59	96″	5.2	48.64	0.0020	0.28	"

TABLE 4 (*contd.*)

Date of collection	Depth	pH value	Conductivity in micro mho	Total solid %	Oxygen requirement in p.p.m.	Nitrite nitrogen in p.p.m.
			Block VIII			
11—7—58	14"	7.0	221.9	0.0168	2.6	0.213
19—7—58	17"	6.0	221.9	0.0120	3.0	Trace
26—7—58	21"	6.3	281.20	0.0162	2.95	,,
2—8—58	25"	6.0	205.2	0.0148	5.3	0.022
9—8—58	17"	6.0	92.72	0.0144	2.0	Trace
21—8—58	13"	6.2	65.36	0.0080	1.80	0.011
5—9—58	23"	6.5	288.8	0.0126	2.75	0.1800
19—9—58	33"	5.0	174.8	0.0098	2.10	Trace
3-10—58	52"	5.0	486.4	0.0534	0.30	,,
17-10—58	37"	6.4	116.52	0.0134	1.35	0.010
1-11—58	45½"	6.5	114.00	0.0135	1.92	0.015
15-11—58	45"	5.7	36.48	0.0064	0.44	Trace
29-11—58	45"	5.8	76.00	0.0146	1.04	0.023
13-12—58	50"	5.6	88.00	0.0052	1.00	0.0144
27-12—58	58"	5.0	56.24	0.0042	0.76	0.027
10—1—59	57"	5.0	45.00	0.0084	0.24	Trace
7—2—59	58"	4.8	148.96	0.0102	0.32	,,
21—2—59	66"	4.8	89.68	0.0092	0.28	,,
7—3—59	74"	4.9	77.52	0.0086	0.38	,,
21—3—59	82"	4.7	86.64	0.0074	0.24	,,

TABLE 5

Showing the results of Analysis (mean values of quadruplicates) of drainage waters collected from soils kept waterlogged in pots

Horizon	Duration of waterlogging	pH	Conductivity in micro mho	Total solid %	Oxygen requirement in p.p.m.	Nitrite Nitrogen in p.p.m.
A	8 weeks	6.2	114.00	0.0102	14.20	0.30
	10 ,,	6.3	132.75	0.0121	16.53	0.18
	20 ,,	6.4	163.78	0.0162	16.75	0.16
	30 ,,	7.1	106.02	0.0084	8.10	0.19
B_1	8 weeks	6.0	89.68	0.0124	12.80	0.80
	12 ,,	5.8	79.04	0.0097	11.53	Trace
	22 ,,	6.1	99.56	0.0152	14.05	0.05
	32 ,,	6.2	82.08	0.0060	9.75	0.12
B_2	8 weeks	5.5	32.44	0.0080	2.6	Trace
	14 ,,	5.7	71.95	0.0087	4.4	,,
	24 ,,	5.6	49.78	0.0102	2.4	,,
	34 ,,	5.5	33.89	0.0031	2.2	,,
B_3	8 weeks	5.6	62.32	0.0102	2.6	Trace
	16 ,,	5.5	53.18	0.0069	11.0	,,
	26 ,,	5.6	47.12	0.0085	3.4	,,
	36 ,,	5.6	35.97	0.0028	1.0	,,
B_4	8 weeks	5.9	25.80	0.0026	2.9	Trace
	18 ,,	5.8	60.80	0.0096	7.9	,,
	28 ,,	5.7	45.22	0.0066	2.7	,,
	38 ,,	6.2	27.74	0.0026	1.55	,,