ON THE WATER RELATION IN LIMESTONE AND DIABASE VEGETATION IN THE LEEWARD ISLANDS OF THE NETHERLANDS ANTILLES

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Abstract

In a same macroclimate on the islands of the Leeward Group of the Netherlands Antilles two types of vegetation are chiefly found. A vegetation pertaining to the dry evergreen formation series on limestone and a vegetation on diabase belonging to the seasonal formation series. Study was made of the water relation at the end of the rainy season during which transpiration, water deficit, suction pressure and soil water were investigated. From the course of transpiration curves it was concluded that water relations in diabase soil are more sever than those in the limestone. Water deficit in plants, growing on diabase appears to be much higher than those of limestone. Suction pressure divergates strongly in both cases. In the upper soil layers the amount of water that can be taken up by plants is small both in limestone and diabase. In deeper layers of the limestone soil there is more water than in diabase of the same level. Vegetation on diabase is determined by a sufficient amount of water in the soil during the rain season and a great drought during the other months. On the other hand in limestone the amount of water in the soil is larger during a longer period. Because of the higher suction pressure of this soil only plants developing a higher suction pressure can occur.

1. Introduction

The vegetation of the Leeward Islands of the Netherlands Antilles, situated at a distance of 27 to 87 km from the Venezuelan coast, is determined by the tropical temperatures, but more so by the great drought which exists here during several months of the year (Boldingh, 1914; Stoffers, 1956). An exception must be made for vegetation types such as mangrove woodlands, vegetations of saltflats and salinas, and fresh and brackish water communities. These types are indicated by Beard (1944, 1949) as 'Edaphic climax Formations and derivates'.

Boldingh (1914) distinguishes besides these vegetations – indicated by him as littoral vegetations – a Croton vegetation '. . . determined by *Acacia* and *Croton*, which has either a *Capparis* or a *Rhacoma* type, to be found on diabase and limestone respectively. In the higher parts of the island this *Croton* vegetation changes into a more forest-like type'. Stoffers (1956) distinguishes besides the edaphic communities a seasonal formation series on diabase and a dry evergreen formation series, mainly on the quaternary limestone. The distinction in the two mentioned series was based on the classification of vegetation types of tropical America put foreward by Beard (1944, 1949).

These seasonal and dry evergreen series differ not only in composition of the species, but especially in structure. BEARD (1949) assumes that the seasonal formations as a rule are 'an expression of physical drought and consequently deciduous trees are typical, rather than hard-leaved evergreens. Under the driest conditions thorniness and microphylly become characteristic. On the other hand, dry evergreen formations occur in relatively dry areas, but they are the expression of physiological rather than physical drought'. The species typical for these formations are hard-leaved evergreens; under drier conditions microphylly is characteristic, but not thorniness.

In spite of strong anthropogenic influences there is a marked difference between the vegetation of the limestone plateaux and that of the non-calcareous areas in the islands of Aruba, Bonaire, and Curaçao. Therefore, these islands seem to be very suitable for an ecological investigation as here limestone and diabase are found side by side in the same macroclimate. Meteorological observations do not indicate that there are differences in amounts of precipitation between limestone and diabase areas, through which the difference in vegetation could be explained.

Seeing the great correlation of seasonal formations and derivates with diabase on the one side and dry evergreen formations and derivates with limestone on the other side, one could decide to a calcifuge and a calcicole vegetation. Species that could be taken into consideration as calcicole are among others *Antirrhoea acutata*, *Bulbostylis curassavica*, *Rhacoma crossopetalum*, and *Erithalis fruticosa*. This is definitely not the case with species such as *Coccoloba swartzii*, *Bumelia obovata*, and *Metopium brownei*, species that are particularly characteristic of the limestone area and often determine the physiognomic aspect. However, they also occur on the slope of the Seroe Christoffel in Curaçao, on the steep slopes of the Brandaris and the Joewa Hills in Bonaire (STOFFERS, 1963), and on the Arikok in Aruba. BEARD (1949) has also reported similar observations.

The purpose of this investigation was to gain an insight into the ecological differences between these vegetation series.

From an ecological point of view five primary factors must be discerned (WALTER, 1960): 1. heat, 2. water, 3. light, 4. chemical, and 5. mechanical. This investigation was deliberately limited to heat and water factor. The other primary factors were not studied since there is no reason to suppose that great differences in light or sharp variations in mechanical damage occur on limestone and diabase. This, of course, is not the case with the chemical factor. Distribution of a number of species mentioned earlier indicates that the influence of calcium is probably not a primary one. It possibly influences the water relation of the soil, where it plays an important role in the development of the clay complex.

Results concerning the heat factor, especially the differences in micro-meteorological circumstances will be published elsewhere.

Since the water factor affects both in the atmosphere and in the soil, an effort was made to obtain data not only on transpiration, suction pressure of the leaves, and the water saturation deficit, but also on the water content of the soil. It must be emphasized that for some measurements it was not the intention to gather absolute but rather relative values e.g. for soil humidity and saturation deficit.

2. Methods

Under field conditions one is strongly limited in the applied methods as it demands portable instruments. We had devised the following methods for our use:

Transpiration. It was determined by the Momentan-method (Stocker, 1929; Steubing, 1965). The loss of water per minute, per gramme of the leaf was measured. Leaves not older than one year and of the same exposition were used. These were weighed on the spot immediately after being removed from the plant and were freely exposed for two minutes and weighed again. A torsion balance (Verenigde Draadfabrieken, Nijmegen, The Netherlands) was used for these measurements.

Evaporation. It was measured with the aid of a Piche evaporimeter.

Suction pressure of the leaf. This was determined by the method of Schardakow, a method which had already proved to be very useful (Schardakow, 1956; Mouravieff, 1959; Rehder, 1959, 1960, 1961; Rehder and Kreeb, 1961; Steubing and Wilmanns, 1962; Steubing, 1965). In this method, pieces of leaves are placed in a series of saccharose solutions of decreasing concentrations. After 90 min. this test solution is coloured with methylene-blue and a drop is introduced into the corresponding initial concentration. The suction pressure is found at the value at which the drop remains afloat. This method was used since relative values rather than absolute values were sought.

Water saturation deficit. For the saturation deficit, a method developed by Čatský was used in which punched-out pieces of leaves measuring about 1½ cm in diameter were employed instead of branchlets (Čatský, 1960; Steubing, 1965). Saturation takes place in a foam-plastic plate. The saturation deficit is given in percentages of the saturation weight and is calculated according to the formule

$$S_{rel} = \frac{W_{max} - W_1}{W_{max}} \times 100,$$

in which S_{rel} is saturation deficit, W_1 the initial weight and W_{max} the weight of the pieces at saturation.

Water content of the soil was determined by a somewhat modified plasterblock method after Bouyoucos and Mick (1940). In this method electrodes made of small-mesh wire-netting are separated from each other by a 3 mm broad plastic ring (Köhn and Person, 1950). Then to both sides of these electrodes plastic rings also 3 mm broad, are applied and the entire structure is filled with plaster of Paris (Néo-Mouledur, Poliet and Chausson, Paris). The electrical resistance between the electrodes in the plaster blocks was used as an indication for the soil humidity. This electrical resistance was measured with the aid of a Wheatstone bridge.

3. Vegetation

The areas of investigation lie scattered across the island of Curaçao. The measurements mentioned here were taken at five sites with a vegetation like that which is characterised here:

3.1. *Malpais*

A *Croton* thicket on diabase, which is only slightly or not at all under the influence of the trade-wind, with some scattered trees. Outside the plot some specimens of *Balanites aegyptica* were found, a tree that was introduced in 1880 and since then has spread over the eastern part of the island. Vegetation covers 65 % of the surface and reaches a height of 70 cm. Composition of the vegetation is given here after the Braun-Blanquet scale (Braun-Blanquet, 1951; Knapp, 1958). *Croton flavens* 3.2; *Acacia tortuosa* + 0.1; *Opuntia wentiana* + 0.1; *Acacia curassavica* 1.2; *Heliotropium ternatum* 1.2; *Haematoxylon brasiletto* r; *Aristida adscencionis* 1.2; *Bouteloua heterostega* + 0.1; *Euphorbia thymifolia* + 0.1; *Anthephora hermaphroditica* + 0.2.

3.2. *Hill near Janwé*

A diabase hill with a *Croton* vegetation in which some scattered trees occur. This site is highly exposed to influences of the wind. Vegetation height amounts 50–60 cm and cover about 40%. *Croton flavens* 3.2; *Lantana camara* + 0.1; *Opuntia wentiana* + 0.1; *Bourreria succulenta* r; *Haematoxylon brasiletto* + 0.1; *Caesalpinia coriaria* + 0.1; *Pectis humifusa* + 0.1; *Anthephora hermaphroditica* + 0.2; *Euphorbia thymifolia* + 0.1. Outside of the plot some specimens of *Bursera bonairensis* were found.

3.3. *Noordkant Plantation*

The soil occupies pockets and crevices in a general expance of hard limestone pavement. Vegetation height is 2–3 m and this is overtopped by some scattered higher trees. It is classified as dry evergreen woodland, and is considered to be one of the best vegetated limestone plateaux of the islands. *Coccoloba swartzii* 3.2.; *Rhacoma crossopetalum* 1.2; *Caesalpinia coriaria* r; *Bourreria succulenta* r; *Haematoxylon brasiletto* + 0.1; *Metopium brownei* 2.2; *Antirrhoea acutata* 2.2; *Cordia cylindrostachya* + 0.1; *Casearia tremula* + 0.1; *Lantana camara* + 0.1; *Opuntia wentiana* r; *Cephalocereus lanuginosus* v.r.; *Croton flavens* + 0.1.

3.4. *Siberie*

A limestone plateau in the middle of the island with a rather dense vegetation comparable with the former. *Coccoloba swartzii* 3.1;

Haematoxylon brasiletto 1.1; *Metopium brownei* + 0.1; *Bumelia obovata* r; *Randia aculeata* + 0.2; *Bourreria succulenta* 1.1; *Acacia tortuosa* r; *Croton flavens* r; *Antirrhoea acutata* 2.2; *Lantana camara* + 0.1; *Phyllanthus botryanthus* + 0.1; *Erithalis fruticosa* + 0.1; *Cordia cylindrostachya* + 0.1.

3.5. *Mahoema*

A limestone plateau near the north coast of the island. The vegetation is considered to belong to the '*Croton-Lantana-Cordia* thicket derived from dry evergreen woodland' (Stoffers, 1956). The vegetation in which Antirrhoea acutata and Erithalis fruticosa dominate is in general less than 1 meter high and a few scattered higher shrubs or small trees occur. *Antirrhoea acutata* 2.2; *Erithalis fruticosa* 2.1; *Cordia cylindrostachya* 1.1; *Croton flavens* + 0.1; *Lantana camara* + 0.1; *Opuntia wentiana* + 0.1; *Casearia tremula* r; *Haematoxylon brasiletto* r; *Cyperus planifolius* + 0.2.

4. Observations

4.1. *Transpiration*

Figures 1 and 2 show an example of transpiration in plants on diabase obtained at Janwé and Malpais. It is evident that in both cases transpiration reaches a maximum value in the morning hrs. This is followed by a sharp fall. The time at which the maximum is reached differs from species to species and the place where the plant grows. At Janwé, *Croton flavens* and *Bourreria succulenta* have a maximum in the early morning hours while for *Bursera*, *Haematoxylon*, and *Caesalpinia coriaria* this maximum is shifted to a time more close to noon. Both of these types occur also in Malpais. *Acacia tortuosa*, *Acacia curassavica*, and *Phyllanthus botryanthus* have their maximum in the morning hours. For *Balanites* and *Croton* the maximum is shifted to an earlier hour in the case of Janwé. This phenomenon could be explained on the basis of the trade wind as on sites strongly exposed to this wind a shift of the maxima to an earlier hour is always observed for the species. In the case of *Caesalpinia* and the non-native *Balanites* a maximum is found considerably higher in comparison with the other species while a conspicuously lower transpiration maximum is found in *Phyllanthus botryanthus*. The course of transpiration in the mentioned species is thus represented by a 'one-topped' curve in which the maximum is found in the early morning hours or about noon.

A different type of curves is seen in Fig. 3, 4, and 5. Here the majority of the species show two maxima in the Course of the day, a 'two-topped curve'. The first top is found in the early morning hours and the second one in the afternoon and these are separated by a minimum at about noon. As can be seen in Fig. 3 it is evident that *Antirrhoea*, *Erithalis*, and *Phyllanthus* can decrease transpiration to a value that could not be measured by the applied method. *Antirrhoea* has a strong xeromorphic structure with heavily cutinised shiny leaves. *Erithalis* has more or less succulent leaves with a thick

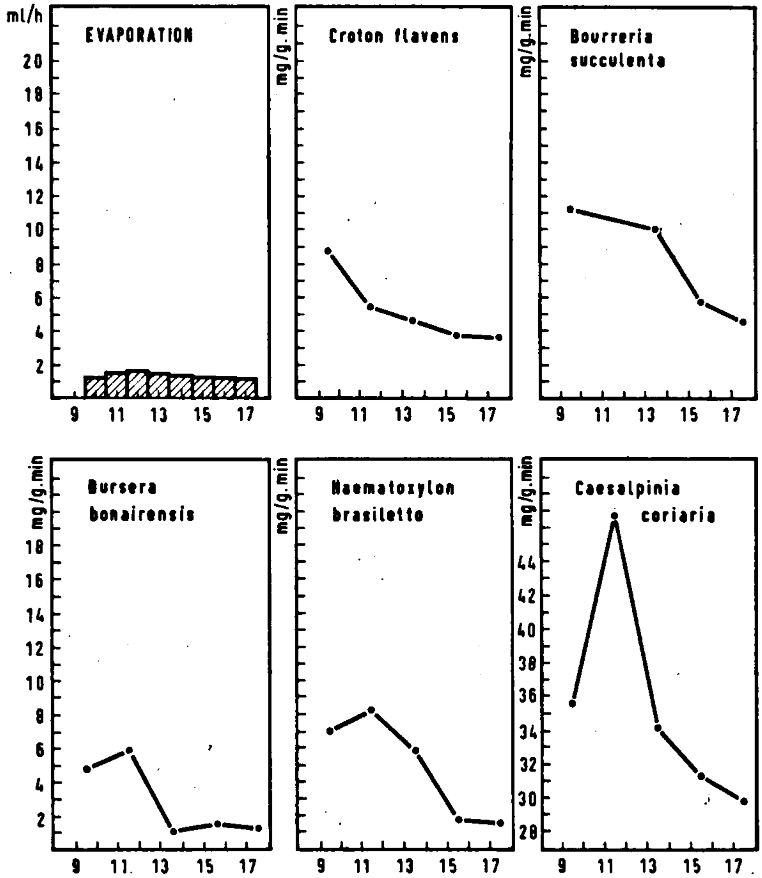

Fig. 1. Evaporation and transpiration. Janwé, 14–2–1964.

cuticle, while *Phyllanthus* can curl the leaves to decrease transpiration. *Metopium* is conspicuous in this group by its high maximum values which, however, were not found in other locations. Among the most striking species are *Croton flavens* and *Haematoxylon brasiletto* where completely different types of curves are seen. In *Croton* corresponding with the evaporation curve, a slow increase is noticed during the morning hours and a gradual decrease in the afternoon. *Haematoxylon* represents the 'one-topped' curve with a maximum strongly shifted to the morning hours. The same is seen in Fig. 4. The majority of species show a 'two-topped' curve with a minimal transpiration about noon time. *Croton* here again forms an exception with a gradually increasing transpiration more or less proportional to the evaporation. However, there is a strong decrease in the course as the afternoon approaches.

In the third example of a vegetation on limestone, Fig. 5, where the low shrubs determine the aspect, the two-topped curves occur

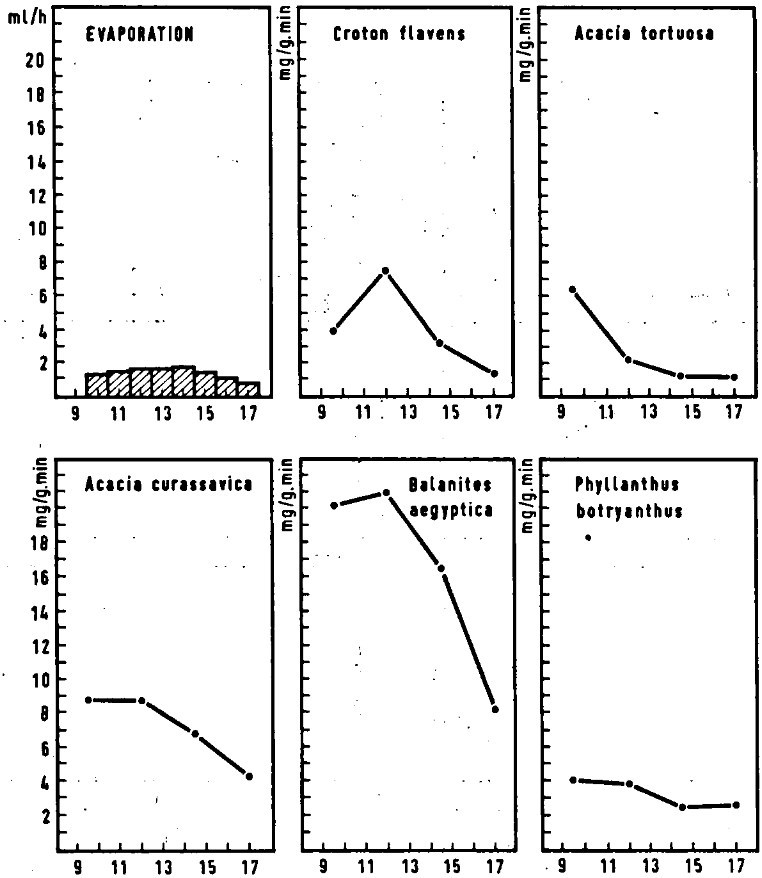

Fig. 2. Evaporation and transpiration. Malpais, 12–2–1964.

in four of the five species. Here again an exception is seen in *Croton flavens* which shows a curve parallel to evaporation. It is evident from the examples given, that three types of transpiration can be discerned viz.:

1. a two-topped curve in which the minimum is reached about noon-time indicating a strong decrease in transpiration;
2. a one-topped curve in which the maximum is shifted to the early hours of the day;
3. a symmetrical curve which runs more or less parallel to the evaporation curve.

4.2. *Water saturation deficit*

The saturation deficit will increase faster and to a higher value depending upon the lower resistance to periods of drought by the

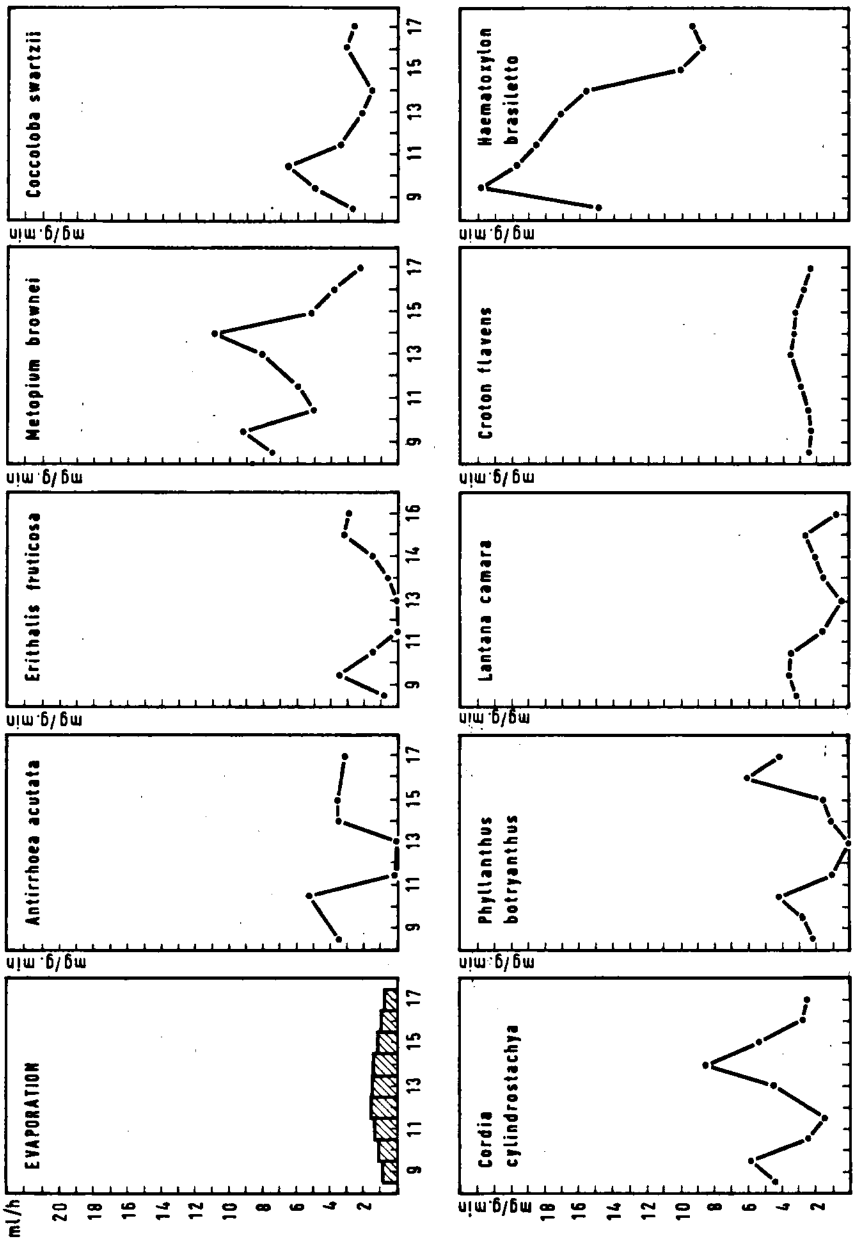

Fig. 3. Evaporation and transpiration. Siberie, 7-2-1964.

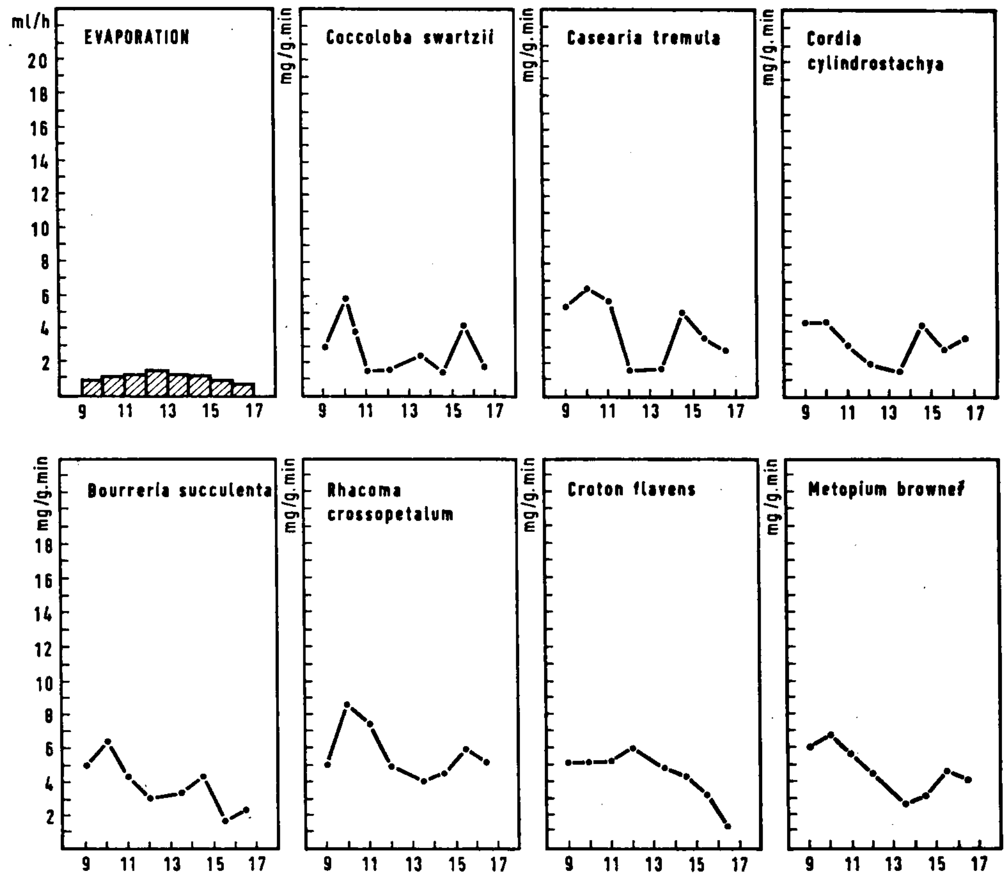

Fig. 4. Evaporation and transpiration. Noordkant Plantation, 27-1-1964.

plant. In general this is the case with species which have higher demands on the water household. Table 1 confirms the conclusions drawn from the course of the transpiration.

It is evident that on days of observation at the end of the rainy season a difference becomes apparent between plants which grow on limestone and those which grow on diabase. In the species on the limestone plateaux there is a maximal saturation deficit in the order of 10 % at this time of the year. This maximum value seems to be a minimum in the plants on diabase, the maximum in these plants being 30 %. These differences are well brought out in the cases where the saturation deficit was measured in plants that occur both on limestone and on diabase namely *Croton flavens*, *Bourreria succulenta*, *Haematoxylon brasiletto*, and *Phyllanthus botryanthus*.

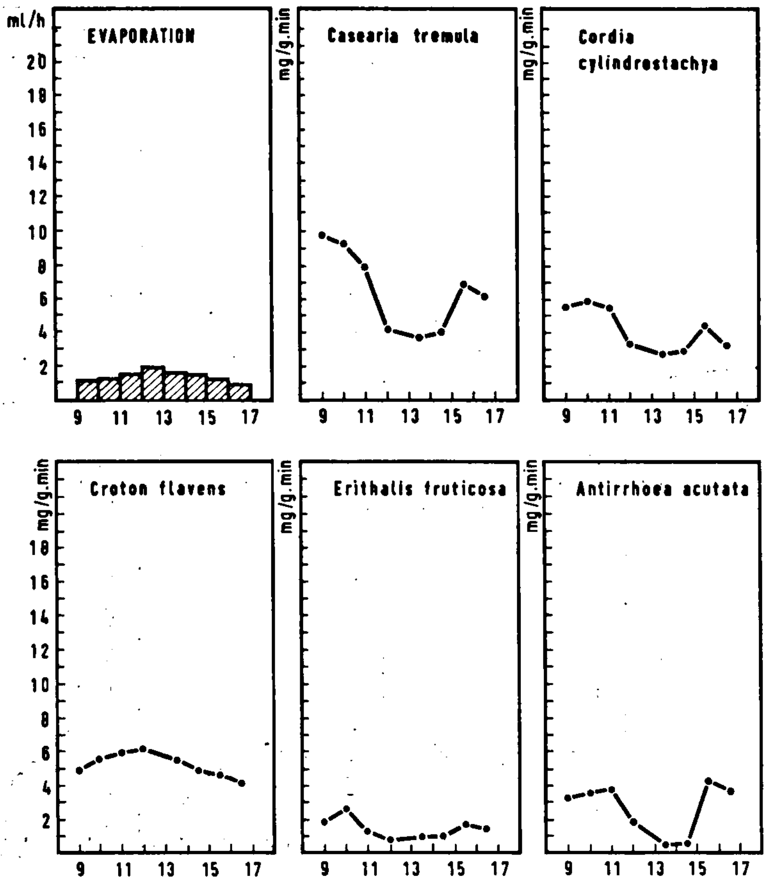

Fig. 5. Evaporation and transpiration. Mahoema, 23–1–1964.

4.3. *Suction pressure*

The observation that transpiration-decrease can be the result of lower suction pressure, a better insight in the water relation can be obtained through informations gained from the measurements of the suction pressure.

In contrast to the osmotic values which can be regulated within certain limits in relation to the location, the suction pressure is a more variable unit which is determined by the interplay of the osmotic and the turgor pressure (MEYER, 1956). The suction pressure is not very much dependent on general average circumstances, but on momentary meteorological and soil water conditions. As a result of this, the suction pressure often shows considerable daily fluctuations. In Table 2 the suction pressure of a number of plants is shown along with their locations. Some of the measurements which the present authors for some purpose consider not reliable altogether are indicated by x.

TABLE 1

Water saturation deficit in plants growing on diabase and limestone

	Janwé	Malpais	Siberie	Noord kant	Mahoema
Bursera bonairense	13 %				
Bourreria succulenta	27 %				
Haematoxylon brasiletto	24 %		10 %		
Croton flavens	28 %	17 %	6 %	7 %	9 %
Acacia curassavica		10 %			
Balanites aegyptica		30 %			
Phyllanthus botryanthus		21 %	5 %		
Coccoloba swartzii			9 %	7 %	
Cordia cylindrostachya			5 %	6 %	7 %
Metopium brownei			4 %	10 %	7 %
Erithalis fruticosa			11 %		10 %
Antirrhoea acutata			3 %		10 %
Lantana camara			8 %		
Rhacoma crossopetalum				4 %	
Casearia tremula				6 %	8 %

TABLE 2

Suction pressure of some plants growing on diabase and limestone

Diabase

Janwé

	9.30	13.00	17.00 h.
Caesalpinia coriaria	10	31	23
Bursera bonairensis	3.5	18	21
Haematoxylon brasiletto	21	45	x
Croton flavens	12	32	24
Bourreria succulenta	8	30	26

Malpais

	9.30	13.00	17.00 h.
Acacia curassavica	10	32	27
Croton flavens	13	34	25
Acacia tortuosa	13	27	24
Randia aculeata	19	29	29
Phyllanthus botryanthus	16	33	27

Limestone

Noordkant Plantation

	9.30	13.00	17.00 h.
Coccoloba swartzii	6	13	19
Antirrhoea acutata	6	10	10
Rhacoma crossopetalum	4	15	13
Bourreria succulenta	13	21	19
Cordia cylindrostachya	8.5	22	20

Near Willemstad

	9.30	13.00	17.00 h.
Croton flavens	9	16	13
Cordia cylindrostachya	x	8	10
Acacia curassavica	x	4	6
Acacia tortuosa	x	8.5	5

Near Piscadera

	9.30	13.00	17.00 h.
Bourreria succulenta	8.5	26	18
Casearia tremula	9	25	14
Haematoxylon brasiletto	20	22	15
Caesalpinia coriaria	20	20	22
Prosopis juliflora	15	11	11.5
Acacia tortuosa	16	18	15

Siberie

	9.30	13.00	17.00 h.
Bumelia obovata	19	18	x
Rhacoma crossopetalum	18	22	18
Randia aculeata	26	26	21

4.4. *Water content of the soil*

A frequent and regular measuring of the water content of the soil was impossible. Firstly these locations are situated too far from each other and secondly, the stay in Curaçao was interrupted by a trip to the island of Bonaire. However, a good impression is given by the data collected near Janwé and at Noordkant Plantation. These measurements were made on the same day at 5 and 25 cm depths at 5 days intervals during the end of the rainy season. The electrical resistance (in Ohms) between the electrodes in the plasterblocks is given in Fig. 6.

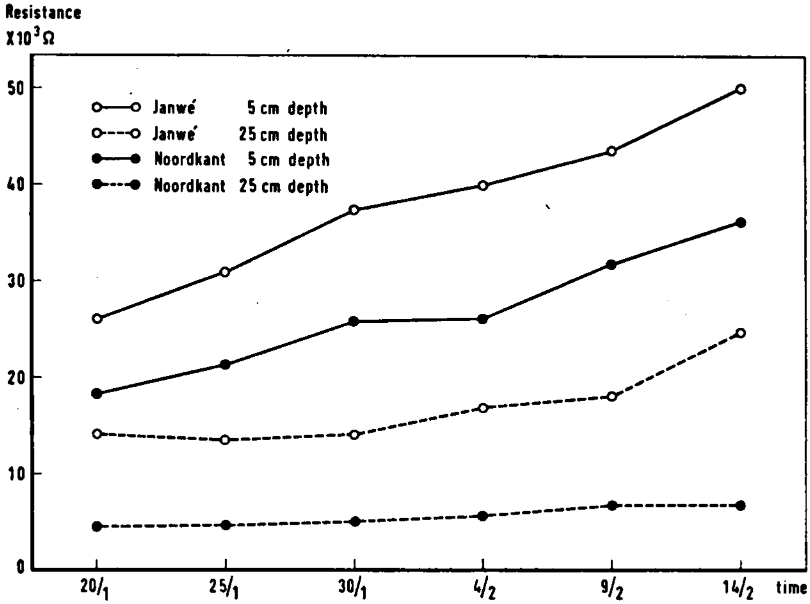

Fig. 6. Soil moisture; data obtained by the modified Bouyoucos-method. Resistance given in Ohms.

These data are mean values of three measurings. From the data it is clear that at this time of the year the limestone soil below 25 cm depth is moister than the diabase soil. Differences are smaller at 5 cm depth. It must be emphasized that water relations may shift strongly in the course of the year, as is shown by data collected in the island of Bonaire during the rainy season.

5. Discussion

If the data presented here are overlooked, then a marked difference in the water relation between plants growing on diabase and limestone becomes evident. In the first place this difference is seen in transpiration. The three types in the transpiration curves seen, reflect

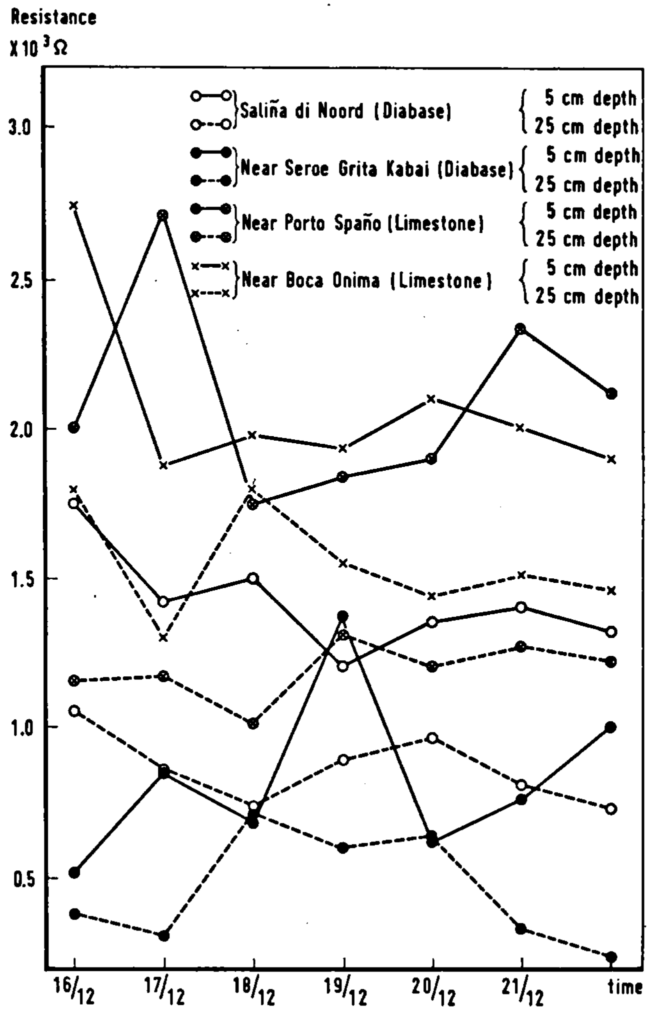

Fig. 7. Soil moisture data obtained in the island of Bonaire. Resistance given in Ohms.

clearly the water relation in the soil. If the amount of soil water is adequate the transpiration curve runs parallel to the evaporation curve (STOCKER, 1956). This is the case with *Croton flavens* growing on limestone. If this species occurs on diabase then the rate of transpiration decreases after reaching the maximum disproportionate to the decrease in evaporation. This implies that in the soil, the water supply is impeded and the water relation becomes more severe. However it is remarkable that for *Croton flavens* growing on diabase the transpiration maximum is higher than that on limestone. This could be explained either by a capability of *Croton* to develop and stand a high suction pressure in the cell or by a low suction pressure of the diabase soil.

The second type found on diabase can be discerned as the 'one-topped curve' ('Eingipflige Kurve', STOCKER, 1956) in which the maximum is found in the earlier hours of the day. This is brought about due to decrease in transpiration which, however, does not cause a recovery in the hydrature. Therefore, under less unfavourable circumstances in the late afternoon an increase or recovery of the transpiration fails. Due to the occurrence of the one-topped curve in diabase areas it can be concluded that in this time of the year water supply in the soil is not adequate.

In contrast to this, the 'two-topped curve' ('Zweigipflige Kurve') is characterised by the presence of two maxima: one in the morning and one in the afternoon. According to STOCKER (1956) this type is found when there is a more severe water supply in those plants which already limit the transpiration by closing the stomata at a slight loss of water. The decreasing of transpiration will better the water relation and in the course of the afternoon the stomata are reopened and transpiration increases again. This type of transpiration was indicated by BERGER-LANDEFELDT (1936) as iso-hydric. While this type is not found on diabase at all, it is found in the majority of cases on limestone. An exception is seen in *Croton flavens* and in *Haematoxylon brasiletto*. In the former transpiration is proportionate to evaporation. In the latter a one-topped curve is seen and moreover, the difference in transpiration found on the two locations given is very large: 8 mg/gr. min on diabase (Janwé) and 22 mg/gr. min on limestone (Siberie). As can be seen that under given circumstances the evaporation on the site near Janwé is more than near Siberie this difference in transpiration may be explained by a smaller amount of water at the disposal of the plant in the diabase soil.

From the transpirational relations as found at the end of the rainy season it is evident that at this time of the year the hydrative circumstances in the limestone area are more favourable than that in the diabase soil. This conclusion is also supported by the difference in water deficit that is found in plants on diabase-soil and those which grow on limestone. In the latter case values are found that do not surmount 10–11 %. These figures are found at a minimum on diabase.

The low saturation deficit found in plants on limestone is not attained through a high suction pressure in comparison with those which are found on diabase. In general values obtained in the suction pressure measurements in the diabase area are higher than those in the limestone area. In the opinion of the present authors there are not sufficient data available to make a definite conclusion. Probably species growing on limestone may develop a higher suction pressure under more severe circumstances than are found on the mentioned time. This is suggested by some stray observations at the very end of the dry season. Here, values of over 60 atmospheres were measured in *Coccoloba*, *Antirrhoea* and *Bourreria* growing on limestone.

Seeing that measurements made of the soil humidity show the limestone soil is more humid than that of diabase, as well as the indication that plants growing on limestone may develop a high suction pressure, it was supposed that the greater humidity of the limestone-soil was the result of a greater water capacity due to a better developed clay-complex. On the other hand the water capacity of diabase soil would be lower. Reason for this hypothesis was the granulometric composition of the soils derived from the three main geological formations in Bonaire (WESTERMANN and ZONNEVELD, 1956) as well as the investigation of HAMILTON and SESSELER (1945) on the soils of the West Indies. An analysis of two samples taken from Siberie and Malpais gave the following results:

	Siberie	Malpais
$CaCO_3$	2.6 %	2.0 %
Material finer than 2 μ as percentage of the mineral material smaller than 2000 μ	50 %	30 %
Humus content	7.7 %	10.4 %
Material 2000 μ	99 %	80.9 %
*p*H	8.1 %	7.4 %

The composition of the material smaller than 2000 μ is given in Fig. 8. From this it can be seen that the fraction smaller than 2 μ, which is the most important factor in the formation of the clay complex, is appreciable higher in limestone than in diabase. In the humid climates clay soils, so soils with a fine texture and with a high water capacity, provide moister habitats than soil with a coarse texture such as sandy soils. In arid regions, however, it is quite contrary (WALTER, 1932, 1960, 1964). The fact must be emphasized that the soil on limestone plateaux is only found in fissures and rock

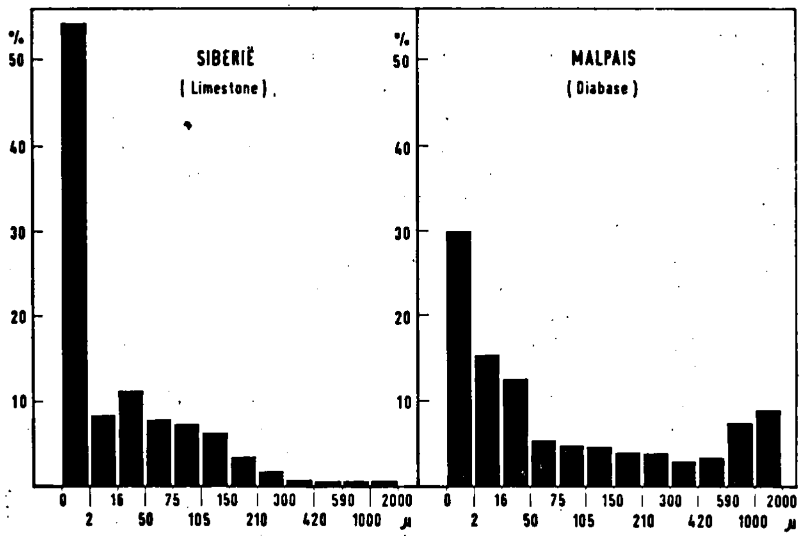

Fig. 8. Granulometric composition of the fractions smaller than 2000 μ of two soil samples taken at Siberie (limestone) and Malpais (diabese).

crevices so that only the upper layer can strongly dry out, while the deeper layers, approximately beneath 20 cm, are entirely protected against evaporation. The presence of a more luxuriant vegetation on limestone plateaux in this arid area must therefore be seen as a further example of what WALTER (1960, 1964) indicates as 'Das Gesetz der relativen Standortskonstanz und des Biotopwechsels' the 'Law of relative constant environment through changes of habitat'.

This might be an explanation for the phenomenon that species restricted to the limestone plateaux in this area are found on non-calcareous soils in other parts of the West Indies where the amount of precipitation is appreciable larger. It is also characteristic for those parts of the Seroe Christoffel where e.g. *Coccoloba swartzii* and *Metopium brownei* are found in large numbers that they have a higher water content in the soil than the diabase area (Stoffers unpubl.).

So the following picture can be given. In the diabase areas a shallow soil is found. Owing to the hilly character of these areas much of the rain water flows to the sea during and shortly after a shower. Only a part of the water soaks into the soil and even of this a portion is added to the ground water. (For geohydrological data reference should be made to MOLENGRAAFF, 1929 and WAGENAAR HUMMELINCK, 1940a, 1940b, 1953). Due to its low water capacity the soil becomes very easily saturated. The upper layers will dry out quickly after the rainy season through evaporation and water uptake by the herbs while the deeper layers are occupied by the roots of shrubs and trees. As a result, shortly after the last shower the soil water at the disposal of the plants is exhausted. Seeing that the coarse texture does not cause a rapid water succession the drought will be experienced by the plant very soon. This results in temporary wilting which slowly grades over into permanent wilting and leaf-abscission.

On the limestone plateaux, however, the case is entirely different because all the water disappears into the cracks and holes of the porous rocks in which a soil with a high water capacity is found. This soil becomes saturated and the superfluous water adds on to the groundwater. After the last showers the water content in the upper layers decreases considerably due to evaporation and also to use by the herb layer. But the greatest part of the added water will come at the disposal of the plants. Thus there is sufficient water available all the year round for plants whose roots grow to deeper depths or those plants rooting more superficially but capable to develop a higher suction pressure. Moreover this water is used very economically as the greater part of the plants already limit their transpiration at a small loss of water. Furthermore trees with a deep growing root system can slightly make use of the cavern water as can be seen for instance in the caves near Fontein (Bonaire).

It must be emphasized that the picture concerns only the shrub and tree vegetation. Concerning the herbs in the limestone soil the hydrature is reduced more severely by the high suction pressure of the clay in the upper layers of the soil.

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