Final report

Corallita Pilot Project
St.Eustatius, Netherlands Antilles

Study on the ecology and possible control methods of the invasive plant species *Antigonon leptopus* (Corallita or Mexican Creeper)

Authors:
J.J.Ernst and P.Ketner

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Introduction

This one-year pilot project aims to provide an insight in the ecology of *Antigonon leptopus* (Corallita) an invasive vine, which is overgrowing the native vegetation (Photo 1).
This pilot project is just a first step in controlling the *Antigonon leptopus*. This research was done on a small scale and under controlled circumstances. Our ideas are just for small scale use in town but also to eradicate 'hotspots' to prevent further spreading especially near the National Parks. The government with STENAPA as a consultant should take further actions to continue this project and put it as a high priority. The first step was made and we hope this will contribute in containing the species and monitoring the species closely. More research on the life circle and possible natural enemies and its sensitivity for herbicides should be done in order to start a larger scale eradication campaign. The project does not stand on its own, the vine contributes in the prevention of soil erosion on the island. A full size project including replanting/reforestation with native species and renewed agricultural activities should be set up for the long term.

1. Background and justification

St.Eustatius native vegetation is in competition with *Antigonon leptopus*. This vine was introduced to St.Eustatius many years ago as an ornamental species, and has become a pest on the island. Native vegetation is overgrown with this species, and fences around private houses are torn down by the weight of the vine, allowing roaming animals to enter and destroy yards. Large trees are killed by the vine which overgrows and chokes them.
A very common sight on St. Eustatius is the coverage of vegetation in the southern parts of the Cultuurvlakte, extending east of the Quill and elsewhere by *Antigonon leptopus*. In some places, this plant has covered the whole vegetation, resulting in die-off of the undergrowth. It grows fast over tree crowns, blocking the sunlight from reaching the leaf surface and hence hampering the growth of the plants themselves as well as the under storey plants. Many beautiful and often valuable wild fruit trees are overgrown and do not bear fruit any more.

Although various countries have put the species on their list of pests (potential or already invasive species) which need control management, no proper control methods have been found so far. There are no initiatives for control management of Corallita in the Caribbean[1].

Additionally, hardly any ecological research has been done on this species which makes the problem more complicated.
Without greater ecological knowledge and understanding about how to manage this plant, no pest disease chapter in the management plan of the National Parks of St. Eustatius can be integrated. Many people working in the field of nature conservation on the Antilles were approached. After many reactions we can conclude not much is known. Therefore, this present project is unique and must be considered as a pilot project. This project hopes to contribute to the maintenance of biodiversity of flora and fauna on St. Eustatius

Photo 1: Antigonon leptopus

[1] CABI, 2002, personal communication.

2. Review of available knowledge

2.1 Invasive plants general

Since Charles Darwin (1858) described his findings of plants in new areas[2], researchers have been intrigued by the concepts of this ecological phenomenon. Nowadays we know that introductions or 'invasions' of alien species can cause great damage to the invaded ecosystems by reduction or replacement of the indigenous species. Men introduced most invasive plants as a result of deliberate or accidental transport of planting material or seeds. Also the change in climate, atmosphere and land use creates new possibilities for a successful establishment of a new species in an area[3]. Researchers study invasions for the reason that many invasions become pests. In order to avoid a plant introduction from becoming a pest and to protect indigenous species against extinction, knowledge on the strategic characteristics of invaders is needed.

2.2 *Antigonon leptopus*

2.2.1 Taxonomy

Order	Polygonales
Family	Polygonaceae: Buckwheat family
Genus	Antigonon Endl.
Species	*Antigonon leptopus* Hook. & Arn.

Synonyms: *A. platypus*, *A. cordatum*, *A. cinerascens*, *Corculum leptopum*

Vernacular/common names:
Coral vine, Corallita Mexican creeper, mountain rose, confederate vine, chain-of-love, heart on a chain, love-vine, coral bells, queen's jewels, kadena de amor, Queen's wreath, cemetery vine.

2.3 Morphology

Robust vine to 10 m long or more; petioles 1-5 cm long; leaf blades 2.5-7.5 (10) cm long, cordate-ovate, hastate-ovate, or triangular, prominent reticulately veined, acutish to acuminate (and often apiculate), the lower ones much larger; inflorescence paniculate, the branches bearing flowers (Photo 2) in clusters along the rachis, the rachis tip tendrillate; racemes up to 20-flowered; at each leave axil at the end of a vine; pedicels 1 cm flowers bright pink ; a white-flowered horticultural variety exists (f.i. on Curaçao), which also is invasive, enlarging 1-4 (5) cm long tepals ovate to elliptic 4-8 x 2-6 mm. Pollination is by bees, wasps, flies, butterflies and thrips, with bees as dominant. The pollination vectors are unspecialised and promiscuous even for short-tongued arthrophiles[4]. The flowers are also visited by hummingbirds.

Photo 2: *Antigonon leptopus*

Corallita is a good source of both pollen and nectar for bees 5.
Fruit is an achene; achenes conical, sharply 3-angled above, ca 6 mm long, much exceeded by the veiny, persistent, enlarged perianth, shiny. The Corallita vine has tubers buried deep up to 2 meters in the soil. These can weigh up to 8kg
Chromosome numbers: 2n = 14, 40, 42-44, 48.

[2] Darwin, 1858; The origin of species by means of natural selection. Murray, London.
[3] D'Antonio & Vitousek, 1992; Hobbs & Humphries, 1995.
[4] Raju *et al*., 2001.
[5] Bees for Development Journal, #68.

2.4 Distribution

The species is native to Mexico (from Baja California, Sonora, Chihuahua) through Oaxaca south to Central America (Guatemala, Salvador, Costa Rica) and common in many tropical and warm countries, where it has been intentionally (as an ornamental plant) or unintentionally introduced and in many places naturalized to become a pest

In South America it has been recorded as a weed such as in Honduras [6]. It is also present in Venezuela, Margarita, and on the Galapagos islands.

The species is found on many islands in the Pacific, such as on Guam where it is classified as a dominant invader overgrowing vegetation in many areas; on Niue it is classified as a moderate invader, while on others it has not yet become a pest, but is recorded as potential invasive species[7]. It is recorded as a (potential) pest for a great number of Caribbean islands[8] (Annex I).

It occurs on Java and Timor. On the latter it covers hillside vegetation, rocky headlands on foreshores and wastelands around Kupang.
It is commonly cultivated and naturalized in Pakistan and Taiwan.
In Australia the species is listed as a priority environmental weed. It is a common garden plant in Darwin. It is spreading in various places in Western Australia, Cape York and Queensland. Townsville has listed the species as a threat. It also occurs on Papua New Guinea.
On Christmas Island (Au) it is spreading quickly in disturbed areas and has already infested some 20 ha [9].
In the USA it is naturalized in Florida and Southern Texas. Records from other States are probably plants that have persisted from cultivation. The species is widely planted in gardens and sold in many garden centres. In Puerto Rico it is cultivated and naturalized, growing along roadsides.

In Africa it is found, amongst others, in Gambia, Kenya, Zanzibar, Seychelles (Cousin & Cousine Islands)

St. Eustatius
On St. Eustatius the species seems to be everywhere on the island except above about 200m on the Quill volcano and above 50m in the Boven Northern Hills.
The landscape ecological vegetation map of Statia [10] (Figure 1) gives three major areas with Corallita growth: Botriochoa – Antigonon lowlands, north-west of Oranjestad, the Smoke Alley-Godet-Benners area. Pisonia – Antigonon Lowlands, The natural vegetation in both these landscapes is classified as "Thorny woodland derived from seasonal formations"[11].

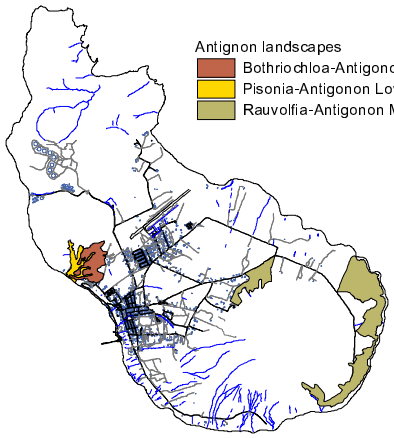


Figure 1: Antigonon landscapes

Rauwolfia –Antigonon Mountains, on the north-eastern lower slopes (below 150 m) of the Quill. On Stoffers vegetation map this area is named "cultivated and semi-cultivated" area.

[6] Holm *et al.* 1979.
[6] Meyer, 2000; PIER, 2003, ISSG Database.
[8] Kairo & Ali, 2003; CAB –International, 2002.
[9] Jeffrey, personal communication, 2006.
[10] Rojer, 1996.
[11] Stoffers, 1956.

2.5 Ecology

2.5.1 Dispersal mechanisms

The species has different dispersal strategies, through seeds and vegetative (Photo 3). Seeds float on water, which helps transport them to new locations. The viability of the seeds in the soil is unknown but is probably several years [12].

It is mentioned that the fruits are eaten and spread by domestic and wild animals (birds, pigs, goats, sheep, donkeys, and cows).

The species disperse at a rapid rate vegetative by developing a dense network of roots and rhizomes. On each knots of the rhizomes new stems and roots with tubers develop. The tubers and root parts are easily dispersed through soil transport. Stem cuttings are probably also able to root again.

Invasion pathways to new locations are established by Internet sales/postal services.

Propagation at garden centres is by seeds, stem and root cuttings.

Photo 3: Vegetative dispersal through rhizomes

2.5.2 Environment

The species prefers dry to moist lowland (< 600 m) areas, it favours limestone (basic soils),

It is well adapted to dry coral cliffs and their derived soils.

Some authors mention that the vine will grow on almost any soil, as long as it is well drained.

In 2003, STENAPA did a soil test for pH that showed that higher altitudes of the Quill had more acidic soil (pH7) and lower slopes had more basic soil (pH 7.5). This may indicate that the distribution of Corallita favours more basic soil on St. Eustatius. Furthermore, simple applications of dilute acid (urea) on some Corallita patches by C. Coker[13] demonstrated die-off of the Corallita plant over a period of time.

However, St. Maarten has more limestone than Statia but does not (yet?) have a serious problem with Corallita which may mean the controlling factor is not soil acidity.

The species is drought tolerant. It grows in full sun to light shade.

The species favours disturbed areas such as roadsides and waste/urban places, from where it spreads further into the natural vegetation.

2.5.3 Uses

In Mexico the tuberous roots are eaten. In the Caribbean, the leaves are made to poultices and rubbed into stings to reduce boils and swelling. A tea from the leaves can be made for diabetes and from the blossoms to treat high blood pressure and menstrual pains. To this day, bunches of Corallita are thrown on to coffins in a grave as a noise abate before the soil is filled in. In India, the species is used in hedges and fences, and for bowers and thatch to cover the roofs of sheds and houses. In the past on St. Eustatius the branches were used to cover the kilns for charcoal making. It was also used as cover in the buckets carrying water to the cattle in the field to prevent spilling. In Thailand the leaves and flowers are dipped in flour, fried and served with vermicelli. The flowers are also mixed into omelettes. Recently it has been recorded the Corallita has antioxidant properties[14].

A. leptopus is used as a stimulant; 5 grams of herb to 1 litre of water, once a day. In India, the species is used in hedges and fences, and for bowers and thatch to cover the roofs of sheds and houses. More detailed information on *A. leptopus* can be found in Annex II.

[12] Swarbrick,1997.
[13] LVV, 2003, personal communication.
[14] Hibbert, 2006, Jamaica Observer

2.6 Ecological threats

No specific (scientific) data is available about the damage this species brings to the ecosystems, besides that it smothers the natural vegetation to form dense impenetrable thickets, killing the native species and thereby changing structure and ecological functions and wildlife habitats. It spreads over the region, whereby regrowth of native species is hampered by the heavy shade, thus disrupting the natural succession.

2.7 Possible Control methods

Manual:
- digging up the tubers. This solution would only be effective if the species has not already taken the chance to spread all around.
- cutting vines only removes the aboveground vegetation. New vines will sprout from the remaining stem stumps, and from the underground tubers.
- grubbing can be effective, but is only feasible on the smallest of infestations on Christmas Island [15].

Mechanical:
- uprooting the plants with mechanical force (bulldozing); however this causes great disturbances, which might favour the re-establishment of the plant.
- alteration of the acidity of the soil; this is a irrational method.

Fire:
Only one reference has been found on the use of fire to combat the species, but no results were given. At the Botanical Garden of Statia, uprooted Corallita tubers are burned.

Chemical
Using herbicides; various application methods: Foliar sprays, basal bark, stump treatment.
One reference has been found on successful use of 'Round up' on NUIE Island.

Biological:
No references have been found in literature on the biological control of *A. leptopus*.

Legal:
On St Bartholomew, people are fined if the plant is seen in their garden[16].

Voluntary actions:
Perhaps owners of this plant could be persuaded to give them up for the good of the islands ecosystems or for a modest cash payment (Micronesia).

[15] Jeffery, 2006, personal communication.
[16] STENAPA, 2006, personal communication.

3 Objectives

The primary research aim is to reduce and control the growth of Corallita on St. Eustatius and to prevent the species from invading the national parks.

In order to achieve this it is necessary:

- To gather information about the ecology of the species, such as its life cycle, dispersal, germination capacity, use of the species by animals etc.
- To gather information about how the species will react on different potential control methods.
- Inform local community about control methods if usable results are obtained.

4 Research questions

1. What is the distribution of *Antigonon leptopus* on St. Eustatius,
2. Where are the problem areas?
3. Which areas are vulnerable to this species?
4. When does the species flower and set fruits?
5. What are the dispersal mechanisms?
6. How deep are the tubers located?
7. Which animals eat the fruits?
8. What is the viability of the seeds?
9. How does the species behave if treated with potential control means?
10. By what means can the species be contained, controlled or eradicated?

5 Methodology

5.1 General

Most of the experiments took place in the Botanical Garden.
Ecological observations were carried out on different parts of the island.
The Staff of STENAPA was instructed and trained about how to continue the research, and what data has (and how) to be gathered (Annex III)

5.2 Ecological data collection

5.2.1 Mapping

Using the topographical map (with scale 1:10,000) as a base, a survey was carried out on the distribution of Corallita, indicating each location that the species is found. Aerial photographs were studied to find out whether Corallita visible and could thus be of help in making the distribution map.

5.2.2 Phenology

In order to gain insight into the seasonal variation in growth of the plant, phenological observations will be made during the year of investigation. At different locations on the island three plants were designated for these observations. Weekly or every 2 weeks, the phenological phases were recorded using notations (Table 1).

Table 1: Notation phenological stages

veg. = vegetative, no flowers or seeds bearing D = plant died above ground H = plant grazed by animals S = plant disturbed				
Flowering			Foliage phenology	
fl1	start of flowering (incl. flower buds bearing)		f 1	new leaf buds present
fl2	in full blossom		f 2	young leaves
fl3	flowering is over		f 3	leaves full grown
			f 4	leaves begin to die off
Fruiting			f.5	all leaves died off
fr1	with unripe fruits		f.6	plant 75 % or more bare
fr2	with ripe fruits			
fr3	with old empty fruits			

The phenological state of the plants is indicated by a 'x'; per growth form, more than one stage can be present and should be indicated; the dominant stage is then showed by encircling the x. If from a stage only a few are present it is indicated by (x).

Example for flowering:
fl.1 (x) / fl.2 ⓧstart of flowering but full blossom dominates.

5.2.3 Animal observations
Field observations were made of animals eating Corallita. It was recorded which animal species eats from the plants and which parts (leaves, flower buds, flowers, fruits).

5.2.4 Faeces analysis
During one year (particularly during the dry season) faeces of cows and goats/sheep were collected, soaked for 24 hours in water with disinfecting agent, then manually and carefully broken into small pieces and washed over a sieve to find out whether it contained Corallita seeds or seed remnants. Whole seeds were laid out on damp kitchen paper and daily checked for germination.

5.2.5 Seed ecology
Seeds were collected for germination experiments. These were led out on humid filtering paper. At 2- 4 days (the number of days will depend on the rate of germination) intervals they were checked daily for germination and moistening. The number of germinated seeds was recorded each time.

5.2.6 Tubers
In the field a 1 x 1 m plot was dug up in order to determine the number and the weight of the tubers. Some authors say the tubers are just below the surface, others mention that they go down as far as 2 m.

5.3 Soil acidity tests
Some simple pH measurements were carried out in order to find out whether there is a correlation between the soil acidity and occurrence of Corallita. A Hellige pH-indicator was used.

5.4 Weather

In order to get better insights on the growing condition, local rainfall was recorded. This was done with rain gauges, which were placed at the same sites where the phenological data was collected.

5.5 Control Experiments methods

5.5.1 General

The experiments were divided into:

- Chemical treatments
- Manual treatment
- Mechanical treatment

In the Botanical Garden a heavily infested area was totally cleared from Corallita and, 12 plots of 1 x 1 m were laid out. In each of these plots, 5 Corallita stems were selected and tagged (Photo 4). Annex V shows more details of the plants.

Photo 4: Experimental plot with tagged stems

These plots were treated with:

1. Glyphosate foliage spray treatments
2. Glyphosate stump treatments
3. Burning treatments
4. Garlon 4E stump treatments
5. Garlon 4E foliage treatments
6. Manual treatment

Each treatment was applied on two separate plots.

5.5.2 Experiment 1: Using chemicals

Four different experiments were done:

- Glyphosate and Garlon 4E foliage spray: the leaves of the 5 tagged stems were sprayed with the herbicide, with a low-pressure sprayer with a 100% concentration.

- Glyphosate and Garlon 4E stump treatment: 5 stems were cut back to the ground and treated with herbicide with a 100% concentration. The herbicide was applied with a paint brush.

5.5.3 Experiment 2: Manual

Reference plots: 5 tagged stems were cut back to ground level.
Every two weeks regrowth was checked and the length measured and the tagged stems were cut again.

5.5.4 Experiment 3: Mechanical

Burning treatments: 5 tagged plants were cut back, the stems were treated with a fire torch (the burning was complete once the bark became black).

5.5.5 Experiment 4: Total plot treatment

On June 20th 2006 the last set of data from the 'single stem' experiments were gathered. After June 20th 2006, data were gathered from the new experiments.

The new experiments used the same treatments as described; the only difference was that the whole plot was now treated. B5 was used for stump treatment instead of A5, where all the plants died. The tubers in plot A5 were dug up and checked for viability.

5.5.6 Experiment 5: Large plots

Four plots of 25 m^2 were laid out at two locations in town down the cliff at Gallow Bay and along Sandy Road. These plots were cleared of all vegetation at ground level and all litter was removed.
After three weeks, the re-growth was measured at random. If there was regrowth of about 30cm the plots was sprayed (foliage spray) with the following concentrations of glyphosate (41% active ingredient):
Location Sandy Road: plot one with a 75 % concentration plot two with 50 %
Location Gallow Bay: plot 1 with a 25 % concentration and plot two with 12,5 %

6 Results

6.1 Ecological data collection

6.1.1 Some historical facts about the distribution of Corallita
Antigonon leptopus has already been on the island for almost one century. It was introduced around 1907 as a garden plant. It escaped cultivation and naturalized and expanded gradually over the island. It was kept under control to a certain extent through regularly cutting, weeding and ploughing by the locals. Former farmers informed us that they use to clean their field continuously.
The explosive growth over the last decennia might be attributed to the fact that during the 1980's and early 1990's agricultural practices came to a halt. Farmers no longer cut away the Corallita from their fields regularly nor ploughed the fields and collected the tubers. This created an ideal situation for Corallita to spread.
In addition to this, increased building activities may have contributed to the spread of Corallita by creating disturbed sites and by transportation of seeds tubers and plant parts with soil and building material.

Old photographs of Statia landscape were studied in order to see whether Corallita was present. Photos taken at the end of the 1970's, by the family of Tina Smith, already showed a lot of Corallita high up in trees along the road to the Botanical Garden; also looking down from Korthals Road and near English Quarter. Slides taken in 1980 by Prof. Stoffers from University of Utrecht reveal various places in town where Corallita grows abundantly: at waste sites and abandoned gardens and near ruins (Photo 5 and 6).

Photo 5: Taken in 1980

Photo 6: Taken in 2007

Pictures from the countryside hardly show any evidence of the plant. Unfortunately there were not many pictures taken from the countryside, so we can not be decisive about absence or presence of Corallita.
The Cultuurvlakte was still used for growing crops.

Many fenced plots are present.
In March/April 1991 Prof. Stoffers and his wife visited St. Eustatius to collect plants to list flora of the trees of the island. Mrs. Stoffers showed photographs taken during that visit. Corallita was only seen on two pictures: along the road down the cliffs, (but not up to the cliffs) and along "the road to the Quill". Mrs.Stoffers (after having seen our photos of the abundance of Corallita) was sure that in 1991 this was not yet the case. She said she and her husband would certainly have noted this.

6.1.2 Mapping

The mapping of the distribution of Corallita was done using a topographical map (1978/1982, with scale: 1:10,000). The field surveys were carried out during the first and second visit (October 25th till November 12th 2005 and May 25th till June 4th, 2006 respectively). A final check was done in January 2007.
For the final map we used full colour aerial photos with scale 1:4,000 & 1:8,800 from KLM Aerocarta. These aerial photographs were taken during the dry season in March and April 1991. It was hardly possible to identify Corallita on the pictures, but were very useful for proper orientation and detection of changes in land-use, boundaries etc. The landscape ecological map from St. Eustatius produced by Carmabi is based on the same aerial photographs[17]. We also used Google Earth to get up-to-date images of the present situation. It was possible to recognise Corallita on the images.

Results
The map gives the distribution of Corallita over the whole island (Figure 2) and shows that around 15-20% of the island is already covered by Corallita. (see Annex IV for large Map)

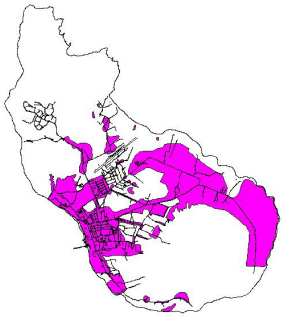


Figure 2: Distribution map

The map also shows that:
The most heavily infested areas are in town, along the road to the Botanical Garden, particularly between the road and the sea, where hectares are completely covered by the species. The infested area has grown in size since the landscape map of Rojer was made (see figure 1).
The second worst areas are Oranjestad and the Smoke Alley / Godet site, around the former leprosy estate. The latter area was also identified as an Antigonon landscape. In the north in the Zeelandia area there are some isolated locations.

It seems as if there is a limit to the distribution of Corallita above 150-200 m altitude. Several explanations can be given for this phenomenon:

- above 150-200m there is a sharp change of slope angle from 15-20º to 30-35º.
- a change in soils from lapille into fine tuffs[18].
- above around 200m altitude there is still dense natural vegetation, with closed canopy.

We can hypothesize that either the soil or the dense natural vegetation are unsuitable for the growth of Corallita. The slopes of the area above 200 m are too steep for agricultural cultivation and thus were left intact.

However there is the danger that Corallita will spread over the adjacent dense natural vegetation and eventually smother and kill it.
Unfortunately this is already the case on the east side of the Quill where the natural vegetation is still present at an altitude of 100 m. The species is dangerously approaching the Quill sector of the National Park. It occurs as high as 200m altitude. It is abundantly found near the main entrance trail to the Park, (near The Farm), and less at the end of the Bird trail and near the Telecom Board.

[17] De Freitas, 2007, personal communication.
[18] Augustinus et al, 1984.

6.1.2 Phenology

General
During 1-12-2005 until 1-12-2006, phenological data was gathered to gain more insight in how the plant develops through the seasons. Because there was no real dry season in 2006 the foliage did not show any changes and is therefore not included in the figures. The whole year round the plant had green leaves in al stages.

The notations of the field observations were gathered (Table 2), see chapter 5.2.2 for notations, and converted into numerate values to do data analyses.

Table 2: Field data converted in numerate values

	Date	FL1	FL2	FL3
1	13-Jan-06	(x)	x	x
2	13-Jan-06	12.5	25	100
3	13/01/06	9	18	73

Legend
(x) = 12,5
x = 25
x = 100

1 The field data collected
2 The field data is converted into numerate scale
3 The results were converted to a 100% scale

Figures 3-11 show the three locations were plants were observed during one year. Also the rainfall was measured and put into a figure to see if there is a correlation between rainfall and the phenological stages of the selected 'plants'.

Discussion and conclusions
In practice it proved rather difficult to distinguish the different stages of flowering and fruiting. This was caused by the almost continuous growth and flowering of the plants and the fact that the flowering of the cymes last about ten days. Thus, particularly when the plants were checked every two weeks, a stage might have been missed. During the observations, fruits often escape notice, as they were overgrown by new shoots.
The plant was never observed turning completely brown. This might be attributed to the fact that rainfall was evenly spread throughout the year and only short dry spells occurred. Vegetative growth is favoured by rain [19]. They mention, that an intermittent dry spell within a period of rain, leads to concentrated flowering. In our observations this seems not to be the case. There is a trend in the Visitor Centre plant, but at Zeelandia (figure 6) there is no flowering at all from August 25th till October 5th, a period with very low rainfall. During this period the plant showed signs of wilting and death of the leaves. This latter might be caused by the fact that the soil of this part of the Cultuurvlakte is highly porous[20]. Rainfall at Zeelandia is much higher than at the other two sites and well above the 30 year average for the island, which is 968.6 mm. The lower rainfall at the Visitor Centre and in the Botanical Garden (835 resp. 888 mm) is attributed to the fact that the rain gauges were not always checked or doubled checked in case of excessive rain, whereby the gauges overflowed.
When a period of high rainfall is followed by a dry one, flowering finishes and fruits are produced. This can be seen in the period between 28-07 and 21-09-2006 (table 3 and 5). When the rainfall increases again, flowering resumes.

[19] Raju *et al.* (2001)
[20] Zonneveld, 1961

Botanical Garden

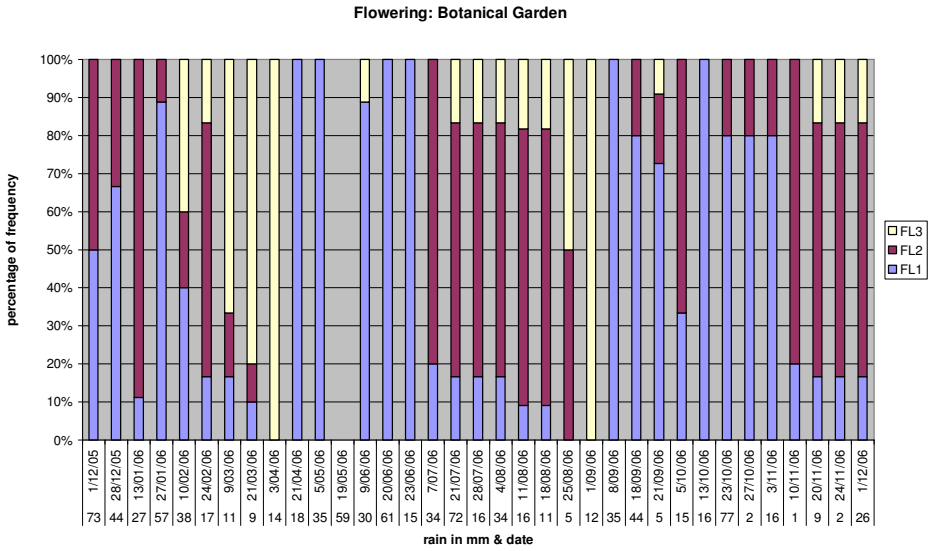


Figure 3: Flowering in the Botanical Garden

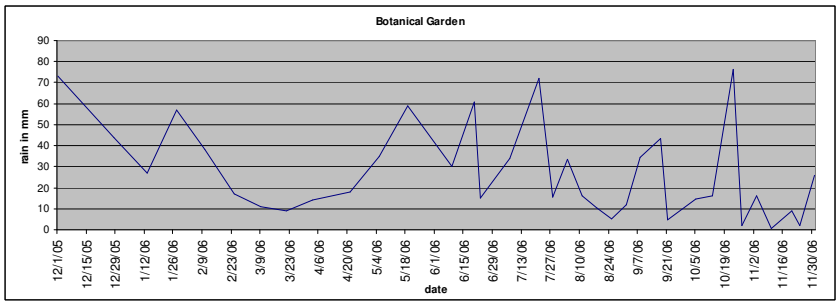


Figure 4: Rainfall in the Botanical garden

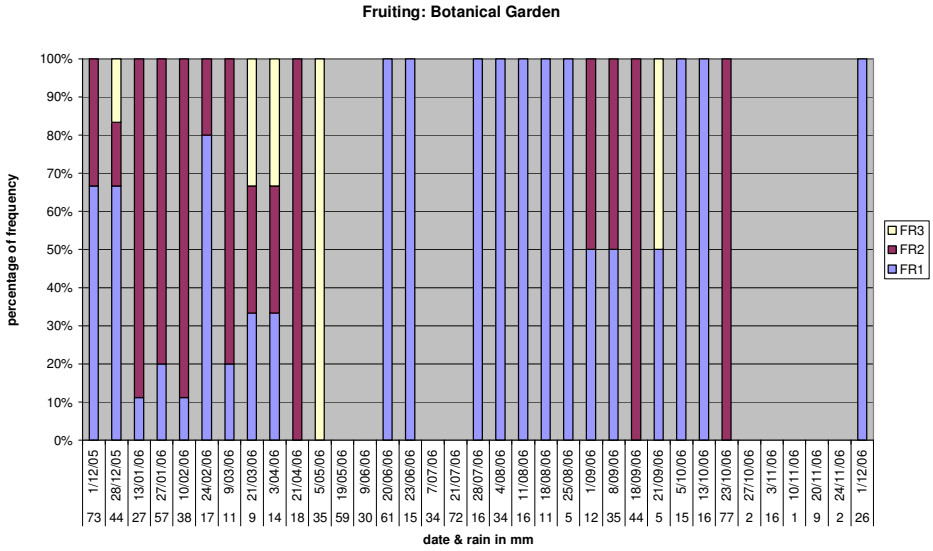


Figure 5: Fruiting Botanical Garden

Zeelandia

In the one year period there was 1183mm precipitation at the Zeelandia site.

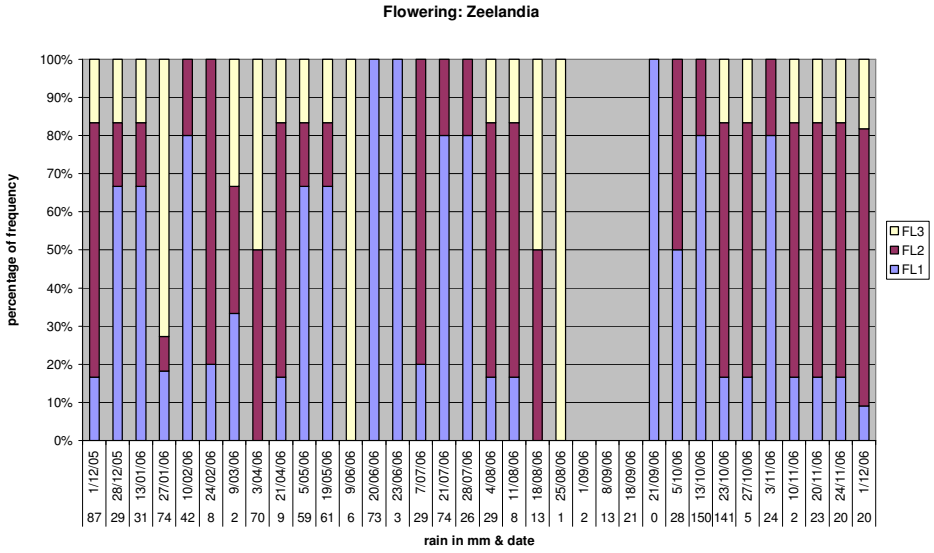


Figure 6: Flowering in Zeelandia

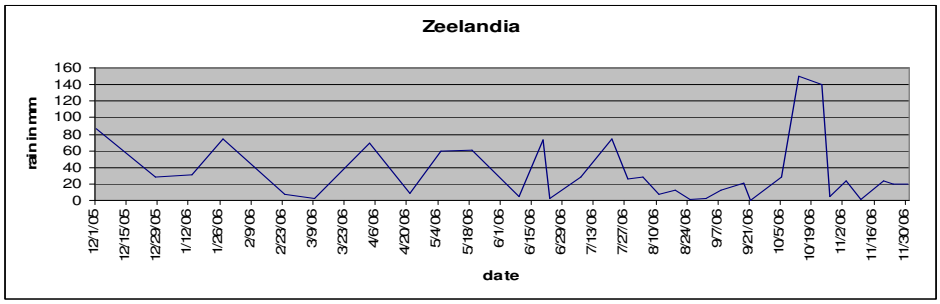


Figure 7: Rainfall in Zeelandia

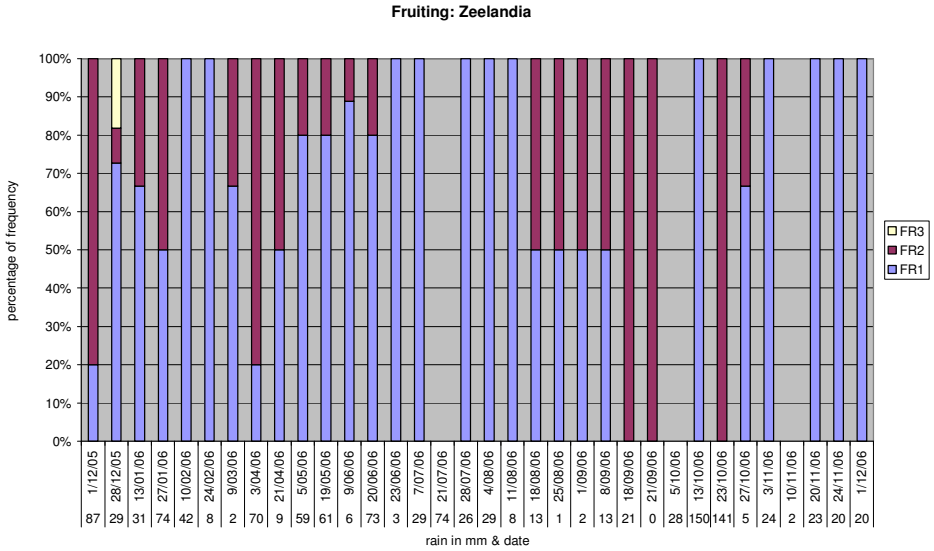


Figure 8: Fruiting in Zeelandia

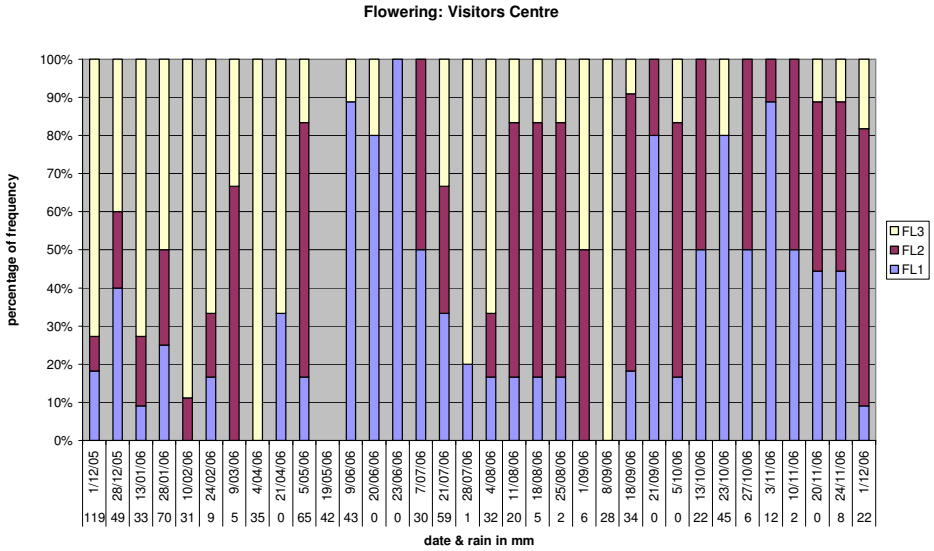


Figure 9: Flowering at the Visitors Centre

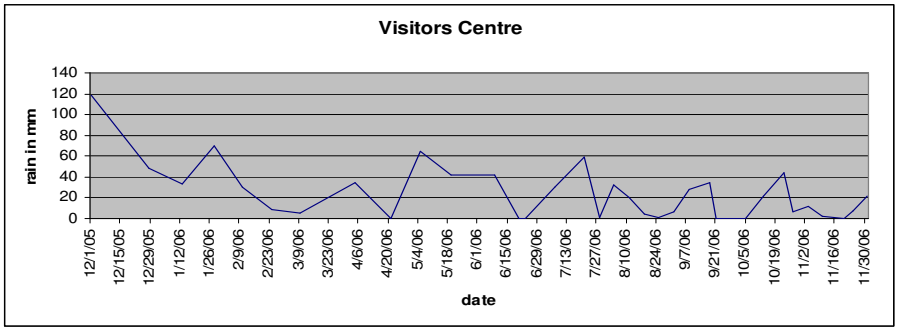


Figure 10: Rainfall in the Visitors Centre

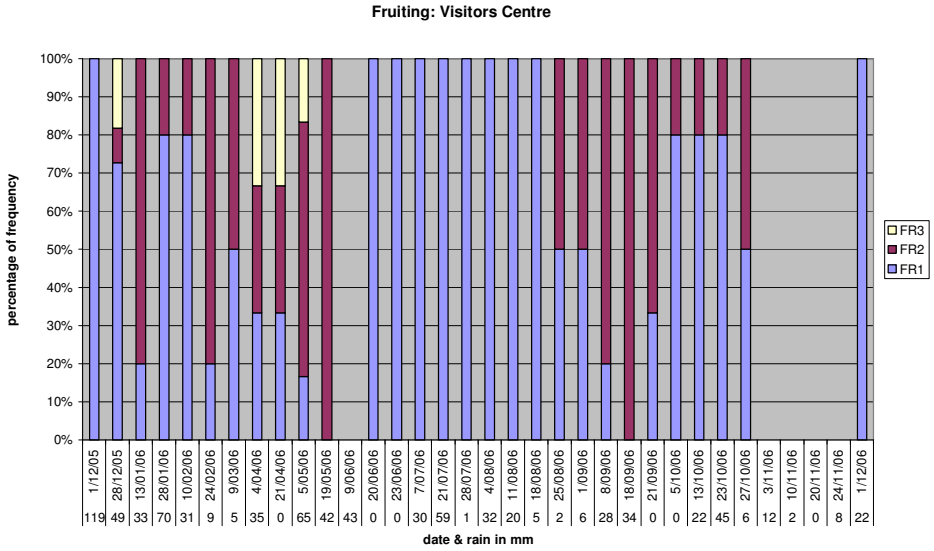


Figure 11: Fruiting in the Visitors Centre

6.1.3 Seed ecology

Germination experiments

In total, 100 seeds per set were tested for germination eleven times. Photo 7 shows on the left side seeds with the dried perianth and at the right the bare nuts. All the seeds were taken from plants (not collected from the ground). It was made sure that the seeds were not empty.
The first seeds already germinated after 3 days. Lowest germination rate was 32 %, highest 87 % (Table 3). Average germination for the 11 trials is 57.5 %. The number of days to reach maximum germination varies from 8 to 70 days. There seems to be no relation between maximum germination and time to reach it. The two highest germination rates, 73 and 87 % were achieved after 9 and, respectively, 17 days. In trial 8 and 9 it took 70 and 62 days before 64% and, respectively, 70% of the seeds germinated. Figure 12 illustrates the results of the 11 trials.

Photo 7: Seeds

Table 3: Germination periods

Exp. no.	germ. rate in %	no. of days	period of observation
1	51	19	27 Jan/ 25 Feb
2	87	17	3 Mar / 1 Apr
3	47	13	15 Jun / 6 Jul
4	61	14	15 Jun / 6 Jul
5	73	9	15 Jun / 6 Jul
6	59	13	15 Jun / 6 Jul
7	32	8	15 Jun / 11 Jul
8	64	70	21 Jul / 29 Sept
9	70	62	21 Jul / 21 Sept
10	46	49	21 Jul / 8 Sept
11	42	49	21 Jul / 8 Sept

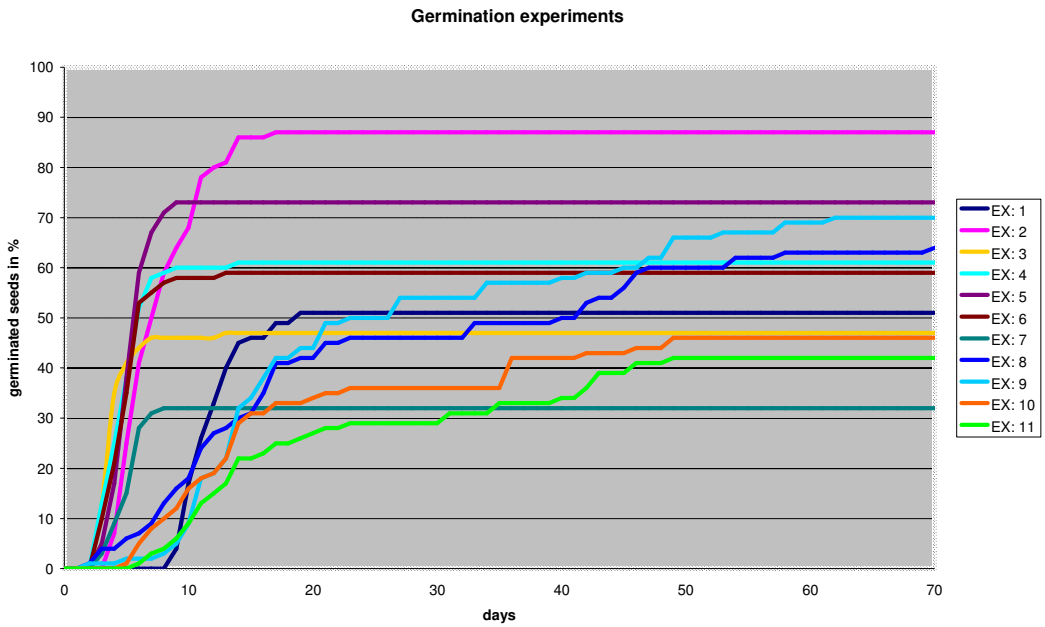


Figure 132: Germination experiments

It should be noted that in the 8-11 trials it took much longer (7-10 weeks) to reach maximum germination than in the earlier trials (8-19 days). This could be explained by the quality of the seeds.

Other observations

At several locations, fruits from the ground (under the mother-plant) were collected and checked for viability. In all cases more than 80 % was found moulded and/or invaded by insects or complete empty.
During the field trips, seedlings and saplings were searched. Only two seedlings were found, one on a rubbish heap in town (Photo 8) and one under a tree, where cows use to rest in the shade. The latter had little chance to survive. Once, a tiny sapling was found, some 5cm high, already with a woody stem and a very small tuber. In January 2007 over a dozen saplings all with a tiny tuber (Photo 9) were found along a road under a tree heavily covered with Corallita. Many times it appeared that what looked like a sapling was a new sprout from the roots from a neighbouring plant.

Photo 8: Sapling

Photo 9: Saplings with tubers

Discussion and conclusions
The germination rate of Corallita seeds taken from the plant varies between 32 and 87%. Some seeds already germinate after 3 days; for others it took 70 days before they germinated. We cannot explain the great difference between experiments 1-7 (rapid germination) and 8-11 (slow germination). This might be a result of difference in origin or age of the seeds in the latter trials. Unfortunately we do not know whether fresh fruits were taken nor how long and how they have been stored. A high percentage of the fruits hanging on plants stay healthy and are capable of germination.

Germination takes place in open spaces. Under a thick carpet of branches and leaves of Corallita, seeds hardly germinate and soon get moulded or eaten.
The fact, that saplings and seedlings were not frequently found in the field, and that fruits falling on the ground under the mother plant are attacked by fungi and insects, might lead to the conclusion that seeds play a lesser role in the dispersal of Corallita than vegetative growth through dispersal of tubers, stem- and root cuttings.

6.1.4 Use of plant by animals

On 11 different days between May 8th and June 27th 2006, systematic animal observations were carried out during 1½ to 2 hour periods. Total observation time was 16½ hours. In total only 6 cows were sighted eating on Corallita (Table 4). Sometimes goats were seen nibbling on what looked like Corallita, but which proved at closer study to be another plant growing in the Corallita. There were no observations of cows or goats eating the fruits. When the plant is in full leave, the fruits are hidden under the foliage and not easy to reach.
In addition to these observations, there were two more observations of animals feeding on Corallita during the fieldwork, one cow and a goat nibbling on the leaves. The animals were not observed eating the fruits.
Pigs have been seen digging up the tubers and eating them. No birds have been observed eating fruits.

Table 4: Results of animal observations.

	pigs	donkey	cows	goats	total animals
Observed	17	53	158	126	354
eating	10	26	80	19	135
eating C.	0	0	6	0	6
total time	17	238	588	149	993 min.

Discussion and conclusions
The farmers on the island were not unanimous about whether cows eat from Corallita or not. Some said they eat the seeds only when it is very dry and no grass is available. Thus the animals may spread the species. Another farmer mentioned that the animals do eat Corallita but only in small quantities, maybe as a medication. They vomit after they have eaten from the plant. This phenomenon was not observed during the field observations.
Pigs might eat the fruits they find on the ground, but it is unlikely that they will pass unharmed through the digestive tract. Pigs have sharp teeth and are used to eating hard fruits[21].
The year 2006 was without a real dry period. It seemed that there was no shortage of food for grazers and browsers. Thus there was no necessity to eat Corallita fruits. To get a more reliable result about whether the animals are eating fruits of Corallita, the observations should be done in a dry year during the dry period.

No birds were observed eating Corallita fruits. It seems that they are not involved in spreading the species. However on Curacao, doves have been seen picking the fruits[22]. It is not known whether they swallow the fruits or that they only transport them to other places.

6.1.5 Faeces analysis

Cow dung was checked for the presence of viable seeds of Corallita. It was suggested that grazing animals spread the plant this way[23]. The first dung analyses were done in October/November 2005. At random, field-dried cow dung was collected from an area infested with Corallita. After soaking it in water and detergent the fluid was searched for Corallita fruits. Some ten samples were studied (Table 5), but no whole fruits were found, except one, which was germinating. In May-June 2006 the experiment was repeated. Also this time no unaffected fruits were found. Additionally, goat pellets were collected, soaked and searched. No intact fruits were found.

[21] Van Wieren, 2006, personal communication.
[22] pers. communication from someone from Curacao 2006.
[23] in literature and personal comments by locals on St.Eustatius.

Cow on a rope

On two occasions, a cow tethered to a rope was fed with Corallita fruits. After 24 hours the dung was collected and searched for unaffected fruits. None were found. Thus we can conclude that if cows eat the fruits they do not pass through the animals unharmed.

Table 5 Results of the dung analysis

	SPECIES	DRY WEIGHT (kg)	RESULT
1	Cow	0.98	No visible Corallita seeds
2	cow fed by C.	1.712 (wet)	No visible Corallita seeds
3	Cow	1.23	No visible Corallita seeds
4	Cow	1.63	No visible Corallita seeds
5	Goat	0.14	No visible Corallita seeds
6	Goat	0.26	No visible Corallita seeds
7	Cow	0.75	No visible Corallita seeds
8	Goat	0.2	No visible Corallita seeds

Discussion and conclusions

From the results it can be concluded that it is unlikely that grazing animals play an important role in the spreading of Corallita seeds. The one viable seed found had probably not passed through a cow, but was present underneath the dung and germinated after the dung was dropped.

In the field, there were no observations of cows or goats eating the fruits. This is no proof that they don't feed on fruits as, during the dry season of 2006, there was still enough grass available and there was no need to eat Corallita. The fruits soon disappear under the foliage of the plant and are thus not easily found. This may hinder cows from feeding on them. The fruits are visible when the leaves are falling off.

Dung analysis should be repeated during a long drought period, when all Corallita leaves have turned brown.

6.1.6 Tubers

In order to find out to what extent Corallita is present underground, two 1 x 1m plots were dug up and all tubers collected to a depth where tubers were no longer found (or till it became to difficult to dig deeper, because of rocks).The plots were located on sites where Corallita cover was 100% and its height up to 60cm.

In the first plot, up to a depth of 35cm, a total of 289 tubers were present plus 4 shrivelled ones. The weight varied from less than 0.3g to 24g per tuber. The total weight was 1280g (3 days air-dried). In the second plot, 245 tubers were found up to 0.25m deep, plus 14 shrivelled. Total fresh weight was 1918g. Photo 10 shows untreated healthy tubers. Photo 11 shows the dug up tubers of one plot. The largest tuber we came across weighed 300g. In literature, weights of 2kg and above are mentioned.

This shows that it will be very difficult to eradicate the species. The above-ground parts can be cut away, but regrowth will continue, unless the tubers are also removed.

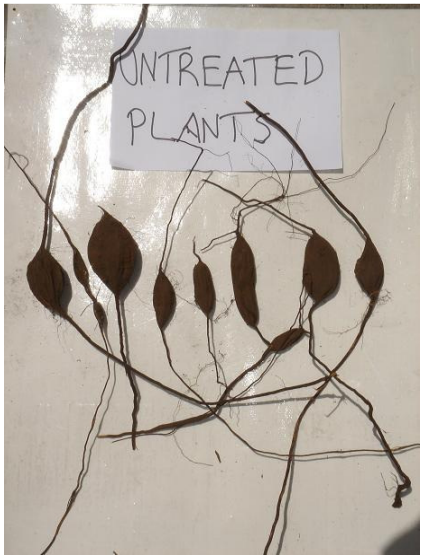


Photo 10: Healthy tubers

These tubers form an enormous food reserve for the plant. Tubers are formed at a very young stage. Tiny plants with a height of 5cm already develop a small tuber. It seems that the species make reserves and waits till the above-ground conditions are favourable to start sprouting. The tubers are dug up by pigs and eaten. Cows and goats also eat tubers, if fed to them. In the past farmers used to plough their field to collect the tubers, which were then either fed to cows and goats or dried and burned.

Photo 11: Tubers from 1*1*0.35m.

6.1.7 Soil acidity tests

These tests were carried out to ascertain whether there is a relation between distribution of Corallita with pH. At 25 locations with- and 25 locations without Corallita, simple, crude pH measurements in the topsoil (0-5 cm) were done using Hellige pH fluid (Photo 12). Table 6 gives the results.

Table 6: pH values and presence or absence of Corallita.

pH	Corallita	no Corallita	Chi-sq	df
4-4.5	4	2	1.00	
5-5.5	10	19	8.10	
6-6.5	6	2	2.67	
7-7.5	5	2	1.80	
Total	25	25	13.57	3

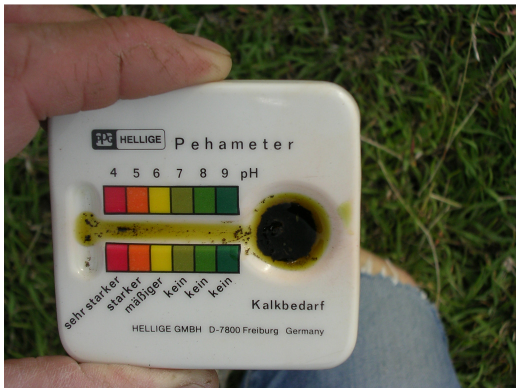


Photo 12: pH test

Results

Corallita occurs over a wide range of pH, but seems to prefer a pH 5 -5.5 (40%) of all measurements. There were no sites with high pH, where Corallita was not present. There is a significant difference between the two sets of data ($P < 0.010$) with 3 degrees of freedom (critical chi-square 11.34). The results are, however, not conclusive. The pH class 5-5.5 contributes highest to the differences. From this we may draw the conclusion that the chances are high that Corallita occur on places with an acidity of 5-5.5. Too few data are present to prove this. It should be born in mind that, also other factors than only pH probably play a role in the occurrence of Corallita, such as soil type. It should also be noted that, at several locations, pH was measured under Corallita, but not near a branch coming out of the soil surface. The plant might have germinated elsewhere and has no relation with the soil underneath. It should also be mentioned that Corallita prefers waste places and urban sites. Soil acidity might have changed from the original value because of human activities, such as fertilizing and building activities.

The soil of the flattest areas of the Cultuurvlakte consists mainly of volcanic efflata and is very permeable. The highest point of the Cultuurvlakte is 80m. Groundwater level is deep (60m). The vegetation, and formerly the crops, had to rely only on precipitation and water that flows from elsewhere to deeper layers [24]. Thus in years with low rainfall, the present secondary vegetation suffers from drought. This might be a reason that Corallita grows far less here. Soil acidity values for Cultuurvlakte, range from 6.2 – 8.3, for the 0-15 cm [25].

[24] Zonneveld, 1961.
[25] Veenenbos, 1955

6.1.8 Weather

6.1.8.1 Hurricane and dispersal of Corallita

We hypothesize that hurricanes might have influence on the dispersal of Corallita in three ways. Firstly, because during the strong winds, the fruits and parts of plants might be ripped off and transported over some distance, before falling down, away from the mother plant. If conditions for germination are favourable, a new plant can establish and form a nucleus for further spreading. Secondly, hurricanes are accompanied by heavy rains often resulting in increased sheet erosion. Fruits on the ground are thus transported over some distances. In general the fruits of Corallita are not dispersed by wind, as they are rather heavy.
Thirdly, hurricanes cause great damage creating disturbed sites, which are prone to be colonized by pest species, such as Corallita, which favour such sites.

Over the past 35 years (1971-2006), St. Eustatius has been affected by six hurricanes (Table 7), causing damage to the island. Between 1991 and 2000, St. Eustatius was hit by four hurricanes, a fourfold increase per decennium[26]. We have no proof at all, but this might directly or indirectly have contributed to the spread of Corallita, The opportunities were present for increased dispersal of seeds and plant parts to newly created suitable locations. It coincides with the observed increased spread.

Table 7: Hurricane occurrence in the Leeward Islands area and the number of hurricanes hitting St. Eustatius

Hurricane period	Number	Average. speed (km/hr)	Statia
1971-1980	2	180	1
1981-1990	4	148 km	1
1991-2000	6	157 km	4
2001-2006			0

6.1.8.2 Relation between rainfall and growth

Looking at the rainfall data of the past 15 years (Figure 13 and Table 8) with the assumption that there might be a relation between amount of rainfall and increase of Corallita (968.6 mm is 30 years average). This assumption is based on the fact that, during real dry spells, flowering and growth is retarded. It is said that during exceptionally dry periods the leaves of Corallita turn brown and growth comes virtually to a halt and that in extreme wet years plant growth is enhanced.

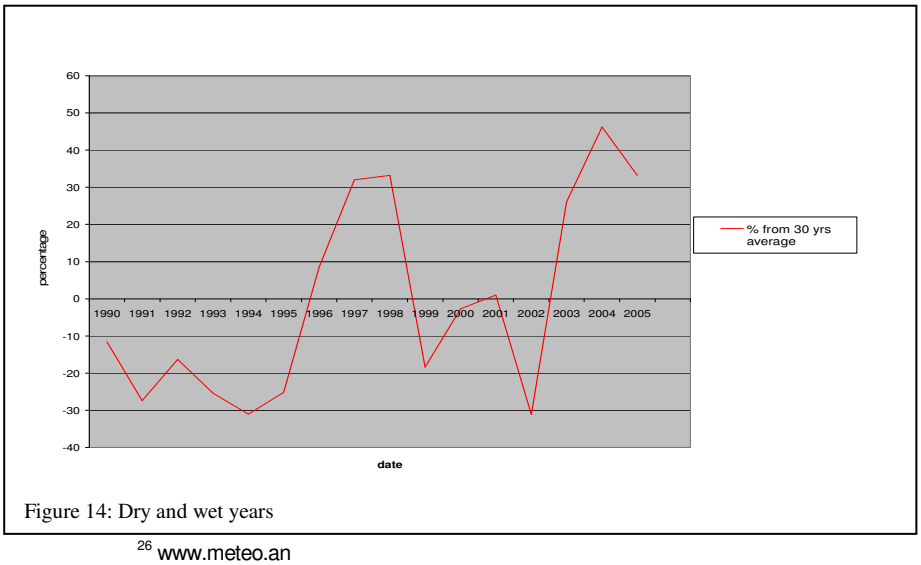


Figure 14: Dry and wet years

[26] www.meteo.an

Table 8 shows that during the first 6 years of the 1990's, rainfall was far below the 30 year average. On the aerial photographs of that year, taken in March and April, Corallita is hardly visible.
The years 1997 and 1998 have an increase of over 30% more rainfall with 8 and 10 months respectively having greater than average rainfall; 1999 was a dry year 2000 and 2001 can be considered as 'normal' years, while 2002 was an extremely dry year. Some people told us that at several places Corallita leaves had turned brown.
The years 2003, 2004 and 2005 were very wet. In the normal dry season period, several months had excess rainfall.
If there is a relationship between excessive growth of Corallita and rainfall, we might conclude from the above that, for many years during the 1990's, growth of Corallita was less than normal (six consecutive years with lower than normal rainfall). Since 1997, rainfall has been far above average for five years, around average for two years and well below average for two year.
We are of the opinion that plant have profited from the extreme wet condition over the three years, which followed the extreme dry year of 2002. This corresponds with Raju[27], who found that heavy rains favour vegetative growth. Photo 13 shows the rainfall on the Quill.

Table 8: Rainfall over 15 years

Rainfall on St.Eustatius over the Last 15 years		
Year	Amount	% from 30 yrs average
1990	871.8	-11.6
1991	716.2*	-27.4
1992	826	-16.3
1993	746.1	-25.4
1994	681.8*	-31.0
1995	737.6	-25.2
1996	1069.6	+8.5
1997	1301.8	+32.0
1998	1313.6	+33.2
1999	823.8	- 18.4
2000	960*	- 2.7
2001	995.8	+1.0
2002	667.0	- 31.1
2003	1243.6	+26.1
2004	1441.4	+46.2
2005	1343.8	+33.2
2006	788.4	-21.0
* estimated on the base of real values and 30 yr average 968.6 mm		

Photo 13: Clouds around the Quill

[27] Raju et all, 2001

6.2 Experiments

General
The experiments are divided into:

- Chemical treatments
- Manual treatments
- Mechanical treatments

All experimental plots of 1 x 1 m were cleared of the vegetation on November 1st and again one month later, as the experiments could not start earlier, as was planned before. For a detailed description of all the plots see Annex V.

Table 8 shows the interval between monitoring. A second application of herbicide or a second burning only took place, when the tagged plants showed a re-growth (one shoot) of about 30 cm.

Table8: Observation times

Date	interval
1- 12- 2005	30 days
6-1 or 13-1-2006	30 days
27-1-2006	21 or 14 days
17-2-2006	21 days
23-3-2006	34 days
5-5-2006	13 days
19-5-2006	14 days
26-6-2006	48 days

6.2.1 Chemical treatments

Figure 14 shows the four different chemical experiments. Some plots did have more regrowth comparing with the other plots. This can be explained by the viability of the selected stems.

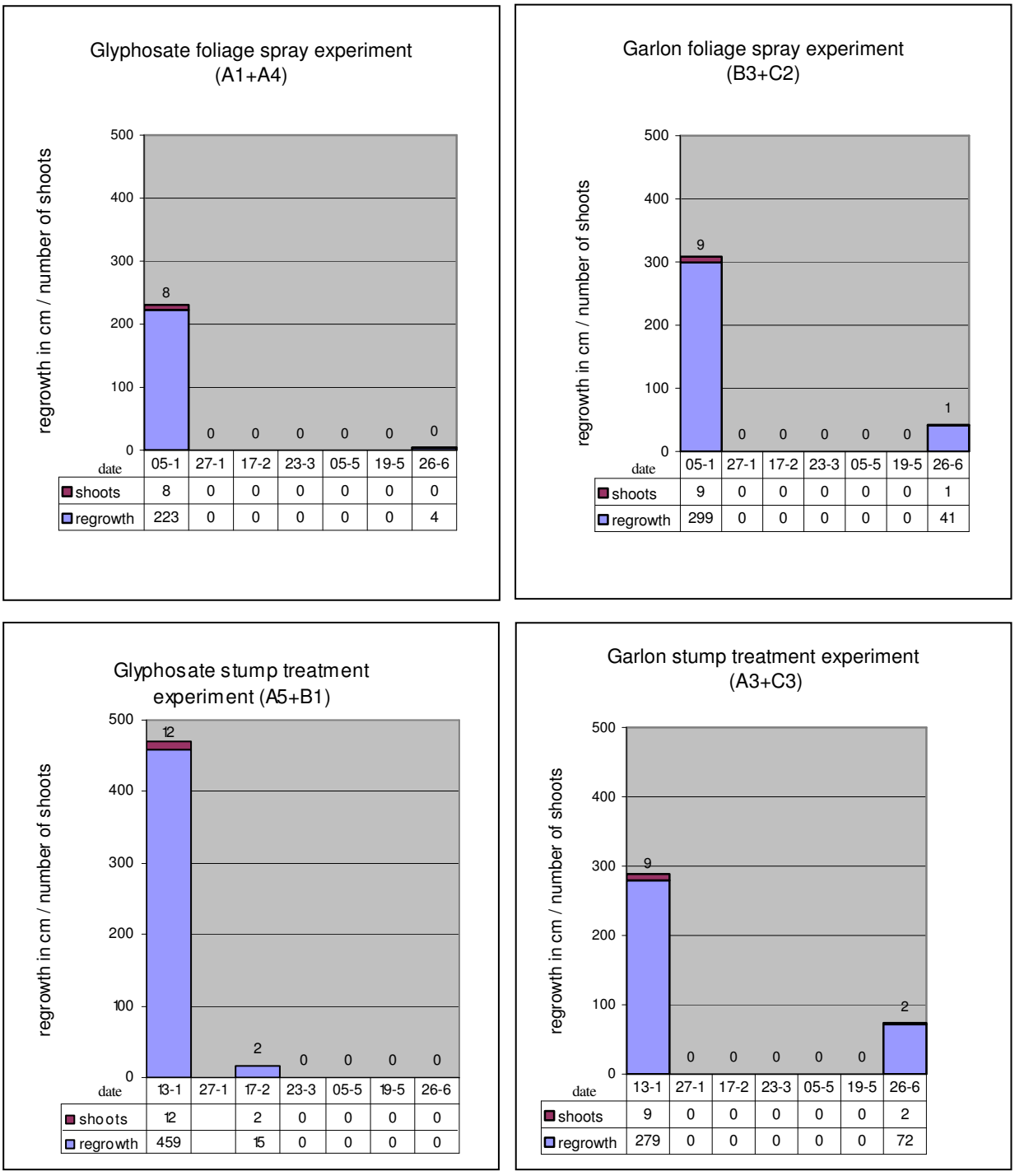


Figure 14: Chemical treatments

Discussion / conclusion
The average regrowth before the first treatment is approximately 30cm. In the Glyphsate treatment plots only one plant showed some regrowth 6 weeks later. The Garlon treated plots had no regrowth during 6 month. It is clear that the herbicides seriously influence the vitality of the plants and thus regrowth.

Comparing the chemical treatments

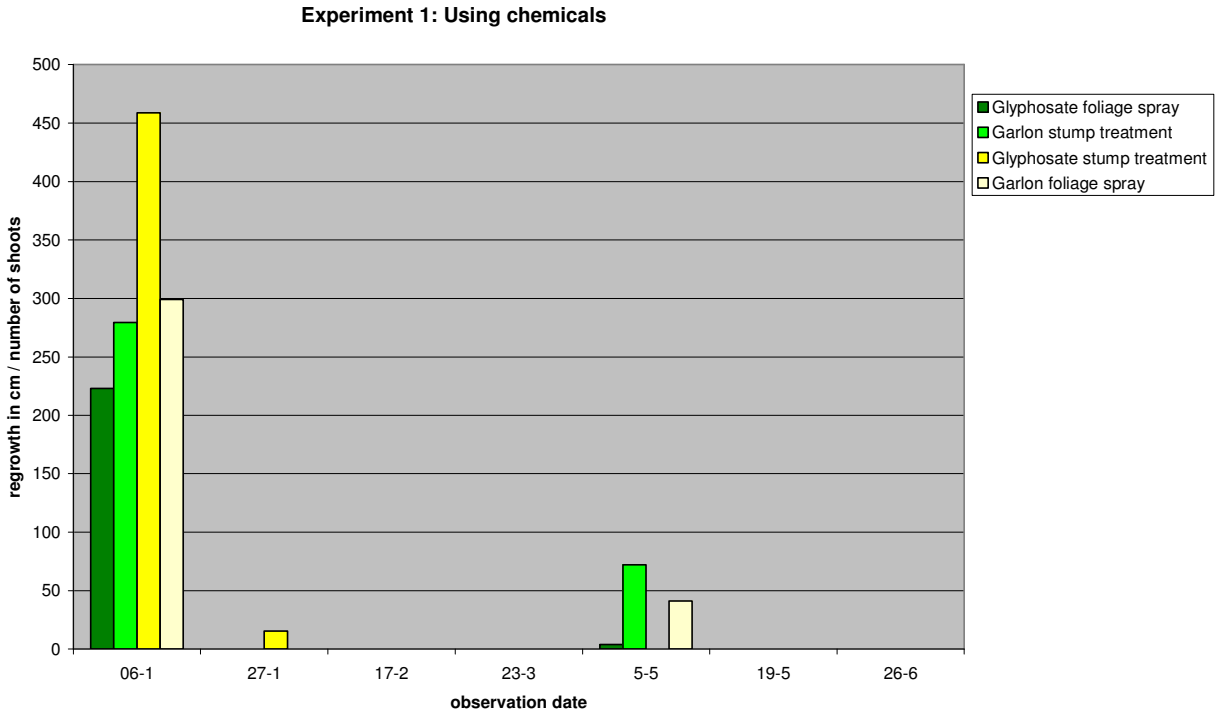


Figure 15: Comparing chemical treatments

Figure 15 shows the observation from 6 January until 26 June 2006. This is the starting point after the treatments took place, 6 January shows the first treatment after the plots were cut back twice and shows the re-growth after about one month. There is almost no regrowth after the first treatment. The 15cm re-growth of the glyphosate stump treatment within 6 weeks can be explained by the fact that the individuals of plots A3 and B1 were larger than in other plots (4 large knots). A5 + B1 show the regrowth of 459cm, this is about 200 cm more regrowth comparing with the others see figure 15. In Annex V the viability of each individual stem is given. This also explains the regrowth in the foliage spray plots after 6 month.

The Glyphosate foliage spray treatment plot (plot A4) was dug up, and all the tubers were found dead, shrivelled and rotten. Healthy tubers are firm and solid, dead tubers are wrinkled or rotten (Photo 14). Cutting the tubers in half confirms if the tubers are healthy or rotten. These results show the glyphosate stump treatment seems most effective.
Some factors have to be taken into account like weather conditions. Very rainy periods reduce the effectiveness of the herbicide.

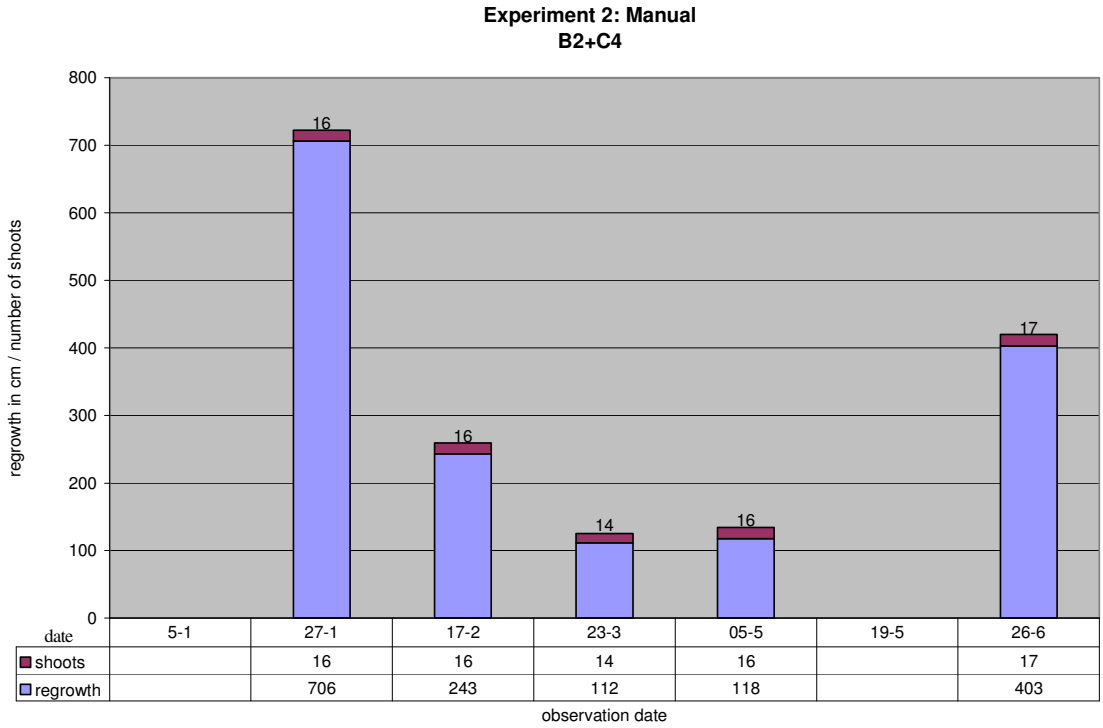
Photo 14 Tubers from treated plants

Discussion and conclusions

Wind is factor that played a role with application of herbicides to the plants. No wind and rain will increase effectiveness of the herbicide. Therefore, the timing of the experiments varied. The effectiveness of a foliage spray treatment can be observed after one or a few days. If the application was done properly the foliage wilts and the leaves turn yellow. Stump treatment as well as foliage spray with Garlon or Glyphosate results in the dying of the plants. However stump treatment it is a time and labour consuming exercise. Foliage spray is a much better option, because of the visible effects after the application of the herbicide.

6.2.2 Experiment 2: Manual

The experiments were set up to get more insight into how fast the plants grow after manually cutting all above-ground plant parts.



date	5-1	27-1	17-2	23-3	05-5	19-5	26-6
shoots		16	16	14	16		17
regrowth		706	243	112	118		403

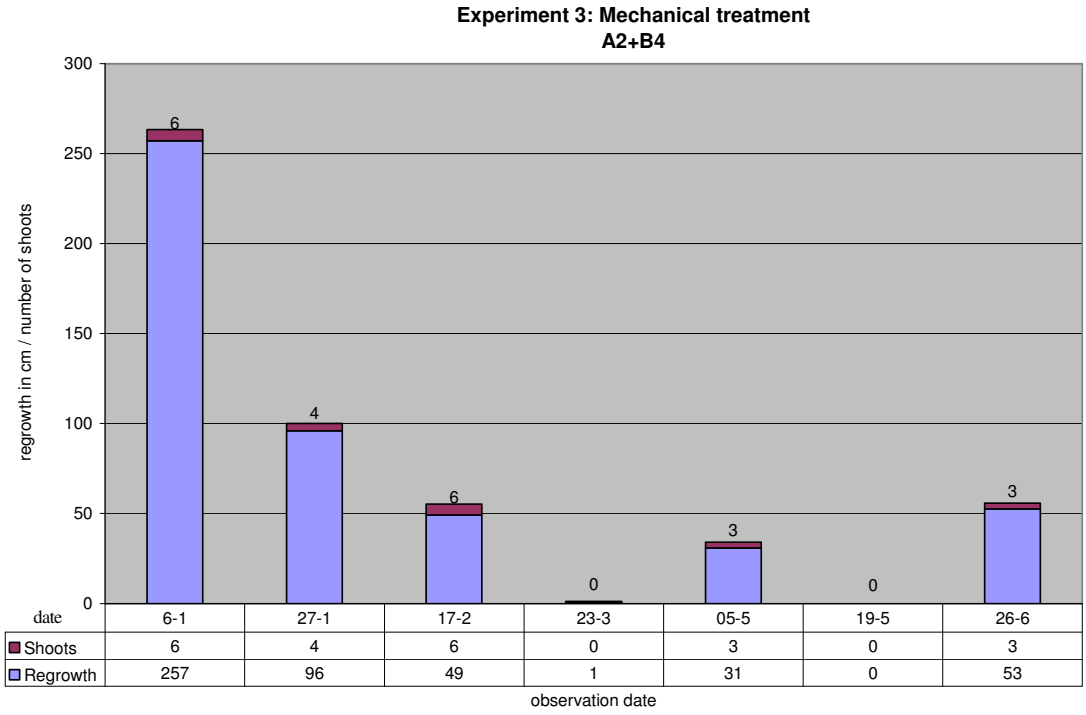
Figure 15: Manual experiment (no observation on 05-1 and 19-5-2006)

Figure 16 shows that each time the new shoots are cut, regrowth diminishes (average length of the new shoots is shorter), indicating a weakening of the plants. The January values show how vigorous Corallita grows; an average of almost 50 cm in less than two month.

Discussion and conclusions
Regular cutting of Corallita will keep the plant under control, but is no option to get rid of it. It may weaken the plants, if cutting is very frequent. In view of the amount of tubers it is not very likely the plant will die eventually.

6.2.3 Experiment 3: Mechanical

This experiment used a fire torch to burn the stems that had been cut to ground level.
Figure 17 illustrates the results. It shows that every time there was regrowth after burning, but the new shoots are much shorter.



date	6-1	27-1	17-2	23-3	05-5	19-5	26-6
Shoots	6	4	6	0	3	0	3
Regrowth	257	96	49	1	31	0	53

Figure 16: Burning experiment

Discussion and conclusion:

Burning is a short term option, to keep the plants under control. Due to the fact that the roots and tubers are not affected, the plants keep coming back.

6.2.4 Summary of all treatments in the small plots

Figure 17 summarizes the results of the different treatments. It shows that manual treatment is not an effective way to kill the plant as discussed before. It would also take a very long time to control the plant. It could only work in combination with digging up the tubers. Additionally, mechanical treatment (burning) was equally not a good way to kill the underground root system of the plants. This method is also accompanied by a fire hazard. Using chemicals is the most effective way to get rid of the plants. The advantage of foliage spray is that it is possible to see whether the spray has been fully completed as the leaves will show symptoms of dying. Experiments with different concentrations of Glyphosate will be discussed in chapter 6.2.6 where glyphosate was used on 25m² plots.

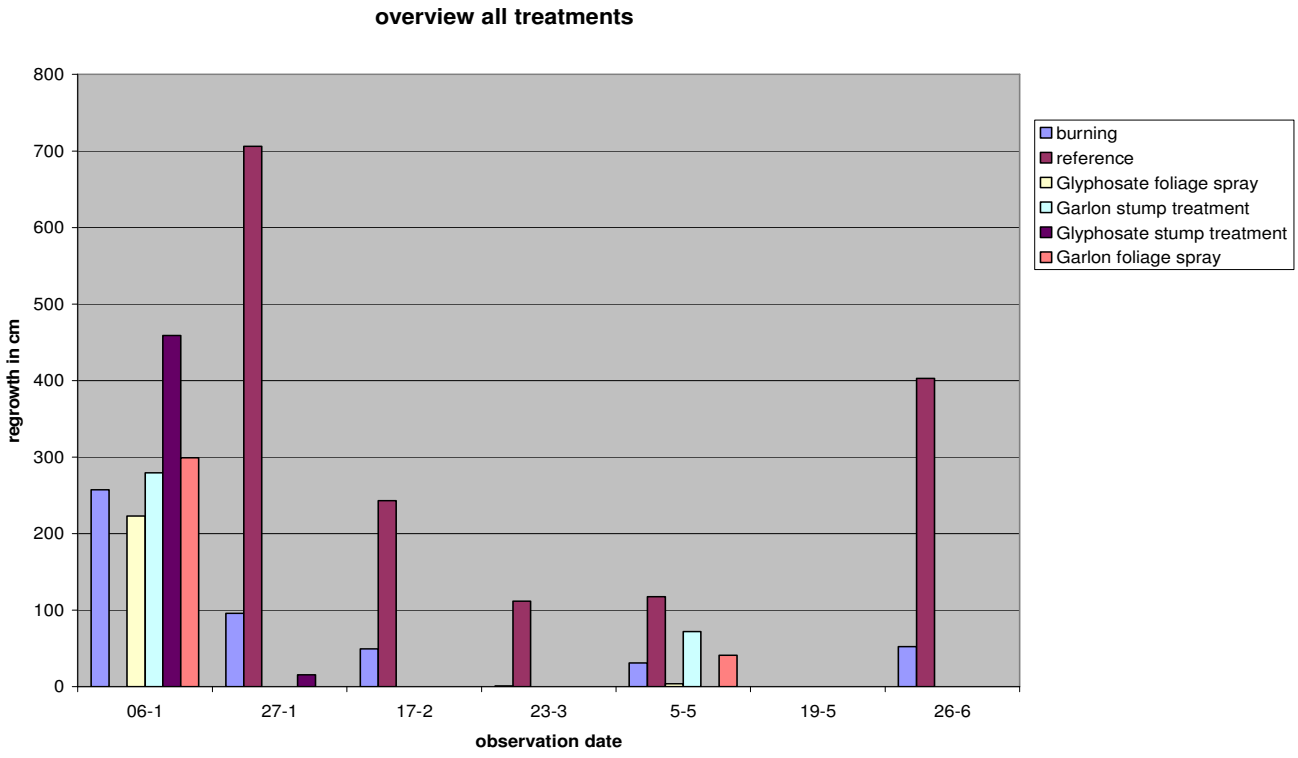


Figure 17: Comparing all treatments

6.2.5 Experiment 4: Total plot treatment

General
In the previous treatments, only single stems were treated and results checked. All other plants in the plots were cleared regularly. However, each treated single stems could not be considered as an individual plant as they might be connected with each other via the intensive root system and tubers. Therefore, a follow up experiment was done by applying the herbicides to the entire 1 x 1m plots. The herbicides were applied on June 26th 2006 and re-growth checked at regular intervals.

Almost all of the plots did not have any regrowth over three and a half months after treatment, except the Garlon stump-treated plot. The plants in the latter plot kept growing even after a second treatment. Re-growth is likely from vigorous stems and tubers, which were not completely effected by the herbicides, and the roots that intrude the small plots from the outside of the plots (Table 9).

Table 9: overview of results whole plot treatments

Observation date	Glyphosate foliage spray	Glyphosate stump treatment	Garlon foliage spray	Garlon stump treatment
31-jul-06	No regrowth	No regrowth	No regrowth - plants still dying	Regrowth one plant
18-aug-06	No data	No data	No data	Some regrowth of plants observed
25-aug-06	No regrowth	No regrowth	No regrowth	Plants treated as regrowth observed
22-sep-06	No regrowth	No regrowth	No regrowth	No regrowth
5-okt-06	No regrowth	No regrowth	No regrowth	No regrowth
13-okt-06	Regrowth on 1 plant	No regrowth		Regrowth on more than 2 'plants'

Discussion and conclusion
This small experiment showed again that Corallita can be killed with herbicides Garlon and Glyphosate. The herbicides also reach the tubers and kill them (Photo 12).
Glyphosate stump treatment seems slightly more effective than Garlon stump treatment, but this is based on a very small experiment. The advantage of foliage spray is that it is possible to assess whether the herbicide has been applied in a correct manner after a few days, as the foliage turns yellow and wilts.
Weather conditions also have to be taken into account. Very rainy periods reduce the effectiveness of the herbicide. Time of the day and wind are other factors that played a role with applying the herbicide to the plants.

6.2.6 Experiment 5: Large plots

The large plots were treated two times with a Glyphosate foliage spray. The two plots located on the side of Gallow Bay were treated on 15th September 2006 and checked on 7th October 2006. No regrowth was observed. On 27th October some regrowth was present. On the 3rd of November in the 12.5% plot a lot of regrowth was observed and the 25% plot 14 plants were growing back. The plots were checked on 13-1-2007, the plots had still some Corallita, but also a lot of grass.

The two plots located on the Sandy road were treated on 15th September 2006 (Photo 15 and 16). 7th October 2006 the plots were checked, no regrowth was observed. Also on 27th October no regrowth was observed. On 6 November regrowth was observed; 11 plants in the 50% plot and 12 plants in the 75% plot. The plots were checked again on 13-1-2007, there was not a lot of regrowth. Most of the regrowth came from outside the plot. Secondary vegetation is developing in both plots. In the 50% plot Corallita is climbing into the newly grown vegetation.

Photo 15 : Gallow Bay 2-11-2006

Photo 16 : Gallow Bay 24-11-2006

Discussion and conclusion
Three weeks after the first treatment at Gallow Bay no regrowth was observed, this means the herbicide does work with smaller concentration (12.5% and 25%) on short term. After six weeks the first regrowth was observed. The tubers are still intact after the first treatment. It is not known how many times the treatment with these concentrations is needed.

In both plots of Sandy Road the plants have regrowth after 7½ weeks. Our observation on 13th January 2007 showed that a lot of Corallita was growing from the border into the plots covering the soil. The treatment did work but probably needed a second treatment if there is regrowth of 30-40cm. Further monitoring of large plots (during one year) is needed to make sure smaller concentrations will kill the plants. Tubers should de dug up and checked on viability. New plots should be selected.

6.2.7 Indication of time for the treatments

Manpower

- clearing	45 min. per m² depending on the density of the Corallita
- preparing the spraying equipment	5-10 min
- spraying the herbicide	5- min
- burning litter	5-10 min
Total	60-70 minutes

Herbicides

1 litre of fluid is enough to spray app 7.3m^2 (3 parts water, 1 part herbicide).

To the above should be added the time to go to the sites to be cleared and of course the manpower.

7 Threats to the environment

7.1 Corallita

From our observations in the field, we can list the following threats posed to the environment of St. Eustatius by Corallita:

- The species hampers the natural vegetation development (succession) on former arable fields, through smothering the plants under a thick carpet of branches and leave.
- The species prevents the germination of native species. This can be particularly detrimental for the survival of (rare) tree species. If there is no regeneration, the population diminishes.
- The species forms a danger to the survival of the wild and ornamental trees and large shrubs along the roads and in gardens of Statia, by smothering the crowns, hampering flowering and fruiting and eventually killing the tree.
  The species thus forms a threat to the biodiversity of the island.
- The species seems to change soil conditions through accumulation of litter. A layer of up to 20-30 cm of decomposing litter can be found under the smothering vines.
- The species might invade the national parks from the borders, where it climbs into the tree crowns. From there seeds can disperse into the park and germinate in open spaces.
- The status of the Lesser Antillean Iguana (*Iguana delicatissima*) is endangered and Corallita is probably a threat to the natural diet of this reptile [28]. They do not seem to eat Corallita, although we have no proof of that.
- The effects on other reptiles will be minimal. Anoles, dwarf geckos, wall geckos and snakes should not be affected in any substantial way. Ground lizards might be excluded from some areas (they prefer open habitats and will only utilize the margins of densely overgrown areas). Iguanas may also be affected to some extent. Because they're primarily arboreal, their habitat should be affected only in areas where Corallita overgrows trees and large bushes. Overgrown areas may preclude movement from tree to tree, simply because movement through dense Corallita is difficult. However, for the most part, the direct impact should not be great. On the other hand, indirect impact might be substantial. If Corallita displaces native plants, affecting pollinators and other interactions, the effects on reptiles could be considerably greater [29].

[28] Esteban, 2006, personal communication.
[29] Powell, 2006, personal communication.

7.2 Other potential invasive plant species

While on St. Eustatius, we came across at least three more plant species that are listed as (potential) invasive species. These are *Cryptostegia grandiflora*, *Schinus terebinthifolius Leuacena leucocephala* and perhaps *Cuscuta americana.*

- *Cryptostegia grandiflora* (Rubber vine) is planted in several gardens on the island. It is a vigorous climber with prolific growth, with dark green shiny leaves and purple flowers. It has become invasive at many parts in the world. It smothers other vegetation to form dense impenetrable thickets. On Curaçao, it is a great menace.

- *Schinus terebinthifolius* (Brazilian pepper tree) is a tree, introduced as an ornamental tree in gardens. It produces great numbers of small fruits. It is native to Argentina, Brazil and Paraguay. It is a pioneer on disturbed sites and one of the most aggressive of the invasive non-indigenous plants in Florida. It is also successful in undisturbed natural environments, where it can displace native vegetation [30].

- *Leucaena leucocephala*
  This is a 'conflict tree' being widely promoted for tropical forage production and reforestation whilst at the same time it is spreading naturally and is widely reported as a weed. This seedy thornless tree can form dense monospecific thickets and is difficult to eradicate once established, rendering extensive areas unusable and inaccessible, and threatening native plants in some areas[31].

- *Cuscuta americana* (American Dodder or Yellow Dad, Yellow Death) is a parasitic plant, growing on other plants and weakening them. Various host plants are infested. It has also been found growing on Corallita. It is native on St. Eustatius and other islands in the region. People told us that the species is expanding. However, we have not found any reference to the species as being invasive in the area. However, in several states of America the species is listed as noxious weed, where it forms a threat to agricultural crops.

8 Potential methods to contain and control Corallita on St.Eustatius

8.1 Control methods

Total eradication of Corallita is not possible on St. Eustatius. The species has been on the island for too long and has spread too vigorously.
Containment is feasible to a certain extent: at sites where the species is not yet present in large quantities, where they can be eradicated locally. “Hotspots” of occurrence of Corallita such as close to national park; and isolated locations with low abundance also control is possible to a certain extent. The species can also be kept under control with some effort in private gardens.
Mitigation: “to live with” this species in the best achievable way to mitigate impacts on biodiversity and endangered species. Methods not directly affecting invasive species but which protect native species should be sought.

[30] www.issg.org
[27] Global Invasive Species Database

8.2 What can be done?

8.2.1 Clearing trees in gardens and along roads

How?

1. The best way to do this is cutting down all plants in a circle of at least 3 metres around the tree crown.
2. Pull the stems of Corallita from the crown.
3. Burn all the debris that come from the ground and the trees to prevent dispersal of seeds or plant parts.
4. Pruning up tree crowns will reduce the risk of Corallita reaching the branches and growing into the tree again.
5. The most important thing to do is to keep up the maintenance, otherwise all the hard work is done in vain.

8.2.2 Clearing backyards, hedges and fences

How?

Manually

1. Clear infested areas by cutting down the plants to ground level
2. Burn the debris to prevent dispersal of seeds
3. Dig up or if possible hand plough the area and remove the tubers and roots and burn them
4. Sow grass, and mow it regularly; thus keeping Corallita under control. We have been told that Guinea grass (*Panicum maximum*) is a good competitor with Corallita [32].

Chemically using herbicides

In case of persistent regrowth of Corallita, herbicides could be applied, but strict precautions should be taken! (see Annex 6)

1. Remove all the Corallita and burn the debris.
2. Wait 3-4 weeks to let Corallita sprout again until 30-40cm.
3. Spray now with Glyphosate with concentration of maximum 25%.
4. Wait till the vegetation has died and remove all dead parts.
5. Repeat the spraying treatment if regrowth occurs again (30-40cm regrowth).

8.2.3 Clearing hotspots

Where Corallita is growing at isolated spots or spots where it may spread into the National Parks, all plants should be eradicated. Main hotspots are:

- Around the Telecom board
- Near the entrance paths to the Quill
- End of bird trail in Botanical Garden
- Isolated habitats near Fort de Windt
- Various isolated habitats in Zeelandia , such as along the road, outside the garden of Nicole Esteban; downhill of the house of Wendy Collins and others.

How?

Manually and chemically

1. Cut all Corallita to ground level and burn the debris
2. Let the plants sprout again till the new stems are about 30 cm (3-4 weeks) and spray the foliage with herbicides with concentration… Take the necessary precautions!
3. Repeat the cutting and spraying again, if necessary
4. Keep on monitoring the effects of the treatments.

[32] G. Lopes, 2005, personal communication.

8.3 Monitoring

8.3.1 Monitoring the effects of control measures

Identification of specific sites for regular monitoring the effects of control measures
Hotspots:

- Around the Telecom board.
- Near the entrance paths to the Quill.
- End of bird trail in Botanical Garden.
- Isolated habitats near Fort de Windt.
- Various isolated habitats in Zeelandia (such as along the road, outside the garden of Nicole Esteban; downhill of the house of Wendy Collins and others).

8.3.2 Monitoring the presence/absence of Corallita as an early warning system

Identification of specific sites for monitoring.

Suggested:

- (New) building sites.
- Along the border of the Quill sector of the National Park, where the chances are high that Corallita will appear, because of transport of fruits, small tubers or cuttings.
- In the Boven sector of the National Park.
- Beyond the Botanical Garden, passed the present border of Corallita.
- On the compound of the Oil Terminal.
- Locations between Fort de Windt and Oranjestad.

What to do:

- Monitoring every 2 months; if plants are found note the abundance and phenological state;
- If fruiting, take away the fruits and burn these.
- Return to the site and remove the plants burn the debris. Make sure that the tubers and roots are dug up.
- Large plants should be cut and after about 3 weeks of regrowth (new stem about 30 cm), sprayed with Glyphosate.

9 Recommendation

9.1 Research

- State of the art concerning the distribution of Corallita in the region.
- Research on the genetic variability of the species.
- Study on the effects of Corallita on the underlying vegetation.
- Study on the effects of Corallita on fauna.
- Research on the competition between certain grass species and Corallita.
- Experiments with different concentrations of herbicides to find out the most effective and economic way to spray.

9.2 Steps towards addressing the Corallita problem

9.2.1. For St.Eustatius

Preparation of an action plan

1. An awareness programme should be set up involving government officials and local public.
2. A programme to contain and control Corallita should be set up involving government officials and local public. With modest financial means a start can be made to contain Corallita.
3. Inventory of trees infested with Corallita, which should be cleared.
4. Train volunteers to clear single trees and large shrubs in urban areas.
5 Training people to how to apply herbicides
6. Experiments with different concentrations of Glyphosate should be initiated in order to find out the most effective and economic way to spray.
7. A monitoring programme should be set up by Stenapa. This involves
   a) Monitoring the effects of control methods
   b) Monitoring vulnerable sites where the species might appear, but is unwanted there.
8. Determine goals in the form of "What do we want to achieve and when?"
9. Rules and regulations should be created to prevent soil transport from infested sites.
10. Create legal instruments (e.g. fines) for controlling and containing Corallita.

9.2.2. For the region

1. Neighbouring islands should be warned about the threats of Corallita. If agricultural practices change and fields turn fallow, Corallita may become a pest.
2. On all the islands in the region, Corallita should be declared as a noxious weed with a great potential to spread.
3. The results of the pilot study should be made available to neighbouring islands. The study has already been communicated to nature organisations of the six islands of the Dutch Caribbean through the Dutch Caribbean Nature Alliance (DCNA).

4. A regional consultation should be initiated to discuss the threats of Corallita for biodiversity.
5. A region-wide programme should be set up to control further spread of the species.
6. A list of all (potential) invasive alien species for Saba, St Eustatius and St. Maarten as well as for the ABC islands should be prepared.

A handout of chapter 8-9 was made for the public and governmental departments on St.Eustatius (Annex VII).

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