Leucaena leucocephala suppression in Sint Eustatius

A study on possible control methods for the invasive *Leucaena leucocephala*

Sheila de Leeuw, National Park Intern (Nov 2013 – Mar 2014)
On behalf of Sint Eustatius National Parks (STENAPA)
12 August 2014

Table of contents

Introduction

On Sint Eustatius *Leucaena leucocephala* (local name Tan Tan) is present in parts of the island. In some areas the invasive tree forms dense monospecific thickets, which might suppress and/or replace other native species that are important for the island's biodiversity. Even in areas where there are no conservation concerns the tree can make the area unusable and inaccessible. The tree is invasive in open, semi-natural and disturbed areas on the island, especially in the Boven National Park, the Miriam C. Schmidt Botanical Garden and on the borders of the Quill National Park where it forms a threat for other native species. In the protected areas of the island it is of great importance to conserve and enhance biodiversity and protect endemic and native species. Threats to local biodiversity therefore need to be addressed and controlled.

The main problems facing control management of *L. leucocephala* include difficulty eradicating established plants; long dormancy of the seeds (10 to 20 years); and vigorous re-growth of the tree after cutting. Currently the trees are cut by hand, however only in areas that are easily accessible, where management is a priority and where there is manpower available. Since the trees re-sprout after cutting, regular maintenance is necessary. However, given that the area where the trees grow is relatively large and difficult to access, regular manual cutting of the entire area is too labour intensive and expensive. Therefore, it was necessary to find other ways to control the invasive *Leucaena leucocephala.*

The goal of this research was to find effective ways to reduce and control *L. leucocephala* on a large scale. Different control methods were tested to see which is the most effective. To determine the most effective eradication method, different indicators were taken into account, including total costs, total labour hours required, and the effect of the method on the growth of *L. leucocephala*.

The results of this study can be used as a guide for STENAPA and other interested parties to effectively control *L. leucocephala*.

1. Factsheet *Leucaena leucocephala*

1.1 Taxonomy

Order : Mimossoideae
Family : Fabaceae (Leguminosae)
Species : Leucaena leucocephala (Lam.) de Wit
Synonyms : Leucaena glauca Benth., Mimosa glauca sensu L., Mimosa leucocephala Lam.and Acacia leucocephala (Lam.) Link
Common name: Tan tan tree(Dutch Caribbean), Wild tamarind, Leucaena, ipil-ipil(philippines), lamtora/-o(Indonesia),Guaje, Yaje, Unaxin(Latin America), Lead tree, Jumby bean (Bahamas)

1.2 Morphology

Thornless long-lived shrubby, highly branched, medium sized tree which can grow to heights of 5-18m. Leave are bipinnate with 6-8 pairs of pinnae bearing 11-23 pairs of leaflets that are 8-16mm long. The bark of the young branches is smooth, grey-brown/salon pink. Older branches are darker grey-brown and less smooth with sallow rusty orange-brown vertical cracks with a deep red inner bark. Flowers are white or pale cream-white. The flower heads are 12-21mm in diameter with 100-180 flowers per head. Flowers occur in groups of 2-6 in leaf axils of actively growing young shoots. The mid- to orange-brown pods are 11-19cm long and 15-21mm wide with 5-20 pods per head. They are linear-oblong, flat and contain 8-18 hard dark brown seeds. The seeds are 6.7-9.6mm long and 4-6.3mm wide. The tree is deep rooted, can extend its roots 5m in the ground. The leaves can fold up when it is too hot, too cold or when there is lack of water.

Figure 1: Drawing of L. leucocephala showing the leaves, branches, flowers and pod.

1.3 Distribution

L. leucocephala is a native tree in the southern part of Mexico but is widely distributed throughout the tropics, especially in Central America. In the Philippines the tree was introduced in the 16th Century to produce fodder for ruminant livestock. After this the tree spread further throughout the Asian-Pacific region. It was mainly used in agroforestry but is nowadays no longer commonly planted. Since the tree has been extensively cultivated over centuries it is difficult to identify its natural range.

1.4 Ecology

Soil requirements

Requires a pH above 5.0 and is intolerant of soils with a low pH, low P, low Ca, high aluminum saturation and high salinity. The tree requires well-drained soil; it cannot withstand soils that are waterlogged. Can tolerate soils with moderate salinity and alkalinity.

Rainfall and moisture

L. leucocephala prefers sub-humid and humid climates where the annual rainfall lies between 650 and 3,000mm. However, yields are low in dry environments. The tree is very drought tolerant and can tolerate dry seasons that last up to 7 months. The roots can reach a depth of 5 meters in the ground to exploit underground water. The tree does not tolerate waterlogged soils and flooding that last for more than 3 weeks.

Temperature

Grows optimally where the temperature lies between the 25 and 30 °C. Growth stops at temperatures below 15 or 16 °C. Light frosts will kill the leaves while heavy frosts will kill the stems up to ground level, however this will not kill mature plants.

Light

Shade can reduce the plant's growth. However, compared with other tree legumes *L. leucocephala* has a moderate tolerance for shade.

1.5 Uses

Young pods, young leaves and flower buds can be eaten. Tree is also used to produce fodder for livestock, to produce fuel wood, create shade for crops such as coffee and cocoa, function as a windbreak or firebreak, function as a living fence and support vines such as pepper and passion fruit. The tree is also an important species in alley farming systems where it functions as a soil improver since it can fix nitrogen into the soil.

1.6 Threats to the environment

L. leucocephala can form a threat to native biodiversity. Especially in suitable sites it can form dense, homogenous thickets that suppress native species. Once established it is difficult to control. . Invaded areas can also promote suitabel conditions for the establishment of other aggressive invaders. Invaded areas can become unusable and inaccessible where most other vegetation is replaced. Another threat is that the mimosine, that is present in the leaves of *L. leucocephala*, can cause hair loss, infertility and stomach problems in livestock.

2. Possible control methods

2.1 Manual

L. leucocephala can be controlled manually. Two methods are most commonly used. The first is digging out all the roots in the soil. This method is very labour intensive since the trees are very deep rooted (Gutteridge, 1998). The second method is the cutting of stems with a handsaw. This method is less labour intensive but needs to be carried out more often since the tree re-sprout vigorously after cutting (Walton, 2003). Regular cutting needs to be carried out to exhaust the energy reserves of the plant, which can take many years (Mattrick, n.d.). The chance of survival after the first method is very low (if there are no more roots present) whereas the survival rate of the second method is very high after the first treatment. After applying one of the methods above the soil can be mulched with the leftovers of the tree. The mulch can function as a green manure and will also suppress the development of new seedlings (Walton, 2003).

2.2 Mechanical

L. leucocephala can also be removed mechanically. The eradication of undesirable trees can be done with the use of bulldozers. However, this might cause great disturbances to the soil and other native vegetation, which might favour the re-establishment of *L. leucocephala* (Ernst, 2007). Another method that is often applied in weed control is suffocation. By applying plastic or another impenetrable barrier over the saplings or cut stumps, the plant will not get enough sunlight and water to grow and will eventually die of suffocation. The sheet should at least stay in place for one growing season. However, to be effective a longer period of time is desirable (Mattrick, n.d.). Keep in mind that the sheet will kill everything underneath it, undesirable plants as well as desirable plants. Another method is cutting the stems with a chainsaw. This method will have the same effect as cutting the stems manually with a handsaw, only this method is less labour intensive.

2.3 Fire

Fire can be used to control *L. leucocephala* stands. However, *L. leucocephala* is known for its fire resilience and mostly re-sprouts rapidly from burned stumps. A second fire or other control method would be necessary to reduce or eradicate the stand successfully.
Previous research on control methods has shown that after a fire most plants quickly re-grew, from above as well as below ground. Also a high germination of seedlings occurred after the fire, indicating a high seed bank and possible seed scarification after a fire (Walton, 2003).

2.4 Chemical

Research shows that using herbicide to control *L. leucocephala* is an effective way to suppress the tree (Walton, 2003). Herbicide will not only kill the tree fast, the method is also relatively less labour intensive than other effective controlling methods.

There are different methods available to control the species chemically, the most common being basal-bark treatment, cut-stem treatment and foliar spray treatment. In basal-bark treatments herbicide mixed into (natural) oil is applied on the bark, preferably on the lowest

12 to 24 inches of target stems (band of at least 6 inches). In the cut-stump treatment herbicide mixed with water is applied with a brush or a spray on the freshly cut stump of the tree. In the foliar spray treatment herbicide mixed with water is applied on the plant foliage of the tree (Kline, 1996). Care should be taken to prevent damage to desirable plants close to the treated plants. The first two methods are most commonly used in controlling *L. leucocephala.*

2.4.1 Herbicides

Most commonly herbicides used for the control of invasive species are: glyphosate (the active ingredient in Roundup, Accord, and Rodeo) and triclopyr (the active ingredient in Ortho Brush-B-Gon, Garlon, and Crossbow).

Glyphosate is a broad-spectrum herbicide (it will kill almost all plants) which is absorbed by the leaves or the bark of the plant and is transported within the plant. Almost all herbaceous plant and woody plants are sensitive to Glyphosate. After application symptoms will appear within a week. This includes: chlorosis and growth inhibition of the youngest leaves and growing points. It takes two weeks or more for the plant to die. Symptoms and death will happen more quickly when the temperatures are high and when the plant is still young and grows actively.

Triclopyr is a broad-leaf herbicide (kills most broad-leaf plants but will not kill grasses or grass-like plants). This herbicide disturbs the normal expansion and division of plant cells, causing a distorted growth of the plant. Symptoms occur more rapidly compared with Glyphosate, the plants showing injury symptoms within 24 hours and dying within a few days. Triclopyr has the best results when applied on young actively growing plants (CT Invasive Plant Working Group, 2008).

2.4.2 Safety and environment

When herbicides are used to eradicate invasive species, the label must be read carefully to prevent and reduce environmental hazards and guarantee human safety. In some countries it is a violation to use herbicides in any way other than directed. Glysophate has low toxicity to humans and animals. In addition, this herbicide does not persist or bioaccumulate in the environment, and when used properly it poses minimal risk to humans and the environment. The herbicide is rapidly and tightly bound to soil particles and is therefore not taken up by plant roots. Glysophate is also rapidly biodegraded by microorganisms in the soil, causing no damage to other plants in the direct vicinity.

Triclopyr is relatively low in toxicity compared with other herbicides, however not as low as Glysophate. It is not strongly bound to soil particles, causing potential leaching into groundwater. Since Triclopyr has residual activity in the soil with a half-life of 6 weeks, it may cause damage to other plants in the immediate vicinity. When herbicides are used to control invasive species, always read and follow label directions in order to avoid damage to the environment, other plants, animals and yourself (CT Invasive Plant Working Group, 2008).

2.5 Biological

Biological control is the control of invasive populations through the use of animals, fungi or disease and might be an option to suppress *L. leucocephala.* When considering this method a couple of things need to be taken into account. Firstly, it does not eliminate the invasive species and takes several years to see results. Secondly, before a new species can be introduced a study needs to be conducted in order to ensure the introduced species will only affect the target species and not other native species. Permits are required when new species are being introduced into an area (Moore, Kearns, & Boos, 2012). In South-Africa the seed feeding bruchid beetle Acanthoscelides macrophthalmus has been introduced to control *L. leucocephala*. The seeds are the only part of the plant that is affected by this beetle. In addition, the impact of the beetle is only patchy and seasonal. Results so far indicate that the damage done by the beetle is consistent but variable (Olckers, 2011). The beetle was also accidently introduced to Queensland, Australia. However, no data is available about the effect of *A. macrophthalmus* on the abundance of *L. leucocephala* (Walton, 2003)

Other natural predators of *L. leucocephala* that affect its growth are the Leucaena psyllid, the caterpillar *Ithome lassula* and the log brown scale *Coccus longulus*. The leucaena psyllid does not kill the tree, however affected trees have shorter and thinner stems, are less vigorous and will reduce the establishment of seedlings. *I. lassula* feeds on flower buds, reducing pod production of the tree. The scale *C. longulus* can reduce the growth of *L. leucocephala* by sucking sap out of the trees. The honeydew that the scale produces can cause lower foliage and stems (Walton, 2003).

Grazing animals can also be used for biological control. Cattle, rabbits, hares, marsupials, termites and grasshoppers have been recorded destroying seedlings before the tree is well established (Walton, 2003). To be effective, grazing must be done multiple times per year and for a longer period of time, preferably during the early growth stages of the plant. Care should be taken since grazers can also eat desirable plants (Moore, Kearns, & Boos, 2012).

2.6 Other possible control methods

Copper nails

Some people on Sint Eustatius say they have killed *L. leucocephala* with the use of copper nails (Schats, 2014). There is, however, no scientific data available to support this. On internet forums opinions about this method vary. Some people say it is a myth while other people claim the tree will die because the wound (created by the copper nail) may cause a fungal attack. According to professor Nicholas Lepp from the Liverpool John Moores University, copper can kill trees but only when the copper is dissolved and transported to the roots and shoots, and when high concentrations of copper are applied. In addition, the slow rate of release from copper nails does not cause significant problems to a healthy tree. The water movement pattern is also important for the transportation of copper within a tree. Since water movement patterns vary between species, different trees will have different susceptibilities to the use of copper nails. In general, more copper nails are needed to kill a tree (Lepp, n.d.)

Copper(II) sulfate

Copper sulfate is used as a herbicide to kill roots and plants. It can also be used to kill bacteria, algae, roots, plants snails and fungi. Copper is a required nutritional element for plants and animals. In plants, copper is needed for photosynthesis and plant enzyme systems. However, too much copper can be toxic and hinder photosynthesis. The toxicity of copper sulfate depends on the copper content. It is toxic when animals and plants receive too much copper sulfate. For plants this counts for levels higher than 0.01 ppm (parts per million), for aquatic animals levels between the range of 1.0 - 2.0 ppm are toxic (Crystal Lake Improvement Association , n.d.). Birds and mammals are more tolerant to copper toxicity than plants and aquatic animals.

Safety and environment

As mentioned above, too much copper can become toxic. In the soil copper accumulates mainly in the top soil, binding it tightly and precisely to organic matter, minerals and some metal oxides. The level of binding depends on the acidity of the soil, 30% of copper is bound at pH 3.9 and 99% of copper is bound at pH 6.6. Copper can easily dissolve in water and bind to sediments (Boone, Jervais, Luukinen, Buhl, & Stone, 2012). When using copper sulphate always follow the instructions and take steps to avoid exposure to other plants, animals, the environment and yourself.

Paint

Hannah Madden, Terrestrial Areas Manager at STENAPA, had observed paint being used in an eradication program on another tree species in the Dominican Republic (Madden, 2014). It was suggested as a potential treatment method. However, information about this method was not found in any article or website on the internet.

3. Methodology

3.1 Study area

The control method experiments were carried out at the Miriam C. Schmidt Botanical Garden (see figure 3). Inventories for the distribution map were carried out in areas where *L. leucocephala* is the most abundant on the island and where conservation of the native species is important (mainly in the Boven National Park).

3.3 Experiments/possible control methods

At the botanical garden a large population of *L. leucocephala* could be found. Figure 3 shows which areas of the garden the experiments took place. For every control method between 3 and 10 trees with a DBH of <3cm (5 trees), between 3-6cm (5 trees) and >6cm (5 trees) were chosen. The trees used in the experiments were marked with paint to distinguish the different methods applied during monitoring surveys.

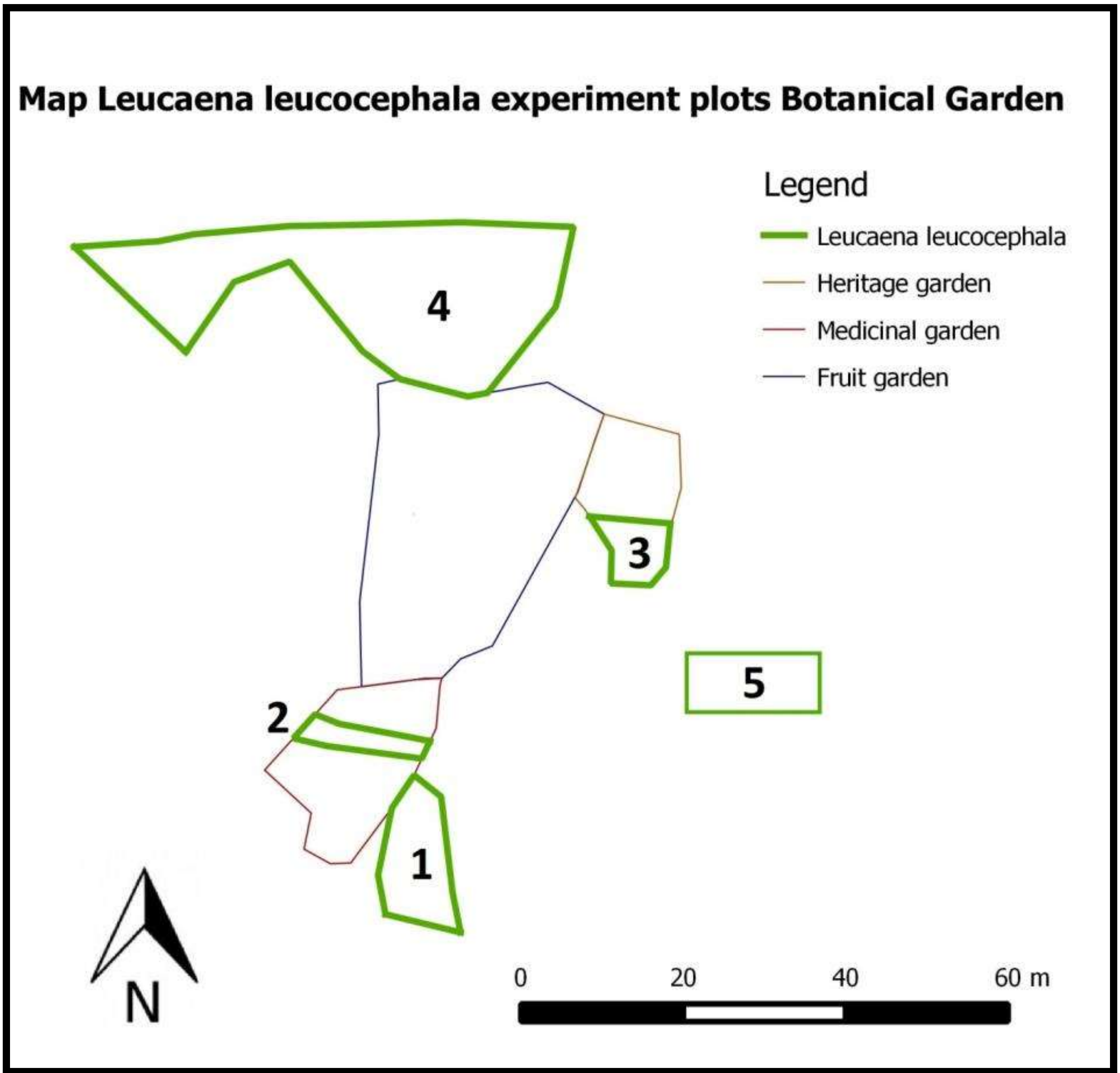

Figure 3: map of the *L. leucocephala* sections in the botanical garden where the control experiments will be carried out

The following methods were used in the experiments:

3.3.1 Manual

Cutting

The above-ground vegetation of *L. leucocephala* was cut with a handsaw or lopper between 10 and 30 cm from the base of the tree (see figure 4).

Figure 4: tree stump marked with the cutting control method.

Digging

The above-ground section was cut with a handsaw or a lopper. Thereafter the roots of the tree were dug up with a pick axe and/or a shovel as far as possible (see figures 4 & 5). Roots that were too deep rooted were cut off with a lopper. After digging out (part of) the roots the hole was filled with the extracted soil. The spot was marked with a painted stone.

Figure 4: digging up the roots with a pick axe

Figure 5: cut root stump below ground

3.3.2 Mechanical

The mechanical method used in this experiment was suffocation. Trees were cut with a handsaw and/or lopper at the base. After this, stumps were covered with an impenetrable plastic (see figure 6). Rocks were used to keep the plastic sheet in place and to prevent light infiltration.

Figure 6: *L. leucocephala* tree stumps covered with plastic to suffocate the trees.

3.3.3 Chemical

In this experiment the cut stump was treated with triclopyr herbicide. This herbicide was already available at the time the experiments began. However, the use of glysophate is less damaging to the environment (see chapter 2.4.2). Since the two herbicides almost have the same effect, the use of glysophate (Roundup super concentrate- tree stump and root killer) is recommended when applying herbicides to woody plants (http://www.uaex.edu/publications/pdf/FSA-6124.pdf).

<u>Cut stump treatment</u>

Trees were cut at the base with a handsaw. Herbicide was applied with a paint brush or spray. The cut stump was treated within two hours after cutting since a delay of more than two hours can cause a significant reduction in the effectiveness of the treatment. The cambial and sapwood area (outer 2.5 cm of the stump) were also treated.

3.3.4 Other

Copper sulfate

The first step in applying this method is to drill (a) hole(s) with a downward angle in the tree near the base. This method is more effective when the hole is longer and wider, allowing more copper sulfate into the tree which increases the chances of killing the tree. The second step involved filling the hole with the copper sulfate using a squirt bottle until the hole was almost filled. Finally, after the hole was filled, a small piece of cotton wool was inserted into the hole to prevent the copper sulfate from leaking out and/or be washed out by rain (figure 8).

Figure 8: *L. leucocephala* tree injected with copper sulfate and covered with cotton wool.

Paint

This method can be compared with the chemical method of the cut stump treatment. Instead of applying herbicide to the cut stump, paint was applied. First the tree was cut near the base. Secondly, paint was applied with a brush to the freshly cut stump (figure 9), ensuring that paint was applied over the entire stem and no spots were missed.

figure 9: *L. leucocephala* tree stump treated with paint.

3.4. Applying methods & Monitoring

To determine which method was most effective different indicators were taken into account when applying and monitoring the different methods. Indicators included total labour time, cost and re-growth of each different method. In addition, the DBH (diameter at breast height) and height at which the method was applied were also measured.

The labour time includes the time it took to apply the method on one tree (excluding preparation time). The time was tracked with a stopwatch starting at the beginning of the treatment and ending when the tree as treated. To determine the costs, the variable costs and fixed costs of the materials needed for each method (see appendix 1) were taken into account, excluding labour costs. To measure re-growth the average length of sprouts per tree were measured. The development of trees was measured twice after the methods were applied, with intervals of 3 to 4 weeks.

4. Results

A detailed presentation of all the results for each indicator (re-growth, labour time and costs) is given in this chapter.

4.1 Re-growth

To measure the re-growth per tree and per method the average length of all sprouts was measured. Appendix B details the re-growth of every tree together with factors that might have influenced the re-growth development of the tree(s).

Figure 1 shows the average re-growth of all methods applied, with the copper sulfate method excluded since the tree was still standing and alive when measurements were taken. Cutting and painting are obviously not effective in controlling *L. leucocephala* since all the trees treated with these methods re-sprouted and grew quickly following treatment.

The difference in average re-growth between cutting and painting can be partly explained by the fact that painting only took place in locations 1 and 2 while cutting also took place in location 3 where none of the sprouts were eaten. However, it should not be ruled out that painting can have had an effect on the re-growth of shoots.

Trees that had been treated with the suffocation method were still alive after the second monitoring but the stems were rotting and re-growth was not substantial. Suffocation could be an effective method but further monitoring will be required in order to prove its effectiveness.

The most promising methods, when considering re-growth, were removal of the roots and treatment with herbicide. Both methods showed little to no re-growth after the first and second monitoring.

Re-growth results can contain errors since some trees were overgrown with Corallita (*Antigonon leptopus*) or were grazed by roaming animals, particularly goats. Locations 1 and 2 were especially affected by grazing. In location 3 the re-growth of shoots was slightly higher when compared with other locations, which can be explained by the fact that location 3 is more remote and contains denser vegetation, therefore this location is less accessible to potential grazers. Pictures of tree development following the second measurement can be found in Appendix C.

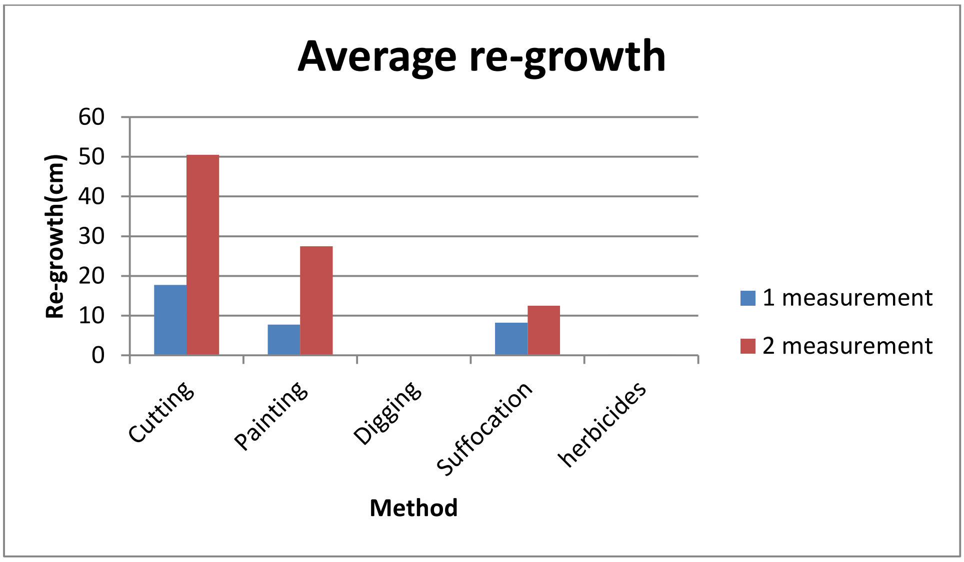

Figure 1: Results of 1st and 2nd measurement of the average re-growth of each control methods.

4.2 Long term results

Two and a half months after the second measurement the re-growth of all the methods was checked again. Stems that had been treated with herbicide had no re-growth. The first plot (DBH <3cm) of the suffocation method had no re-growth, however the second plot (DBH 7-8 cm) had produced yellow shoots. The length of the shoots, however, was the same as those measured during the second measurement.

4.3 Labour

Figure 2 shows the total labour time in minutes per tree. Digging and suffocation take the most time, while the cutting, painting and herbicide take the least. Digging is by far the most labour intensive since the tree needs to be cut and the roots, which are very deeply rooted, need to be removed from the soil.

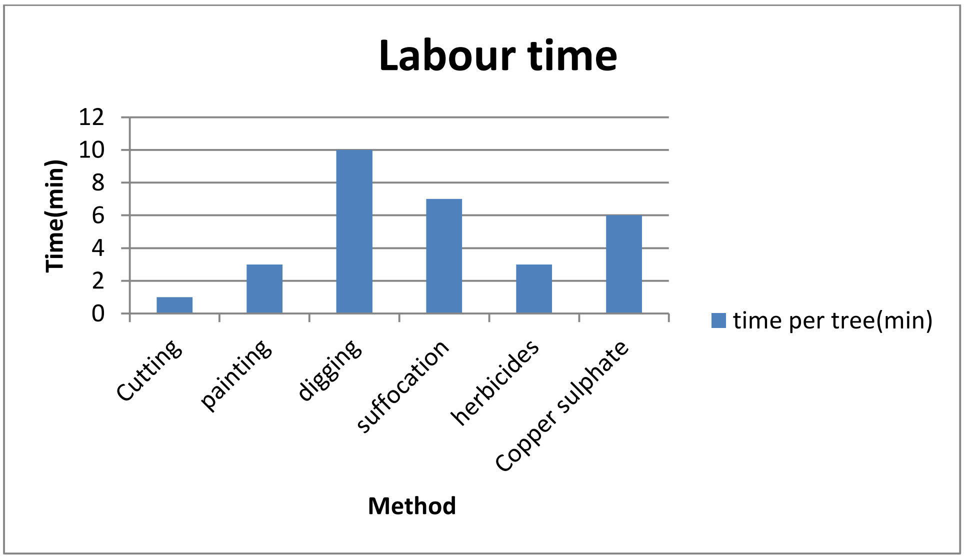

Figure 2: total labour time in minutes of one tree per control method.

4.4 Costs

Figure 3 shows the total cost per method. A detailed list of all the costs can be found in appendix C. Suffocation is by far the most expensive since the material required is expensive. Another expensive method is treatment with copper sulfate.

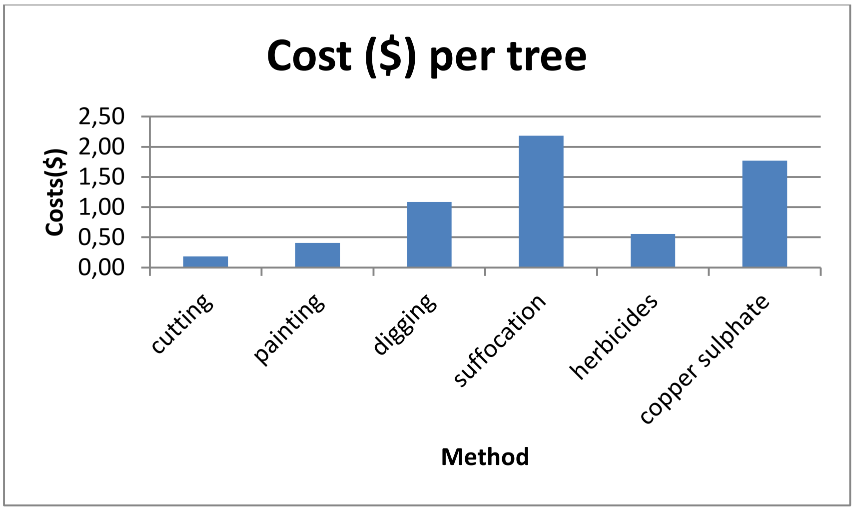

Figure 3: total cost per tree for each control method.

4.5 Results conclusion

To determine the most effective method, all indicators were given a score from less effective (5 or 6) to most effective (1). In Table 1 all rates per method are shown. Re-growth is x 10 since that is the most important indicator when measuring the effectiveness of a method. Cutting is the least labour intensive and less expensive but the tree will re-sprout quickly and follow-up treatments are necessary, which makes it more costly and labour intensive in the long term. The use of herbicides is by far the most effective method to control *L. leucocephala*.

Method	**Re-growth (x10)**	**Labour (x1)**	**Costs (X1)**	**total**
Cutting	5	1	1	52
Painting	4	2	2	44
Digging	2	5	4	29
Suffocation	3	4	6	40
Herbicides	1	2	3	**15**
Copper sulphate	X	3	5	X

Table 1: Ratings per method for the different indicators to determine the most effective method

5. Discussion and Conclusion

This study was carried out to find an effective method to control the invasive *L. leucocephala*, potentially on a large scale. Cutting methods that had previously been were not effective since the tree quickly re-sprouted quickly thereafter. Regular cuttings were therefore necessary to keep the population under control. However, this is method is too labour intensive. Six control methods were applied to find out which method was most effective in the control of *L. leucocephala.* The treatments were carried out in the botanical garden and were monitored twice, one and two months following treatment. The herbicide method was expected to be the most effective since previous research has shown its use is most promising compared with digging, cutting, fire, biological and grazing treatments. However, in this experiment three other methods were used that were never used before in *L. leucocephala* control studies.

This study showed that using herbicide to control *L. leucocephala* is the most effective way of controlling the population. The herbicide and root removal method both showed no re-growth. However, removal of the roots is very labour intensive, therefore using herbicide is more preferable.

Cutting and painting showed the most re-growth. Differences between and within the collected data of these methods can be explained by the fact that some of the trees were eaten by and/or overgrown by Corallita. Tree stumps that were eaten and/or overgrown had less shoots and these were shorter than unaffected tree stumps.

The use of copper sulfate showed no effect after the first and second measurements. Tree stumps that were suffocated showed decay after the first and second measurements but were still alive. Two and a half months after the second measurement the plot with the small DBH (<3cm) had no sprouts, however the plot with the bigger stems (7-8cm) still had yellow shoots. More measurements are required over a longer period of time to be able to accurate conclude the effectiveness of this method.

Although there were some errors in the data (eaten and overgrown trees stumps), research design (different locations for different methods) and number of measurements (only two measurements) the results give a general idea about the different control methods and their usefulness in the control of *L. leucocephala.*

It should be noted that once *L. leucocephala* is controlled the problem is not necessarily solved. *L. leucocephala* produces a high amount of seeds that can stay dormant in the soil up to 20 years. Once a tree is killed new seedlings will take its place. The best way to control the *L. leucocephala* population therefore is prevention of new establishments in unaffected areas.

Further research can be conducted about reforesting disturbed areas with native tree in order to replace and suppress new *L. leucocephala* seedlings and saplings. In addition, a distribution map could be made to show the tree's distribution across the island and (estimated) density per area.

Appendix A: Data sheet monitoring 1st and 2nd measurement

		1 measurement						2 measurement				
#Tree	Location	Method	Regrowth(Y/N)	# sprouts	#sub sprouts	average Length(cm)	Comments	Regrowth(Y/N)	# sprouts	#sub sprouts	Length(cm)	Comments
1	1	Cutting	Y	5	6	20		Y	4	6	35	
2	1	Cutting	X	X	X	X		X	X	X	X	
3	2	Cutting	Y	5	>10	20	overgrown	Y	5	>10	35	overgrown + eaten
4	3	Cutting	Y	4	>10	15		Y	4	9	75	veryshady
5	4	Cutting	Y	6	>10	25		Y	6	>10	45	eaten
6	3	Cutting	Y	5	>10	25		Y	4	>10	100	very shady
7	3	Cutting	Y	5	>10	25		Y	5	10	85	very shady
8	1	Cutting	Y	4	>10	20		Y	4	>10	40	
9	2	Cutting	Y	>10	>10	12		Y	>10	>10	55	eaten
10	2	Cutting	Y	4	>10	15		Y	5	>10	35	eaten
11	2	Painting	Y	4	7	7	overgrown	Y	5	8	20	overgrown
12	1	Painting	Y	8	9	7		Y	4	>10	15	eaten
13	2	Painting	Y	4	5	7	overgrown	Y	5	10	40	overgrown
14	1	Painting	Y	7	>10	10		Y	7	>10	35	
16	3	Digging	N	0	0	0	new seedlings in place	N	0	0	0	new seedlings in place
17	3	Digging	N	0	0	0	new seedlings in place	N	0	0	0	new seedlings in place
18	4	Digging	N	0	0	0	new seedlings in place	N	0	0	0	new seedlings in place
19	5	Suffocation	Y	>10	>10	10		Y	>10	>10	15	regrowth yellow+funghi on stem
20	5	Suffocation	Y	6	>10	10		Y	>10	>10	15	regrowth yellow+funghi on stem
21	5	Suffocation	Y	>10	>10	9		Y	>10	>10	15	regrowth yellow+funghi on stem
22	5	Suffocation	Y	1.0-4.0	5.0-10.0	4		Y	1--5	5--10	5	
23	2	Herbicide	N	0	0	0		N	0	0	0	
24	2	Herbicide	N	0	0	0		N	0	0	0	
25	2	Herbicide	N	0	0	0		N	0	0	0	

26	2	Herbicide	N	0	0	0		N	0	0	0	
27	2	Herbicide	N	0	0	0		N	0	0	0	
28	2	Herbicide	N	0	0	0		N	0	0	0	
29	1	Herbicide	Y	2	3	2		Y	1	1	2	
30	1	Herbicide	N	0	0	0		N	0	0	0	
31	1	Herbicide	N	0	0	0		N	0	0	0	
32	1	Herbicide	N	0	0	0		N	0	0	0	
33	1	Copper	Still alive				brown jelly substence	Still alive				brown jelly substance
34	1	Copper	Still alive				brown jelly substence	Still alive				brown jelly like substance
35	1	Copper	Still alive				brown jelly substence	Still alive				brown jelly like substance
36	1	Copper	Still alive				brown jelly substence	Still alive				brown jelly like substance
37	1	Copper	Still alive				brown jelly substence	Still alive				brown jelly like substance
38	2	Copper	Still alive				brown jelly substence	Still alive				brown jelly like substance
39	2	Copper	Still alive				brown jelly substence	Still alive				brown jelly like substance
40	2	Copper	Still alive				brown jelly substence	Still alive				brown jelly like substance
41	2	Copper	Still alive				brown jelly substence	Still alive				brown jelly like substance
42	2	Copper	Still alive				brown jelly substence	Still alive				brown jelly like substance

Appendix B: Cost per tree per method

	Cost ($)	100	trees			
materials	**cutting**	**painting**	**digging**	**Suffocation**	**Herbicides**	**copper sulfate**
suffocation sheet	x	x	x	200	x	X
paintbrush	x	2	x	x	2	X
herbicide	x	x	x	x	30	X
copper sulfate	x	x	x	x	x	80
paint	x	20	x	x	x	X
Squirt bottle	x	x	x	x	x	2
handsaw	18.5	18.5	18.5	18.5	18.5	x
pickaxe	x	x	50	x	x	x
shovel	x	x	40	x	x	x
drill	x	x	x	x	x	90
chem. protect. gloves	x	x	x	x	5	5
total costs	18.50	40.50	108.50	218.50	55.50	177.00
cost per tree	0.19	0.41	1.09	2.19	0.56	1.77

Appendix C: Photos of trees after 1st measurement

Cutting: re-sprouted

Digging: new saplings in place

Painting: re-sprouted

Herbicides: 1 sprout

Suffocation: Yellow sprouts and fungus on stem

Copper sulphate: brown jelly like substance on bark

Appendix D: Photos of trees after 2nd measurement

Suffocation: yellow shoots and fungus

Painting: shoots eaten by roaming animals

Painting and herbicide: overgrown by Corallita (*Antigonon leptopus*)

Bibliography

CT Invasive Plant Working Group. (2008). *Safety and Environmental Considerations for the Use of Herbicides to Control Invasive Plants*. Opgeroepen op March 12, 2014, van Horticulture University of Connecticut: http://www.hort.uconn.edu/cipwg/art_pubs/GUIDE/consideration.htm

Ernst, J. &. (2007). *Study on the ecology and possible control methods of the invasive plant species Antigonon leptopus (Corallita or Mexican Creeper).*

Gutteridge, R. &. (1998). *Forage Tree Legumes in Tropical Agriculture.* St. Lucia: The Tropical Grassland Society of Australia Inc. .

Kline, W. &. (1996). Management of invasive exoticplants with herbicides in Florida. *Down To Earth , 51* (2), 22-28.

Lepp, N. (n.d.). *Speculative Science*. Opgeroepen op March 8, 2014, van The Guardian: http://www.theguardian.com/notesandqueries/query/0,5753,-2347,00.html

Mattrick, C. (n.d.). *Managing Invasive Plants - Methods of Control.* Framingham: New England Wild Flower Society.

Moore, C., Kearns, K., & Boos, T. (2012, October 1). *Control methods*. Opgeroepen op March 10, 2014, van Wisconsin Department of Natural Resources: http://dnr.wi.gov/topic/Invasives/control.html#biological

Olckers, T. (2011). Biological control of Leucaena leucocephala (Lam.) de Wit (Fabaceae) in South Africa : a tale of opportunism, seed feeders and unanswered questions. *African Entomology : Biological control of invasive alien plants in South Africa* , 356-365.

Walton, C. (2003). *Leucaena in Queensland: Pest status review series - land protection.* Brisbane: Department of Natural Resources ans Mines.