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THEME B:
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THEME B

SCIENCE

SOME TRADITIONAL PLANT USES IN SLOVENIA

Photo credit : *Lycopodium clavatum L.* using with the equipmet for cleaning the oven before puting bread inside , ***Jože Bavcon***

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02. Abstract

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IN THE PAST SLOVENIA WAS A RATHER RURAL COUNTRY. PEOPLE WERE LIVING CONNECTED WITH NATURE AND MANY PLANTS WERE USED FOR VARIOUS PURPOSES. HOWEVER A LOT OF KNOWLEDGE ABOUT PLANTS WENT FORGOTTEN DUE TO CHANGES IN THE LIFE-STYLE.

In the University Botanic Gardens Ljubljana besides our field work in various parts of Slovenia we also collect the oral history of our plants. Once the use of wild plants was namely very diverse and due to their massive collection and harvesting, many of them had to be protected. With the changes in life-style also the need for their protection has changed. Today some among them actually do not need a protection anymore while others, mostly medicinal plants, are more and more endangered, especially due to returning back to natural way of living. To the visitors of our botanic garden we like to point out their often forgotten role in order to broaden the awareness about the importance of ethnobotany also in our home area. Among the plants used for various purposes in the past definitely *Ruscus aculeatus* L. is worth mentioning. It was used for funerary wreaths, brooms, in Istria it was put onto the barrels filled with water, as the plant layer prevented water from splashing over the barrel edge. Common ivy was used for making Easter bundles, and for making decorative wreaths in churches. It was also used for ceremonial purposes, which today still can be seen during the ceremony of warding off the winter by "laufarji" in Cerklje, where one among them is wearing clothes made of ivy. *Lycopodium clavatum* L. was once used as a broom for cleaning the ovens before bread baking or for filtering the milk in the mountains. Tufts of different ferns were hanged in the stables to catch flies. Dogwood (*Cornus mas* L.) has a very hard wood and for this reason it was used as teeth for hay-rakes. Also the hop-hornbeam (*Ostrya carpinifolia* Scop.) has a very hard wood and was used for making wooden hammers for wood-chopping or for central parts of the wooden wheels. The bushes of *Euonymus europaeus* L. were often present between the fields and in times of hand-seeding for convenience their shoots were used for marking the already seeded areas. However the most commonly used plant was the common hazel (*Corylus avellana* L.). Its fruits represented food, sticks from its shrubs were used as basket harnesses. Kids were using hazel for making bows and dogwood for making arrows. Among medicinal plants nowadays already almost forgotten species *Inula hirta* L. should be mentioned. Once it was so important in popular medicine that it was given even a popular scientific name *Astra montana*. According to tradition it was able to heal everything even snake bites. Today only seldom it is being collected. The knowledge about past uses of the plants is getting forgotten and for this reason in the Botanic garden of University of Ljubljana we try to preserve it by recording this oral history.

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Photo credit : *Lycopodium clavatum* L. using with the equipmet for cleaning the oven before puting bread inside, ***Jože Bavcon***

HISTORY OF PLANT USE IS AS OLD AS CIVILISATION ITSELF. USE OF PLANTS IN ANCIENT EGYPT IS ALREADY WELL-KNOWN (OGRIN, 1993). IT HAS BEEN ESTABLISHED THAT CONQUERORS OF NEW TERRITORIES ALWAYS BROUGHT ALONG PEOPLE THAT HAD KNOWLEDGE OF PLANTS.

Some even had renowned teachers that taught natural sciences. Aristotle (384–322 BC) taught Alexander the Great (356–323 BC), who introduced citruses to Europe from India (Curtius & Rufus, 1809, Martin & Blackwell, 2012). Theophrastus (371–287 BC) already described around 500 plant species and varieties, especially medicinal and useful plants. (https://www.tcd.ie/Botany/tercentenary/origins/theophrastus).

Dioscorides (40–90 AD), a Greek physician that treated Roman legionnaires, wrote a famous book on plants (http://www.greekmedicine). Pliny the Elder (23–79 AD) also wrote about plants (Jones, 1966). Later on, knowledge of plants was passed on through monasteries from antiquity into the Middle-Ages, and then into cities and newly formed universities. Mathioli (1570), Clusius (1583), brothers Bauhin (1596), and much later Linnaeus (1753), who is considered the founder of ethnobotany, thus wrote about plants. The latter's Expedition to Lapland is especially famous, as it is considered the pioneering work of ethnobotany (Cox, 1999). Botanic gardens also began paying attention to ethnobotany, thus bringing the world of plants even closer to the people (Balick & Cox, 1996a, b).

In the territory of present-day Slovenia, the first to start studying botany was a physician for the miners of Idrija – Scopoli. In 1760 and 1772, he published his works – Flora Carniolica (Petkovšek, 1977). Hacquet, who also studied alpine flora, came to Idrija because of Scopoli (Hacquet, 1782; Praprotnik, 2014, 2015). He was followed by other researchers, who, in addition to botany, also wrote about the use of plants for different purposes. Pharmacists gathered plants and made tinctures out of them. Among them was also Freyer, the first curator of the Provincial Museum (Predin, 2002). Hladnik, the founder of the Botanic Garden, also wrote about the use of plants (Voss, 1884, 1885; Praprotnik, 2012), whereas his student, Andrej Fleischmann, studied the use of plants extensively (Voss, 1884, 1885; Praprotnik 1993, 2015). The latter wrote about the healing power of downy elecampane (*Inula hirta*), locally known as *Astra montana*, which cures all diseases, even snake bites (Praprotnik, 1993).

As in days past, interest in use of plants is today quite high (Lewington, 1990; Schultes & Reis, 1995; Balick & Cox, 1996 a, b; Minter, 1999; Milliken &

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Bridgewater, 2013). However, this knowledge is disappearing rapidly (Wyse Jackson, 2014), as our research has also shown. In the past, knowledge of plants was necessary for survival. In the countryside of Slovenia, it was impossible to buy flowers for a bouquet. People therefore gathered plants in meadows, forest edges, and in forests, and used them to decorate houses, chapels, and churches. Various plants were thus always present in the vicinity of human dwellings, and lived inside farm houses or on windowsills throughout winters. Of course, only plants that weren't sensitive to lower temperatures, as houses were not heated properly. It was the change of heating methods – central heating, which had started becoming widespread in countryside houses during the 1970s – that represented the change for plants on windowsills. Many plants disappeared from badly heated rooms and remained only in the warmer region of Slovenia along the coast. In that region, there is no great need for heating, and many of these plants survive outside during normal winters.

Methods

We collected material on the use of plants for various purposes for many years. We used the interview method for data collection, interviewing older people during various traditional gatherings. In the past, in the 1970s and 1980s, many tasks were performed with traditional farming tools. In this way, some of us could see these tasks in real life. However, other customs were disappearing and were preserved only in stories of the elderly. Not so long ago, in 2011, tools for sweeping the furnace were still in use in one village. Even though we noticed this by coincidence, we oftentimes notice a truly traditional use of plants while conducting fieldwork for the research of plant biodiversity in Slovenia. Ethnobotanical traditions were also collected by attending traditional gatherings, were various tasks are carried out in traditional ways. This has become extremely popular in Slovenia during the last decade. Various local books, wherein older authors reminisce on certain tasks and customs, also include many notes on the use of plants. Even today, certain plants are still being used in traditional ways. In addition to the aforementioned methods of data collection, we also collected data with reviews of old literature in individual regions of Slovenia. We reviewed ethnological collections in individual museums and read literary works by certain authors that described plants. Lately, there have been numerous notes in local chronicles that present the history of individual towns. During the 1970s and 1980s, there were quite a lot of studies conducted with primary school pupils from various schools in Slovenia. These studies were later used for further detailed collection of data in the field.

Results

Below, we present a few plant species that were traditionally used in Slovenia in the past. Ground pine (*Lycopodium clavatum* L.) is classified in the family *Lycopodiaceae* and is, in the wider sense, a fern. The plant can be over one metre long. From a prostrate stem, branches grow upwards and, at the end of summer, may develop spore spikes, which grow on intermediate stems with less leaves than light green-yellow spikes. Leaves are narrow and gentle, spirally arranged, and tapered to a fine hair-like point. The plant grows in forests with abundant sunlight, but will start to disappear quickly if tree canopy

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becomes too dense. We therefore most often find it on forest edges, and even more frequently on meadows or on once-mowed grass meadows. The plant prefers acidic soil, and can often be found near common heather (*Calluna vulgaris* Salisb.). The plant is very flexible and can be simply pulled out of the ground with a single pull. It is sparsely rooted, as it most often covers weak grass turf or dead leaves. Because of these very characteristics and its evergreen nature, we can still find it during late autumn and winter, as long as there is no snow. This may have contributed to its use. In autumn, when people were raking leaves for bedding, the plant kept getting stuck on the rakes. The use of plants was just a step away. In the western part of Slovenia, primarily in hilly regions, houses were equipped with tiled farmhouse stoves that were used for baking bread, drying fruit, walnuts, and, of course, resting on top of them during winter evenings. To prepare the stoves for baking, they had to be heated first and then swept. This was done with a simple broom that was locally known as *uadla* or *pometovnca*. They fastened the ground pine into a wrought-iron hook attached to a wooden handle. Gathered in a bunch, it was a very good broom with no immediate fire risk.

If there was no ground pine, they used other plants (various species of fern, among them also eagle fern – *Pteridium aquilinum* (L.) Kuhn). Eagle fern was mowed during autumn on meadows or in forests, and used as protection against snow for hayracks for storing hay. During spring, it was then used for bedding. In one region of Slovenia (White Carniola), some forests were called *steljniki* (literally, bedding forest), as the ferns mowed each year in these forests were used for bedding.

Common hazel (*Corylus avellana* L.) grew everywhere as a bush where mowing was not done regularly. In Slovenia, the common hazel and the people were in constant contact. Every few years, the common hazel – which grew as a bush on forest margins – was cut down to make bundles of firewood. They were tied together with a branch from a common hazel or traveller's joy (*Clematis vitalba* L.), and used as firewood, for distilling brandy, cooking in livestock cauldrons, and for drying fruit in special drying rooms. Bushes of common hazel were occasionally left in meadows for shadow or for making a simple sled, which they loaded with hay and then pulled downhill to the hayracks. During autumn, the common hazel yielded hazelnuts, which were used for preparing potica, a special type of nut roll. As common hazel branches were oftentimes bent in an arch, they were used for many things, i.e. handles. Oftentimes, they bent the branches themselves, so they grew in the desired shape. The common hazel was thus oftentimes used for hooks on ropes with which they tied the hay. The common hazel might have been an apparent nuisance for a farmer, but was also extremely useful, and man and common hazel got along quite well with one another. During autumn, squirrels made a kind of "baskets" from hazelnuts, as they quite often gnawed on nuts only from one side. These baskets – sometimes they even had handles – were quite a fun toy for children. When a basket harness tore off, a straight two or three-year-old hazel branch was the perfect thing to make a new one. If it tore while walking, a replacement part could be found immediately in the nearby bush, and the walk home could continue. A hazel branch had to be suitably hydrated, so it could be nicely bent when you stepped on it with a shoe and started slowly winding it around its axis. It cracked a bit along the length, but only enough so it could be split apart somewhat to complete the weave of the thinner end. If there was enough time, people gathered straight two to four-your-old hazel branches with as little side branches as possible. These were placed in a warm spot in a barn, and after a few days, when the wood became hydrated, wrapped into new baskets. The common hazel

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didn't just serve as fuel for a fire, but was used for weaving as well. They cut straight and erect common hazel branches, splitting them by pulling them between two knives stuck in a hazel trestle. This way, they made four wide and equally thick strips. Young, straight, or even slightly arched shoots were peeled white, placed into the holes in the basket bottom, and weaving with *vitre* – as these strips were called in certain places – could begin. If the weaver was skilful, the basket was weaved so thick that not even one grain of wheat could fall out. In some places, these baskets were called *zahmašni koši* (literal translation: "baskets for the Mass"), as they were really only used when they want shopping in larger villages. Other baskets were for more everyday use, e.g. for hay and leaves. The latter were especially large and wide. They were also used for carrying manure. Farmers also used the common hazel to weave so-called *berače*, baskets with handles for picking up potatoes and other crops, for carrying lunch, etc. In some places, they used the common hazel to weave baskets for waggons and other uses. A late-winter bouquet on a farmhouse table always included hazel branches with male hazel catkins.

European cornel or dogwood (*Cornus mas* L.), as one of the harder woods in Slovenia, was always used for rake teeth. Forked boughs were used for rope hooks to tie hay stacks or loaded waggons. In Police, on the edge of Šentviška Gora Plateau, common dogwood (*C. sanguinea* L.) was used for *bergle*, which they filled with hay and then carried from higher or lower areas home to the plateau. .

In the past, traveller's joy (*Clematis vitalba* L.) was useful for tying things together. They made harnesses for baskets from branches of thumb thickness. In hilly regions in the spring, with this kind of baskets they carried the soil from the lower end of the field to the top end. Traveller's joy could handle all that with ease. It was also used to tie together a thatched roof. Like the roof itself, which could last over thirty years in sunny locations, traveller's joy held the planks that were holding the straw in place all this time. Many simple fences were also tied with it. Side planks were tied to handles on waggons with traveller's joy. As a weaving material, it was used for baskets and many other things. Much of this has been lost, as access to other tying materials has become easier and primarily cheaper. The value of traveller's joy, a nature-friendly material that could ultimately be used as an extremely flammable fuel, has been forgotten.

Common ivy (*Hedera helix* L.) is categorised in the ivy family (*Araliaceae*). It is a woody, clinging, climbing plant. It climbs on any surface – walls, trees – and can reach up to 30 metres in height and 20 centimetres and more in width by older plants. Or it can simply cling to and cover the ground. It grows slowly and has a very long life, so it can reach a few hundred years. The epidermis of the later woody stem is ashy grey. Because it was evergreen, ivy was one of the most traditionally used plants. It was used to make wreaths for church decorations. These wreaths were very diverse. The leaves could be rolled and attached to a string two or three at a time. Between such tufts, they attached parts of wheat straws. Another options was to attach one leaf at a time, thus making long wreaths that could be hung inside the church. On Palm Sunday, ivy branches with fruits were used in many parts of Slovenia to make bundles. These bundles were large and were used by boys to show off. Ivy was used for other ritual purposes. In some places, they used ivy branches or leaves for Shrovetide. The traditional *Cerkljanska laufarija* (literally, the running in Cerkno) includes, among the 25 costumes, an ivy costume as the character of spring. Its entire attire, including the hat, is covered with ivy leaves, which are arranged as fish scales, causing the water to flow over

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them. Each year, they used about 10.000 of the nicest and largest leaves for such a costume. Nice ivy offshoots must be collected each year anew. The leaves are then plucked off the offshoots and sown to the costume from the bottom up. Not a single patch of clothing can be visible under the ivy leaves. The leaves must also nicely fit on all folds and ends of the costume, so the whole costume looks perfect. This work is, of course, very precise, and the ivy costume was therefore always made by someone skilful, most of the time a woman. Each year, the ivy costume shows how much effort was invested by the festival organisers in the making of the costumes. The character holds in his hand an ivy branch with fruit. With a smiling mask from lime wood, green clothing, always friendly gestures, and a beautiful companion, the daisy, he invites spring back to the country. Including this costume, three characters are made from plants: the main character *Pust* (literally translation, Shrovetide) is made from moss and carries a spruce, and his brother is made entirely from spruce branches and bast made of corn. In Karst, a plucked ivy branch placed on a crossroad symbolised the number eight, eight days, when every winemaker could sell wine at home without paying taxes. The branch led you to the farmhouse where the wine and local delicacies were sold. During Saint George's Day (24 April), the retinue of the Green Saint George wears costumes of birch twigs or ivy leaves and walks from house to house. The Green Saint George represents the reawakened nature and new life.

In Karst, on the Sunday before the St John's Eve (24 June), they make wreaths from plants for ritual purposes. The tradition has been revived. Most often, these are small wreaths from goldmoss stonecrop (*Sedum acre*), which can remain fresh for very long in a wreath. The wreaths are then hung above house entrances, where they can protect the house throughout the year. Other Karst species are also used for weaving, e.g. smoke bush (*Cotinus coggygria*, Scop.), rock knapweed (*Centaurea rupestris* L.), St John's wort (*Hypericum perforatum* L.), feather grass (*Stipa pennata*), and others. A very versatile plant species growing on Karst and Slovenian Istria was the naturally occurring butcher's broom (*Ruscus aculeatus* L.) (Bavcon, 1992). During the 1970s, it was still used to make funeral wreaths. It has phylloclades, stems transformed into leaves, which, in addition to its woody characteristics, provide it with increased firmness. Wreaths on graves therefore lasted a very long time. It was also used for sweeping chimneys. They made a tuft of offshoots, which was then pulled through the chimney. Offshoots were used to make brooms, which were very good for sweeping courtyards in Karst. In this region, water was scarce, so it was often transported with donkeys in special, open bushels. They prevented spillage from these bushels by placing cut butcher's broom offshoots on the surface. They could thus transport as much water as possible. When moving, only small ripples formed, which did not cause enough splashing for water to spill out. Nowadays, butcher's broom is mostly used for bouquets during the winter, as female plants have very nice, shiny red berries, which remain on the plant for a very long time.

Of course, the most famous use of plants is for medicinal purposes. In Slovenia, one of such plants is the downy elecampane (*Inula hirta* L.). Primarily in the Dinarides, it was known over 150 years ago in the folk tradition as *Astra montana*, the plant that cures everything. People gathered inflorescences, soaked them in alcohol, and used them for tea (Fleischmann 1848). In addition to medicinal plants, farmhouse tables were always, and especially in spring, decorated by bouquets of natural species. The first were usually hellebores, which flowered during the winter. They were followed by common snowdrops (*Galanthus nivalis*) and spring snowflakes (*Leucojum vernum*), hazel branches, larch branches with female inflorescences, lungwort (*Pulmonarila*

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officinalis), forget-me-not (*Myosotis arvensis*), and lilies of the valley (*Convallaria majalis*). Lilies of the valley were an especially nice home decoration. Plucked lilies of the valley were arranged in a ray pattern on a deep plate, covered with a gravel-stone, and then watered. Through the night, the lilies of the valley rose up, and the bouquets looked like a tuft of lilies among the grasses. A farmhouse table was therefore never without a flower bouquet on Sundays until late spring. Bouquets were also used to decorate chapels, markers, and churches. Later one, these natural species were joined by those growing on the home garden.

Discussion

Even though knowledge of plants is disappearing rapidly, Slovenia, as a very traditional society, recently still held on to quite a bit. During the 1970s and 1980s, this knowledge was still abundant. At that time, interest in such knowledge was slightly renewed, and for this reason quite a lot of it has persevered. Some of it was passed on with oral tradition, and even more is written in local books, which were written relatively late (Prezelj, 1997; Komac, 2003; Čemažar, 2009; Rihter *et al.*, 2014). A lot of them were written predominantly in the last 15 years. Almost every somewhat larger town has its own local chronicle. These, of course, vary in quality, but quite often they hold some interesting facts on the use of plants, which represents an additional impetus for research in that area. A lot of this has re-emerged due to a renewed interest in preserving old traditions (Kuret, 1989), which are oftentimes related to plants and their use. In the past, many traditions have begun to disappear, while others persevered unchanged until today (Kuret, 1989, http://www.stanjel.eu/dogajanje/etnologija/; www.rutars.net/kazalo/index2.htm). Various museums and societies strive to reawaken in these towns some aspects of the past. Photographs depicting traditions have been preserved, a lot is written in old works, and even more in newer ones. But the newer the work, the higher the chance that it includes mistakes, as oral tradition was passed on indirectly. Even though much of the knowledge on use of plants in the past (Cilenšek, 1892) has been forgotten, as some authors conclude (Ramirez, 2007; Turner & Turner, 2008; Wyse Jackson, 2014), much of it has been preserved until today in Slovenia (Kuret, 1989). Reason for this lies in the fact that Slovenia was a very traditional and quite a rural society. Even though many of the old traditions were abandoned or were unwanted after the Second World War due to the social system changes (Kuret, 1989), a lot of such knowledge was preserved in the oral tradition or writing. With new trends and awareness of the cultural heritage, old traditional knowledge, and with it ethnobotany, is beginning to be revived. Old traditions have once again become modern, and various societies in different parts of Slovenia have started bringing back former traditions. These are mostly related to seasons, and almost all related to plants. Today, one of the main problems is a lack of knowledge of plants. Various authors came to this conclusion (Akeroyd, 1997; Balick, 2007; Vandebroek & Balick, 2012), and Slovenia is no exception. Even more so: sometimes, there is even less of this general knowledge. Nowadays, there is no more difference between the countryside and a city, since the traditional method of managing the land has more or less ended (Bavcon, 2013). Modern agriculture is conceptualised completely differently, causing the knowledge on primarily natural species to slowly disappear. The school system also doesn't offer such education; knowledge of plants is therefore vanishing. This is something we wish to rectify in the Botanic Garden with various activities (Bavcon, 2010; Bavcon *et al.*, 2015).

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People in Slovenia used plants for various purposes. Use of some was widespread, whereas others were only used in a small area (Bavcon, 2004, 2013). Plants were used for consumption (Mlakar, 2006, 2007a), as medicine, as well as for making various tools and equipment (Komac, 2003; Dular, 2007; Mlakar, 2007b; Čemažar, 2009). Use of some plants is described only in oral tradition (Bavcon, 2004, 2013). Therefore, such use had to be tested with experiments. This helped us determine the actual use of specific plants. In the Botanic Garden, we're attempting to conduct tests of various uses of plants on the basis of collected materials, stories, and traditions, and on this basis determine if such use was possible in the described manner. The test with the butcher's broom, forget-me-nots, and the ground pine showed that the use of plants is even simpler than it seems. During various workshops that we organise in the Botanic Garden for the general public, we pass on this use of plants to younger generations. We have thus presented the tradition of weaving with plants, making whistles, small ships for the *Gregorjevo* (literal translation: George's day), dolls and slippers from bast, and much more (Bavcon *et al.*, 2015).

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SOLVING THE QUEST OF AN AMPHORA NEAR 2.000 YEARS OLD DEAD SEA SCROLLS, FOUND IN QUMRAN

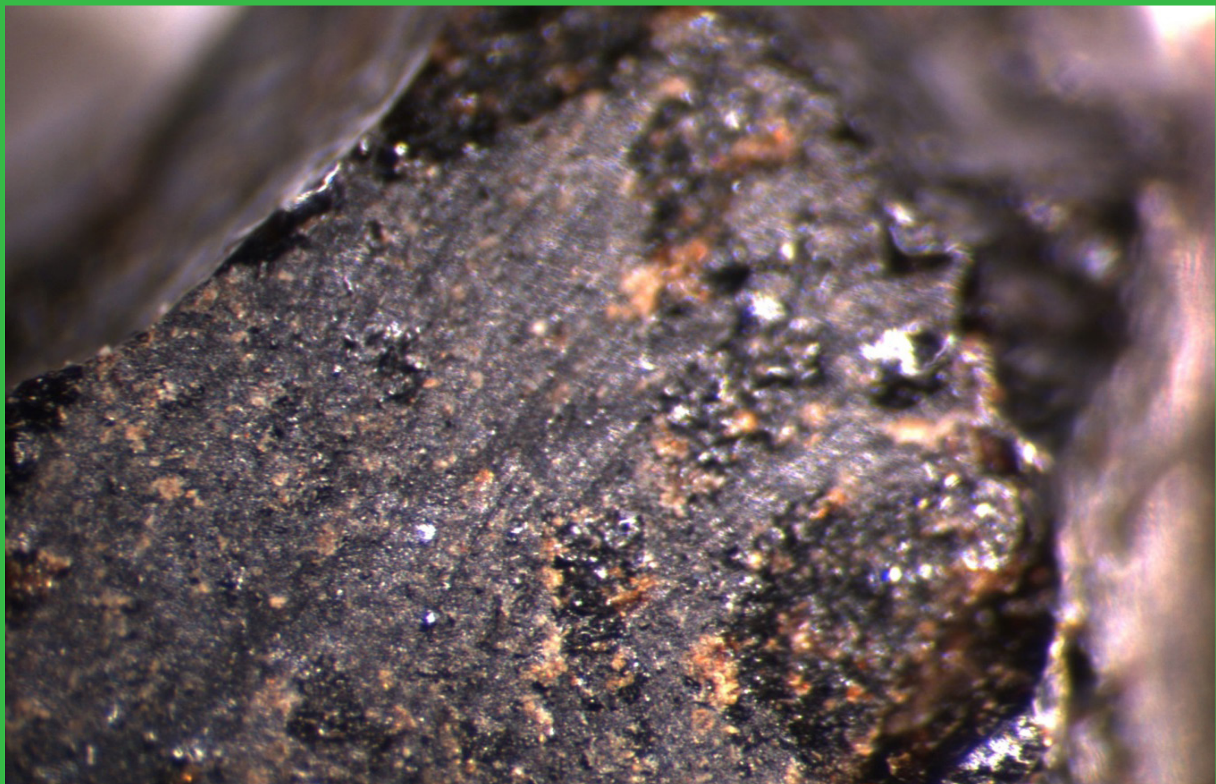

Photo credit : Remnant piece of the inner edge of the jar or amphora, *Bob Ursem & Wolfgang F. Gard*

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02. Introduction

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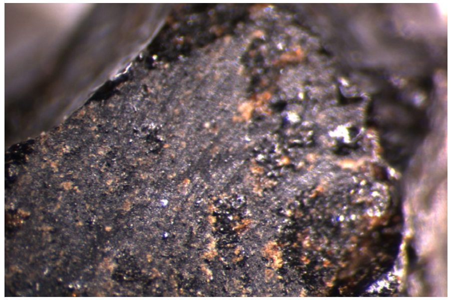

Photo credit : Remnant piece of the inner edge of the jar or amphora, ***Bob Ursem & Wolfgang F. Gard***

THE ESSENES SETTLED CIRCA 150 YEARS BEFORE CHRIST AT QUMRAN AND REMAINED THERE UNTIL THE ROMANS DESTROYED THE CITY IN 68 AFTER CHRIST. THE PEOPLE WERE KNOWN FOR THEIR HIGH INTELLIGENCE AND SKILLS IN MANUFACTURING GOODS AND CLOTHING.

They wrote on papyrus paper and copper plates and possessed a huge scroll library. In addition they had the knowledge of farming, cattle breeding and keeping goats and sheep (Magnes, 2003). Inhabitants of Qumran cultivated several crops and date palms near the spring at Ein Fehkha at the southern edge of the settlement (Magnes, 2003).

Furthermore they are known to wear white clothes, which was quite exceptional in those days and the whole area. White clothing means a knowledge of fibre cleaning with a deep penetration with strong cleaning materials. Normal clothes are brown coloured, because only surface areas could be cleaned and thus the inner fibre textures remain untouched and appear as brown fabrics.

The current knowledge of the people of Qumran could only be traced now by scroll readings and excavation of artefacts. The Romans destroyed in 68 the whole khirbet or city and most of all the treasured library, except for a significant number of over 900 documents and a small amount of amphorae discovered in 11 caves (between 1947-1956: 5 by Beduin; 6 by archaeologists). Amphora number two at Qumran cave is a special one. This amphora has been made without a bottom part, and it contains a remnant piece at its inner edge of 4 X 5 millimetre. This remnant piece was studied without destruction at the Hebrew University, University of Jordan and many others. Dr. Jan Gunneweg, nuclear chemist and material scientist of the Archaeometry Task-Force Unit of the Hebrew University, send it on instigation to Delft University for further investigation. So far nobody has a clue what it was and why the amphora had been made on purpose without a bottom part. The quest remain unsolved for nearly 2000 years.

Methods

Old 2000 year old material of the inner edge of an amphora or jar number two was first analysed by hand lens, then in a sequence of non-destructive methods, ESEM analysis, chemical component optical analysis, Infra-Red mi-

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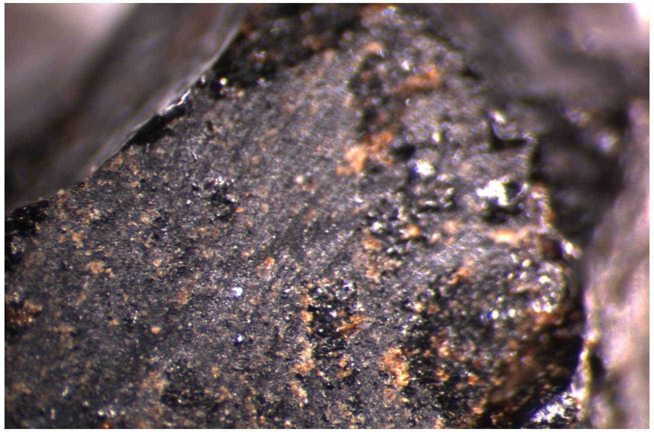
croscopy analysis. After literature studies fresh date palm seeds were burned in an enclosed heating process till potash. The potash remain material was analysed by ESEM, chemical component optical analysis and Infra-Red microscopy analysis and matched with data gathered from the 2000 year old material.

The content of the remnant piece in amphora number two

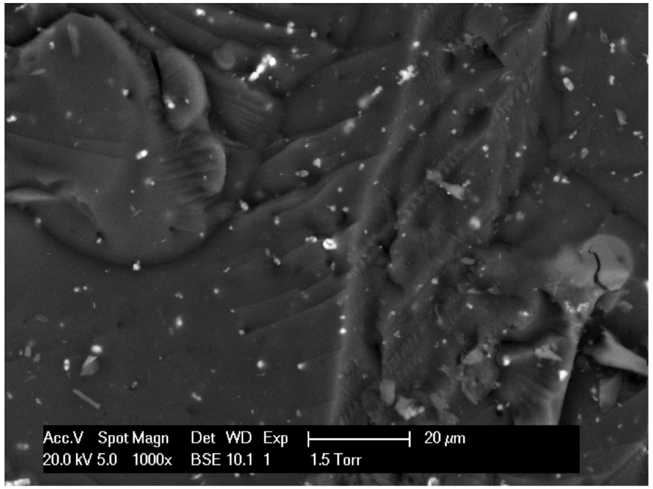
The primary question was: What is the content of amphora or jar number two? First, an hand lens analysis proof a structural pattern of diverse materials. An uniform core area and a partly rough outer area with a linear fine surface pattern as depicted in **Figure 1**. The overall colour dark grey up to almost black with small remnants of brown oxygenated iron.



> FIGURE 1.

Photo of remnant piece of the inner edge of the jar or amphora (photo by authors)

A deeper and non-destructive analysis with an ESEM to get a structural insight as given in Figure 2. The remnant material showed clearly collapse plant cell wall fragments as can be observed at the green indicated arrow points in this figure. Collapsed plant cell structures show a distinct thick cell wall and that differs very much from animal cell membrane structures, and when collapsed a double cell wall could be seen as a distinct white line of two cell walls. Next to Collapsing cell structures, also cell wall fragments can be seen in **Figure 2**. It is obvious that this material has been heated while processing.



> FIGURE 2.

ESEM photo showing collapsed cell structures in a sample of the remnant piece of the inner edge of the jar or amphora (photo by authors)

The quest continued with a possible list of plant species from the area that could resist high temperatures and still show such a distinct collapsed structure, like woody shrubs, trees, seeds or carpels. The Essenes were known for

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their agriculture of crops, like barley, date palm wood or fruit, olive wood or seed, wild peach seed, and also for their gathering of native plant species like Sodom apple seed, acacia wood, common caper bush, tamarisk wood, rose of Jericho and many others. A needle in a hay stack puzzle at a first glance.

Back to literature of Dead Sea scroll translations and publications. The most important information was given in the translation of the Great Isaiah scroll, discovered at two kilometres distance of khirbet Qumran by Bedouins together with the French archaeologist Henri de Contenson in March 1952 (**Figure 3**). They found two lumps of what is now known as the famous Copper Scroll. This highly oxidized scroll was broken into two separate rolled up sections. In its original state it measured 0.3 m in width, 2.4 m in length, and was about 1 mm thick. No one knew quite how to open it up without damaging the text. One lunatic suggestion was to try to reduce the copper oxides with hydrogen, or even electrolysis, to recover the copper! After considerable preparatory research for three years by John Allegro of Oxford University, and in 1955 the first piece of scroll was finally 'opened' by Professor H. Wright Baker at *Manchester College of Science and Technology* (now UMIST), followed by the second piece in 1956. In 1991 the world was astonished to hear that one of the unpublished scrolls included incredible references to a "Messiah" who suffered crucifixion for the sins of men. The scroll was translated by Dr. Robert Eisenman, Professor of Middle East Religions of California State University. He declared, "The text is of the most far-reaching significance because it shows that whatever group was responsible for these writings was operating in the same general scriptural and Messianic framework of early Christianity." Because of this translation we also know something about the daily habits of the Essenes, like frequent bath taking, wearing white clothes, and evidence of a tannery or date press. In 1993 carbonized dates were found by the Israeli archaeologist Yitzak Magan that apparently could be associated with a date press at the southern edge of the settlement Qumran. This suggests that the inhabitants of Qumran cultivated date palms by the spring at Ein Fehkha. It is likely they cultivated other crops as well, and they undoubtedly raised herds of sheep, goats, and cattle, as could be traced by animal bone deposits in the same area. So this limits the quest to the focus on date palms.

> FIGURE 3.

The Great Isaiah scroll (photo Alexander Schick)

Date palm seeds and wood have been collected at the vicinity of the khirbet Qumran and also on other areas around the Dead Sea, Qumran, in the south near En Gedi, Massada and furthermore two locations in Jordan (**Figure 4**).

> FIGURE 4.

Dead Sea area depicting Qumran and with red star markings seed collection sites of date palm by Ursem

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Fresh date palm seeds were burned in an enclosed manner in order to create potash. The potash material was sampled and analysed by gas chromatography and mass spectroscopy, with a focus on traces of potassium and sodium. With this focus on potassium and sodium, we could make the connection to soap manufacturing. Sodium with animal fat will form a solid block of soap, while potassium combined with animal fat will turn out in a liquid soap. Because of evidence in literature on the Dead Sea scroll 'Great Isaiah' describes the significance of Essenes wearing white clothes. Soap as a block could not deep penetrate the fibres as liquid soap and thus stay more brown or brown in colour. Liquid soap purifies the fibre structure as a whole and thus results in a white performance.

The Dead Sea has been used since ancient time for harvesting minerals. The first scientist to analyse the seawater content of the Dead Sea was the famous French chemist Antoine Laurent de Lavoisier in 1776. Lavoisier already noted a high content of magnesium-chloride, calcium-chloride, sodium-chloride and magnesium-bromide, but overlooked the presence of potassium. In 1817 the French famous chemist Joseph Louis Gay Lussac also analysed the seawater of the Dead Sea and tried to find the presence of small microorganisms, but no 'microscopic animals' were found. Arie Nissenbaum discussed the results of all published paper on the Dead Sea seawater so far known to the chemical analysis and clearly show how the industrial chemical potential could be used for industrial production of commodities and products like soap manufacturing (Nissenbaum, 1979). The unique seawater content makes the Dead Sea to the world's saltiest natural lake of the world. The average salinity is 280 grams per kilo water and compared to the average salinity in oceans is about 35 grams per kilo water. In addition, especially in the northern part of the lake, it has a high content of potassium and bromine, so nowadays known for potash making en bromine open air mining (Nissenbaum, 1993). The Dead Sea has no outlets to balance between precipitation, runoff, and evaporation, except in northern part where the Jordan River and the Arnon River supply large amounts of fresh water in conjunction with the presence of water springs in the vicinity of Qumran and due to the annual runoff and floods in the rainy winter season. In addition, the water intake various considerably, which result in the late 1950s in an annual discharge of 1.200 X 10^6 cubic metre and an intake of 1.600 X 10^6 cubic metre, and a decline of the water level and higher rate of salinity. The annual renewed water of the Dead Sea is a little more than one percent of its total, because of agricultural water use of the Jordan River in mainly Israel and Jordan. The water is rich in chloride and an unusually high content of magnesium and bromine, and an unusually low sulphate and carbonate content. The seawater of the Dead Sea has an extreme high content of calcium (15,75 %). Still no trace of potassium could be noted in literature and be explained. The German, Israeli scholar in Law, Linguistics, Physics and Geology Yaakov Bentor (1961), was the first scientist that unravel the geological history of the Dead Sea. At the end of the Mesozoic times tectonic disturbances frequently occured and fault formation resulted in the sinking part of the Jordan-Arava rift, followed by a lacustrine deposition, leaving deposited sediments behind as a result of natural drainage, evaporation or other geophysical processes. Although there is evidence found of an open sea connection in the Pliocene age based on traces of marine micro fauna in the upper tertiary Sodom formation of Mount Sodom. Later, the Jordan River filled the inland depression with fresh water that eventually turned salty and known as the Lisan Lake. After several hundred thousand years the Lisan Lake started to shrink til its present level as Dead Sea in the late Pleistocene. According to Bentor the Lisan Lake only contributed in a very small part to the total salts content in

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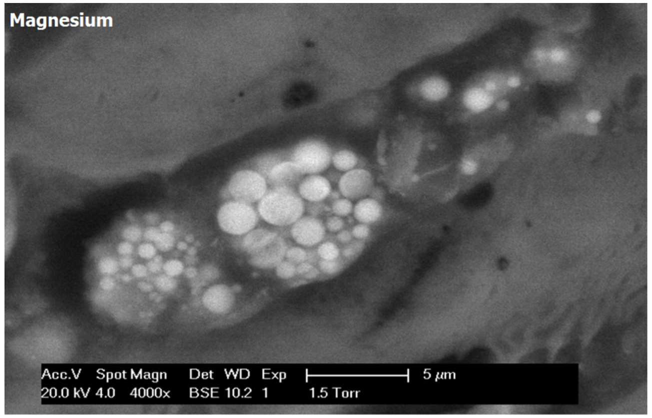
present-day Dead Sea. The presence of the bromine enrichment may lead to the existence of organic life forms, similar to oil waters that carry considerable amounts of bromine and iodine elsewhere in the world. Life forms were never found until the Israeli microbiologist Benjamin Elazari Volcani or Benjamin Wilkansky showed that bacterial organisms could grow in water taken from the sea at depth up to seven metres as phytoflagellates. He also discovered the presence of halo-obligatory bacteria next to green algae *Dunaliella* species in the Dead Sea (Wilkansky, 1936). *Dunaliella* algae solved the problem of differences in osmotic pressure by developing a special metabolic pathway of producing large amounts of intracellular glycerol, that could feed the *Halobacterium*. The *Halobacterium* incorporates potassium up to a high intercellular concentration (up to 4.8 m) and extraordinary specificity for potassium ions (K^+) over sodium ions (Na^+). The biota microorganisms exert a critical influence on some biogeochemical processes that occur in the Dead Sea and as a result it explains the extreme high levels of potassium near Qumran. This has most likely never changed since the late Pleistocene and give evidence that date palm growth near the shore in Ein Fehkha were planted in potassium rich soil and water environment. Date palms, like many other plant species, do have a tendency to store secondary metabolites in their seeds. This explains also the high content of potassium in the fresh seeds. Conditions as we encounter today didn't differ very much in compare to the Essenes existence. Potash making, like today, was clearly a special skill of the Essenes and could only exist on potassium rich environment that happen to be optimal at Qumran and its vicinity.

It is remarkable that the area of Qumran has this high content, which differs very much from other location around the Dead Sea. It is known in Dead Sea scroll analysis that most people at that time weared brown clothes, except in khirbet Qumran and its vicinity.

In addition, analysis was made with ESEM on optical observation of chemicals. The 2000 year old material shows evident traces of magnesium, which gives substantive information that this material is definitely of plant origin. Magnesium is the metal component of chlorophyll (**Figure 5**).



> **FIGURE 5.**

Magnesium in 2000 year old material of the inner edge of the jar (photo by authors)

Furthermore, the analysis of the 2000 year old material shows also other components that contribute to match chemically this material to the present produced potash of fresh date palm seeds, like carbon, calcium and trace elements such as aluminium and bromine. ESEM analysis in samples of the 2000 years old material and the sample material taken from fresh seed potash show a clear match of other aggregates like carbon, calcium and aluminium and bromine as can be seen in **Figures 6** and **7**.

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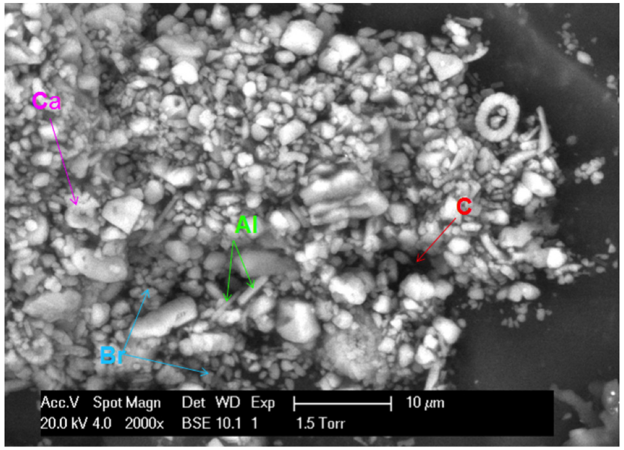
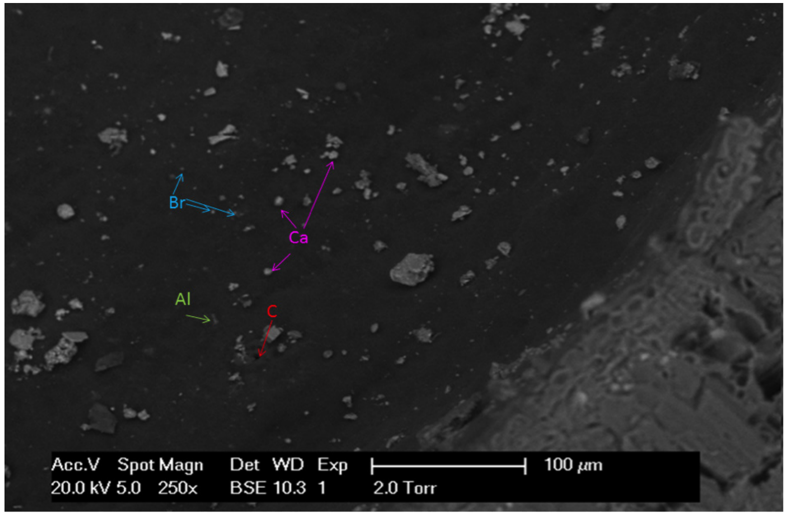


> FIGURE 6.

Carbon, Calcium, Aluminium and bromine in 2000 year old material of the inner edge of the jar. Carbon is the black area indicated in red with C, Calcium given in pink as Ca, Aluminium given in green as Al and Bromine indicated in blue as Br. (photo by authors)

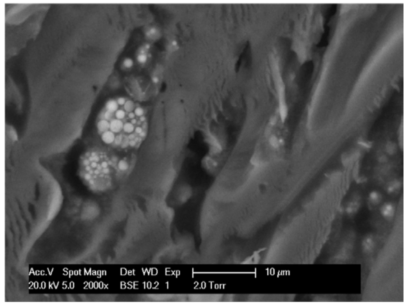


> FIGURE 7

Carbon, Calcium, Aluminium and bromine in potash material of fresh date palm seeds. Carbon is the black area indicated in red with C, Calcium given in pink as Ca, Aluminium given in green as Al and Bromine indicated in blue as Br. (photo by authors)

This evidence, especially the trace elements Aluminium and Bromine, indicates that the palm trees in the area of Qumran do still give the same chemical composition in present time as it could be traced in the period of the Essenes before the destruction in 68 after Christ. Conditions of date palm growth didn't change so much in almost 2000 years as a remarkable finding.

The investigation on traces of magnesium in the potash of fresh date palm seeds has been carried out and evidently shows a similar distribution as the old potash remnant of the inner edge of the jar. ESEM analysis show the same clustering and proof of magnesium traces in this new made potash as shown in **Figure 8**.



> FIGURE 8.

Magnesium traces as seen in typical clusters in potash made of fresh date palm seeds (photo by authors)

In addition, the potash material of fresh date palm seeds do shows collapsed cell structures and proofs that the potash making could have taken place in the same manner as we did and presumed (see **Figure 9**). It could be made, like in many other places in the world, in an enclosed burning stove, but that is of course still a speculation. The principle process of potash making could not be very different, according to the similarity of the chemical analysis so far.

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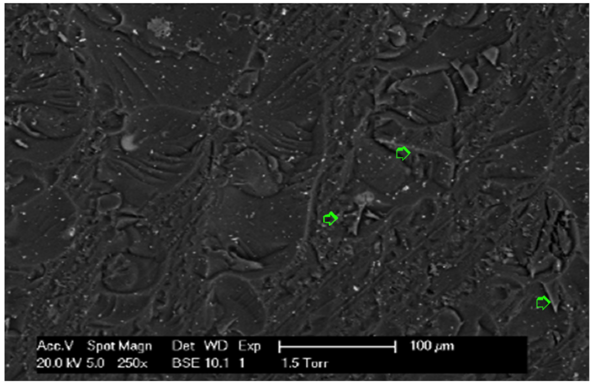
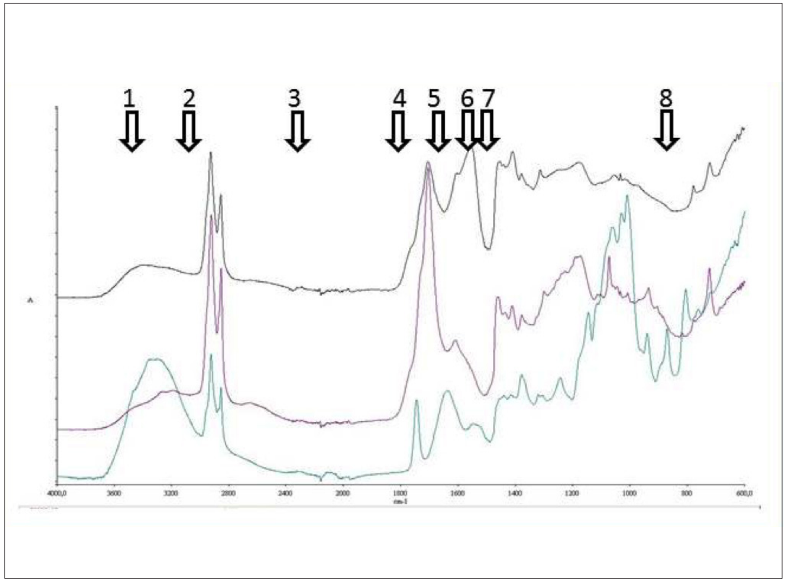


> FIGURE 9.

ESEM photo showing collapsed cell structures of a sample taken from potash of fresh date palm seeds. Green arrows indicate collapsed cell structures (photo by authors)

So far we know that the Essenes used date palm seeds for food production and, in addition, also known is the use potash in an unique Essenes method of leather production. Chemical analysis of the sediment in the tannery basin at Ain Feshka at Qumran area revealed no traces of tannin, which was usually indispensable for the production of leather, but instead, calcium carbonate was found as evidence of potash use for a better quality of leather and as a proof of a completely different kind of manufacturing from that was in use elsewhere (Stegeman, 1993). In our sample is also no sodium been traced. The connection of the use of date palm seeds and potash production is so far never been seen as a correlation.

An Infra-Red microscopy analysis followed on the 2000 year old material of the inner edge of the jar and the potash samples of fresh date palm seeds to possibly match it with the results of the chemical analysis. The potash of fresh seeds were taken from two different origins. The first sample was taken from potash of the outer seed skins only and the second samples were taken from exclusive inner core material of the fresh date palm seeds. The result shows a distinct match of peaks, to give equal evidence as the chemical ESEM analysis (see **Graph 1**). The blue curve is the old remnant material of the inner edge of the jar number two and the purple curve is of the exclusive inner core material, while the black curve represents the potash sample of the outer skin material of fresh date palm seeds. A little hump, distinct peaks of two thousand year old material and new materials show a very well distinct correlation given in Graph 1 at eight given arrows. However, the graph of potash taken from old and inner edge origin shows two extra distinct peaks that didn't correlate, but can be an influence of decay over time or external aging effects.



> GRAPH 1.

I-R analysis of 2000 year old potash taken from the inner edge of jar two (blue curve), and combined with potash taken from fresh date palm seed skins (black curve) and samples taken from potash made of the inner core material of fresh date palm seeds (purple curve). Every arrow above indicates similar peak locations in all given graphs (left to right: hump 1), peaks (2), turbulence (3), peak (4), area near peak (5), peak (6), peak (7) and inclination area (8)

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02. The quest of amphora number two: what is it?

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The amphora number two was conscious made without a bottom part, and also without a lid. Reference was not given in the transcription of the Great Isaiah scroll. The Dead Sea Scrolls were buried in Qumran at 68 AD most possibly by the Essenes themselves. The Essenes are also known to take at least one or more daily baths before community dinners and of wearing white clothing. Soap making was essential at that time and it must be an important part or role of their social and spiritual culture. Other communities covered themselves in more brown coloured fibres. The expectation was that the Essenes were the very first in their world of soft soap making, instead of hard soap blocks based on sodium for only cleaning surface areas.

> FIGURE 10.

Amphora number two of Qumran with a present traditional flat basket weaving filter of date palm leaves as possible filter bedding. Photo amphora: The SchØyen Collection MS 1655/1; photo traditional basket weaving: B. Ursem

The amphora number two of Qumran must been enclosed underneath and filled with potash and operates as a filter system as shown in **Figure 10**. If water washes through, the effluent will be a potassium hydroxide solvent and the residue will be potassium poor, but could be in the top of the amphora, and especially hidden underneath the inner edge still enriched with potassium as remainder. Potassium hydroxide solvent can easily be condensed by sun radiation to a syrupy but still a viscose liquid pasta. This pasta product can be mixed with goat fat or sheep fat and through an esterification process into soft soap.

Soft soap making was very unusual in the early century and before the date counting according to the Christian calendar. The function of the jar had to be an early manufacturing filter for soft soap industries of the Essenes. The feature of soft soap is a deep penetration into the fibre structure and because of that a better cleaning effect on clothes. The result is the famous bright white clothes as can be seen in any image of the Essenes, even in all depicting of Jesus Christ. It is well accepted to believe that Jesus at his time must have been educated by the Essenes. The Essenes did have an exceptional practical and spiritual knowledge and wrote down over 900 scrolls, thus can be seen as one of or the largest library in the whole region. Archaeological evidence indicates the settlement of Essenes in the khirbet Qumran since about 150 B.C.E. At the late time period of the Essenes, it has been noted that the Essenes were inter related with a Jewish sect, an intensely messianic, apocalyptic, baptist, wilderness, new covenant group, led by a priest they called the "Teacher of Righteousness" who was opposed and possibly killed by the establishment priesthood in Jerusalem or most possible the people that could be associated to the followers in the circumference of the figure of Jesus. It is also noted that at time of the outbreak of the Jewish-Roman

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War (66 C.E.) the scrolls were already hidden in caves near the khirbet. The library represents over 900 documents in 350 separate works in multiple copies. Cave four alone contained the most, 520 texts in a total number of over 15.000 papyrus fragments. Copper scrolls, like the Isaiah scroll, was an non-canonical book, known as Enoch, and the holy writings, rules of faith, commentaries on scriptures and other fascinating writings were found in cave three. In addition, Cave 3 contains a list of 64 hiding places where gold, silver, sacred objects and other more valuable scrolls were hidden. The amphora was one of the item among these treasures. The bulk of the scrolls were in Jordanian control and were placed with a team of mostly Catholic and non-Jewish scholars who published till now eight volumes of material and still it needs decades to unravel all Essenes writings. Overall it contains many important parallels to the Jesus movement, or could collide with the life of Jesus at that time. Time will tell. Next to the Qumran discovered scrolls are also scrolls found at Masada in the south, the Herodian fortress taken over by Jewish Zealots after the fall of Jerusalem in 70 C.E. and finally taken by the Romans in 73 C.E. Remarkable to note is the discovery of an ostracon or inscribed pottery shred that contains only 16 line letters and obviously has been written before 68 C.E. that concerns a property transfer of an individual to the community of Qumran. So date palm and crop 'orchards' were present and lively transferred in ownership as well at the Essenes period. The knowledge of leather making via potash by Essenes and the clear match in several distinct similar results of old and new materials in the Infra-Red-analysis, and the fact that the old material was left over inside the amphora, indicates a high skilled and knowledgeable society. It also proofs that the Essenes used these special prepared amphora's for an unique manufacturing of potash for leather preparations and for cleaning their original brown tainted fabrics. Essenes are exclusively known for trading the best white fashion, as well as the best documented library at that time in the area.

So this indicates that the Essenes can be seen as the very first soft soap manufacturing industries in the world, a remarkable thought after answering the quest of amphora number two and its content.

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PLANTS AND ITS ELECTRICAL PHENOMENA AND RESPONSES

Photo credit : *Populus X canadensis* with electric transpiration damages due to high Voltage charges as seen below in the silvery discoloration of the leaf tip and above of the carbonized petioles, *Ursem Bob*

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> Keywords PLANT ELECTRICITY NATURAL PHENOMENON UTILIZATION

02. Abstract

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PLANTS DO REACT TO ELECTRICAL CHARGES AS A NATURAL PHENOMENON, LIKE AN EXTREME INCREASE OF TRANSPIRATION STARTING ALREADY AT FOUR HOUR BEFORE A THUNDERSTORM GENERALLY APPEARS.

As a possible result it shows a silvery discoloration of leaves, especially at the tip, or a physical-chemical reaction in the vascular phloem and converts the sugar content into caramel or a typical transformation of the wood into an orange colour. Furthermore i.e. in high altitude studies it shows readings of a potential field strength of E = 5000 Vm^{-1} measured at the top of Alpine plants and thus shaping it into a cushion growth pattern while the same species shows a more widespread carpeting genetic growth pattern at low altitudes in the Netherlands. Until recent research at the Botanic Garden of Delft University of Technology, growth responses to electrical field charges were so far hardly studied and understood in plants. Next to different observations in nature and measured experiments in the Botanic Garden in addition and due to this study also a total new insight on electrical plant responses and applications in studies of transpiration and contribution to humidity, cloud formation and precipitation patterns could be understood in another viewpoint and provide a novel insight on current available scientific knowledge. This possibly remarkable research leads to transpiration calculations of trees and shrubs and provides a contribution to a more complete insight of the hydrological cycle.

In addition, electrical responses of plants can be applied in technologies like data logged plant transpiration measurements and satellite programmes, ultrafine dust removal for indoor and outdoor air purification, electrical milking of secondary plant metabolites for food and pharmaceutical properties, new pesticide crop control systems and many more.

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• *Ursem Bob*

Photo credit : *Populus X canadensis* with electric transpiration damages due to high Voltage charges as seen below in the silvery discoloration of the leaf tip and above of the carbonized petioles, *Ursem Bob*

ELECTRICITY AND PLANTS IS A TOPIC THAT NEED TO BE FIRST EXPLAINED IN NATURE'S PHENOMENON AS A WHOLE. THE PRINCIPLE OF NATURAL ELECTRICAL CHARGING STARTS WITH SOLAR RADIATION ON EARTH AND EARTH'S ATMOSPHERE.

The sun radiates the earth, and in electrical terms bombards the globe with negatively charged electrons, positively charged protons and neutrally charged neutrons. The protons are relatively large and can be thus intercepted at the outer atmosphere layers of the electrosphere, charging positively at approximately at a height of 50 kilometres. In addition protons activate the effect of photoionization in the ionosphere belt and results in a splitting of several chemical air-borne components.

Photo-ionization, where photons act on atoms, ions and molecules became activated and results in the ejection of electrons which join other electrons travelling on the solar wind to earth. The electrons are extremely small and faster in speed than protons, impacting on earth, particularly on the poles due to the effect of the earth's magnetic field.

A sun-flame outburst during a sunspot causes an intensive corona discharge with currents that reach an amperage of 20 million coulomb per second at 50.000 volts and, in addition, in an enormous ionizing of oxygen and nitrogen by electrons above the electrophori altitude and in the upper stratosphere. This results in an aurora borealis in the Northern Hemisphere and an aurora australis in the Southern Hemisphere at an approximate height in the atmosphere of between 30 and 200 km.

This natural electrical phenomenon correlates with the sunspot activity in an 11 year cycle of the sun. At a sunspot, solar winds move at a speed of 1.5 million kilometres per hour and electrons reach the earth's atmosphere about 40 hours after the corona discharge at the sun, and follow the lines of magnetic force generated by the earth's core.

First the electrons ionize atoms of nitrogen, from an altitude of 200 kms downwards. This shows as green and blue colourations in the following image taken from personal observation in Kakslauttanen (Lapland, Finland) on March 1st, 2013. Secondly, the electrons ionize atoms of oxygen (at an approximate altitude of 30-100 kms) showing a yellow or a red colouration (above a height of about 60 kms and at lower altitudes) as a blue aurora moving con-

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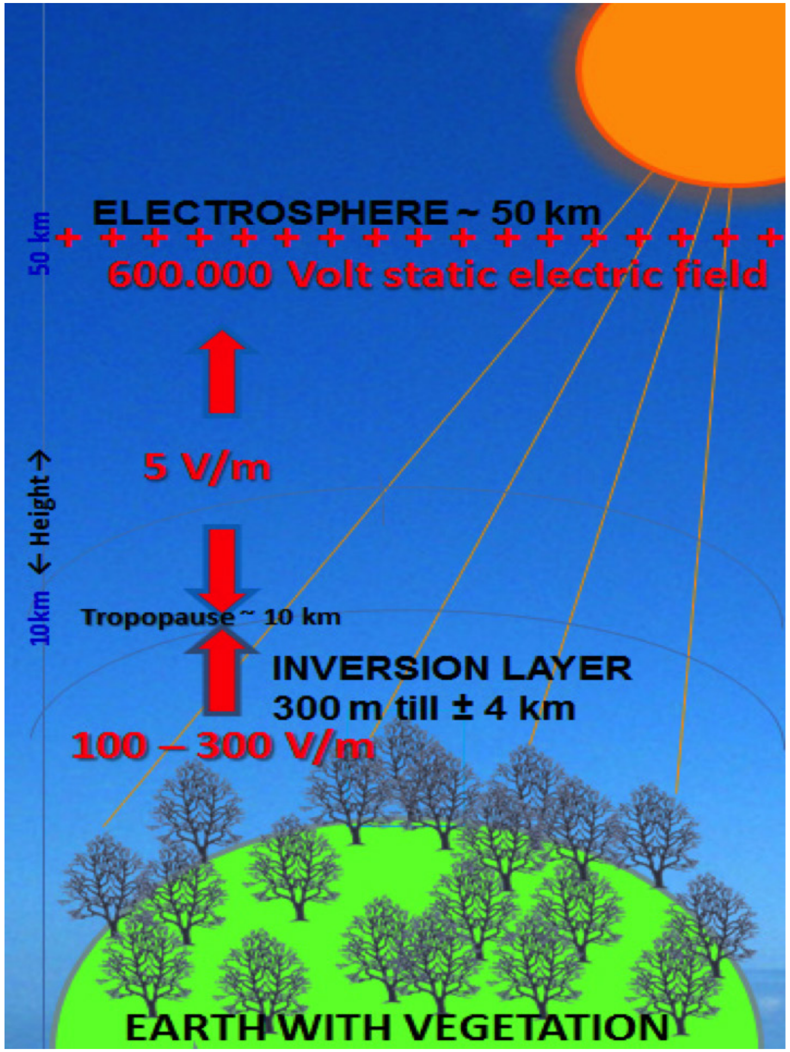
stantly, shifting combinations of clouds in a dance as captured in the frozen moment of **Image 1** (Brekke, 1994).

> IMAGE 1.

Aurora borealis at Kakslauttanen, Lapland (Finland) showing ionizing oxygen (Photo: author)

Normally electrons pass unhindered through the electrosphere and impact on the earth, charging the earth's surface negatively. All biological life, connected to the earth or plants rooted in the soil are therefore, in principle, negatively charged, while the atmosphere is, by definition, positively charged due to proton impaction at the electrosphere altitude. The result is an electric field between earth and all its connected biological life and the atmosphere.

Near the earth's surface the field strength is approximately E=100Vm-1 up to E=300Vm-1, depending on air humidity and temperature (Brillouin, 1897; Le Cadet, 1898).



> IMAGE 2

Electric field pattern in the atmosphere (Source: author)

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It changes at the inversion or boundary layer, where thermals of warm and less dense air rise into cold air as a result of convection and condensation, thus producing a reversed temperature profile with a stable mass of dense cold air positioned below a lighter warm air.

At lower levels of the inversion layer, there remains the normal pattern of air warmed by solar radiation on the surface of the earth, below a steadier cold air caused by the adiabatic processes of increasing height. Above the boundary layer, however, temperature rises due to extremely low humidity and the insignificance of the impact of solar radiation.

This results in a weaker electric field strength of V=5Vm-1 with a static electric field charge of 600.000 volts at the 50 km electrosphere in the stratosphere as seen in **Image 2**. The increase of electric field charges is according to the measurements of Burke field data, measured with a balloon (Burke, 1975).

At troposphere level, between the tropopause and the earth's surface, electric field strength can vary between approximately E=100Vm-1 to E=300Vm-1, but could increase significantly in thunderstorm conditions which in a flash, could exceed up to 660 million volts per second as also measured in data of Burke's field studies (Burke, 1975). In the vicinity of a thunderstorm, even 4 hours before lightning starts, the electric field strength can increase to a value of over 1.000 volts per metre. The impact on plant life is huge.

In nature the static electric field increases the electrical transpiration of plants. This is evident in strong local earth electric field areas during a thunderstorm discharge. A spectacular example of this can be seen in Broceliande Forest in the Brittany region, France where old, large beech trees grow downwards as depicted in **Image 3**. Plants are generally shaped according in reference to the existing natural electric field, despite their genetic growth pattern and the way of growing in tree stands of just a single species or as in a forest resource of several different species, they do grow all rooted in the ground and normally erect in upward directions, which is very much in contrast to the trees as observed in Broceliande Forest.

This phenomenon of extreme twisted bendy growth of trees can be also observed in high mountain altitudes where all herbal plants and also very small shrubs grow in a fully electrical spherical cushion shape, while the lowland equivalent species grow undisrupted by electrical field charges in a flowerbed arrangement.

> IMAGE 3

Broceliande Forest
(Source: author)

Normally, plant transpiration depends on temperature and humidity, strongly influenced by solar radiation. If we consider the impact of electricity,

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we may observe the increased responses of plants and the effects on growth patterns (**Image 3**) and heat or joule responses in the vascular system (**Image 4**).

Plant responses on electric field charges in nature

All plants, except epiphytes, grow normally, rooted in the soil and are thus negatively charged. They transpire water in balance with their root uptake. Transpiration will become unbalanced if the temperature or exposure to direct solar radiation induces a greater water loss due to transpiration, but also when nearby lightning causes an increase in the electric field, as can be observed from photographs (**Image 4**) of a silver or a warty birch tree (*Betula pendula*) in the Botanic Gardens of Delft University in the summer of 2005.

Here we can clearly see an orange discolouration as a result of caramelization of all sugars in the phloem underneath the bark. The recent scientific botanical discovery of conversion of sugar into caramel can only possibly be explained by friction in the vascular phloem system, causing extreme transpiration due to the proximity of a thunderstorm creating a massively strong electric field. Caramel can be easily detected by its characteristic smell and its chemical reaction in solution with hydrochloric acid as black flocculation (Schweizer, 1937).

Similar data in sapwood are obtained as a measuring tool for data-logging the transpiration of trees. This can be done with 2 steel pins that cover the whole sapwood in a radial direction at a pre-determined distance. Both steel pins are connected and charged with a high voltage. When both pins are equally charged, it results in a difference in temperature. These readings can be correlated with the ions and transportation of sugar inside the vascular phloem of a living tree.

Another method of measurement is that of stem compression, causing friction in the vascular phloem system, which provides an equally accurate transpiration reading. A whole tree trunk embracement would result in the total transpiration figure for the whole tree canopy. Thus we can measure tree transpiration in a 24 hour data log system, or even extrapolate these transpiration figures for individual tree stands and even whole forests.

Rainfall interception experiments using stem compression are novel approaches for understanding the contribution of transpiration to the hydrological cycle in tree stands and forests (Friesen, 2008; Friesen *et al.*, 2008).

> IMAGE 4

Betula pendula with caramel in phloem (Photos: author)

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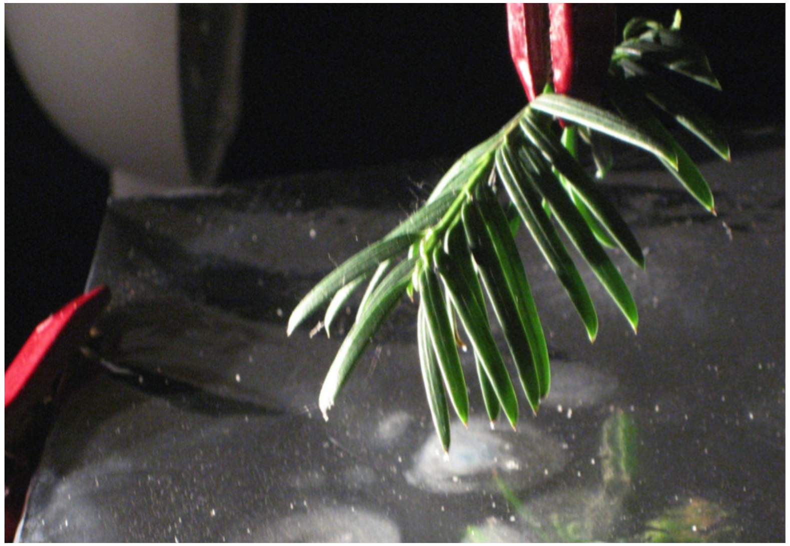
Another natural electric response to a thunderstorm in close proximity is observed in leaves of the hybrid black poplar (*Populus* X *canadensis*) in the Botanic Garden of Delft University of Technology. It shows a very clear silvery discolouration of the leaf tip due to extreme transpiration. Carbonisation of the narrowed part of the petioles has also been observed as in **Image 5**.

> IMAGE 5.

Populus X canadensis with electric transpiration damages due to high Voltage charges as seen below in the silvery discoloration of the leaf tip and above of the carbonized petioles (Photo: author)

The electrical response as a natural phenomenon has also been tested in the yew tree (*Taxus baccata* CV *dovastoniana*) branches in laboratory conditions with a controlled mimicked set-up of a high voltage and micro amperage electric field charging environment as shown in **Image 6**.

The branch was exposed to alternating voltages of V1=8KVs and V2=11KVs with a correlated current of I1=0.002mA and I2=0.017mA. The result is a circular pattern of deposition of Baccatine III, 10-Deacyctylbaccatine III or



> IMAGE 6

Taxus baccata CV *dovastoniana* in laboratory experiment exposed to a 10 kVolt and 40 micro-Ampere pulse charged aluminium sheet and deposition of secondary metabolites (taxanes, taxoteres, and paclitaxel) and brown discoloration of the needle tips (Photo: Caner Yurteri)

Docetaxel, Cephalomannine and Paclitaxel as given in graph 1 of the yield in Autumn 2006, Spring 2007 and Summer 2007, taken from the branches of a specimen (Botanic Garden of Delft University of Technology). Paclitaxel, and other taxanes (baccatine III, 10-deacettylbaccatine III or docetaxel, cephalomannine) will be esterifiable converted into the anti-cancer treatment medicine.

As well as these distinct extracted secondary metabolites as shown in **graph 1**, we also observed a brown discolouration of the needle tips. This brown colour is the result of a high flow extraction in a powerful field charge. This burning of the tips can also be seen in some needles in **Image 6** as a result of electro-spraying.

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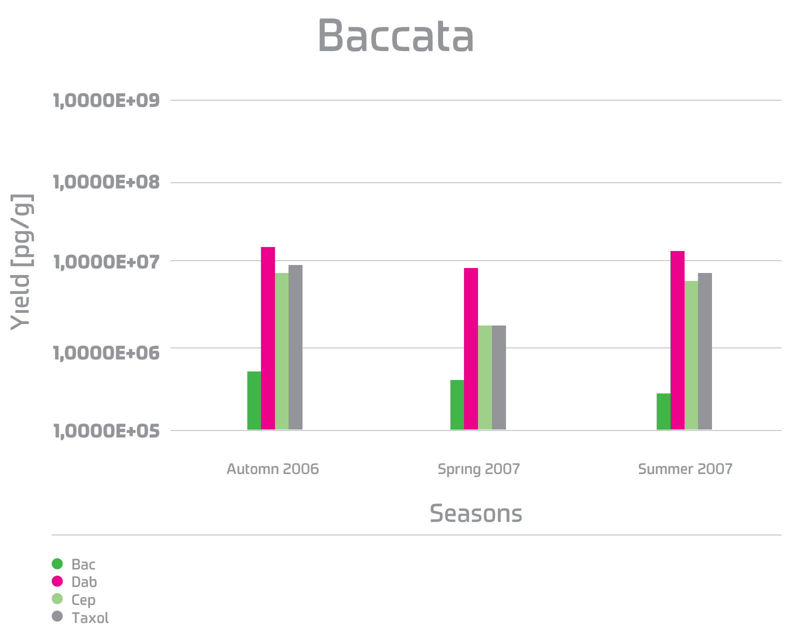
Streamlining of field lines concentrates the most at needle tips as shown in Image 7 of the empiric field line results. Due to this field line density, the electro-transpiration is highest at the tip. Transpiration droplets at the needle tip are forced into a Taylor cone mode when electro-spraying is active. At higher voltage exposure total brown and even black discolouration due to burning of a needle has been recorded. If the needles are not damaged by burning, they can recuperate and be re-harvested after a few months. This applied technique doesn't harvest any sugar, only distinct secondary metabolites.



> GRAPH 1.

Yield of Baccatine III, 10-Deactylbaccatin III, Cephalomannine and Paclitaxel (=Taxol) as a result of electrospraying from branches of *Taxus baccata* CV *dovastoniana* in autumn 2006, spring 2007 and summer 2007 in picogram secondary metabolite to dry weight in gram (Source: Sylvia Widjaja, 2009)

In addition to experimental observation of needle burning, other electro-spraying extractions have been conducted showing tissue variation due to high voltage exposure (Vance *et al.*, 1994; Wheeler *et al.*, 1992). The secondary metabolite extraction of taxoteres via electrospraying was a discovery made at Delft, by Jan Marijnissen and Rein Roos, which focused only on the extraction or 'electric milking' itself and not on the associated natural phenomena as described in the article (Marijnissen *et al.*, 2001).

These phenomena in high voltage exposure, observed in the Botanic Garden in Delft, can be seen elsewhere in nature. An example of this, is a scent of terpenes from pine trees, as a transpiration reaction of high electric air charges which occurs, in the author's observation, about 4 hours before actual lightning occurs. Another personally observed phenomenon, is the inversion of lime tree leaves, in the same time period and conditions. The reversal of lime leaves is consistent with the closing of the stomata to reduce transpiration, and manifests itself in the silver lime (*Tilia tomentosa*) in particular, which has leaves with a whitish waxy layer, silvery pubescent leaves underneath and a green top surface. Turning over of leaves closes the stomata almost automatically, because there is more exposure to wind, radiation and immediate reduction of humidity in the leaf surface. Stomata are normally found under the leaf, and it is a fact that humidity happens at a slightly higher rate than in a more exposed leaf surface without stomata. These observations on the silver leaf lime tree phenomenon have not been published in any scientific papers to date other than by the author.

The strength of electric field also shapes plant growth, as clearly indicated in **Image 3**. In normal conditions, plant follow their genetic pattern. However, they can often be disturbed and shaped by a combination of predominant

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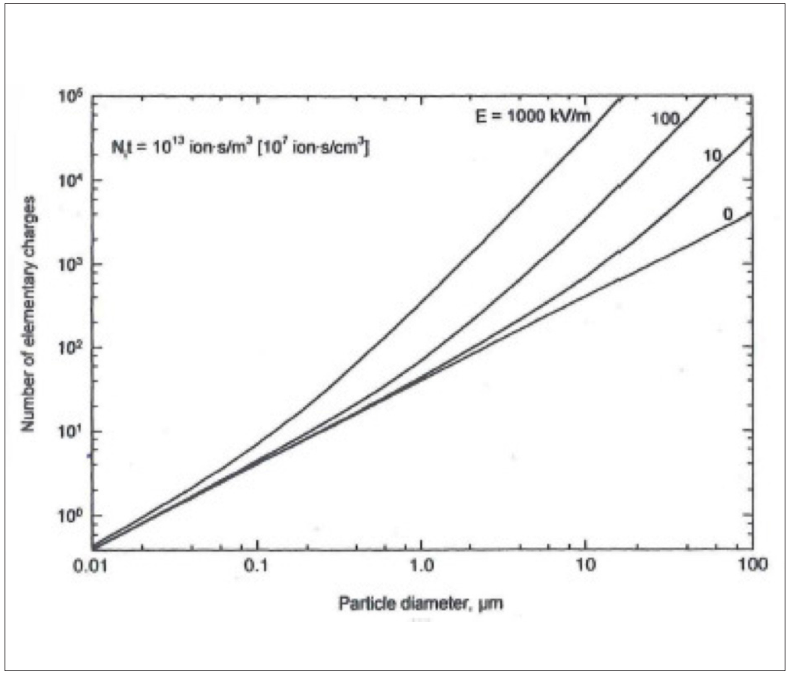
meteorological and electric winds and increased electrical field charge exposure due to high altitude or solitary growth e.g. trees in an open field. The combined effects of these winds in coastal areas can be seen in the bending of trees depending on the predominant wind direction or fixed in a bent position as a result of electric transpiration. If the sugar in the vascular phloem can convert into caramel, it can also fixate a tree into a fully bent position. Naval builders in particular have, historically, used this bent wood in ship manufacturing using steam to ensure that the wood holds its curved shape. It is interesting that in nature, the combined forces of meteorological and electric winds also cause extreme transpiration and bending.

Electric wind has its origins in earth or in biological matter which starts out as negatively charged airborne particles carried on meteorological wind or by convection becoming fully negatively charged due to friction in the air. Both effects result in a total negatively charged flow of particulate matter in the air which also drifts in full coherence on the meteorological wind. In this situation, the wind velocity accelerates to gale force and locally, extreme gusts of wind. This can be seen during forest fires, where inflammable particles, ejected by fire and heat are released. Polyphenols, in particular, found in eucalyptus trees increase wind speed, resulting in devastating conflagrations.

The same high altitude alpine plant species were studied in lowland areas at the Botanic Garden of Delft University. Plants in high altitudes are exposed to a huge increase in electrical field charge in comparison to those species growing in lowland areas. This results in a pincushion-shaped growth in high alpine areas, whereas in lowland areas, specimens of the same plant species grow in a multi directional scattering pattern. This phenomenon can be fully explained by an increase in field line density and electric charge thereafter.



> GRAPH 2

Field and diffusion charging with the number of charges acquired versus particle diameter for field strength of 0, 100, 100 and 10.000 V/cm at $N_i t = 10^{13}$ s/m³ [10^7 s/cm³] and $\varepsilon = 5.1\ C^2N^{-1}m^{-2}$ (Source: Hinds)

As can be seen in the Hinds' experiment graph, a discharge from a point results in a spherical pattern of field lines with a single fully charged 0.1 um particle diameter with 4 elementary charges or a charge (Q=6.4x10/19 Coulomb) in standard conditions, meaning field and diffusion charging according to **Graph 2**, and its stream line electric field of the empiric study in **image 7** (Hinds, 1999). The maximum charge on solid particles is reached when the self-generated field at the surface, due to the field strength in that given position, reaches the value requiring a spontaneous emission of electrons at the surface. When the number of electrons or elementary charges exceed

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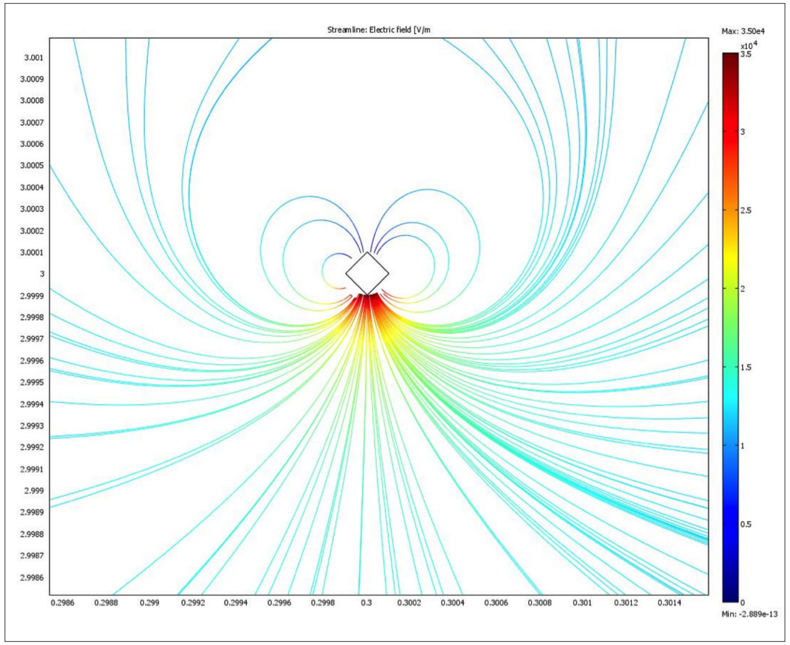
this equilibrium, it results in ejection of the crowded electrons at the surface. If, on the other hand, it fails to reach this equilibrium, electrons can still be added to the charging of a particulate.

On study of **Image 7**, it is an empiric fact that the indicated pattern of field lines from a spatial sphere and a field line density near a particle or any pointed object will increase in such a spatial sphere. Therefore, a plant that grows with just a single branch outside a spatial sphere pattern will face another set of its own spatial sphere pattern on the tip of this branch, as opposed to the first spatial sphere of lower positioned round shaped branches which have a strong density and another set of their own field lines at the protruding exposed branch tips.

Every single point, in this case the sharp end of a leaf tip or thorn will act like a solitary electrical discharge point. This results in higher electric transpiration than with lower branches and provides an extra stress effect. It is preferable, therefore, that plants grow according to the natural electric field pattern, become a round-shaped growth and don't follow a genetic growth pattern at the outer canopy under relatively high charged electric field conditions.

In high altitudes, which generally have a higher electric field than lowland areas, the result is a dominant growth of herbal plants in pincushion patterns. However, in lowland areas it is only clearly visible in the spherical dome-like growth of a free-standing tree group. Measurements with a hand-held field strength meter at the top of a dwarf- growth pincushion plant (moss campion or cushion pink - *Silene acaulis*) show a reading of nearly E =5000V/n at an altitude of approximately 2200m in the Alps.



> IMAGE 7

A single fully charged 0.1 µm particle and its streamline electric field (Vm^{-1}) with a maximum value of $E = 3.50 \times 10^4$ V/m in red near the particle and decline in distance up to $E = 1.5 \times 10^4$ V/m in light blue (Source: author)

The natural electric field charge of a single fir tree has been measured in low mist conditions to ensure a natural isolation layer just above ground level. In these conditions measurements were taken with a hand- held field strength meter at the top of a Greek fir (*Abies cephalonica*) which has been growing since 1932. Measurements in the Botanic Garden showed a reading of nearly E=20.000V/m consisting of pure static electricity.

Mist is in fact only drifting micro-sized droplets in the atmosphere. In low or wind-free conditions, they can be charged in the same way as nearly all

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particulate matter and may have maximum negative charge. Because of this increase in negative charge, they may in time become larger droplets due to water adhesion and so easily convert to a dense fog. Fog and mist always take the form of low lying drifting droplets because both equal charges cancel each other out. Mist is lifted by its own electrical force and stabilizes at a few decimetres above water or earth, balanced by the downward force of gravity. This natural phenomenon is a very useful application because we can utilise fog lights positioned low on our vehicles to enhance vision in foggy or misty conditions.

The final example of plant response can be found in electric field charges in the wind dispersion of pollen and spores. Pollen is released at 17 degrees Celsius or higher as observed by the author in the Botanic Garden. Pollen releases as negative particulate in the air and drifts on the wind to the stamens of other flowers of the same species to pollinate them. Pollen drifts downwards during solar radiation but remains at the same level in al dry-weather conditions. Spores are released at the moment of maturity regardless of temperature.

That both natural dispersions show a negative charge due to friction in the air on particulates, is in fact a generic principle of nature. The uplifting electrical force on pollen or spores is in balance with the downward pull of gravity and so results in a very effective system to ensure optimal pollination or sporulation by the wind. The digressive effect on pollen and spores during drifts of solar radiation could be explained by photovoltaic effects. Solar radiation affects the pollen and spores with photons that diminish the negative charge. If the negative charge declines due to existing electrons absorbing the photon energy, gravity takes over and pollen are forced towards the ground.

When electrons absorb photon energy they become excited and jump to the conduction band or outer surface of the pollen or spore and become free (Becquerel, 1839). This results in a momentum in which pollen and spores are forced down by gravity. Near the stigma are the field lines closer together, similar to image 7, and thus become electrical attracted to stigma. Pulled on to the stigma, grounded added electrons discharge the pollen and convert it into a chemical bonding retained by the strongest physical Van Der Waals forces.

Applications of nature's plant electricity

Plant electricity can be directly utilized in the earlier mentioned secondary metabolite harvesting, and applied in space engineering programmes, crop protection methods, and in a peculiar plant correlated discovery and unique application of an air purification system as the ultra-fine dust removal system which will be discussed in a separate and more detailed part hereafter. Plant electricity applied in space engineering programmes has its origin in the electrical joule effect on the vascular system of trees and its plant transpiration by the author and the rainfall interception experiments of using stem compression as a novel approach in understanding the contribution of transpiration to the hydrological cycle in tree stands and forests by Jan Friesen (Friesen, 2008). Both combined approaches on plant electrical responses result in a novel programme of Mirjam Gerrits dissertation research (2010) at Mount Kilimanjaro and in addition the successor satellite readings on the older advanced high resolution raiometre satellite to measure tree

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transpiration on top of the earlier noted infrared global vegetation index. The PhD thesis research of Mirjam Gerrits shows a clear relation between the annual forest depletion at the foot of Mount Kilimanjaro and the retreat of the glacier on the summit. Her findings underlines the importance of a forest belt as also given by Fresen, that 50 percent of the precipitation recirculates in the hydrological cycle. Mount Kilimanjaro forests at its lowland belt captures circa 50 percent of its precipitation to recirculate into the hydrological cycle, while only 8 percent additional precipitation is contributed by atmospheric influx. The remaining precipitated water is circa 40 percent of the hydrological cycle, which has its origin in evaporation and adiabatic cooling during rising effects along the mountain slope. As side effect, these findings are very perpendicular to the general opinion that climate change could cause the glacier depletion of Mount Kilimanjaro.

Another and entirely different application of electricity and plants can be found in a similar technical way given in secondary metabolite harvesting of plants, but in a reversed setting. In the process of 'electric milking' droplets are charged and directed towards a high voltage charged plate, but in the process for crop protection the opposite can be utilized by charging micro-droplets with the use of a grounded connected plant as receptor. If pest control chemicals dissolve in water and get dispersed via a Taylor cone by a positive high voltage as air borne charged micro-droplets, these can only move to the grounded plants. First a charged micro-droplet will get fixed. The following charged droplet will settle next to the first fixed micro-droplet, because the area is more opposite (negative) charged than the covered adjacent droplet surface. As a result, a nanostructured film layer of solvent pesticides will cover and protect the whole plant. Traditional pest control is sprayed in clusters of insecticides and will cover never the entire plant. Furthermore this novel approach of nanostructured film pesticide technology only needs 200 times less pest control material in compare to the same plant coverage.

The discovery of the phenomenon of electric field charge that results in the ultra fine dust reduction principle

Knowledge and understanding of the phenomenon of field charges and the natural electric field, is the first step to the single observation of particulate matter, for example, salt and biological particles, solar radiation drifting from seashore to hinterland, tiny particles seen with the naked eye lifting above sea buckthorn (*Hippophae rhamnoides*) up to a higher level and continuing in the airflow. Relevant characteristics of seabuckthorn are its woody spines and narrow pointed leaf tips as pictured in **Image 8**.

> IMAGE 8

Hippophae rhamnoides with woody thorns and narrow pointed leaves (Photo: author)

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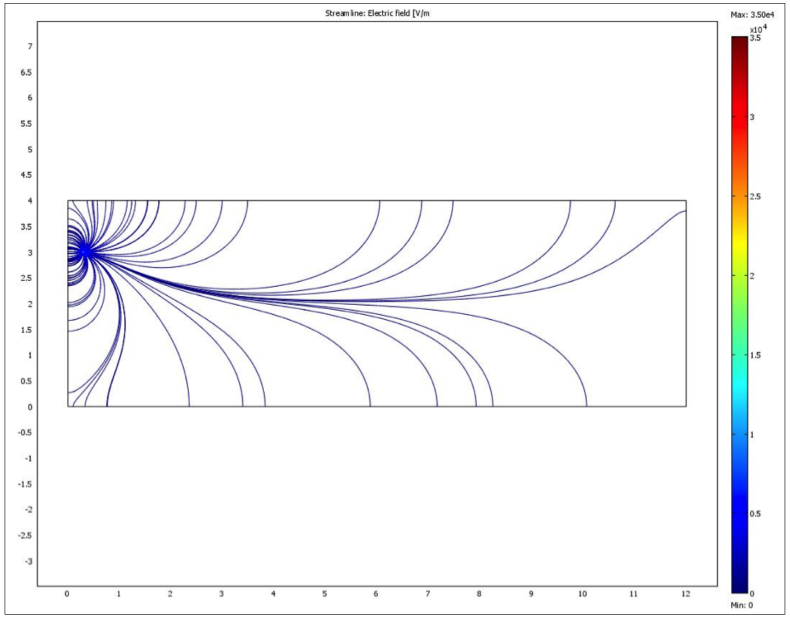
The lifting of these large particles above the spiny, narrow, pointed leaves would be an unusual phenomenon in nature without electrical friction charging. Particles are normally only pulled downwards by gravity, unless due to friction, they are equally charged by pollen drift. The clear lift of particles which remain at the same height above seabuckthorn bushes whilst still drifting on the meteorological wind can only be explained by the fact that negative charging of particulates cannot suddenly become higher, but their response is due to the very pointed structure of the seabuckthorn leaves.

As shown in **Image 7**, a number of pointed ends contribute to a larger field effect on equally charged particles and thus facilitate a lift to a higher level until there is once again a balance with gravity. If various negative points are arranged in close proximity, the electric field will be directed upwards with an increase in the total electric field as seen in **Image 9**.

This image represents an empiric streamline electric effect of a fully charged 0.1µm particle with 4 elementary charges or a charge (Q = 6.4x10-19 Coulomb) in standard conditions (Hinds, 1999) in an enclosed setting with an equally negative field charge on both sides. Thus, it can be seen as an overall lower intensity of electric field strength, but a more enlarged field in one direction when compared with a fully charged particulate of 0.1 um in a free-ranging environment as shown in **image 7**.

If a number of these fields, as shown in **Image 8**, are formed by a cluster of thorns or distinctly pointed leaf tips in close proximity to each other, the result is a larger impact of the electrical force and this acts as an unidirectional uplifting vector. This summative effect of parallel unidirectional vectors of each spiny point or sharp leaf tip, results also in a total lift of equally charged airborne particulates just above these shrubs. Because of this larger electric repellent force and the fact that it opposes the downward pull if gravity, eventually an airborne particle gains further uplift. The field strength diminishes in distance until a new equilibrium between the electrical force and gravity has been attained.



> IMAGE 9

A single fully charged 0.1 µm particle influenced at both sides with an equal charged field and its streamline electric field (Vm^{-1}) with a value of approximately E = 0.50×10^4 V/m in blue (Source: author)

As observation of nature explains, the concept of airborne particulate matter with positive high voltage charging and the capturing of particulates can only be optimally processed by the use of opposite electric poles. At the high voltage pole, a corona discharge ensures that charges of all airborne

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particulates are captured and affixed to the conductive receptor. The reason for a positive high voltage charge is that it works together with gravity, and positive charging of particulates also creates a healthy human environment, for instance mountainous areas (Elster & Geitel, 1900), with an additional incidental of extremely low ozone production (King, 1963; Mittler *et al.*, 1957).

A corona discharge with a positive high voltage and a micro-amperage or higher strength of current, turns nearly all various sized particles uniformly positive, except for particles of less than 10 nms in diameter. A 10 nm particle is fully charged with one elementary charge, whereas a smaller sized particle cannot keep this elementary charge because of its own Brownian movement. All particles larger than 10 nms in diameter will become positively charged due to electron expulsion, or jump off to the conduction board or outside the surface area of the particulate. As a result positive particles drift off in ionic, molecular or particle wind from the corona discharge, following the electric field lines towards to a grounded conductive receptor. The lacking of electrons of each particulate will be added from the earth as soon as it connects the grounded conductive receptor, and thus fixate this discharging air borne particle with a chemical covalent bonding.

These particles will add electrons via the grounded or negative charged receptor and become affixed with a covalent bonding fastened by Van der Waals forces, or as electrostatic molecular interactions with a total effect by a super adhesive force. Because of conductivity, other particles can be added to earlier depositions and eventually grow into fluffy structures, remaining strongly bonded together and preventing fixed particles from rising into the air.

The principle of the Ultra Fine Dust Reduction System (UFDRS) relies very much on principles which can be observed in nature. The only difference can be found in the addition of a very small current, in the magnitude of micro-amperage. Current is lacking in static electric fields in nature. This low current can be viewed as the loss of electrons by discharge on ejecting other excited particle electrons or, as impelled by the electronic jump to the conduction board or the outset surface of particulate matter of 10 nms or more that become free.

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CREATION OF A RAISED BOG IN THE BOTANICAL GARDEN OF NEUCHÂTEL: A TOOL FOR RESEARCH, COLLECTIONS AND PUBLIC INFORMATION

Photo credit : The raised bog of the Botanical Garden of Neuchâtel at the beginning of the growing season (march 2016), *Blaise Mulhauser*

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> Keywords PEATLAND'S PLANT COLLECTION
EX SITU CONSERVATION
CLIMATIC EFFECTS ON VEGETATION

02. Abstract

• Mulhauser Blaise
• Mulot Matthieu
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• Gueniat Sylvian
• Koenig Isabelle
• D'inverno Mirko
• Mitchell Edward A.D.

IN SEPTEMBER 2014 WE CREATED A SMALL RAISED BOG OF CA. 100M² IN THE BOTANICAL GARDEN OF NEUCHÂTEL. THE MATERIAL (MARL AND PEAT) WAS COLLECTED FROM A DEGRADED PEATLAND IN AN INDUSTRIAL AREA OF THE REGION. THE BOG WAS PLANTED WITH OVER 30 SPECIES OF MOSSES AND VASCULAR PLANTS COLLECTED FROM BOGS IN THE JURA MOUNTAINS AND FROM EXISTING COLLECTIONS.

This object corresponds to the three missions of the garden : 1) to inform the public as well as students about these unusual, fragile and threatened ecosystems, 2) to present characteristic peatland plants from the Jura Mountains (*Sphagnum, Drosera, Eriophorum, Betula nana,* etc.), and 3) to conduct research projects.

During the winter 2014-15, the snow remained longer on the peatbog that on the adjacent path and meadow, thus providing evidence for a microclimatic effect of the bog. The excessively dry and hot summer 2015 allowed testing the resistance of the newly established bog vegetation. Most plants resisted well, including graminoids *Eriophorum vaginatum, Trichophorum cespitosum* or *Carex* sp., *ericaceous* (*Vaccinium oxycoccos, myrtillus* and *vitis-idea*) and mosses (especially *Sphagnum*). This living laboratory provides a unique opportunity to inform the public about the characteristics and functions of these ecosystems and the challenges of conserving and restoring them in a warmer world.

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02. Introduction

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Photo credit : The raised bog of the Botanical Garden of Neuchâtel at the beginning of the growing season (march 2016), *Blaise Mulhauser*

PEATLANDS PLAY A MAJOR ROLE IN THE GLOBAL CARBON CYCLE AS THEY STORE CA. 1/3 (CA. 600 GIGATONS) OF ALL SOIL CARBON DESPITE THE FACT THAT THEY ONLY COVER 3% OF THE TOTAL LAND AREA (YU *ET AL.* 2011, MOORE 2002, LIMPENS *ET AL.* 2008).

Regionally they also control hydrology and climate (Mitsch & Gosselink 2000). However in many developed regions peatland have been almost totally destroyed through conversion to agricultural land or peat harvesting. Switzerland is a typical example with a loss of ca. 90% of its initial raised bog surfaces, mostly between the 19th and 20th centuries (Grünig 1994, Joosten & Clarke 2002). For example the 400 km^2 of lowland peatlands (fens) located in the « three lakes » region (between the lakes of Neuchâtel, Biel and Morat) have been converted to agricultural land (Grünig 1994). In 1987 a popular initiative aiming to protect the remaining peatlands of Switzerland - including the largest ones in the Jura Mountains - was accepted by the people.

The challenge today is to preserve the remaining peatlands and to restore damaged ones. Indeed a monitoring program has shown that even the protected bogs are on average suffering from degradation such as reduced moisture, increased nutrient load, encroachment by bushes (Graf *et al.* 2010, Klaus 2007). The main challenges for successful peatland recovery include restoring an appropriate hydrology, hydrochemistry, and microclimate, introducing diaspores of target species and avoiding unwanted invading species (e.g. *Betula, Molinia*) (Gorham & Rochefort 2003, Rochefort & Bastien 1998).

Climate change and especially extreme climatic event represent a threat to the maintenance of existing peatlands (Bragazza 2008, Pastor *et al.* 2003) as well as to their restoration (Samaritani *et al.* 2011, de Jong *et al.* 2010). Climate-induced lowering of the water table is recognised as a key factor in controlling vegetation changes (Breeuwer et al. 2009), CO_2 balance (Bubier *et al.* 2003, Strack *et al.* 2009) and peat decomposition (Freeman *et al.* 2001).

A further challenge for the conservation and restoration of peatlands is public perception. Peatlands are often considered as useless land and their drainage and conversion to agricultural land is referred to as "improvement". There is therefore a need to educate the general public about the roles of these ecosystems in global climate regulation, local hydrology and climate, as habitat for rare species and as precious archives of past environmental changes and history of human activities (Barber 1993, Warner & Asada 2006,

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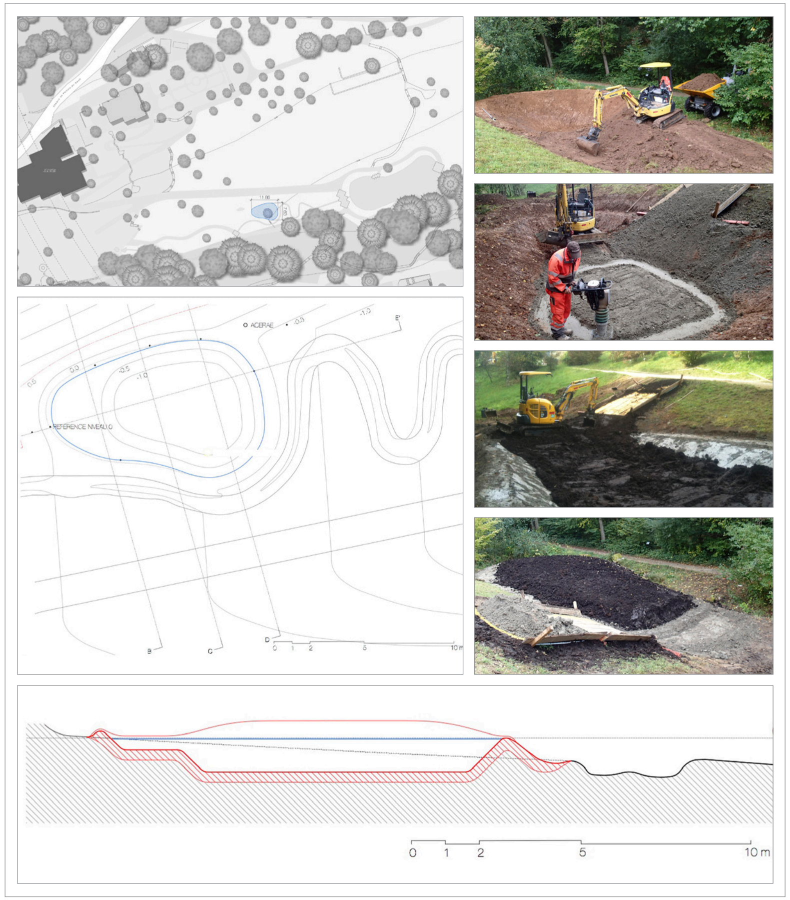
Buckland 1993). The construction in September 2014 of a small raised bog in the botanical garden of Neuchâtel, corresponds to the three missions of the garden: 1) to inform the public as well as students about these unusual, fragile and threatened ecosystems, 2) to present characteristic plants from the Jura Mountains (*Sphagnum, Drosera, Eriophorum, Betula nana*, etc.), and 3) to conduct research projects.

Materials & methods

At the beginning of September 2014 we created a small raised bog of ca. 100m^2 in the botanical garden of Neuchâtel. The map showing the location of the bog and the different stages of construction of the peatland are illustrated in **Figure 1**. First a large (ca. 100m^2) hole was dug. The hole had a maximum depth of 210cm, with one half being deeper and the other shallower gradually reaching the surface of the natural terrain. Then ca. 60m^3 of marl was delivered and brought to the site. This material was distributed homogenously over the surface to produce a 60cm thick impermeable layer over which the peat (also ca. 60m^3) was then deposited. The peat thickness reaches 160cm at the deepest part. The material (marl and peat) was collected from a degraded peatland in an industrial area of the region (town of Le Locle).

The bog is divided into two parts, with shallow (30-100cm) and deep (100-160cm) peat. A shallow pool was dug in the centre of each part. Around each pool the surface was divided in six slices half of which were planted (at low density) with over 30 species of mosses and vascular plants collected from bogs in the Jura Mountains and from existing collections (**Table 1**), and the other half left bare to study colonisation. The two treatments are referred to as "planted" and "non-planted". Plants from the surrounding meadow and forest provide ample sources of seeds, which germinate on the bog. In one half of the 12 surfaces (randomly selected) these plants are left to develop naturally while in the other six surfaces non-bog plants are removed. These two treatments are referred to as "weeded" and "non-weeded". There is thus four combination of these 2x2 treatments and three replicates of each.



> FIGURE 1.

Map of the botanical garden of Neuchâtel and construction of the peatland.

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The surface of the peatbog was marked with wooden sticks every meter along perpendicular lines, to delineate ca. 100 plots of 1m². The vegetation of each of these plots is monitored three times a year, in spring, mid-summer and autumn using semi-quantitative estimation of the percentage cover of each species (Londo scale) and with aerial photography done by a drone (**Fig. 2**). A picture is taken from each plot at the time of each vegetation survey. Following this the alien (i.e. "non bog") species are removed in the surfaces corresponding to this treatment. Alien shrubs and tree seedlings which have very successfully germinated on the bare peat (e.g. *Salix*) are also removed from all plots as their development would have excessively large impacts on the bog vegetation in relation to the size of the overall peatland.

> **FIGURE 2.**

Map of the peatland and pictures taken on 15.06.2015 and 15.09.2015 by a drone.

A dense network of sensors in being installed to monitor micro-environmental conditions (temperature, water table depth, moisture, etc., **Fig. 2**) and will also do regular measurements of other factors including hydrochemistry (pH, macro-nutrients, etc.) and functioning (soil respiration, decomposition, photosynthesis, methane emissions). One of our goals is to assess to what extent such a lowland bog exposed to hot and dry summers is capable to develop a typical bog vegetation and act as a carbon sink. This research ties in with several research projects conducted in Switzerland and other countries in Europe and beyond to which the University of Neuchâtel collaborates.

> **TABLE 1.**

List of plant species introduced on the peatland of the botanical garden of Neuchâtel

Sampling site - Name of the peatland	Bois-des-Lattes	Bois-des-Lattes	Le Cachot	Le Cachot	Le Cachot	
Place / Lieu-dit	Ancienne zone exploitée	Drain bouché	Gouille du centre	Fossé Pochon	Partie NO	
Sampling date / Date d'échantillage	07/10/14	07/10/14	07/10/14	07/10/14	01/04/12	
Coord N	46'58'21.94''N	46'58'22.02''N	47'0'19.52''N	47'0'16.71''N	47'0'21.63''N	
Coord E	6'42'20.35''E	6'42'45.13''E	6'39'56.20''E	6'39'52.44''E	6'39'50.57''E	
Vascular plants / Plantes vasculaires						**Code IPEN**
Andromeda polifolia L.	●					CH1NEU20140200
Andromeda polifolia L.					●	CH1NEU20140201
Betula nana L.					●	CH1NEU20140202
Calluna vulgaris (L.) Hull	●					CH1NEU20140203
Carex rostrata Stokes			●			CH1NEU20140204
Carex nigra (L.) Reichard*						CH1NEU20140205
Carex rostrata Stokes		●				CH1NEU20140206
Carex rostrata Stokes				●		CH1NEU20140207
Comarum palustre L. (*Potentilla palustris*)				●		CH1NEU20140208
Drosera rotundifolia L.					●	CH1NEU20140209
Dryopteris cristata (L.) A. Gray*						CH1NEU20140235
Eriophorum angustifolium Honck	●					CH0NEU20140210
Eriophorum vaginatum L.	●					CH0NEU20140211
Eriophorum vaginatum L.					●	CH0NEU20140212
Filipendula ulmaria (L.) Maxim.*						CH0NEU20140213
Pinus mugo subsp. *uncinata* (DC.) Domin	●					CH0NEU20140214
Trichophorum cespitosum (L.) Hartm. (s.str.prov)	●					CH0NEU20140215
Vaccinium myrtillus L.	●					CH0NEU20140216
Vaccinium oxycoccos L.					●	CH0NEU20140217
Vaccinium uliginosum L.	●					CH0NEU20140218
Vaccinium uliginosum L.					●	CH0NEU20140219
Vaccinium vitis-idaea L.	●					CH0NEU20140220
Mosses / Bryophytes						
Aulacomnium palustre (Hedw.) Schwägr	●					CH0NEU20140221
Hylocomnium splendens (Hedw.) Schimp	●					CH0NEU20140250
Pleurozium schreberi (Brid.) Mitt.	●					CH0NEU20140222
Polytrichum alpinum Hedw. (=P.strictum)	●					CH0NEU20140223
Sphagnum angustifolium (Russow) C.E.O.Jensen	○					CH0NEU20140224
Sphagnum capillifolium (Ehrh.) Hedw	○					CH0NEU20140225
Sphagnum cuspidatum Hoffm			●			CH0NEU20140226
Sphagnum fallax (H.Klinggr.) H.Klinggr		●				CH0NEU20140227
Sphagnum fallax (H.Klinggr.) H.Klinggr				●		CH0NEU20140228
Sphagnum fuscum (Schimp.) H.Klinggr					●	CH0NEU20140229
Sphagnum magellanicum Brid.	●					CH0NEU20140230
Sphagnum magellanicum Brid.					●	CH0NEU20140231
Sphagnum rubellum Wilson	●					CH0NEU20140232
Sphagnum rubellum Wilson					●	CH0NEU20140233
Sphagnum squarrosum Crome*						CH0NEU20140234

* In the botanical garden of Neuchâtel before 2012, from "vallée des Ponts-de-Martel" (Bois-des-Lattes or Marais rouge)

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02. Results

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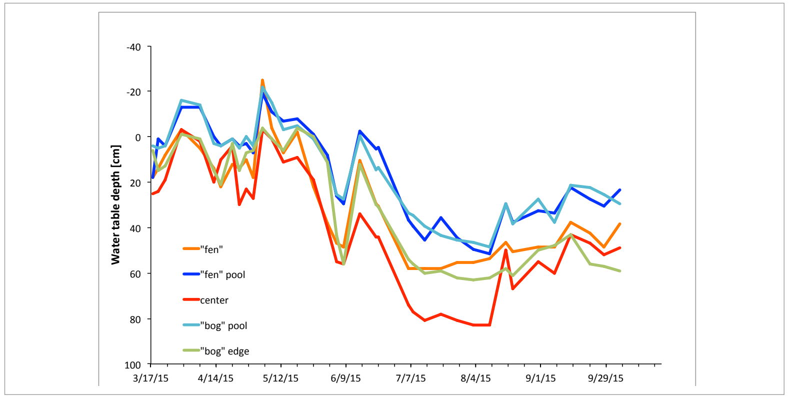
After one year of development some preliminary results can already be shown, including the thermal inertia of the peatland, the resistance of the plants to the heat wave and drought of the summer 2015 and the colonisation of herbaceous plants on the bare peat surface.

> **FIGURE 3.**

The peatland on 24.02.2015 with snow still on the surface.

1. THERMAL INERTIA

The first observation is the thermal inertia of the peat body relative to the surrounding mineral soil. This was very obvious during the winter after a period of snowfall. The thickness of the snow and the duration of snow cover were measured from November to March on the peatland and on the adjacent path and meadow. The water-saturated peat body froze during the winter and the snow remained longer than on the adjacent well-drained mineral soil that heated up much faster as soon as air temperature increased (**Fig. 3**). Thus once the peat body has cooled it remains colder than the surrounding land. These temperature patterns will be more precisely monitored in the future once temperature loggers are installed.

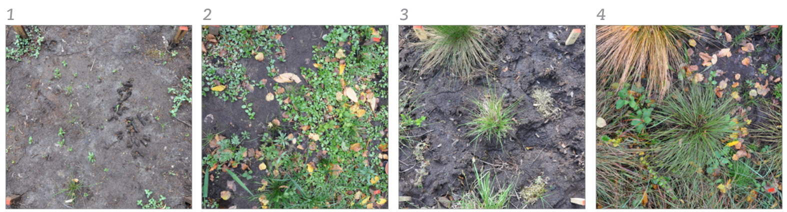


> **FIGURE 4.**

Patterns of water table depth [cm] measured in five spots on the bog (colors are the same than Piezometer of Fig. 2).

2. RESISTANCE OF THE BOG VEGETATION TO THE HOT AND DRY SUMMER 2015

The summer 2015 was especially hot and dry. We therefore feared that the newly planted bog vegetation would not survive such extreme conditions. However we observed that almost all plants survived. Deep rooted vascular plants such as *Carex* ssp., *Eriophorum* ssp., *Trichophorum caespitosum* and ericaceous shrubs all survived well (see especially difference between pictures of **Fig. 2**). Likewise the mosses including *Sphagnum* were still mostly alive. The only exception was the bog pool species *Sphagnum cuspidatum* that died in the dried out pools. This general good resistance of bog plants may be explained by the fact that, although the summer was indeed especially hot and dry the spring had been quite wet, with high water table recorded from March to June (**Fig. 4**). The development if the vegetation in two 1m² plots representative for two of the four treatments is illustrated in **Figure 5**.



> **FIGURE 5.**

Vegetation development of two 1m² plots of the bog corresponding to two treatments: **1:** non-planted & non-weeded (plot C-6). **2**: planted & non-weeded (plot B-8). **3**: July 8th 2015. **4:** October 16th 2015.

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3. DEVELOPMENT OF PLANTS ON OPEN PEAT SURFACES

We left 50% of the bog surface totally bare to study the primary colonisation by diaspores from the surrounding plants. Given the extreme climatic conditions of the summer we wondered how successful this colonisation would be. Interestingly a high number of plants germinated on the peat. These were however mostly plants from the adjacent meadow and forest while bog plants seemed to have colonised these surfaces from vegetative lateral growth (especially clear for *Vaccinium oxycoccos*, **fig. 6**).

> FIGURE 6.

Development of *Vaccinium oxycoccos* on the bare peat surface from an adjacent vegetation patch during the summer 2015. (Grey pieces are IPEN labels with name of plants introduced)

Discussion

The peatbog of the Botanical Garden of Neuchâtel, created at low elevation (ca. 500m) and in a region with moderate rainfall (ca. 900mm/yr) is primarily useful to understand the evolution of such an ecosystem under apparently unfavourable climatic conditions. After only one year of observations it is clearly too early to draw any firm conclusions on the long-term development of this peatland. However the drought and heat wave that lasted from May to September 2015 already provided the opportunity to evaluate how the plants reacted to a long-lasting hydric stress. We were pleasantly surprised to see how well the vegetation had survived and indeed the comparison of the two aerial images (**fig. 2**) and the images of the two plots (**fig. 5**) clearly show the strong growth of the vascular plants. The mosses may not have grown much but mostly seem to have survived as well. The exceptions are the smallest patches or isolated moss plants and the characteristic *Sphagnum* species of bog pools (*S. cuspidatum*) that died in the dried up pools. The peatland therefore already represents an invaluable object for scientific research.

The second advantage of this peatland is that the characteristic plants of this unusual ecosystem can now be present in their "natural" context rather than in suboptimal small surfaces. Having these plants growing on a massive peat body also offers a higher chance of maintaining these plants over a long period, as attested by their good survival during the stressful conditions of the summer of 2015. This peatland already is proving very useful to the public inform about the value and fragility of peatland ecosystems. The peatland thus also clearly serves educational purposes.

This peatland also offers opportunities to test the growth conditions of rare and endangered peatland plants, of multiplying them with the goal of re-introducing them in some newly restored peatlands in the region without having to samples in fragile natural populations. As 90% of the remaining peatlands in Switzerland have been damaged directly or indirectly by human activities there is now a good potential for conducting ecological restoration projects and indeed many ambitious projects are in progress. In many cases

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it would be desirable to re-introduce the characteristic plants of these ecosystems and here the peatland of the Botanical Garden of Neuchâtel can be useful both to experiment growth conditions and to multiply characteristic plants. The peatland thus also serves conservational purposes.

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AN INTERNATIONAL PLANT SENTINEL NETWORK

Photo credit : Mealy bug infestation, *Suzanne Sharrock*

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> Keywords PEST DISEASES SENTINEL PLANTS INVASIVE MONITORING CAPACITY BUILDING

02. Abstract

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INVASIVE PESTS AND DISEASES CAN HAVE A DEVASTATING IMPACT ON PLANT LIFE AND THEIR ASSOCIATED ECOSYSTEMS. IN RECENT YEARS, THE WORLD HAS SEEN A SHARP RISE IN THE NUMBER OF THESE HARMFUL INVASIVE ORGANISMS WHICH CAUSE LARGE SCALE ENVIRONMENTAL AND ECONOMIC DAMAGE.

This rise is a result of the increased globalisation of trade in plants and plant material, an ever-growing industry. A major issue in addressing this increasing threat is that the majority of organisms that have caused outbreaks in temperate forests were either not known to be damaging or were unknown to science before their introduction.

Most European countries utilise a process called Pest Risk Analysis (PRA) to regulate risk within trade which focuses on known threats. As a result, damaging unknown organisms ('unknowns') are often left unregulated, increasing the chances of their introduction into new countries. Botanic gardens and arboreta are in a unique position to aid in the identification of such unknowns; within their collections they play host to expatriate plants that can act as sentinels for these potentially invasive and damaging organisms.

The International Plant Sentinel Network (IPSN) aims to generate information valuable to global plant health in order to safeguard against the threat of [such organisms] / [new introductions]. The developing network consists of gardens and diagnostic institutes who work together to provide an early-warning system for new and emerging plant pests and diseases. The IPSN focuses on increasing knowledge and awareness among garden staff, seeking best practise, developing standardised approaches and providing training materials and methodologies for monitoring and surveying. Established as part of a European-funded (EUPHRESCO) project the IPSN is led by the UK's Food and Environment Research Agency (FERA) in collaboration with Botanic Gardens Conservation International (BGCI) and partners in Europe (Julius Kühn-Institut, Germany; National Plant Protection Organisation, Netherlands; DiBAF, Italy; Forest Research, UK and CABI: Centre for Agriculture and Biosciences International). Although a European project, the network aims to be truly international as the issue of invasive organisms needs to be tackled on a global scale.

> Keywords PEST DISEASES SENTINEL PLANTS INVASIVE MONITORING CAPACITY BUILDING

02. Introduction

• *Barham Ellie*
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Photo credit : Mealy bug infestation, ***Suzanne Sharrock***

INVASIVE ALIEN PESTS AND DISEASES OF PLANTS HAVE DEVASTATING ENVIRONMENTAL, ECONOMIC AND SOCIO-CULTURAL EFFECTS AND THUS ARE A PROMINENT CONCERN OF INDUSTRIES, THE PUBLIC AND GOVERNMENTS AROUND THE WORLD.

They are particularly worrying for botanic gardens and arboreta that care for extensive collections of diverse, valuable and rare plant species. This threat is ever-growing, largely as a result of the globalisation of trade in plants and plant material, used by unwanted organisms to hitchhike into a new region (Aukema *et al.*, 2011, Tomoshevich *et al.*, 2013). This concern is amplified by issues surrounding the prediction of future threats. The majority of temperate forest pests and diseases in recent years were either not known to be damaging or were unknown to science before outbreaks (Kenis *et al.*, 2011). This is because invasive organisms are often not considered significant pests in their native region, largely due to evolved resistance by natural host species and population control by natural enemies.

In order to manage threats, countries need to know of their existence. Pest Risk Analysis (PRA) is used by many European countries to regulate risk within trade; it is used to decide if an organism should be recognised as a pest of concern and subsequently regulated. It also aids decision-making regarding the strength of any phytosanitary measures (Baker *et al.*, 2009). However, PRA is reliant on known organisms with sufficient levels of information available. Therefore, it leaves many organisms unregulated and able to move into a new region freely; e.g. the 'unknowns' or organisms lacking enough information to complete PRAs. Sentinel plants offer a unique opportunity to address this issue.

Sentinel plants

Monitoring plants maintained outside of their natural ranges, so-called plant sentinels, that are exposed to pests and diseases in their adopted region can help to detect potential future threats (Britton *et al.*, 2010). In this way damaging organisms can be initially identified which can guide research to determine if they pose a significant threat to plant species in native regions. In turn, sentinels can also be used to collect information in order to address knowledge gaps for organisms suspected to be potential threats to

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plant health (e.g. for PRAs). Studying invasive species in their natural regions, or where they have already been introduced, can be used to increase our understanding of the pest including life history and interactions with natural predators, e.g. potential biological controls. Importantly, using plant sentinel within these regions can help identify further pest-host associations, categorise and describe the type of damage they cause and the susceptibility of plant species. All of this information is vital for assessing the risk an organism poses, particularly for PRAs. In addition, information can be used in the creation of robust eradication, containment or, preferably, prevention management programmes.

Botanic gardens and arboreta

There are over 2,500 botanic gardens and arboreta globally, playing host to an estimated 30-40% of known plant species (Kramer and Hird, 2011). Importantly for plant sentinel research, gardens contain exotic plant species from countries around the world. This presents a significant opportunity to carry out sentinel research on a large and global scale.

In return, contributing gardens receive significant benefits for their role in carrying out sentinel research and being part of the network. Firstly, it will help ensure staff are hyper-vigilant for new outbreaks. Detecting damaging organisms quickly greatly increases the chances of management programmes working, thus mitigating damage caused and protecting the rest of the collection. It will enable contact with local diagnosticians and experts, establishing good links to professional help at a local level and beyond. It offers an opportunity for botanic gardens and arboreta to showcase the research and scientific potential that their living collections have to offer. It offers professional development opportunities to staff. Finally, it provides networking opportunities and increased communication on a local, regional and global scale, not just with plant health scientists but also with staff from other gardens working in the area.

The International Plant Sentinel Network

The International Plant Sentinel Network (IPSN) is a developing network of botanic gardens, arboreta, government organisations and plant health scientists. The IPSN aims to provide key information on plant pests and diseases that can be used by plant health scientists and National and Regional Plant Protection Organisations (NPPO & RPPO) in order to conserve global plant health. The network supports botanic gardens and arboreta in carrying out such important research by providing key training and coordination. This includes developing and providing links to resources, identifying potential collaborations, facilitating surveys and research, and sharing information. In this way, it is hoped these institutes, supported and coordinated by the IPSN, will work collaboratively to provide an early warning system for new and emerging plant pests and diseases.

The IPSN provides a centralised platform for communication, dissemination of information and coordination of efforts for carrying out sentinel research. This includes surveying tools and training materials which can be

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• *Baker Richard*

used to promote awareness and train and support staff in the areas of plant health, identification and biosecurity. The IPSN website (www.plantsentinel.org) includes various resource materials from comprehensive guides to pest and disease identification and surveying tools to good biosecurity practise guides, examples of best practise and posters. It also provides links to forums and external databases, resources and information.

All IPSN materials have been developed in collaboration with leading diagnostic scientists alongside botanic garden staff. This includes the Yorkshire Arboretum (UK), the Core Facility Botanical Garden at the University of Vienna (Austria), the Royal Botanic Gardens, Kew (UK), the Royal Botanic Gardens Edinburgh (UK) and Botanischer Garten der Universitat Potsdam (Germany).

As part of its role in providing training, the IPSN runs workshops in order to provide on the ground training for garden staff. These workshops are also a great opportunity for participants to network with individuals working within horticulture, plant health and government organisations, from within their country and further afield. So far workshops have been held at Shenzhen Fairy Lake Botanical Gardens (China), Huntington Botanical Gardens (U.S.), Royal Botanic Gardens, Kew (UK) and the Yorkshire Arboretum (UK). All hosting gardens have experience in the area of plant health from surveying to identification and were able to share examples of best practises with attendees.

A global network

The IPSN is funded through EUPHRESCO, an ERA-NET project; the UK's participation is led by Fera and funded by the Department for Environment, Food and Rural Affairs (Defra). Other current EUPHRESCO partners are the Julius Kühn-Institut (Germany), the Plant Protection Services (Netherlands), the Department for Innovation in Biological, Agro-food and Forest systems (Italy), CABI (UK) and Forest Research (UK). The network is guided by an International Advisory Group comprising leading experts from organisations around the world. This includes representatives from the European and Mediterranean Plant Protection Organisation (EPPO), the American Public Garden Association, the South African National Biodiversity Institute (SANBI) and Centre of Invasive Biology (CIB), the New Zealand Better Border Biosecurity (B3) consortium and the Food and Agriculture Organization (FAO) among others. A full list is available at www.plantsentinel.org/international-advisory-group

The IPSN is coordinated by Botanic Gardens Conservation International (BGCI). BGCI have extensive links to the botanical gardens and arboreta community, and are leading authorities in the area of plant conservation. Their two unique databases, GardenSearch and PlantSearch, are exceptional resources which can be utilised to facilitate and support research. GardenSearch lists all known gardens and includes key information such as location (country, region) and contact details. PlantSearch catalogues living plant, seed and tissue collections in gardens around the world and can be used to identify the gardens which hold a specific plant species. This not only lets the IPSN identify gardens in areas where the pest or disease is present, but also helps to pinpoint those institutes that house host plants of interest.

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02. The future

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The IPSN has been running for nearly 3 years, and is soon to start the next phase of its development; using the network to provide meaningful data to plant health regulators. This information will be used to prevent and/or mitigate the impact of pest and disease outbreaks, to help conserve plant species around the world. The IPSN will facilitate and coordinate research projects as well as continue to provide support, guidance and training.

Currently, in collaboration with CABI, the IPSN is in the pilot phase of developing an online reporting system and front-facing database. CABI are a not-for-profit research and publishing organisation that has much experience in this area having previously developed various databases. It is hoped this new reporting system will simplify and ease data collection and will provide data storage for results. This will help garden staff to manage their surveying work and track the progress of any damage.

The IPSN is working to create a viable and robust network that meets the needs of its key stakeholders; botanic gardens, arboreta, National Plant Protection Organisations, Regional Plant Protection Organisations and plant health scientists. It is hoped the network will become an established and important tool that will be championed by these stakeholders and supported by BGCI.

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MONITORING OF COLLECTION ESCAPES IN THE BOTANIC GARDEN MEISE

Photo credit : *Ranunculus parviflorus* growing along a wall of the old Boechout castle, *Anne Ronse*

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> Keywords GARDEN ESCAPES BOTANIC GARDEN SURVEY NEOPHYTES INVASIVE HYBRIDIZATION

02. Abstract

• *Ronse Anne C.M.*

A MONITORING PROGRAMME OF COLLECTION ESCAPES HAS BEEN INITIATED IN THE DOMAIN (92 HA) OF THE BOTANIC GARDEN MEISE. FIRST, A NINE-YEAR VEGETATION SURVEY OF THE (SUB) SPONTANEOUS VASCULAR PLANTS WAS CARRIED OUT FROM 2002 TO 2010; IT WAS FOLLOWED BY A SYSTEMATIC MONITORING OF THE ESCAPED NEOPHYTES DURING 5 YEARS FROM 2012 ON, RECORDING SEVERAL PARAMETERS SUCH AS THEIR NUMBER AND PERSISTENCE.

Up to 2014, a number of 202 species of collection escapes has been observed, which amounts to 2,5% of the taxa in open air collections. Of these, 57 species have not been reported before as a neophyte in Belgium. Some neophytes with invasive tendencies appear to come from outside sources rather than from the plants in the collections. A recent spreading of several thermophilic species has also been observed, some of which subsist long after the species have disappeared from the collections. Most of the escapes are ephemeral but some display strong invasive behaviour. The botanic collections seem to favour the appearance of escapes in some cases, such as the co-occurrence of both sexes of dioecious plants, and also by the presence of cultivated native species coming from colder areas than the local representatives. The hybridization and back-crossing of cultivated taxa with native species is an ongoing process which appears to occur simultaneously both in the botanic garden and on outside locations.

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02. Introduction

• Ronse Anne C.M.

Photo credit : *Ranunculus parviflorus* growing along a wall of the old Boechout castle, ***Anne Ronse***

THE MAIN SOURCE FOR ALIEN INVASIVE PLANT SPECIES IN SEVERAL PARTS OF THE WORLD CONSISTS OF PLANTS THAT HAVE BEEN INTRODUCED FOR HORTICULTURAL USE BY NURSERIES, BOTANICAL GARDENS AND INDIVIDUALS (E.G. DEHNEN-SCHMUTZ *ET AL.* 2007; GROVES *ET AL.* 2005; REICHARD & WHITE 2001).

Some of the cultivated species are able to escape from cultivation and become established or naturalized; they are called garden escapes. In order to minimize the risks of invasive garden escapes, codes of conducts for horticulture have been developed in several countries (Heywood & Brunel 2011). However, several invasive species have originated from collections of botanic gardens, which have been reported as biased towards invasive species (Hulme 2011). That is the reason why voluntary codes of conduct on invasive alien species have also been developed for botanic gardens and arboreta in different parts of the world (e.g. Heywood & Sharrock 2013; *http://www.centerforplantconservation.org/invasives/DownloadPDF/bga.pdf*). One of the recommendations included in these documents is to carry out a monitoring of the escapes from the collections (called collection escapes) on the garden site. This can yield valuable information about the invasive potential of species in a certain area and climate, which may especially be useful as many of the species are not (yet) available in commerce. The importance for alien plant research of listing the species naturalizing in botanic gardens was already stressed in the 19th century by Martins (1856) and by Devos (1870).

For these reasons a programme was started for the monitoring of collection escapes in the Botanic Garden Meise, with the aim to evaluate the invasive potential of plant species in the collections and to prevent them from spreading in- and outside the garden.

Materials & methods

The Botanic Garden Meise (formerly called National Botanic Garden of Belgium) is located at a distance of about 10 km to the north of Brussels. It contains large collections of about 18000 taxa, of which 8000 are grown in the open in a domain of 92 ha. This old castle domain contains diverse habitats such as greenhouses, open air collections, buildings, roads, woodlands, grasslands, lawns, and ponds. Some of them are (semi-)natural areas with a high conservation status, such as petrifying springs with *Cratoneurion* (habi-

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tat type H7220) (Oosterlynck & Van Landuyt 2012). Several studies have been made on the (sub)spontaneous flora of the domain, including plants but also lichens, fungi, myxomycetes and other organisms (Hoste 2011).

For the vascular plants, a nine-year vegetation survey was carried out from 2002 to 2010. During that first survey period, all subunits of the domain (called sectors) were visited at least twice, once in spring and once in summer or in early autumn, and a list of species was made for each sector. In a second phase, from 2012 on, all plant species are again recorded by sector, following a schedule aiming at visiting each sector within 5 years. Moreover, a systematic monitoring of the escaped neophytes is done, and several parameters are noted in order to characterize their invasive potential: the number of plants, their age, their distance from the mother plants in collection, and the habitat type where they are found. Several species traits will be considered for further analysis, such as the means of dispersal, the type of propagation and the original geographical range.

Results & discussion

The first survey revealed the presence of 586 (sub)spontaneous species of vascular plants in the domain, of which 156 species (26%) were neophytes that had probably escaped from the collections (Ronse 2011a). Of these, 38 species were recorded for the first time as a neophyte in Belgium (Ronse 2011b). The ongoing monitoring of the second phase has already resulted in a further increasing number of species that have been found escaping outside the collections, as more sectors are visited. From 2012 to 2014, 64 new plant species were recorded, of which 46 (72%) are collection escapes: the proportion of escapes in the new discovered species has strongly increased in the second phase. This brings the (provisional) total number of escaped species in Meise to 202, of which 57 have not been reported before as a neophyte in Belgium (Verloove 2006a).

However, it is not always easy to distinguish between species that have escaped from the collections and neophytes that have spread from outside sources. One of these examples is *Duchesnea indica* (Andrews) Teschem. (Rosaceae), a creeping plant that is called Indian strawberry or Mock strawberry. In the domain a steady expansion of the species has been observed between 2002 and 2014. This is shown in **table 1**, which displays the number of sectors in which this species was found per year (as averaged over time periods of 1or 2 years), as well as the number of sectors per year in which the species was first recorded (new occurrences per year).

Time period	Average n° of sectors/year	Average n° of new sectors/year
2002-2003	3	3
2004-2005	2,5	2,5
2006-2007	1,5	0,5
2008	9	9
2009	11	6
2010	7	4
2011	3	0
2012	11	5
2013	6	0
2014	4	0

> TABLE 1.

Number of sectors of the domain in which *Duchesnea indica* was found annually

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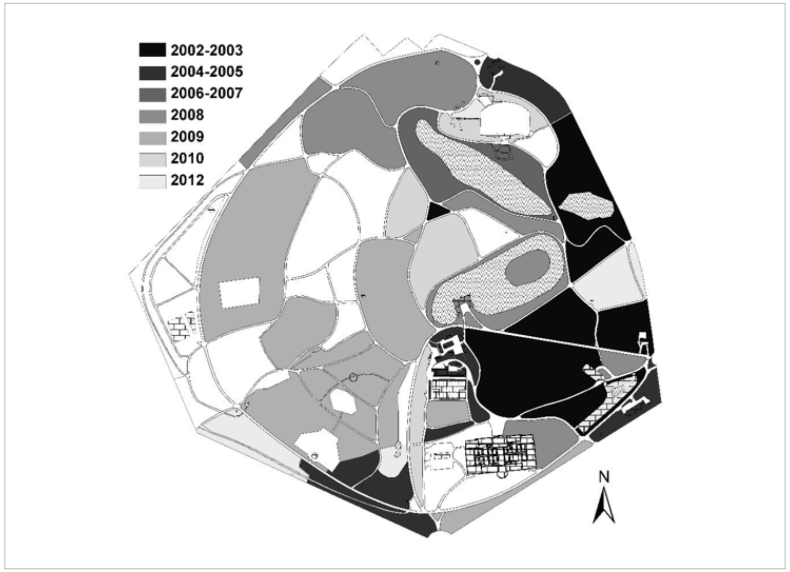
• Ronse Anne C.M.

The latter shows clearly that a very strong increase of the species has been recorded between 2008 and 2010, especially in 2008 and 2009. The low occurrence in 2011 might seem erratic, as compared to the occurrence of 2010 and of 2012, but it is due to the fact that only sporadic observations were made in that year, as the first survey had already been completed then, and the second had not started yet.

Duchesnea indica has been placed in the watch list of invasive species in Belgium (Branquart 2015), and it is known that this species had gone through a significant expansion in parks in the Brussels area since 1990 (Saintenoy-Simon et al. 1995). This is why I suspected that the source of the invading plants in the domain lied outside, even if the species was cultivated in the garden. In order to investigate this hypothesis, a spatial analysis was made of the progression in time of the species in the domain (**Figure 1**). This displays an initial presence that is largely restricted to the eastern side of the domain, close to the main visitor entrance. Gradually the species has expanded to the other parts of the domain, and it still had not been found in a number of sectors by 2014, mainly in the western part. The cultivated plants of D. *indica* are located in the central and the southern part, while one former location was close to the eastern entrance, but the plants there had died since several years. This seems to confirm the hypothesis that the spontaneously occurring plants of D. *indica* in the domain have come from an outside source, and that they have entered the domain by the main entrance. Other neophytes, such as *Senecio inaequidens* DC. (Asteraceae), have also been observed to enter the domain by this entrance.

On the other hand, many species in the domain are obviously collection escapes, as they are not present in the surroundings outside. Some of them don't show invasive behaviour and are restricted to one or a few sites, where they remain present year after year, only reproducing locally. This is the case for instance for some wall-dwelling species, such as *Asarina procumbens* Mill., a decorative member of the Plantaginaceae that grows on the outer sides of greenhouse walls. More surprisingly, I also found a cactus, probably *Mammillaria* sp., which has subsisted for at least ten years on the outer wall of a greenhouse. But other collection escapes clearly display invasive behaviour. One such species in Meise is *Nothoscordum gracile* (Aiton) Stearn (Amaryllidaceae), which has been cultivated until the summer of 2010, when it was removed from the collections. It was present within its flower beds, but also outside at distances up to several tens of meters. The attempt to eradicate has not worked well, as in 2015 still many tens of plants were present. This should not surprise, as the species is naturalized in parts of the United States, and in scattered locations of Europe, Asia, Africa, Australia, and various oceanic islands (https://en.wikipedia.org/wiki/Nothoscordum), even if the species was not known as a neophyte in Belgium (Verloove 2006a).



> FIGURE 1.

Progression of *Duchesnea indica* from 2002 to 2012 in the domain of the Botanic Garden Meise

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Another escape displaying invasive tendencies is *Juglans mandshurica* Maxim. (Juglandaceae), a species of walnut that is very hardy. Seedlings of this species are found in several sectors of the domain, and we assume that the nuts may be disseminated by birds. The seedlings often remain unspotted as they grow in the woody areas, which are not regularly weeded, and as they look much like *J. regia*, a cultivated tree that is increasingly found naturalized in the northern part of Belgium (Verloove 2006b). A few of the seedlings in the domain have become mature trees that are reproducing. *J. mandshurica* is mentioned as introduced and potentially invasive in Central Russia by the EPPO Global Database (https://gd.eppo.int/taxon/IUGMN), and the related Japanese species J. ailantifolia Carr., that is also known as *J. mandshurica var. sachalinensis*, shows invasive behaviour in some areas of New Zealand (http://whangareiflora.weebly.com/invasive-plants.html).

Some escapes in Meise have been found surviving long after the mother plants in the collections have disappeared. This is the case for *Mentha pulegium* L., a mint species that is a very rare native species in Belgium; recently some new sites have been discovered, where the species is probably present as a neophyte (Ronse 2012). It has been cultivated in the botanic garden from 1987 to 1991 and then died, but it is increasingly found in lawns in the domain. A second example of escapes surviving the mother plants is the thermophilic *Ranunculus parviflorus* L., which has been cultivated between 1974 and 1992, and then disappeared from the collections; it is now increasingly found as a weed in disturbed or weeded parts (Ronse 2011c).

A special case of neophytes that are not strictly speaking collection escapes are hitch-hiking weeds that are introduced in botanical collections together with cultivated plants, and that can spread from there. One such example in Meise is *Euphorbia humifusa* Willd., a small annual spurge from south-eastern Asia that has naturalized in several parts of Europe and south-western Asia. It is known to have grown around 1900 in the systematic garden at the former Botanic Garden location in Brussels, from where it has been brought to Meise together with the collections (Ronse 2011d). It has been rapidly increasing since 2010, and maybe the recent increase of this thermophilic species has also been triggered by global warming, as is also suspected for *Mentha pulegium* and for *Ranunculus parviflorus*.

The provisory results of the monitoring of escapes have allowed us to identify some mechanisms going on in botanic gardens that seem to favour the escape of cultivated species. The first concerns dioecious (tree) species, of which plants of both sexes are present in each other's vicinity in botanic gardens, whereas this is not so often the case in private gardens or parks. This means that in botanic gardens they produce seedlings that are often not found elsewhere. One example of this is *Cercidiphyllum japonicum* Siebold & Zucc. (Cercidiphyllaceae), a tree from eastern Asia that is frequently grown in European parks but that had not been recorded as a neophyte in Belgium yet (Verloove 2006a). In Meise many tens of seedlings grow in several locations. Another example is *Diospyros lotus* L. (Ebenaceae), a dioecious tree from south-eastern Europe and south-western Asia that produces edible fruits called date plums. In Meise it shows invasive behaviour, and hundreds of seedlings have been found up to one kilometre away from cultivated trees (Groom et al. 2011).

A second mechanism is the escape of native species that are cultivated from a non-local provenance in the collections. In some cases they are better adapted than the locally native plants, for example when the latter are on

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the edge of their distribution area because of climatic constraints, while the cultivated plants are adapted to colder climates. In Meise, plants of *Oenanthe pimpinelloides* L. (Apiaceae) show expansive behaviour, whereas this species is very rare in Belgium and is included in the Red List of vascular plants in Flanders (Ronse 2005). However, the cultivated plants come from Bulgaria, with hardiness zone 6 or 7, whereas the garden is located in hardiness zone 8.

A third mechanism that I found in the botanic garden at Meise is spontaneous hybridization of a native species with a cultivated alien species. The hybrid often displays invasive tendencies and gradually replaces the native parent; sometimes further introgression occurs by back-crossing. One such example is *Hyacinthoides* x *massartiana Geerinck* (Asparagaceae), the hybrid of the native H. *non-scripta* (L.) Chouard ex Rothm. And of the cultivated *H. hispanica* (Mill.) Rothm. Plants with intermediate characters invade flower beds in the vicinity of the flower beds of both parents in the collection, and pop up at different locations throughout the domain as well. A similar process also occurs elsewhere in northern Belgium, where hybrid plants have increasingly been found growing both in forests and in gardens (Verloove 2006c). Within the garden it seems that the hybrid plants originate from the cultivated plants, rather than come from the outside, given their location.

Another example is *Ilex x altaclerensis* (hort. ex Loud.) Dallim., a man-made cross between *Ilex perado* Ait., a non-hardy species in Belgium, with the native Holly (*Ilex aquifolium* L.) as male parent. Several cultivars of *I. x altaclerensis* have been planted in gardens and in public places. Within the Botanic Garden Meise many plants with intermediate characteristics between the primary crosses and Holly are growing in woodland; further investigation has shown that similar back-crossing is occurring in several other locations in northern Belgium (Ronse, in preparation).

Conclusion

Since 2002 more than 200 species have been found to escape from the collections in the botanical garden Meise, and this number is steadily increasing. This represents one third of all vascular plant species that were found growing (sub)spontaneously in the domain. Compared to the 8000 taxa grown in the open air collections, the number of escapes represents 2.5 percent, which may seem a low proportion. However it should be kept in mind that probably a large number of escapes is not recorded, due to the frequent weeding in the collections, and due to the fact that the monitoring of the collection escapes has only been done for a few years. Yet more than one quarter of the collection escapes concern species that have not been reported as a neophyte in Belgium before. This shows the importance of monitoring in botanic gardens as an information source about invasive behaviour of alien species. However, it is not always easy to discern whether a species that is spreading in the domain originates from the collections or from outside, when it is present in the collections but also occurs as a neophyte in the area around the garden. A spatial analysis of the progression in time of the species within the garden domain can give indications for this.

> Keywords GARDEN ESCAPES BOTANIC GARDEN SURVEY NEOPHYTES INVASIVE HYBRIDIZATION

02. Conclusion

Most of the collection escapes occur in low numbers and are ephemeral, as the areas in the vicinity of the collections are frequently weeded. Some of them show strong invasive behaviour and are very difficult to eradicate from the collections, in some cases also for species that have not been reported as a neophyte in our country before, such as for *Nothoscordum gracile*. Several species that have been observed to spread during the last decade(s) are thermophilic species or species that are on the northern edge of their distribution, so it is well possible that global warming is involved. Some species even survive as escapes after having died in the collections. A few mechanisms or processes that take place in the botanic garden turn out to favour the appearance of taxa with invasive properties, such as the co-occurrence of both sexes of dioecious plants. The cultivation of native species with a provenance from colder areas than the local conditions has led to frequent escapes, as found for the rare *Oenanthe pimpinelloides*. This phenomenon of escape and aggressive behaviour of native species from a non-local provenance might be more common than visible at first glance. Indeed, this is easy to monitor in the case of locally rare plants, but it is more difficult to discern for more common species, and it would require genetic analyses to prove this. Another ongoing process is the hybridization and back-crossing of cultivated taxa with native species, and this has been found to take place more or less simultaneously in the botanic garden as well as on other locations outside the garden.

Acknowledgements

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> Keywords GARDEN ESCAPES BOTANIC GARDEN SURVEY NEOPHYTES INVASIVE HYBRIDIZATION

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STUDY OF EXOTIC PLANTS' NATURAL REGENERATION IN THE VILLA THURET BOTANIC GARDEN: AN EARLY EVALUATION OF THE BIOLOGICAL INVASION RISKS

Photo credit : Arbres exotiques acclimatés au jardin botanique de la Villa Thuret, *C. Ducatillion*

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> Keywords BOTANICAL GARDEN INVASIVE SPECIES EXOTIC SPECIES RISK ASSESSMENT INVASION MONITORING ACCLIMATION NATURALIZATION DISPERSAL

02. Abstract

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- *Chevallier Joëlle*
- *Mellerin Yannick*
- *Ducatillion Catherine*

MANY EXOTIC PLANT SPECIES HAVE BEEN - AND STILL ARE - INTRODUCED IN BOTANIC GARDENS AS BIOLOGICAL RESOURCES AND OBJECT OF STUDY.

These resources could become acclimatized to provide services, especially in the situation of climate change. However, some species may become invasive. The Villa Thuret botanic garden is located on the coastline of the Mediterranean area, considered as a biodiversity hotspot. As soon as the 19th century, its director Charles Naudin identified the risk of plant invasion. Nowadays, scientists and gardeners have set an experimental design in order to assess the naturalisation's ability of introduced species and to prevent any invasion. The protocol aims at studying the species fecundity and dispersal as well as the survival of the potential spontaneous seedlings of these plants. Besides the seedlings inventory and monitoring by the maintenance staff of the garden, this survey will also consist in installing and monitoring representative unmaintained observation plots. Their size and number are limited by technical issues and by the acceptability of the staff and of the visitors. Ten 16m²-plots have been set in the garden in summer 2014. A phytosociological census was achieved for each one to precisely assess the spontaneous or planted plant species growing. Every six months, an inventory of the regenerating exotic species' seedlings is performed to identify the impact of rainfall, cold and drought through the germination, the seedlings' survival and the height growth. There will also be an estimation of the species fertility by seed collection and germination tests. This study will result in a list of species able to spontaneously regenerate within the botanic garden, but also in the characteristics of the regeneration: dispersal distance, seedlings' survival and growth rate and habitats propitious for germination. Here are the first identified plants: *Acacia* spp., *Ailanthus altissima* (Mill.) Swingle, *Albizia polyphylla* E.Fourn., *Araucaria bidwillii* Hook., *Arbutus* x *thuretiana* Dem. Nothosp. Nov., *Celtis* spp., *Cocculus laurifolius* DC., *Cotoneaster divaricatus* Rehder & E.H.Wilson, *Diospyros whyteana* (Hiern) F. White, *Elaeagnus macrophylla* Thunb., *Jubaea chilensis* (Mol.) Baill., *Phoenix* spp., *Koelreuteria bipinnata* Franch., *Pistacia* spp., *Pittosporum* spp., *Prunus ilicifolia* (Nutt. ex Hook. & Arn.) D.Dietr., *Quercus* spp., *Sapindus* spp., *Syzygium paniculatum* Gaertn., *Umbellularia californica* (Hook. & Arn.) Nutt., *Xylosma congesta* (Lour.) Merr., *Zanthoxylum simulans* Hance and *Zelkova serrata* (Thunb.) Makino. This experiment is planned for five years. The collected data will be processed with risk analysis tools already applied on forestry arboreta. This experimental design could be tested in other local botanic gardens to confirm its efficiency. It would be a valuable tool to precociously assess the risks and to warn against the escape and the proliferation of the concerned species.

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02. Introduction

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• *Chevallier Joëlle*
• *Mellerin Yannick*
• *Ducatillion Catherine*

Photo credit : Arbres exotiques acclimatés au jardin botanique de la Villa Thuret, ***C. Ducatillion***

INVASIVE EXOTIC SPECIES ARE ONE OF THE MAIN CAUSES OF BIODIVERSITY LOSS WORLDWIDE, ALONG WITH HABITATS DESTRUCTION (SIMBERLOFF *ET AL.*, 2003). THESE SPECIES TEND TO DEVELOP IN THE NATURAL, SEMI-NATURAL AND MAN-MADE ENVIRONMENT OF THEIR INTRODUCTION AREA.

They compete with native species, seizing available resources. This leads to a weakening of native species' populations and, in the long run, to biodiversity loss and ecosystems disturbance (Hulme *et al.*, 2009). Thus, ecosystem services are disrupted (Cardinale *et al.*, 2012), damaging human health and economic activities (Pimentel *et al.*, 2000; Díaz *et al.*, 2006). In the European Union, the annual cost of exotic invasive species has indeed been estimated at 12 billion euros (Genovesi, 2014).

The invasion process has been thoroughly documented and discussed, especially by Richardson *et al.* (2000), Colautti & MacIsaac (2004) and Blackburn *et al.* (2011). It has been defined as the crossing of different barriers by a species: geographical, environmental and reproductive barriers. Each crossing refers to different processes: introduction, naturalisation and invasion, respectively. This terminology has been controversial and is still discussed (see Blackburn *et al.*, 2011 for a review). Richardson *et al.* (2011) proposed a glossary to precisely define the different concepts involved in invasion Ecology. According to this glossary, a species is considered native in a given area if it has evolved in this area or if it arrived by natural means. Besides, a species is considered exotic in a given area if its presence is due to human intentional or accidental actions that spread it out of its native range. Here we consider that a species introduced by human actions in a region before 1500 is native. A species is invasive when it is able to reproduce over several life cycles in large numbers and to spread at considerable distance from the parents. This definition does not take into account the potential environmental, economic and health effects of such species. It only relies on ecological and biogeographical criteria. Few exotic species become invasive in a given area. According to the probabilistic "ten rules" (Williamson & Fitter, 1996), 10% of imported species would escape cultivation or captivity. Then 10% of these escaped species would naturalize. Finally, 10% of naturalized species would become invasive. Thus, one imported species out of a thousand would become invasive.

Amongst the identified invasive exotic species responsible for the most harmful consequences, plants represent one of the main groups (Vilà *et al.*,

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2009). The ecological success of an exotic plant species in its range of introduction depends on its own characteristics, but also on its interactions with the ecosystem it has been introduced in (Meerts *et al.*, 2004). Several hypotheses have been suggested to explain the ecological success of invasive exotic plant species (Hierro *et al.*, 2005), such as the propagule pressure, the enemy release or the disturbance hypotheses. These have been put into practice on some case studies of exotic plant species invasion, such as *Lantana camara* L. (Sharma *et al.*, 2005) or *Acacia dealbata* Link (Lorenzo *et al.*, 2010), bringing a better understanding of the underlying invasion mechanisms. Given the available knowledge, some risk assessment methods and good practices guidelines have been developed to prevent the introduction and the expansion of invasive species in susceptible ecosystems (Pheloung *et al.*, 1999; Weber & Gut, 2004; Branquard, 2009; Heywood & Brunel, 2009; Brunel *et al.*, 2010).

Exotic plant species introductions are known to occur through botanic gardens (Hulme, 2011). These have been implicated in the import of multiple invasive species, considered harmful according to the International Union for the Conservation of Nature (Lowe *et al.*, 2000). At the moment, risk assessment tools and good practices guidelines are not widely employed within botanic gardens (Hulme, 2015), paving the way to new potentially invasive plant species' introductions. The introduction and acclimatization roles of botanic gardens are indeed far from being obsolete. In a context of global climate change, botanic gardens represent a unique plant germplasm acclimatized to local environmental conditions that can be used to find new species of economic relevance (Heywood, 2011). They could also be used to identify potential pests and pathogens native to the gardens' area, susceptible to attack exotic plant species (Britton *et al.*, 2010). This could provide information on potential future invasive pests and pathogens in the countries from which the plant species originate.

In this context, the Villa Thuret botanic garden is willing to set up an invasive plant species policy. This garden is located in Antibes, France, on the coastline of the Mediterranean basin. This basin is considered as one of the main biodiversity hotspots worldwide (Myers *et al.*, 2000), with about 13,000 endemic plant species. As other hotspots, it is threatened by invasive species (Muller, 2004; Underwood, 2009). At a regional scale, an invasive plant species management strategy has already been set up in France (Terrin *et al.*, 2014). Nonetheless, an early detection of these species in introduction areas such as the Villa Thuret botanic garden could make the management easier and cheaper. The garden counts more than 1,000 exotic species divided into 140 families and 450 genera, originating from diverse regions of the world and potentially able to regenerate.

To early assess the invasion potential of these species, a field experiment has been set up in the botanic garden itself. This study aims at (i) detecting the exotic plant species able to regenerate and spread, (ii) determining the likely death causes of the spontaneous seedlings and (iii) knowing the key factors allowing the species at risk to reproduce in the garden.

Materials & methods

1. STUDY SITE

The study site is the Villa Thuret botanic garden, located on a peninsula in Antibes (France) at the coordinates 43°33'50"N, 07°07'27"E (NTF system).

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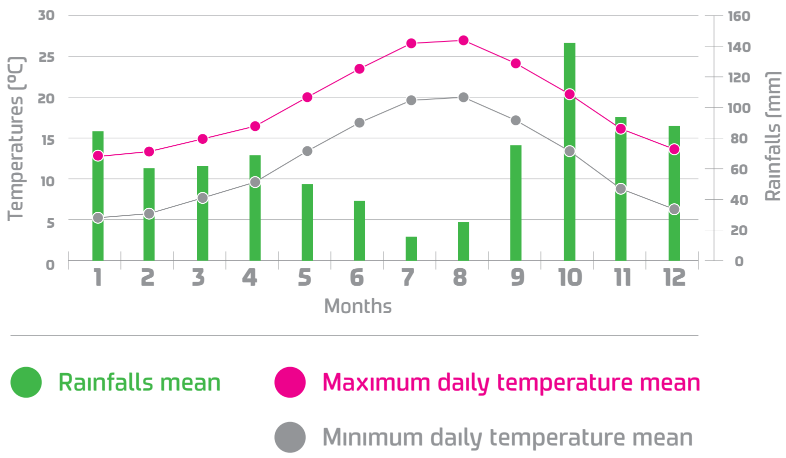
This is a 3.5ha-garden created in 1857 on a basic soil made of volcanic clay. The climate is Mediterranean, consisting of fall and winter rainfall, as shown on **fig. 1**, and a hot and dry summer. The average annual rainfall and temperature are respectively 803 mm and 15.6°C. The garden is not watered and does not receive neither amendments nor chemical treatments. Every species planted in the garden is taxonomically identified at least to the genus.



> FIGURE 1.

Monthly rainfalls, maximum and minimum daily temperatures at the botanic garden; means of the period 2004-2013.

2. SEEDLINGS INVENTORY AND CREATION OF A SEEDLINGS HERBARIUM

In order to list the plant species able to reproduce, a seedlings inventory is conducted on a regular basis, namely during the garden maintenance operations. The number of seedlings of each spotted species is not determined, only the names of the genus and of the species are ascertained. Since the seedlings' morphology may not be similar to the adult plants' morphology, the taxonomic identification may be problematic. Thus, a seedlings herbarium has been created to facilitate the identification process.

Type	*Characteristics of the micro-habitats*			*Surface (m²)*
	Ground cover	*Tree cover (%)*	*Drainage*	
1	gr.	< 5	+	9900
2	gr.	25-50	+	3800
3	d.l.	25-50	+	1100
4	d.l.	50-75	+	7100
5	d.l.	> 75	-	2200
	Not characterised			4800

> FIGURE 2.

Left: Distribution of the observation plots in the different micro-habitats of the garden; ***Right:*** characteristics of the micro-habitats regarding the chosen criteria ("gr." = grassland; "d.l." = litter of dead leaves; "+" = no stagnant water; "-" = stagnant water).

3. OBSERVATION PLOTS MONITORING

One of the main constraints of the botanic garden is the maintenance, which aims especially at removing weeds and at keeping the garden clean and safe for the visitors. In this context, the development of natural seedlings may be impaired, preventing any study. Hence, ten 16m²-plots without any maintenance operation have been set up in the garden. Their number and size arise from a compromise between scientific issues and the acceptability of the staff and of the visitors. To prevent any edge effect, an additional one meter wide strip without maintenance is established around each plot.

To distribute these plots, a characterisation of the different micro-habitats of the garden has been carried out, based on three qualitative criteria possibly impacting the seedlings development: ground cover (grassland or litter of dead leaves), tree cover (determined as classes of percentage of covering) and drainage (stagnant water after rainfall or not). It is presented on **fig. 2**. The plots have been distributed across the different micro-habitats according to the total surface of each one in the garden. Furthermore, they did not contain any planted individuals. Some areas of the garden did not display the chosen characteristics. They were not taken into account for this study, except for one area with conifers, where an additional plot was set up.

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At the beginning of the monitoring, a phytosociological census has been performed to determine the different species growing in each plot. Afterwards, inventories of the exotic species' natural seedlings have been planned every six months for each plot. More precisely, these inventories take place between the rainy season and the dry season, in order to assess the impact of rainfall, cold and drought. Several variables are measured: species, new seedlings germination, distance from the presumed parent plant, seedlings survival and seedlings height. The presumed parent plant of a seedling is the closest adult plant of the same species known to produce seeds. This monitoring has been planned for five years and started in April 2014.

Results

1. SEEDLINGS INVENTORY

At the presentation date, this study was not completed. Thus, only the first results are available. To date, 29 different exotic species have been identified among the detected seedlings in the garden (**table 1**), representing 19 families. The precisely identified species are all represented by planted individuals in the garden. For some seedlings, only the genus has been determined: the species could not be differentiated at the seedling's stage.

Family	Genus	Species	Area of origin
Anacardiaceae	Pistacia	spp.	-
Araucariaceae	Araucaria	*bidwillii* Hook	Australia
Arecaceae	Jubaea	*chilensis* (Mol) Baill.	South America
Berberidaceae	Berberis	sp.	-
Ebenaceae	Diospyros	*whyteana* (Hiern) F.White	Africa
Elaeagnaceae	Elaeagnus	*macrophylla* Thunb.	China, Japan
Ericaceae	Arbutus	*x thuretiana* Dem. Nothosp. Nov,	France (hybrid)
	Arbutus	spp.	-
Fabaceae	Acacia	*implexa* Benth.	Australia
		iteaphylla F.Muell. ex Benth.	Australia
		melanoxylon R.Br.	Australia
		paramattensis Tindale	Australia
	Albizia	*polyphylla* E.Fourn	Africa
	Vachellia	*nilotica* (L.) P.J.H.Hurter & Mabb.	Africa, Asia
Fabaceae	Quercus	spp.	-
Lauraceae	Umbellularia	*californica* (Hook. & Arn.) Nutt.	North America
Menispermaceae	Cocculus	*laurifolius* DC.	Asia
Myrtaceae	Eucalyptus	sp.	Asutralia
	Syzygium	*paniculatum* Gaertn	Australia
Pittosporaceae	Pittosporum	spp.	-
Rosaceae	Cotoneaster	*divaricatus* Rehder & E.H.Wilson	China
	Prunus	*ilicifolia* (Nutt. ex Hook. & Arn.) D.Dietr.	North America
Rutaceae	Zanthoxylum	*simulans* Hance	Asia
Salicaceae	Xylosma	*congesta* (Lour.) Merr.	Asia
Sapindaceae	Koelreuteria	*bipinnata* Franch.	China
	Sapindus	spp.	-
Simaroubaceae	Ailanthus	*altissima* (Mill.) Swingle	China
Ulmaceae	Celtis	sp.	-
	Zelkova	*serrata* (Thunb) Makino	Asia

> TABLE 1.

Inventory of exotic species able to produce seedlings. The areas of origin have been ascertained with the GRIN database (Taxonomy Germplasm Resource Information Network – Global Web v.1.9.4.2.; available at: https://npgsweb.ars-grin.gov/gringlobal/taxon/taxonomysimple.aspx)

2. OTHER EXPECTED RESULTS

Besides a list of the exotic species able to produce seedlings, this experiment is expected to provide knowledge about the average dispersal distance from the presumed parent plants, the seedlings' growth and survival rates and the germination conditions depending on environmental parameters.

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02. Discussion

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This experiment aims at detecting potentially invasive exotic plant species before they escape the botanic garden. It also aims at identifying key factors allowing these species to reproduce within the garden and at determining the likely death causes of spontaneous seedlings. Since it has been planned for five years and started in 2014, it is premature to draw clear conclusions from the first obtained results. Nonetheless, it seems that at least 29 exotic plant species were able to cross the reproductive barrier and started the naturalisation process, leading to sustainable populations on multiple lifecycles (Richardson *et al.*, 2000). If they succeed, they would eventually be able to spread into their new environment. To better assess this ability, the collected data could be processed with risk analysis tools, such as those used for forestry arboreta (Ducatillion *et al.,* 2015). Amongst these species, some have already been identified in the botanic garden region as invasive or potentially invasive exotic species, such as *Acacia melanoxylon* or *Ailanthus altissima* (Terrin *et al.*, 2014). Others belong to the same genus as identified invasive exotic species or with high invasion risk, such as *Pittosporum* spp., Elaeagnus spp. or *Eucalyptus* spp. This is considered as an invasion factor in the risk analysis method proposed by Weber & Gut (2004). Hence, a tightened monitoring of these species in the garden should be performed.

To better assess the efficiency of this experimental design to detect potentially invasive exotic plant species, it could be applied in other botanic gardens of the region. Even if each garden has its own singularities, the characterisation used for the Villa Thuret botanic garden is based on general criteria that can be adapted to other gardens. The collected data would provide a valuable source of information on future potential threats regarding invasive exotic plant species.

A stumbling block remains regarding the taxonomic identification of the detected seedlings. Although a seedlings herbarium helps identifying the species, some seedlings do not display enough morphological characteristics to be specifically identified. Thus, it would be interesting to use molecular techniques to address this issue, such as barcoding methods (Kress *et al.*, 2005).

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