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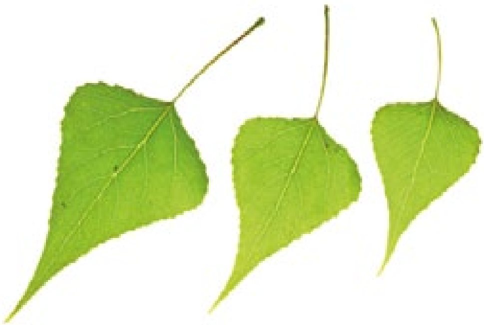

Genetically engineered trees – a ticking “time bomb”?

Report prepared by Testbiotech and Society for Ecological Research (Germany)

Dezember 2010
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STIFTUNG GEKKO
Für eine biologisch vielfältige, sichere und nachhaltige Welt

Genetically engineered trees – a ticking "time bomb"?

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Inhaltsverzeichnis

Summary

The release of genetically engineered trees into the open environment is an internationally disputed issue. Using genetically engineered poplars as an example, the following report gives clear evidence that it is not possible to adequately control the risks associated with the release of such trees, either in terms of space or time. Poplars reproduce via pollen and seed as well as vegetatively via shoots, with seed and pollen capable of spreading over very long distances. Even single events resulting from long distance distribution can be of major biological relevance, as individual trees can produce millions of pollen and seeds every year. In future, it is expected that the consequences of long distance distribution will increase significantly because of climate change.

In view of the commercial growing of over one million genetically engineered poplars in China, there is great concern about cross-pollination and hybridisation with natural poplar populations. The poplar trees grown in China are genetically engineered to produce a Bt insecticide. Due to their resistance against certain pest insects, the trees are likely to have a higher fitness compared to other trees, thus fostering their proliferation. Since these genetically engineered trees express an insecticide throughout their whole lifetime, they also pose certain risks to other organisms such as insects, the food chain and whole ecosystems such as forests. Additionally, there is a risk that pest insects will develop resistance. In the event that damage occurs after a longer period of time, the chances of completely removing the genetically engineered trees from the environment are very low.

In the light of these problems, we urge that regulations be put in place to prevent the release of genetically engineered organisms such as trees or crop plants, if there is no expectation of their successful recall. These regulations are necessary to protect biodiversity and evolutionary integrity.

A high level of precaution must be applied in the context of genetically engineered trees. Due to their high potential for spreading their genetic material, their long lifetime and importance for ecosystems such as forests, they inherently pose – as the example of poplar shows – some unique environmental risks.

1. Introduction

Research on genetically engineered trees concentrates on species such as poplar, pine and eucalyptus. The main focus is on traits such as herbicide tolerance, insect resistance and wood quality, for instance, reduced lignin content (FAO, 2004; Valenzuela et al., 2006). An article in Nature Biotechnology in 2010 (Walter, Fladung & Boerjan, 2010), refers to 700 field trials conducted with genetically engineered trees and states that the first such trees were released in 1988. In the article, the scientists summarised the current state of research and pointed out that in their opinion so far, genetically engineered trees had not caused any ecological damage and that, in general, they are associated far more with benefits than with damage.

Walter, Fladung & Boerjan (2010) cite China as an example, and explain that in this country there have been no reports of ecological damage despite the large scale cultivation of genetically engineered poplar trees:

> *„Approximately 1.4 million Bt poplars have been planted in China on an area of ~300 - 500 hectares along with conventionally bred varieties to provide refugia to avoid the development of Bt resistance in insects. The trees are grown in an area where economic deployment of poplar was previously impossible due to high insect pressure. GM trees have been successfully established and have successfully resisted insect attack. The oldest trees in the field are now 15 years old (Minsheng Wang, personal communication). No harm to the environment has been reported.“*[1]

However, Walter, Fladung & Boerjan (2010) overlook the real problems. Although there are so far no reports of ecological damage in China, without sufficient control the genetically engineered trees are likely to spread. The environmental risks inherent in this situation cannot be limited by parameters such as regional distribution, time and duration. Genetically engineered *Populus nigra* trees producing insecticide toxins were first released into the environment at the beginning of the 90s. Pest insects cause severe damage in the monocultures of huge tree plantations and forestation projects. In 2001, the transgenic trees were authorised for commercial cultivation. Hitherto, China is the only country except Hawaii that allows the large-scale commercial cultivation of genetically engineered trees.

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[1] http://www.nature.com/nbt/journal/v28/n7/box/nbt0710-656_BX1.html

2. Poplar trees – a species with surprising biological properties

The genus of *Populus* (which belongs to the *Salicaceae* – willow family) includes about 35 species (Aas, 2006). They grow in the moderate climate of the northern hemisphere. Their regional distribution encompasses many regions in China, which is regarded as a centre of biodiversity for *Populus*.[2] In central Europe, poplar are the fastest growing tree species. Naturally occurring native species are White Poplar (*Populus* alba), Black Poplar (*P. nigra*), European Aspen (*P. tremula*) as well as hybrids such as Grey Poplar (*P. x canescens* = P. alba x *P. tremula*) (Aas, 2006). In addition, Balsam Poplar (*P. balsamifera*) and Black Cottonwood (*P. trichocarpa*) as well as hybrids of Canadian poplar (*P. x canadensis*) which stem from crossing the European *Populus nigra* with the *Populus nigra* varieties from North America, are grown for commercial purposes. (Aas, 2006)

Poplar species are regarded as pioneering plants that can grow and multiply even under unfavourable environmental conditions. They readily distribute via seeds, rootsuckers or even parts of broken branches and stick cuttings. Poplars will grow almost anywhere – in old quarries, gravel pits, in sand or clay, in wetlands, mountains, plains etc. – and are amongst the first plants to re-grow after a fire. Forests of poplar trees are also found in northern regions.

2.1 Distribution by pollen and seed

In our context, it is important to note that poplar trees are wind pollinated (anemophilous). In addition, rivers and streams can transport seeds over long distances. Poplars used in forestry are between 20 and 60 years old – in plantations they are often harvested earlier. Their maximum life span is about 100 years although some species can even survive as long as 400 years. During their lifetime, poplar trees can produce huge amounts of seeds and pollen that are distributed over large areas.

A female poplar tree, for example, can produce 25 to 50 million seeds every year which leave the tree as ‚poplar wool‘ (Huber, 2010). The seeds will easily germinate where there is sufficient moisture and where there is no ground vegetation. As soon as a young poplar has survived the first six months, it can resist adverse environmental conditions such as flooding, drought, erosion or glacial periods. Under favourable conditions, the genetic material of single trees can become regionally widespread.

2.2 Propagation by rootsuckers and cuttings

Poplar trees are capable of vegetative reproduction through, for instance, root suckers. They cannot be controlled simply by cutting them down. This problem was confirmed in experimental field trials with transgenic poplars planted for the first time in Germany in 1996. After the field trials, the trees and their roots were removed from the ground. However, there are reports that even years after the trials, some shoots were popping up in the field. These shoots are even said to have invaded fields outside the area originally designated for the field trials.[3]

In addition, cuttings and branches from poplar trees can also be transported over large distances along rivers.

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[2] http://de.wikipedia.org/wiki/Genzentrum

[3] http://www.gartenforum.de/threads/6878-Nachrichten-aus-der-Pflanzenwelt?p=92783&viewfull=1

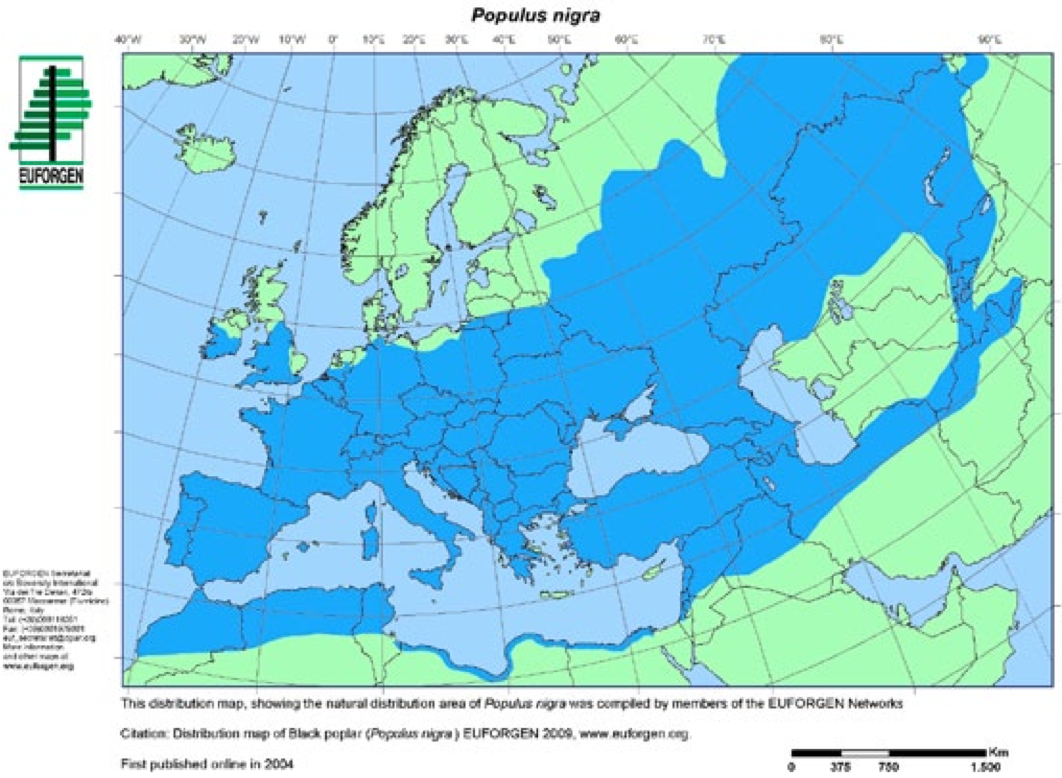
Picture 1: Shoots from roots emerge after (non-transgenic)poplar have been cut down. The rootstock of the original tree is in the background, with another shrub growing close to it. (Source: author)

2.3 Hybridisation

Poplar trees have a high potential for producing hybrids (Aas, 2006). New species which are genetically stable such as the Grey Poplar, emerged by evolutionary processes. Many hybrid forms are known and cultivated, for instance, Black Poplar (*P. nigra*) and Eastern Cottonwood (*P. deltoides*), Black cottonwood (*P. trichocarpa*) and the Canadian hybrid (*P. x canadensis*).

2.4 Gene Flow

The wind can carry the pollen from poplars from defined agricultural areas to trees growing in forests and on riverbanks. In the northern hemisphere, poplar trees are one of the most frequent tree species. In theory, genetic material from the native poplar tree populations in the northwest of China might arrive in Europe after a sufficiently long period of time. Taking into account the dispersal of pollen and seed as well as the huge biological potential for hybridisation, the Eurasian region from China up to Central Europe can be seen as a coherent ecosystem for poplar species such as *Populus nigra*. If genetic material is introduced into this ecological system its gene flow can hardly be restricted, especially if some fitness factor is related to it.



Picture 2: Natural distribution area of Popolus nigra (source: EUFORGEN)

If transgenic poplar are released in China on a large scale, the most relevant question does not seem to be *if* but *at which speed* these poplar will invade this ecological system. It is possible that the ecosystem can eliminate genes once introgressed – but there is no guarantee. Biological or geological barriers limit the natural spread of diverse poplar populations as do factors such as time of pollination, place and time of germination as well as genetic variability within the species. Specific pest insects, lesser viability of hybrids or competition between different poplar species can all be crucial for their true invasiveness. However, with transgenic poplars these factors can no longer be relied upon, especially if the trees show enhanced fitness or unexpected biological qualities that can influence their persistence and invasiveness.

Furthermore, the effects of ongoing climate change (stronger turbulences and changes in the periods of flowering and germination) might also help to overcome these natural barriers. The result would be an abundance of genetically engineered trees that could not be reliably controlled from the moment they entered the natural habitats and forests. Even one of the authors of Walter, Fladung & Boerjan, 2010, Matthias Fladung, in 2007 answered the question of what specific criteria must be observed if genetically engineered poplar trees are released by saying:

> *"Right at the top of the list is preventing vertical gene transfer, i.e. the transfer of the inserted genes to the next generation. The plants must either not flower at all or at least not produce any fertile flowers. Another factor is low (or ideally no) capacity for vegetative reproduction. Poplars have a tendency to reproduce and spread via root suckers."* [4]

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[4] http://www.gmo-safety.eu/science/woody-plants/528.genetic-perspective-potential-huge.html

3. Populus nigra and its hybrids

China now grows transgenic *Populus nigra* trees commercially, it is therefore appropriate to include a brief description of their biological potential for spread and hybridisation at this point. *Populus nigra* is an endangered species in Europe (Bundesamt für Naturschutz, 1996; Cagelli & Lefèvre, 1995). The main reason for this is the destruction of their natural habitats along the big rivers (Aas, 2006).

They are also endangered because other poplar species are grown in Europe such as the Canadian hybrids *P. x canadensis* that can produce hybrids with P.nigra (Aas, 2006; Cagelli&Lefèvre, 1995). *P. x canadensis* grow faster, have many uses and are therefore favoured by forestry. Globally, certain clones and varieties of Canadian *P. x canadensis* are the dominant species in the poplar plantations. (Aas, 2006).

Biologists have described the process of introgressive hybridisation. This implies that there is an increasing tendency for the DNA of other poplar species to be mixed with the genome of *P. nigra*. It is possible for several crosses and re-crosses between hybrid poplars and P.nigra to occur. As a result, it may no longer be possible to distinguish clearly between the two original species.(Aas, 2006). DNA analysis can be used to determine the degree of hybridisation and to enable the identification of the remaining native populations of *P. nigra* (Csencsics et al, 2005). Vanden Broeck et al. (2004) and Ziegenhagen et al. (2008) found, for example, evidence of *P. nigra* and *P. deltoides* hybrids in field conditions. Ziegenhagen et al (2008) found that 20 percent of the juvenile trees in the area they investigated were hybrids.

In Germany, as well as on a European level, there are programmes to stop further introgressive hybridisation and to preserve *P. nigra* as a distinct species. This species is especially relevant for the ecological systems of riparian zones (Schirmer 2006, Huber, 2009). On a European level, conservation efforts are coordinated by the "*Populus nigra* Network" of EUFORGEN.[5]

In contrast to Europe, *P. nigra* is a neophyte in Canada, where it shows potential to invade native species such as *P. deltoides*. As expected, *P. nigra* shows a significant potential for hybridisation with the Canadian species (Natural Resources Canada, 2009; Pospíšková & Šálková, 2006).

The introduction of new poplar species or hybrids can trigger a highly complex and dynamic response, as the example of *P. nigra* shows. This makes it difficult to judge their potential for invasiveness and persistence. Of course, this is also the case with genetically engineered poplar trees. Thus, the feasibility of recalling transgenic *P. nigra* that may be able to propagate and hybridise with native tree populations is highly questionable.

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[5] http:// www.euforgen.org

4. Investigations in China

In China, several experiments involving several species/varieties of poplar as well as eucalyptus and other trees were performed to produce genetically engineered trees. Scientists tested insect resistance, stress resistance, salt resistance, changed content in lignin and disease resistance. In many regions, they experimented with field releases (Wang, 2004; Su et al., 2003). These regions included coastal areas as well as regions along the river Yangtze and the northwest province of Xinjiang (Wang, 2004; Pearce, 2004).

Insect resistant poplar trees are the most widely distributed. Two year-old transgenic *Populus nigra* were planted in Xinjiang on just over two acres of ground as far back as 1994. In 1998, just over 97 acres were planted in the Beijing, Jilin, Shandong, Jiangsu, Henan, Shanxi and Xinjiang provinces. In 2001/2002, commercial cultivation was allowed and by 2004, 740 acres had been planted (Wang, 2004; Walter, Fladung & Boerjan, 2010).

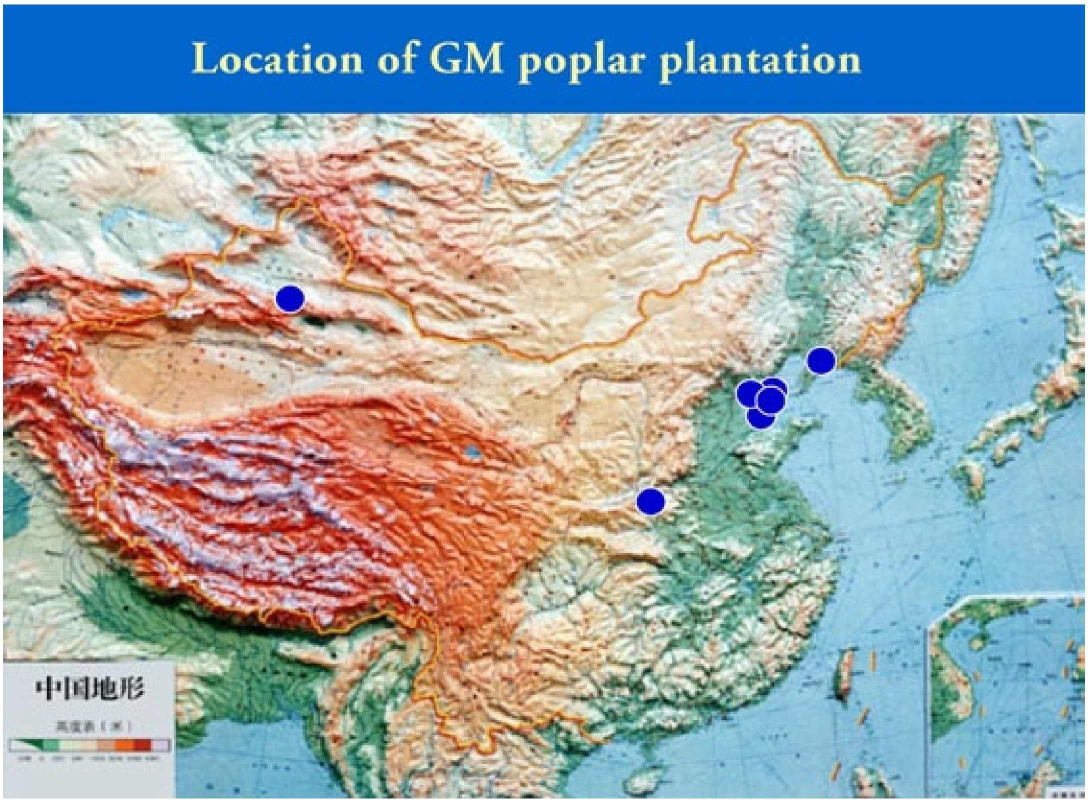
It is estimated that there are about one million genetically engineered *Populus nigra* trees with shortened DNA expressing the Bt toxin classified as Cry1Ac (Wang, 2004; Su et al.; 2003; Wang et al., 1996). Further, about 400 000 other hybrids of white poplar (known as hybrid poplar 741) that also express Bt toxins were propagated and planted between 2001 and 2003. These hybrids are supposed to be unable to germinate under normal conditions (Wang, 2004).

In many cases, the exact locations of release for experimental or commercial purposes are unknown. As Wang (2004) says, the trees are also distributed via regional markets. Poplar trees are easy to propagate from cuttings, therefore there is unlimited potential for distribution:

> *„However, the accurate area of GM plantations cannot be assessed because of the ease of propagation and marketing of GM trees and the difficulty of morphologically distinguishing GM from non-GM trees. A number of individual nursery-men at markets declare that their planting materials are GM trees produced through high-tech, for a higher price. Consequently, a lot of materials are moved from one nursery to another and it is difficult to trace them.“*

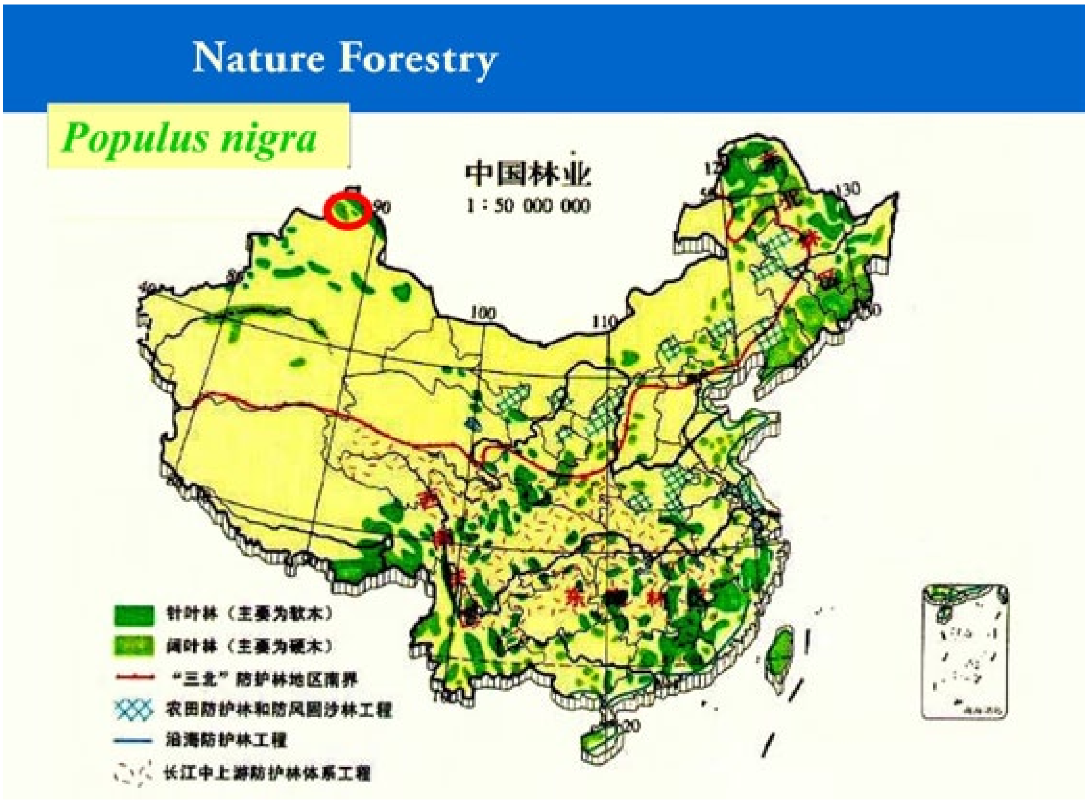
In the northwest province of Xinjiang, where transgenic *Populus nigra* were released in 1994, there were, by 2004, already reports of hybridisation in other poplar trees. (Pearce, 2004). This was also the first region where systematic studies were conducted to assess the invasiveness of the transgenic poplar (Lu et al., 2006). The focus of these field studies was on the spread of their pollen into nearby plantations with other (non-transgenic) poplars. Hybrids between genetically engineered *Populus nigra* and *Populus pioner* were found up to a distance of 500 meters. Overall, the scientists concluded that the trees would not spread widely, because the frequency of cross-pollination was low. This is a statistical finding, which probably originated from competition with pollen from other poplar trees. There were 1000 non-transgenic male poplars compared to 22 transgenic trees.

Further, it was observed that due to the arid conditions in that specific region, the rate of germination and survival of seedlings was very low. In their overall conclusion, Lu et al (2006) state the transgenic poplars are unlikely to spread into native tree populations and forests under these conditions.



Location of GM poplar plantation

Picture 3: Cultivation of genetically engineered poplar in China. Source: Powerpoint presenting the findings of Lu et al. 2006.



Nature Forestry

Populus nigra

Picture 4: Abundance of native poplar tree populations in China. Source: Powerpoint presenting the findings of Lu et al. 2006.

5. Spread of transgenic trees

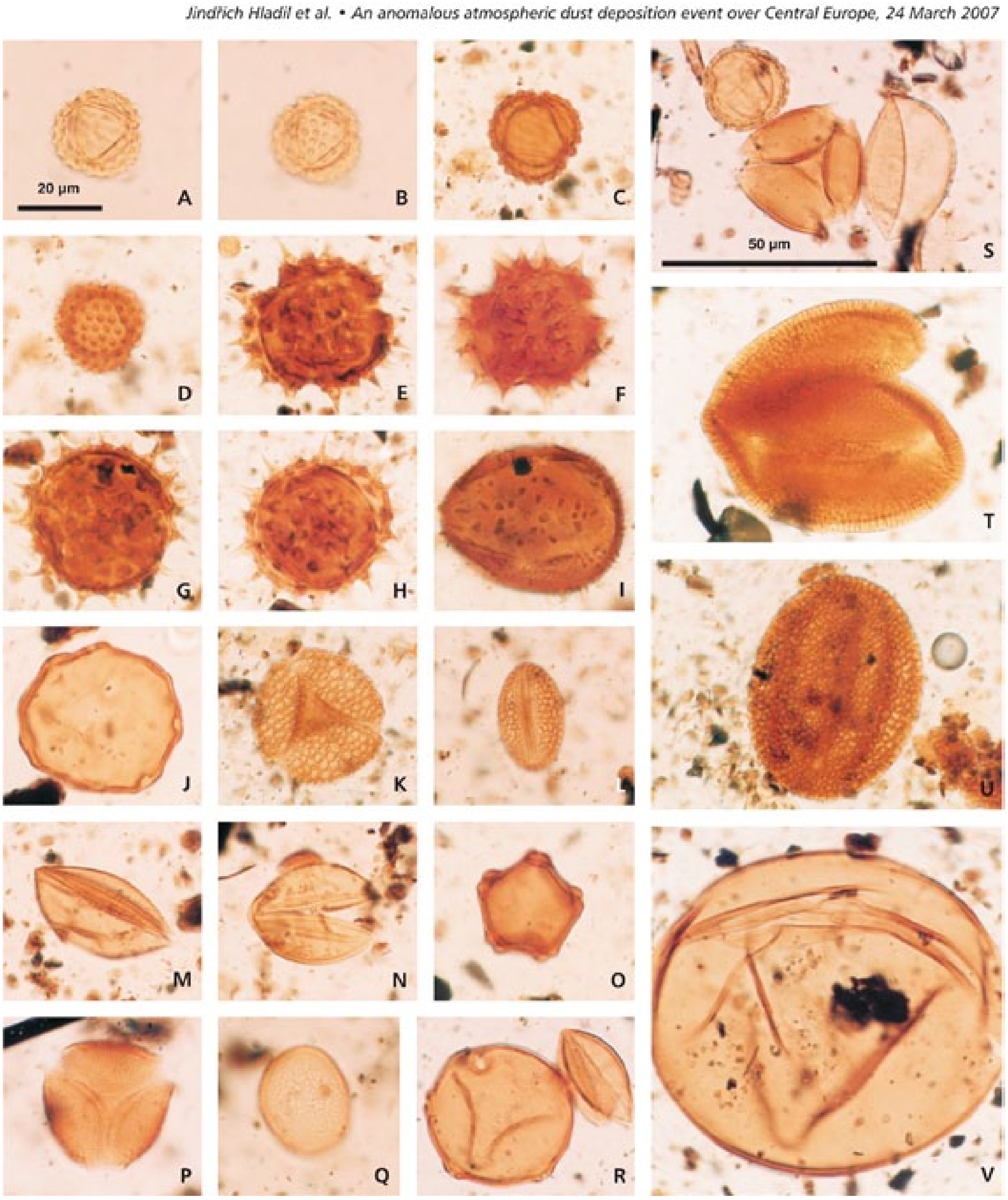
As several publications show, the findings of Lu et al (2006) are inadequate for conclusions on the potential of transgenic poplar to spread into the environment. DiFazio et al., 2004, who did a case study on the invasiveness of transgenic poplars, concluded that there is great cause for concern. According to DiFazio et al. (2004), the long-term spread of genetically engineered trees cannot be judged on data derived from short distances. The long distance transfer of seed and pollen is of more importance because although it is rare, it has a high statistical chance of happening. These single events may be decisive for true invasiveness in the long term. Further, the authors (DiFazio et al., 2004) expect a higher viability factor for poplar that produce insecticides and therefore have less infestation of defoliating insects. Burczyk et al., (2004) refer to DiFazio et al. (2004) and conclude:

> *„In so doing, we confirmed the previously suspected importance of rare, long-distance dispersal events in determining impacts of transgenic plantations, and the strong influence of transgenic competitiveness and habitat availability in determining extent of transgene movement (...). The model also yielded some surprising results, including: Herbicide tolerance had little effect on gene flow from hybrid plantations, and only marginal effects on transgenic poplar establishment in agricultural fields. In contrast, insect resistance had the potential to greatly enhance gene flow when insect pressure was high.*"

Bialozyt et al. 2006 also warns of the dangers of long distance transportation of pollen and seeds. They state that there is insufficient empirical data for poplar species (at least before 2006) showing the actual dispersal of pollen in relation to certain types of landscape. Their computer simulation shows that once DNA is introduced into native populations it can persist for more than 1000 years, depending on the number of trees producing pollen and the occurrence of suitable recipient populations.

Recent investigations show that both the short and long distance transportation of seed and pollen are relevant. The pollen and seeds of poplar are distributed by the wind, a high proportion of which is deposited in the surrounding countryside within a distance of 1000 meters (Rathmacher et al., 2010). As their investigation along the river Elbe (Germany) shows, 4 percent of the poplar pollen and 1 percent of the poplar seeds travelled over distances of more than two kilometres. Considering the enormous number of seeds – 25 to 50 million – these percentages have high biological relevance. Fertilization even occurred at distances of over eight kilometres from the trees releasing the pollen, and seed was found to travel over distances of more than six kilometres (Rathmacher et al., 2010). There should be no misunderstanding that these figures show the highest possible regional distribution.

Atmospheric transportation also plays a role in the dispersal of poplar pollen. For example in 2007, a remarkably high count of poplar pollen was found in a huge atmospheric cloud of dust drifting over an area of more than 2000 kilometres, stretching from the Ukraine to Central Europe (Hldail et al., 2008). It is disputable as to whether the pollen is still fertile after being carried over such a long distance, but there are investigations regarding pollen from pine and oak that show that pollen can still be fertile even after being transported over many kilometres (Williams, 2010; Bohrerova, et al., 2009; Schueler et al., 2005). It should not be overlooked that a single event can give rise to an individual tree that can produce millions of pollen and seeds every year.



Picture 5: Part of an atmospheric transportation – detail showing pollen from poplar (Q) and other plants.
Source: Hldall et al., 2008

McInerny et al., 2009, show that climate change can have an impact on evolutionary processes in several ways. When temperatures rise, air turbulence increases so that seed and pollen are transported over longer distances and into higher regions of the atmosphere. The proportion of pollen in aerosols that is transported over long distances through the atmosphere is already considerable (Poeschl, 2006). In general, climate change is expected to contribute to increasing emissions of pollen, a longer duration of pollen dispersal (caused inter alia by a shift in the period of flowering) and a higher number of seed and pollen being transferred over longer distances (Graetz, 2009). In addition, flooding of large areas will occur more often. Also a higher number of pollen or seeds can be produced by certain species (Williams, 2010).

In this context, it is not only the amount of pollen and seed that is decisive – single events can result in significant effects. The importance of the transferral of just a single seed and pollen is known from paleobotany. Research by Liepelt et al. (2002), shows that these single events were decisive for the development of the ecosystems after the glacial periods. Using silver fir, which has relatively heavy pollen as an example, they were able to demonstrate the flow of genetic information between refugia separated by long distances:

> *„Our results provide striking evidence that even a species with very long generation times and heavy pollen grains was able to establish a highly efficient pollen-mediated gene flow between refugia. Therefore we postulate that an exchange of genetic information between refugia by range-wide paternal introgression is possible in wind-pollinated plant species.“*

The investigations of Lu et al. (2006) take neither a sufficiently long time period into account nor do they mention the impact of climate change on the long distance transportation of pollen and seed or the significance of single events. Therefore, the investigations are inadequate for the assessment the long-term dispersal of pollen and seeds from transgenic poplar trees.

There are reports that the poplar trees being growing commercially are female and show a changed potential for germination. (see for example World Rainforest Movement, 2008). However, this is not mentioned in relevant scientific publications (Su et al., 2003; Wang, 2004; Lu et al., 2006). Further, the Lu et al. (2006) publication shows that there are at least some transgenic poplar trees producing viable pollen. If female trees are being used in commercial cultivation, the dynamics of their invasiveness will be governed by seed dispersal and the rate of germination. There is likely to be a high rate of fertilisation and hybridisation since the transgenic poplars grow close to other populations of poplar trees. The rate of seed germination will depend on regional factors. It is difficult to judge specific geo-ecological conditions because transgenic poplars with various traits were released in many regions of China without sufficient documentation of the precise sites (Wang 2004; Pearce, 2004). In addition, one has to take into account the propagation and distribution of material such as cuttings sold at regional markets (Wang, 2004). Overall, Wang's statement made in 2004 that the gene flow of the transgenic poplar cannot be controlled seems to be correct:

> *„It is almost impossible to reduce the risk of gene flow from GM trees to non-GM trees through isolation distances because of the ease of natural hybridization between poplars of the same section, and poplar trees are so widely planted in northern China that pollen and seed dispersal cannot be prevented.“* [6]

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[6] Wang, 2004.

Mature seeds

Picture 6: Poplar seed covering the ground in poplar plantations in China. Source: Powerpoint presenting the findings of Lu et al., 2006.

6. Environmental risks of cultivating transgenic poplar trees in China

The poplars cultivated in China carry high environmental risks. Poplars that can reproduce by seed and pollen can hardly be controlled in their regional distribution and persistence. Moreover, those hybrids where the supposition is that they will not germinate (Hybrid Poplar 741), pose substantial risks to the ecosystems.

Transgenic poplars are grown in plantations in China for their wood (Wang, 2004). At the same time poplars are also part of the Great Green Wall project to combat increasing desertification (FAO, 2009). Recommendations state that transgenic poplars are harvested before flowering (Wang, 2004) but so far, no reports on the harvesting of the transgenic trees have come to light. On the contrary, Walter, Fladung & Boerjan (2010) reported that some transgenic poplar trees are meanwhile 15 years old. Even if they are cut down, a new generation of transgenic poplars is likely to grow from suckers growing out from the rootstocks.

The environmental risks of large-scale transgenic poplar cultivation can only be partially assessed (for general discussion about risk assessment of transgenic trees see: Steinbrecher & Lorch 2008). Long-term cultivation increases the chances of pest insects adapting to the Bt toxin produced by the plants. Experience from the cultivation of Bt cotton and Bt maize shows that pest replacement as well as resistance and/or tolerances to the Bt toxin may arise (Then, 2010). Bt poplars are grown alongside non-transgenic trees, possibly delaying the emergence of resistances. If this is the case, the transgenic poplars will have a higher fitness in comparison to the other trees, thus conceivably fostering their invasiveness in the mid- or even long term.

The risks for non-target organisms, ecosystems and the food web – even beyond the areas where the poplars are gown – are difficult to assess properly. This is because not all the relevant details of how the Bt toxins work are understood. Efficacy and selectivity of the toxins can be influenced by synergism with additional factors (Then, 2009). If the Bt toxins are secreted by the roots – as is the case with Bt maize, (Saxena et al., 1999) there might be an impact on the soil organisms and mycorrhiza. Decomposed plant material such as leaves and other parts of the trees become part of the biological chain through humus formation.

Additionally, organisms that developed in co-evolution with poplars such as fungal organisms or arthropods can be affected in an unpredictable manner. On a higher level of the food web, even vertebrates feeding on insects within these ecosystem, can be impacted or their populations severely damaged. Indeed, it is known that the ecosystems within the plantations of transgenic poplar are in fact significantly changed in their structure:

> *„It was found that there were significant differences between the GM and non-GM plantation stands in terms of species composition, dominance and community structure of defoliating insects and their natural enemies.“ (Wang 2004)*

Unintended effects caused by the insertion of the additional gene sequences have to be taken into account as well. Trees live much longer than crop plants, increasing the risk of genetic instability (Pickardt & Kathen, 2002). It is not possible to predict whether technically introduced gene constructs will still function in the same way after 10, 20, 50 or 100 years as they did in the first few years of the tree's life. Artificially inserted gene constructs have a higher potential to escape normal gene regulation than those within the native genome. There have been no investigations concerning their reactions under changing conditions such as growth, flowering and ageing of the trees or interactivity with environmental stressors. There are several publications showing that genetic stability is not reliable (Van Frankenhuyzen & Beardmore, 2004; Ahuja, 2009). Unexpected effects in genetically engineered poplars were also observed in experimental field trials in Germany, with the trees flowering at earlier stage than their native counterparts (Fladung et al., 1997).

If the technically inserted gene constructs emigrate to native poplar populations, those additional genes will encounter a much greater degree of genetic diversity in the various species and populations – much greater than that in trees that have for years been cultivated and cloned for uniformity. It is not possible to predict interactivity between the additional DNA and the genomic background of the individual native trees. For example, their resistance to certain diseases or environmental stressors might be lowered if their metabolism is disrupted by the newly introduced genes, proteins or related metabolites.

7. Conclusions and recommendations

Due to their potential for spreading in an uncontrolled manner, there is a high chance that the native gene pool of poplar will be impacted by gene flow from transgenic trees. There are similar cases where, for instance, the cultivation of genetically engineered rape seed in North America became uncontrollable (Gilbert, 2010), and the potential contamination of maize seed in the country of origin (Quist & Chapela, 2001). In conclusion, the situation in China can be considered an environmental ‚time bomb' bearing various environmental risks. If damage becomes apparent, there are no efficient measures that can be taken to remove the trees from the environment. This can have a substantial impact on biodiversity in China where there is great diversity in poplar trees (FAO, 2009).

This is an experiment with potentially harmful consequences for ecosystems, and which may have an impact on evolution for thousands of years (see for example Bialozyt et al., 2006). The possible negative consequences cannot be properly assessed and might be a matter for further investigations and discussions. It is inconceivable that no one should take *responsibility* for this kind of experiment with its unlimited duration. If there is some damage then there is a high likelihood that there will be no way to recall or remove transgenic poplars from the environment.

The example of genetically engineered poplar illustrates the need for implementing better regulation of experimental field trials and cultivation of genetically engineered organisms. In general, genetically engineered organisms and similarly synthetically produced organisms, should not be released into the environment if there are no efficient methods available to withdraw them if necessary. The long-term consequences of releases are uncontrollable so that prevention is the only appropriate measure.

Generally, the actual risks should not be ignored or be presented as having only minor relevance as is the case with Walter, Fladung & Boerjan (2010) or Valenzuela et al. (2006). For example, Valenzuela et al. (2006) argue that the environmental risks are minimal because, in this case, the consequences are only relevant for trees (and forests), but not for the production of food.

> *"The use of transgenic trees in the forestry sector, has very different objectives than those used for crops. They are mainly based in improving wood quality, so as to diminish the pressure on the land. The genes involved in these processes are quite specific and are mainly present in trees,, therefore its possible escape to the environment does not have a major risk." (Valenzuela et al., 2006)*

In the light of recent applications for the deliberate release of genetically engineered trees, there is doubtless an urgent need for regulation. In general, the problems with wind pollinated genetically engineered trees are very similar regardless of whether they are pine or oak. Likewise, other forms of pollination as, for instance, from transgenic eucalyptus, bear similar risks to the environment.

Preventative measures must protect biodiversity and the integrity of biological systems from releases that cannot be withdrawn with sufficient expectation of success. Similar concepts have already been established for chemical compounds that can persist and accumulate in the environment (see Breckling, 2008).

A high level of precaution and prevention is prerequisite in the context of genetically engineered trees. As the example of poplar tree shows, these plants inherently pose huge risks for the environment due to their propensity for propagation and dissemination, their long lifetime and their importance for ecological systems such as the forests.

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