1 Field Trials with Transgenic Trees – State of the Art and Developments

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1.1 Introduction

Research and development on transgenic trees differs from such work carried out on herbaceous model systems first in that it necessarily involves field trials if data on aspects of the mature plant are required. Second, in contrast particularly to field tested transgenic agricultural crops, GM tree field trials are bound to be extended with the same plant individuals over longer than one single vegetative period and can last many years.

Given this, and taking into account the fact that in all cases a large amount of work has to be done before beginning any work beyond the test tube stage in the growth room and a potted plant in a greenhouse, the development of field trials and field releases worldwide is expected to be an indicator for overall development in the field of forest biotechnology.

1.2 Transgenic Trees in Test Tube and Field Trials

A field trial is expected to document in itself a well-developed research project that has led past various testing phases in lab based work to a stage in which the tree can be taken to the next round of tests in the field. It is, however, not just the success of the primary lab-based work that, under consideration of all the other factors, influences what happens in the field. The success of the field trials will also determine whether in the future more work is invested in the lab-based work. The dimensions of field releases of transgenic trees in trials can therefore only with great care be seen as a direct, simple function of the progress made in development in the lab. Many other factors come into the equation.

The closer research and development with transgenic trees gets to the field trial or release and thus the closer it gets to structures of primary production in "classical" forestry, the more it carries on some of the burdens of technical "peculiarities" and socio-economic involvements that are typical for forestry

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worldwide. On the technical and economics side, long production times can be identified that on the one hand cause a low return – whether in a classical management scenario or in the development of a new GM-tree based product – and on the other hand delay the progress of research and development considerably (Speidel 1984). On the social side the involvement of many stakeholders is typical and is found in either, e.g. the afforestation of a stand near a settlement or the start of a field trial (Köpf 2002).

This latter point is well reflected in the fact that a transgenic tree, if studied as a "tree" rather than a "seedling-like plantlet in a test tube" with the release of a transgenic plant in the long term and some potential environmental implications causes a great deal of concern to the public, as documented in a flood of non-technical and newspaper articles, media reports, political and lobbying activities and in some cases vehement protests (Arthur 1999; Highfield 1999; Miller 2003).

Keeping in mind the aforementioned limitations, the number and type of field trials, and the development of these data over time give an impression of both, work on GM trees already carried out successfully at an earlier stage of the development process, but also gives an impression on what further research may build up and, if in the context of present economic and political developments, into what directions future work may be pushed. In the following it is attempted to provide an overview of past and present field trials worldwide, with the aim of developing an image that allows some insight into the future developments that may shape work on transgenic trees.

The global situation regarding releases of transgenic trees to the field is nowhere documented completely and in detail. The main reason for this is a distinct lack of data and information. This is partly due to the nature of some data as "confidential business information" as in recent years a large percentage of field releases were carried out by the Research and Development labs of large forest companies, particularly outside Europe. Some companies, when approached by researchers or journalists, clearly stick to a "no-information" policy, leaving requests ignored and questions unanswered.

Obtaining information is in many cases a particular challenge, as the respective companies are often joint ventures between various other firms, often in the pulp and paper industry, or other industrial branches and are subject to frequent change by merger, takeover, sale, closure, re-naming etc. or partners leaving the joint venture. Under such circumstances it can also be difficult to trace back the historic continuity of work carried out by individual companies. This is true not only specifically for firms that carry out GM work on trees, but also for other companies in the field of industrial and plantation forestry (Carrere and Lohman 1996).

Some insight however is possible due to the legal and administrative structures in some countries that require permission for field trials and list releases together with some limited information in publicly accessible databases.

Therefore, for the following overview several sources that are quite different in nature have been used. For the US there is a detailed database listing all applications for permission, and respective notifications of a field release of a transgenic organism, which also includes trees (http://www.aphis.usda.gov/brs/status/BRS_public_data_file.xls). Equally detailed is the Canadian database published for all field releases of transgenic plants online at http://www.inspection.gc.ca/english/plaveg/bio/triesse.shtml. The same field releases are also partly covered in a database that lists the equivalent applications for Europe, US, Canada, Australia and New Zealand that is provided by OECD (Organisation for Economic Co-operation and Development) (http://www.olis.oecd.org/biotrack.nsf). The situation in the EU is separately documented in an EU database (http://biotech.jrc.it/deliberate/dbcountries.asp and http://gmoinfo.jrc.it/gmp_browse_geninf.asp).

While these databases are thought to be comprehensive, they do not give any specific information on the size of the respective field trial nor on whether this trial has in the end actually been carried out, or indeed at what point in time it has actually been terminated. They also do not show, whether an application for or a notification of a field trial is for a completely new experiment or simply the continuation of an earlier experiment with plants of the same type – or even the same plant specimens.

However, the regulative frameworks in many countries are at present still being developed. In these cases information was sought on work carried out in the respective country via academic networks. This data is backed up with information from scientific publications, non-technical publications and newspaper articles, environmentally concerned publications as well as personal communication with researchers and persons involved in environmental NGOs (non-governmental organization). It is an inherent problem of the evaluation of a range of diverse sources that the information obtained may in some cases not match or even be contradictory.

In this overview, first work on forest trees is covered. This includes species whose traditional use falls in either of the three classical functions of managed forests: production of timber and non-timber forest products, protection of the landscape, and the recreational function (Dieterich 1953). Trees whose main function is the production of fruit are discussed in a separate section. In addition there are also a few examples of genetically engineered trees in field trials, whose potential economic application is in the production of an entirely new product or service that is only tenuously linked to the traditional use of trees in forestry and fruit farming.

There are a few examples of transgenic trees that have been genetically modified to improve their use for ornamental, landscape or environmental purposes, which however do overlap with the function of creating a more productive forest crop. There is one field trial documented for *Amelanchier*, which has mainly ornamental use. In numbers such trials however are completely irrelevant and are mentioned here solely for completeness.

1.3 Transgenic Trees for Improvement of Forestry

1.3.1 Northern America

The region in which the largest number of field trials on transgenic trees has been carried out is North America.

Even though a country with traditionally strong research in forest biology, the share of field releases of transgenic trees in Canada is small. The Canadian database lists for 1997 a poplar with an antibiotic resistance released in Quebec (the only one found also in the OECD database), for 1998 a submission for herbicide tolerant poplar in Alberta, and from 2000–2004 two submissions for black spruce with selectable marker genes, an insect-resistant white spruce and a poplar with a selectable marker. These trials are well covered in the non-technical media. A "National Post" article of 2003, for example, covered a planned field trial with transgenic trees (Jack 2003). The trial comprises 400 transgenic spruces and poplars planted out in a forest near Val Cartier, Quebec. The article pointed out that there were as yet no commercial plantings of transgenic trees in Canada, but that the development by now had reached a point at which use in commercial plantations was within reach. This work was also publicised in CBC (Canadian Broadcasting Corporation) News (2003), quoting Armand Séguin of the Canadian Forest Service, according to whom this was the only field trial with transgenic trees in Canada.

The vast majority of field trials in North America to date took place in the US, for which the database (March 2005) documents about 185 applications respectively notification for releases of genetically engineered forest trees (Table 1.1).

Table 1.1. Present number of field trials with transgenic fruit and forest trees comparing Europe and North America

	Fruit trees Europe	Forest trees Europe	Fruit trees North America	Forest trees North America
Marker	–	7	3	45
Herbicide resistance	–	3	–	45
Insect resistance	–	1	13	15
Disease resistance	11	1	47	12
Sterility	–	1	3	28
Lignin	–	8	–	27
Developmental	6	4	3	27
Heavy metal	–	3	–	6
Fruit quality	–	–	21	–
Other	4	2	3	5
Total	21	30	94	212

For comparison in this paper these trials were grouped according to the nature of the altered trait (herbicide tolerance, insect resistance (Chap. 12), disease resistance (Chaps. 10 and 11), sterility or altered fertility (Chap. 2, Sect. 2.4), lignin content (Chap. 5), developmental traits, heavy metal tolerance (bioremediation, Chap. 7), or other traits. A clear change over time in the type of traits for which field trials were applied for respectively notified could be observed.

The work on *herbicide resistance*, for example, so far "peaked" in 1999 (Table 1.2) with the number of trials for this trait decreasing since. With the long term investments that forestry naturally involves (Speidel 1984), the altered trait has to be of potentially high economic significance. This may partly explain, for example, the reduction of experiments on transgenic trees with herbicide resistance. The then director of Weyerhaeuser forest biotechnology was quoted in a 2002 article in *Science* (Mann and Plummer 2002) with the comment that herbicide application in the forest industry "*is not that large of an expense*". Shifting to different herbicides if necessary may therefore, in the long run, be more economic than generating trees resistant to one particular to allow its extended use. Furthermore, the use of herbicides is a classical environmental issue and hence likely to form a focal point of public criticism.

Table 1.2. Applications and notifications of field trials using transgenic forest trees in the US. The category "other" includes work on gene stability and thus reflects also work on safety aspects. In most cases a release of a plant with a specific trait of interest is accompanied by a release of plants with markers or plants may have more than one trait, including the (visual) marker

Year Type of trait	'89	'90	'91	'92	'93	'94	'95	'96	'97	'98	'99	'00	'01	'02	'03	'04	'05
Marker	1	–	–	–	–	–	–	–	1	1	4	6	10	4	21	31	8
Herbicide resistance	–	–	–	–	–	1	1	1	2	7	13	7	3	7	2	2	1
Insect resistance	–	1	1	–	1	–	–	–	2	3	1	5	1	3	–	11	–
Disease resistance	–	–	–	–	–	–	–	–	2	3	2	1	–	–	1	4	–
Sterility	–	–	–	–	–	–	1	–	1	–	–	2	4	–	6	17	–
Lignin	–	–	–	–	–	–	–	–	–	2	–	2	–	–	6	10	4
Developmental	–	–	–	–	–	–	–	–	–	1	1	–	–	1	4	16	4
Heavy metal	–	–	–	–	–	–	–	–	–	–	–	–	1	–	2	3	–
Other	–	–	–	–	–	–	–	–	1	1	–	–	–	1	–	7	1
Total	1	1	1	–	1	1	2	1	9	18	21	23	19	16	42	10	18

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