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Green Technology for the Clean Up of the Environment- A review

Mohsen Gholamali Majdabadi
Department of Agriculture, Sciences and Research Branch, Islamic Azad University, Tehran, Iran

ABSTRACT– The use of plants is called Phytoremediation to clean up and eliminate environmental pollution. Yet, the detoxification of organic pollutants by plants is often slow, leading to heaping up of toxic substances that could later get free across environment. A current publication by Doty et al describes the development of transgenic poplars (Populous) describing a mammalian cytochrome P450, an enzymes family usually contributes in the metabolism of toxic material. The engineered plants revealed boosted performance in relation with metabolism of trichloroethylene and the elimination of a range of other toxic volatile organic pollutants, including vinyl chloride, carbon tetrachloride, chloroform and benzene. Such work reveals that transgenic plants might be able to play role for the wider and safer utilization of phytoremediation.
KEYWORDS: Polyaromatic, Cytochrome, Green Technology

Introduction

Herbs and Plants are autotrophic organisms able of utilizing sun emitting radiation and carbon dioxide as energy and carbon sources. But plants depend on the root system to take up water and other nutrients, like nitrogen and minerals, from soil and groundwater. As a side effect, plants also absorb a series of natural and human prepared lethal or toxic compounds for which they have developed different types of detoxification mechanisms [1]. Pollutant degrading enzymes in plants probably come out from natural protecting systems against the types of allelochemicals freed by competing organisms, including microbe's insects and other plants [2]. Through this perspective, herbs and plants can be looked as natural, solar-powered pump-and-treat systems for cleaning up polluted and contaminated environments, guiding to the phytoremediation concept [3]. Initially developed for the removal of heavy metals from soil, the technology has since been acknowledged to be efficient for organic compounds treatment including chlorinated solvents, polyaromatic hydrocarbons as well as explosives [3, 4]. Beyond the elimination of contaminants from soil, phytoremediation passes through different processes, like enzymatic degradation, that potentially ends to contaminant detoxification (Figure 1).[5–3] Therefore, despite great promise, rather slow removal rates and potential accumulation of toxic materials and substances in the plants might have limited the application of phytoremediation .[1]In a current investigation, Doty et al. [6] have developed transgenic poplars with a boosted uptake and metabolism of toxic volatile pollutants. In such practice, they have provided a technology that is likely to lead to the wider utilization of phytoremediation in the scope.

From polluted soils to 'toxic

plants' In comparison with other clean-up technologies, phytoremediation has potentially many advantages, including low installation and maintenance costs, less disruption of the environment and other beneficial side effects such as carbon sequestration and biofuel production .[5,6]However, phytoremediation also suffers from several limitations, among which the most commonly evoked are the slow rate of removal, incomplete metabolism and potential increase in bioavailability of toxic contaminants [1,3]. Indeed, in the absence of significant detoxification, parent compounds and toxic metabolites can accumulate inside plant tissues and eventually return to the soil or volatilize into the atmosphere. The recognition that plants can transform xenobiotic compounds emerged in the 1940s, when plants were shown to metabolise pesticides [7]. Since then, the development of genomics, proteomics and metabolomics has exposed the plant metabolism of many xenobiotic compounds.[1] Plants often use pathays and enzymes similar to those of mammals, which led to the 'green liver' concept (Figure 2) [7]. However, being autotrophic organisms, plants do not actually use organic compounds for their energy and carbon metabolism. As a consequence, they usually lack the catabolic enzymes necessary to achieve full mineralization of organic molecules, potentially resulting in the accumulation of toxic metabolites [1]. Hence, the idea to enhance plant biodegradation by genetic transformation was developed, following a strategy similar to that used to develop transgenic crops.[1,5]

Transgenic plants for phytoremediation

Typically, transgenic plants exhibiting new or improved phenotypes are engineered by the overexpression and/or introduction of genes from other organisms, such as bacteria or mammals. Being heterotrophs, bacteria and mammals possess the enzymatic machinery necessary to achieve a complete mineralization of organic molecules; bacterial and mammalian degradative enzymes can therefore be used to complement the metabolic capabilities of plants [1]. Historically, transgenic plants for phytoremediation were first developed in an effort to improve heavy metal tolerance; for example, tobacco plants (Nicotiana tabacum) expressing a yeast metallothionein gene for higher tolerance to cadmium, or Arabidopsis thaliana overexpressing a mercuric ion reductase gene for higher tolerance to mercury [8,9]. The first attempts to transform plants for phytoremediation of organic compounds targeted explosives and halogenated organic compounds in tobacco plants However, although tobacco and A. thaliana are good laboratory models, their small stature might not be suitable for field applications. Hence, there is particular interest in the genetic transformation of poplar trees (Populus sp.), which are fast growing plants with high biomass – ideal attributes for phytoremediation. Plant transformation is usually performed using the 'natural genetic engineer' Agrobacterium tumefactions, a plant pathogen that has become the favorite vector for gene transfer to plants [12]. However, A. tumefaciens-mediated transformation of forest trees is notoriously challenging, which explains why there have been only a few reports about the genetic modification of poplar plants [13]. Gullner et al. [14] developed the first transgenic poplars for phytoremediation. Their transgenic line was designed to treat chloroacetanilide herbicides by the overexpression of a gamma-glutamyl cysteine synthetase, an enzyme involved in glutathione synthesis.

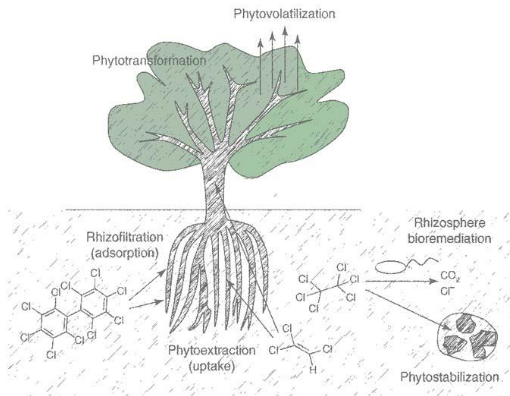

Figure- 1 Beyond the removal of contaminants from soil, phytoremediation involves different processes

Poplar trees overexpressing a mammalian

Cytochrome P450 Cytochrome P450s constitute a large enzyme superfamily commonly involved in the metabolism of toxic compounds. In 2000, Doty et al. [11] described the development of transgenic tobacco plants expressing a human cytochrome P450 and capable of metabolizing trichloroethylene (TCE) 640-fold faster than wild type plants. The same group later reported the introduction of a rabbit cytochrome P450 in transgenic hairy root cultures of Atropa belladonna, which also exhibited a faster metabolism of TCE [15]. In the current study, Doty et al. [6] described the genetic transformation of hybrid poplar plants (Populus tremula _ Populus alba) overexpressing mammalian cytochrome P450 2E1 (CYP2E1). The engineered trees were capable of the enhanced metabolism of five volatile toxic compounds: TCE, vinyl chloride, carbon tetrachloride, chloroform and benzene. Among the different transgenic clones tested, the most efficient one, line 78, expressed CYP2E1 at a 3.7- to 4.6-fold higher level and exhibited the highest level of TCE metabolism (>100-fold higher than in non-transgenic controls). When cultivated in hydroponic solution spiked with toxic compounds, line 78 was capable of extracting _90% of TCE (compared with <3% extracted by non-transgenic controls), 99% of chloroform (Compared with 20% by controls) and 92–94% of carbon tetrachloride (compared with 20% by controls). Enhanced metabolism of organic pollutants in transgenic plants is associated with a faster uptake, which can be explained by a steeper concentration gradient inside plant tissues [10,11,16]. Transgenic plants were also shown to remove volatile compounds from contaminated air at a higher rate than non-transgenic controls: 79% of TCE (none removed by controls), 49% of vinyl chloride (compared with 29% by controls) and _40% of benzene (compared with 13% by controls). All the five compounds under study are listed as Priority Pollutants by the U.S. Environmental Protection Agency (EPA) and figure in the top 50 of the 2005 Priority List of Hazardous Substances defined by the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) . These compounds are as follows: TCE, the most prevalent soil pollutant found in the United States; vinyl chloride, a dead-end carcinogenic compound produced from TCE biodegradation; carbon tetrachloride, a common toxic solvent also found in many polluted soils; chloroform, a toxic by-product formed during water disinfection by chlorination; and benzene, a carcinogenic compound found in association with petroleum pollution.

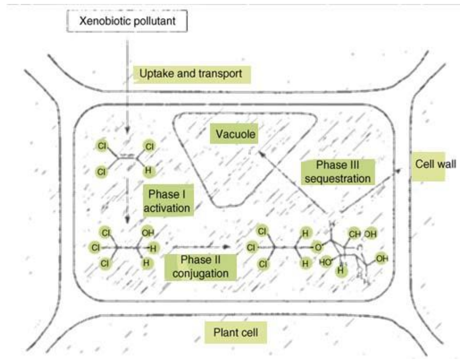

Figure 2. The three phases of the 'green liver' model

Conclusions

Transgenic poplars (CYP2E1) enhance both the uptake and the metabolism of several toxic solvents and could therefore help to overcome a major limitation inherent to phytoremediation – namely, the threat that accumulated toxic compounds would volatilize or otherwise contaminate the food chain. Although the study by Doty et al. [6] is not the first report about genetic engineering of plants for phytoremediation applications, it constitutes a milestone in the field for several reasons: first, it is one of the very few studies describing the successful development of transgenic poplars, which is technically challenging [13]; second, the technology is efficient for the treatment of several important organic pollutants likely to be found in mixture in the environment; and third, it constitutes the achievement of a pioneer work initiated by the same group a decade ago. With federal regulations limiting the use of transgenic forest trees, further developments of phytoremediation are likely to involve genetic use restriction technologies (GURTs) for controlling the dispersion of transgenes in the environment [17]. As for transgenic crops, risks inherent to genetically modified organisms have to be minimized and balanced with the increasing needs of an ever-expanding human population.

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