A car tyre made of **dandelions**

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The demand for bio-based, renewable resources will shoot up considerably in the next decades. One of the plants that has promise in that respect is a Russian dandelion. It can be used to produce natural rubber as an environmentally friendly alternative to rubber trees. Will car tyres in the future be made of dandelions?

A major ambition of the EU production industry is to improve their global competitiveness and sustainability. The goal of the chemical industry sector is to produce 30% of their chemicals and materials from biomass in 2030. The goal of the agro-sector is to secure sufficient supply of food and bio-based products by developing productive, resource-efficient primary production systems alongside low carbon supply chains. These two ambitions can be very well combined by establishing new value chains that link the agro-sector with the chemical industry.

Ambitions

The EU-27 petrochemicals production currently approximates 300 million ton. To meet their bio-based ambition, over the coming two decades 100 million ton of fossil resources have to be replaced with biomass derived feedstocks. Assuming an average 50% conversion efficiency from biomass to green chemical feed stocks, the new demand from the EU chemicals industry will be equivalent to about 200 million ton of biomass. This is, for example, in the range of the global biomass production by sugar beet (230 million ton).

To invest in bio-based value chains is particularly relevant for the Dutch breeding companies. Considering the limited possibilities for extending agricultural land in the Netherlands, much biomass may need to be imported to serve the needs of the Dutch chemical industry. This can still be a positive perspective as long as substantial added value is created by Dutch industrial stakeholders. For bio-based production the best opportunities are in knowledge and technology intensive activities along the value chain. Such activities include the development of elite plant material and seed production, and further down-stream, biorefinery and conversion of bio-based feedstocks into consumer products. Our future vision is that Dutch industry is very well positioned to develop unique refinery technology, to develop refinery facilities at the crossroads of logistic biomass transport routes, but in particular to produce unique plant propagation material (seeds) which leads to, at whichever location in the world, the production of biomass that can be processed into raw material for chemicals and high performance materials in the Netherlands.

A potential new value chain is a Russian dandelion. It can be used for the production of raw material for furan-based chemicals, in combination with a high performance material, natural rubber.

Natural rubber (NR) is a unique biopolymer that is essential for the building-, medical-, personal care- and transportation industries. In many applications, NR cannot be replaced by synthetic – petroleum – rubber (SR). At the moment, NR is harvested almost exclusively from the rubber tree (Hevea brasiliensis) of which 90% is grown in Southeast Asia.

The world market for NR increased from 4.4 Mton in 1985 to 11.2 Mton in 2012. Based on forecasts of the International Rubber Study Group (IRGS), NR consumption is expected to reach 16.5 Mton in 2020. In the current situation, increasing NR demand can only be met with an increasing acreage of rubber tree plantations. To reduce the dependency of the European industry on the rubber tree and on South East Asia, alternative sources of NR should be developed.

A potential NR-producing crop is the Russian dandelion (Taraxacum koksaghyz, TKS) which is indigenous in the low mountain ranges of South East Kazakhstan. In World War II Russia used this rubber for the production of tyres for army vehicles. Dry roots of wild TKS plants contain on average 5% NR. Swedish plant breeders succeeded in increasing rubber content to 15% in six generations. However, in the 1950s the expectation was that synthetic petrochemical rubber would completely replace natural rubber. Therefore, the cultivation of TKS was terminated and the improved and wild ex situ germplasm was lost.

Russian dandelion

With the recent focus on renewable materials there was a revival of the interest in the Russian dandelion This resulted in multidisciplinary research projects on both sides of the Atlantic Ocean (e.g. EU-PEARLS and PENRA). TKS has a number of attractive properties for a new industrial crop. Besides high quality NR, its roots contain 20-40% inulin. Inulin can be used in food, as is the case with inulin gained from the dandelion-related chicory. Inulin can very easily be hydrolysed into fructose. Fructose is the most efficient starting point for the production of 2,5-furandicarboxylic acid (FDCA), a chemical building block

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Taking a latex sample of the Russian dandelion

Russian dandelions from Kazakhstan might replace rubber trees

that is commonly referred to as 'the sleeping giant' and has a very large potential in many applications. FDCA has the potential to serve as an important renewable building block, because it can substitute the fossil oil-derived terephthalic acid (TA) in the production of various polyesters such as polyethylene terephthalate (PET) and polybutylene terephthalate (PBT). So far, all commercially and technically viable production routes for the production of FDCA run from or via fructose. The current market size of purified or polymer grade TA has exceeded 30 Mton/year and the current market price is approximately 1,200 €/ton. According to the furanics industry, this translates back to an inulin/fructose price of about 250 €/ton to produce FDCA at cost price that can compete with TA.

Both rubber and inulin can be simultaneously extracted from dried and stored roots with hot water. Extraction is thus simple and sustainable. TKS can be grown in the temperate regions as an annual crop fitting into crop rotation systems, and can be harvested mechanically.

Hybridization

Today's breeding of TKS is primarily aimed at increasing the rubber production of TKS by increasing the rubber content and producing bigger plants. At KeyGene more robust plants are made by hybridization of TKS with the common dandelion, T. officinale (TO). This latter species is much bigger than TKS, but does not produce high quality rubber. During the EU-PEARLS programme TKS genes that were involved in rubber biosynthesis were sequenced (Cis-Prenyltransferases, Small Rubber Particle Proteins and Rubber Elongation Factors). This allowed the development of gene- and species-specific DNA-markers. In the introgression programme these markers are used to positively select TKS rubber genes and negatively select TO rubber biosynthesis genes. This way it is possible to efficiently introgress recessive TKS rubber genes.

In addition to a higher rubber production, there are secondary breeding goals like an increased inulin content, more uniform germination and no first-year flowering. First-year flowering is undesirable, because flowering occurs at the expense of root development and rubber production. In wild TKS germplasm more than one quarter of the plants flower during the first year (bolters). By selection KeyGene succeeded in developing a pure non-bolting line, which will be registered as a variety. Until very recently TKS existed only as a wild, undomesticated plant species.

The fast development of the new non-bolting variety supports the idea that in species with a short breeding history the larger gains can be made in a short period of time compared to species with a long breeding history, as shown by Kupzow in 1980. Moreover, molecular breeding technologies can further accelerate the rate of plant improvement.