Dyes and additives for fossil-free textile chains: linking fibre production, protected cultivation of high-value products and processing

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Focus
In this project, we aim to select a number of interesting crops that could be used as dyes for textiles. Other prerequisites is that these high-value crops can be cultivated in protected cultivation, that concentrations of secondary metabolites can be controlled in a sustainable way to obtain components that may be used as dyes, and that the waste streams of this process can also be valorized.

Innovative idea and objective

The production of materials for textiles (fibres and auxiliaries like dyes) is one of the largest consumers of fossil-based carbon-based materials. Next to that, the industry is responsible for (water) pollution caused by amongst others dyeing of the textiles. Historically, cloths were dyed with dyes from natural origin, derived from plants, insects or non-organic materials such as soil or minerals. When the chemical industry progressed, synthetic dyes were found to give a more intense and uniform colour and were cheaper to produce. Thereby, knowledge and experience on natural dyes was reduced to a very small group of experts. However, in recent years, interest in natural dyes is increasing again, in search for a non-fossil, circular textile chain.

Relevance to the materials transition in textiles and/or building materials?

Wageningen University & Research is investing strategic funding in the transition towards renewable materials to be applied in fields related to comfort and shelter, such as textiles. Wageningen researchers of multiple disciplines cooperated in a project with the aim to contribute to a to value chain, in which crops are grown in protected cultivation to produce plant -based dyes which can be used in a fossil-free textile chain, (re-)using "waste" material of the production system. This project combines different areas of expertise, such as the cultivation of renewable feedstock, production of high-value crops in fossil-fuel free protected cultivation systems while re-using carbon dioxide from industry, selection of most suited crops and varieties, and knowledge of processing and products in fossil-free value chains.

What did you do?

Selecting crops for dyes

The starting point of the project was the concept of "dual-function" crops, where dyes would be the primary harvestable product, next to fruits (e.g. tomato), flowers (e.g. marigold) or stems for fibres (e.g. nettle). These crops would be grown in controlled conditions (such as greenhouses or vertical farms), so that concentrations of secondary metabolites to be used as dyes in textile chains could be controlled in a sustainable way. Based on these conditions, we made an inventory of plant species that could provide natural colourants that could be used as dyes in textile chains. However, the inventory showed that crops that contain valuable colourants in high concentrations, are primarily trees which do not fit in an indoor cultivation system, or herbaceous plants that do not have another harvestable product than the dye, although fibres might be harvested of some. Thus, we changed perspective, and selected crops primarily on their characteristics as a producer of valuable natural dyes, on their suitability for high productivity protected cultivation, on the gene pool of these crops and the options for valorisation of the side streams of these production systems. Based on this evaluation, we selected two interesting crops that have potential to fulfil the demands from all perspectives used.

Main result, achievement and highlight

Madder and true indigo

Based on the inventory, *Rubia tinctorum* (madder) and *Indigofera tinctoria* (true indigo) seem to offer most perspective to be used as a natural, plant-based dye to be used in a fossil-free, circular textile chain. Both crops yield high quality dyes with intense colours. *Indigofera tinctoria* has been grown in the field commercially and in protected cultivation, and the concentrations of the colourant indican which is the precursor of the indigo dye can be affected by a number of factors, such as the crop variety, plant age, spectral composition of the light (red light), photoperiod, planting density, CO_2 supply and nutrition. The crop offers perspective as a colourant for natural textiles, such as cotton, linen (cellulosics), but also wool and silk (proteins). The side streams offer perspective to be used e.g. to derive proteins. What remains to be done for this crop is set-up a cultivation system and processing system to grow the crop, extract the dye and valorise the side streams. This might lead to a viable business case, which then might be rolled out having a commercial perspective.

The design of a cultivation system for of *Rubia tinctorum* (madder) will be more challenging. Traditionally it was grown in the field, and roots had to be dug out deep, to harvest the red colourant alizarin. To make this into an economically viable business case, new varieties have to be selected or bred that have an altered morphology with smaller root systems that can be cultivated in protected cultivation with altered root substrates (e.g. nutrient solution), with tailor-made control of the environmental conditions. Furthermore, efforts are required to investigate potential use of the main side stream material of madder cultivation which are stems and leaves.

Developing a business case

In the field of using plant-based natural dyes, there is much "old" and (nearly) forgotten knowledge, that is kept in old journals and recipes for colouring textiles. In the decades, the plant-based dyes are largely replaced by fossil-based, chemically produced dyes, that have a more intense and long-lasting colour and are cheaper. However, currently there is a small, but increasing demand for fossil-free textiles, which also includes dyes from natural origins such as plants. Some commercial companies are getting actively involved in the use of fossil-free textiles, using natural dyes and looking for the right species, genotypes, cultivation methods, colourants and business cases. Based on this project, we could support and cooperate with them to make next steps.

Visual abstract

Figure. Rubia tinctorium, a potentially interesting crop to produce dyes of plant-based origin to contribute to a non-fossil circular textile chain.