COLOURING (DYE) PLANTS

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Summary

Although in the past application of natural dyes was the sole possibility of colouring anything, this function has been largely forgotten for about one and a half centuries. Since the early 1990s, however, there has been a resurgence in the use of plant originated dyes, along with the general tendency of turning to nature. Dying plants are an interesting group of alternative crops, which possess a wide spectrum of utilisation. In addition to colouring textiles, leather, wood, paintings, etc., their significance is increasing as dying substances in foods, beverages, medicines, candies, etc. In this respect, they are foodstuffs, which—in many cases—exhibit also additional functions, such as antioxidant or pharmacological effects. The main colouring substances, flavonoids, carotenoids, xanthophylls, anthocyanins, naphtoquinones, etc. accumulate in different organs of the plants, depending on the species. Dye plants can be found in a wide range of vegetation types, climates and growing areas. In addition to an overview, this article describes eight selected dying species in detail, giving a short history, a botanical description, introduction to their ecological requirements, active materials of the utilised plant organs, distribution and methods of consumption, as well as other types of utilisation, and the main aspects of cultivation.

1. Introduction

A special area of utilisation of plants in everyday life is their colouring function. Although in the past application of natural dyes (originating from plants, animals and minerals) was the sole possibility of colouring anything, this function has been largely forgotten for about one and a half centuries. Large scale production of the first synthetic dye, the violet mauvein, began around 1856, and industrial production of these materials increased rapidly. Utilisation of the natural ones correspondingly decreased. As recently as the early 1990so a new fashion of plant originated dyes started to spread, along with the general tendency of turning to nature.

Plant originated dyes can colour almost anything. They had been used for decorating animal leather to be processed as bags, boots or used for preparing household tools. They also dyed wooden products, furniture and a range of domestic instruments, as well as items made of bone or horn. In art, pictures and paintings had been prepared with self-made dyes of plant origins. People decorated not only different objects in their surrounding, but also their own bodies and hair using these natural paints. Dying of textiles and clothes was one of the most important utilisation areas, and, last but not least, people used the natural dyes for colouring everyday food, to make it more enjoyable and attractive. In this chapter we have focused on this latter aspect of dying plants.

Today, in utilisation of dye plants, the following aspects are declared to be important: safety under any circumstances and even at high dosage, stability against temperature, light and pH, flexibility during processing, long lasting effect, profitability. In general, synthetic colouring agents are more advantageous from these points of view. However, in recent years, an intensive and complex development has got underway in different regions of the world, to assure the competitiveness of natural dyes.

Dye plants may produce almost any necessary colours from yellow to black (see Table 1.). Both the colouring plant organs and the colouring chemical compounds are variable, but some grouping seems to be possible.

Main colour	Latin name	English name	Utilised organ	Dying agent
green	Urtica dioica	nettle	young leaf	chlorophyll
yellow	Anthemis tinctoria	mayweed	flower	flavonoid glycosides
yellow, orange	Bixa orellana	annatto	seed	carotinoids
yellow, orange	Carthamus tinctorius	safflower	petal	calconderivate carthamin, safflor-yellow
yellow	Cotinus coggygria	smoke-tree	shoot, leaf	tannins, flavonoids
yellow, orange	Crocus sativus	saffron	stigma	carotinoids
yellow	Curcuma longa	turmeric	root	curcumin (1,7hepadiene-3,5dion)
yellow	Genista tinctoria	greenweed	shoot	isoflavonoid genistein
yellow, red	Hypericum perforatum	St. John's wort	flowering shoot	hypericine and derivatives
yellow	Reseda luteola	weld	flowering shoot	flavonoid glycosides
yellow	Serratula tinctoria	saw-wort	flowering shoot	flavonoid glycosides

yellow	Solidago virgaurea	goldenrod	flower	flavonoid glycosides
yellow	Tagetes species	african marigold	flower	xantophyll
yellow	Tanacetum vulgare	rainfarn	flowering shoot	flavonoid glycosides
yellow	Verbascum phlomoides	mullein	petal, leaf	flavonoid glycosides
red	Alkanna tinctoria	alkanet	root	naphtoquinones
red, violet	Althaea rosea var. nigra	hollyhock	petal	anthocyanin
red, violet	Beta vulgaris ssp. esculenta var. glabra	beetroot	root	betalaines (peptid-derivatives)
red, brown	Origanum vulgare	oregano	flowering shoot	tannins, flavonoide
red	Pterocarpus santolinus	red sounders	wood	santalins (benzoxanthemon derivative)
red	Rubia tinctorum	madder	root	anthraquinone (alizarin)
red, violet	Vitis vinifera	grape	berry peel	anthocyanin
blue, black	Haematoxylon campechianum	logwood	wood	haematoxilin
blue	Indigofera species	indigo	leaf, stem	peptide-glycoside (precursor of indigo)
blue	Isatis tinctoria	woad	leaf	peptide-glycoside (precursor of indigo)
violet, blue	Sambucus nigra	elder	berries	anthocyanin (sambucyanin)
brown	Agrimonia eupatoria	agrimony	floering shoot	catechines, flavonoides
rusty-brown	Allium cepa	onion	bulb leaves	carotinoids
brown, black	Juglans regia	walnut	green fruit shell	naphtoquinones
black	Alnus glutinosa	common alder	bark	naphtoquinones

Table 1. Plant species frequently utilised as source of dying materials

The most characteristic yellow producing chemical compounds are the carotenoids. They belong to the terpenoids, and are widely distributed in the plant kingdom. They give a colour from yellow to orange and red. They accumulate in roots, leaves, fruits, pollen and stigma. Most important utilisation areas are in the food industry, particularly in confectioneries, bakery products, and cheese, etc.

Flavonoids, especially flavons and flavonols are also mainly of a yellow colour. The word flavus means yellow in Latin. In plants they are found in the glycosidic form in almost any plant organs, most frequently in flowering shoots.

Anthocyanins, are related compounds to flavonols; theyr give characteristic colours from red to violet and blue. The actual colour depends on the pH value: in acidic environment they give orange-red while in a basic one they are violet-blue to greenishblue. Anthocyanins are soluble in water, and can be found mainly in flowers. The name of this chemical group is derived from Greek: the word anthos means flower, and kyanos means blue. Anthocyanin dyes are utilised for jams, biscuits, candies, and refreshments.

The quinones (naphtoquinons, anthraquinons) are the next type of natural dying agents, which give red, reddish-brown and brown colours. They are found in different plant organs, and frequently also in roots. The utilisation area is wide, e.g. confectionery, cosmetics, and medicines.

Chlorophylls (pyrrole-dye) give different shades of green. In industrial practice, the central Mg ion is substituted by Cu, in order to stabilize the molecule. It is the substance of fresh leaves, and is utilized for soups, dairy products and sweets.

Less frequently processed natural dyes are the betalaines (peptide-glycosides), giving a dark red colour. They are the characteristic compounds of beetroot.

In addition to their potential for colouring, some dying agents also have significant therapeutic properties. Some plants used for colour, possess antioxidant or other biologically active functions, and often it is the same chemical compound that is responsible for each effect.

2. Alkanet, Alkanna tinctoria (L.) Tausch. (Boraginaceae)

The genus *Alkanna* has seven species, and some of them are cultivated in Europe. *A. tinctoria* (see Figure 1) is indigenous in Southern Europe and Turkey. It is a typical species of grassland vegetations on light, sandy soils. As such, it prefers warmth and much light. It is extraordinarily resistant to drought, a feature which can be explained by its exceptionally effective water uptake and transport within the roots. It develops best in loose, sandy, calcareous soils.

Figure 1. *Alkanna tinctoria* (Photo: Bernáth, J.)

Alkanet is a very interesting, nice, attractive, tiny, perennial, herbaceous plant. The branches are soft and hairy, the stem is angular and narrow, and the leaves are lanceolate. It develops forked, one-sided cymes of bluish-violet flowers. As result of acclimatisation to the growing circumstances, the roots may grow very deep into the soil and the leaves have so-called "light-reflecting" hairs, which decrease absorption of solar energy. The fruits are nutlets, ripening in early summer.

The bark of the roots contains dying substances. On the outside the root is reddish-black, and inside it has a yellowish-white colour. Dyes are naphtoquinones, (aromatic diketones), the most important ones being the alkannins (isohexenil-naftazarines). These are chemical compouds containing a double ring structure and they give an intensive red colour.

There are at least 16 such compounds, which differ in the construction of the side chain and are found in ester form. One of them is alkannin, the isomer of which is the popular shikonin, till now a unique dye compound which is produced in vitro by a biotechnological method on a large scale in Japan. In nature, it can be found in *Lithospermum* species and serves for dying kimonos (traditional dresses).

The roots of alkanet also contain tannins, wax, resins, and may accumulate the poisonous pirrolizidine-alkaloids—a group of ester substances, the liver-damaging effect of which has been proved already in several plant species. In food quality assurance, the limit for allowable daily consumption is fixed at 0.1 μg.

The utilisation of alkanet has been known since the time of ancient Greeks and Romans. Also several European nations used it for colouring the nails and lips, and also in creams and candies. In Hungary, folk marked their sheep with alkanet extract. Alkanet gives a fine deep red colour to oily substances, and to spirit and wine.

When wax is tinged with alkanet, it can be applied to the surface of warm marble and assures a long-lasting nice colour. Today, it is allowed for utilisation in the food industry in twelve European countries. Cheese and beverages are dyed with it. Application is known also in the cosmetic and paper industry.

The therapeutic effect of the roots was described by Dioscorides. The active substances of the dyes are naphtoquinone derivatives. The benefits of the plant in curing wounds, inflammation and skin infections, as well as its UV protection activity and antioxidant effect, has been proven by modern pharmacology. Thus, it is applied mainly externally, in the form of ointments, for the above-mentioned conditions.

There have been successful experiments in establishment of production technology for alkanet. It can be propagated by raising seedlings, sowing the seeds in cold beds in autumn, or in heated equipment in early spring.

Seedlings can be planted into open field in May. During the growing period, regular weed control and occasional irrigation are necessary. In the second year of vegetation, the roots can be harvested in October. As the dyes are relatively readily soluble in water, harvesting should be made in dry weather and the roots may not be washed.

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Biographical Sketch

Dr. Éva Németh is a professor at the Department of Medicinal and Aromatic Plants at the BKA University, Budapest, Hungary. Her main topics in education and research activities are focused on breeding, genetics, chemotaxonomy, production and physiology of medicinal and aromatic plants. In the last decade she has been the leader of 8 scientific projects and partner in a further 12 on the development of biological bases of medicinal plant production, investigations on the influencing factors of drug quality, and modernization of agrotechnology. She is one of the leaders of the PhD School in Horticultural Sciences and scientific supervisor of several students.
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Dr. Németh has been engaged in Hungarian and international scientific activities as secretary of the Hungarian Society for Horticultural Sciences, secretary of the Medicinal and Aromatic Plants Section in FIP, vice president of the Medicinal Plant Committee of the Hungarian Scientific Academy, member of the board of the Medicinal Plant Section of the Hungarian Pharmaceutical Society and a member of the IUCN Medicinal Plant Specialists Group.