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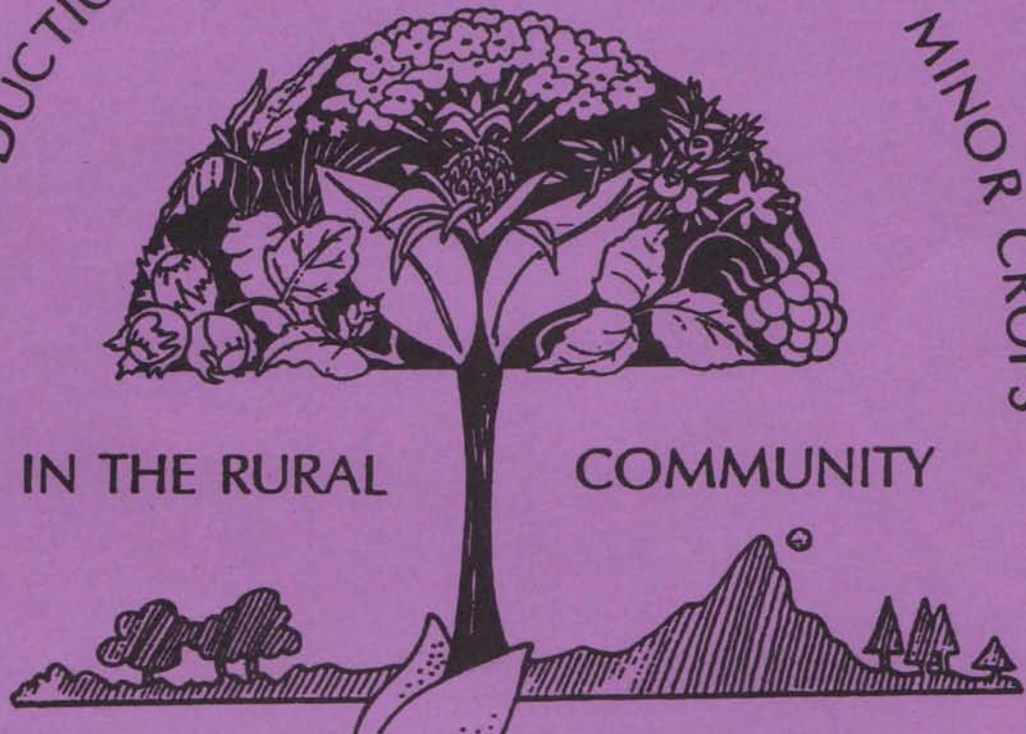
THE PRODUCTION AND IMPACT OF SPECIALIST MINOR CROPS IN THE RURAL COMMUNITY



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The Production and Impact of Specialist Minor Crops in the Rural Community

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DYE PLANTS, THEIR CULTIVATION AND USE IN GERMANY

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ABSTRACT

At present, an increasing demand for natural dye stuffs is confronted with the dependency on imported materials. Numerous dye delivering plant species are adapted to various European climatical conditions; these include: madder (*Rubia tinctorum*), woad (*Isatis tinctoria*) and weld (*Reseda luteola*). Detailed information on the biology, cultivation and production of dyes is presented for the most important plant species. Problems concerning the industrial use of natural dyes, their market potential, ecological and economical aspects are discussed. Future scientific studies are proposed to ensure that specialised dye plants may be permitted to fulfil their potential as an economically viable farming enterprise in the EEC.

1. INTRODUCTION

For centuries dye plants have been of great importance for European agriculture. In the 18th/19th century, however, imports of natural dye stuff - e.g. indigo from Asia - led to a reduced cultivation of native dye plants. Finally, at the end of the 19th century synthetic dyes have been developed and the agricultural production of natural dye stuff stopped almost completely in Europe.

Nowadays however, the ban and the restrictions on the use of carcinogenic and allergenic industrial products imposed by the German legislation has led to competition between synthetic dyes and natural substances in some market sectors. Furthermore, a new consumer attitude increasingly favouring articles produced - and ultimately disposed of - in a manner not harming the environment, and not presenting any health hazard, is one of the most important preconditions for an increased use of natural dyes.

2. IMPORTANT DYE PLANTS AND THEIR CULTIVATION

<u>Dye plants</u>

Dye-delivering plant species produce metabolic substances which can be used for dyeing purposes. While fruit-bearing lignifying dye plants (e.g. *Sambucus nigra*, *Aronia melano-*

carpa, Hippophae rhamnoides, Prunus avium) are mainly used as juices and extracts for colouring foodstuffs, herbaceous species are mostly used as dyes in non-food sectors.

The dye stuffs are produced in different plant organs - such as the petal, stigma, seed, fruit, foliage, wood, bark and root - as well as in different constitutions: In substantive or direct dyes (such as in the case of saffron and safflower) the dye is already fully developed in plants and can be used for dyeing immediately. In mordant dyes (such as in the case of most dye plants), the dye is already fully developed, however, it can only be fixed onto the goods with the aid of a metal salt acting as a mordant. Vat dyes (such as in the case of dyer's woad) are not fully developed in the plants, they are present in a colourless preliminary stage. Before such dyes can be fixed on the goods they must be chemically reduced at first and actual dyeing can take place only after subsequent oxidation in the air.

Among the great number of dye plant species, very few achieved any economic importance, due to dyeing-technical behaviour and good fastness properties. The most important ones are listed in Table 1.

Plant species	main dye-stuff	colour	localization
Rubia tinctorum (madder)	alizarin	red	roots
Isatis tinctoria (woad)	indigo	blue	leaves
Reseda luteola (weld)	luteolin	yellow	above-ground plants

Table 1: Characteristics of selected dye plants

In the following chapters the distribution, biology, dye stuff, environmental conditions, cultivation and harvest methods as well as processing of these dye plants will be described (1, 9).

<u>Madder (*Rubia tinctorum*)</u>

Distribution: Madder is native in South Europe and in the Near East. For three centuries it was the most important source for red colours and thus cultivated in the middle and south of Europe. Finally, the synthetical production of alizarin resulted in a decreasing cultivation of this plant species.

Biology: The perennial plant species belongs to the rubiaceae. Each year the strong root stocks (60-80 cm in length) develop squared stalks (50-80 cm in hight) with lanceolateous edge-shaped leaves and prickles.

Dye stuff: The madder roots are the source for the red dye and the root-barks contain most of the colour. The dye of madder consists of numerous anthrachinon derivates with alizarin as a main component (7).

Environmental conditions: The site for madder cultivation should be sunny with loose, humus, deep soil.

Cultivation: Madder needs a deep cultivation and a high content of nutrients in the soil. Two systems of cultivation were described (5): Seeds were at first sown in a garden in April and in the following spring plants were transfered into the field. Or young root-suckers were cut after land clearing of former madder fields and planted either directly after harvest in autumn or in the following spring after storage in sandy soil during winter. In the former system three years and in the latter two years of field cultivation were required to receive high yield and good quality. A direct sowing, however, was not recommended due to the high cost for seed production.

Harvest: The roots of madder were harvested in autumn of the second or third year of cultivation or in early spring of the following year. By ploughing, the soil was deep broken up furrow by furrow and the roots were collected by hand. The informations on yield are large scaled and rise up to 60 dt/ha fresh roots or 15 dt rough dry matter.

Processing: The harvested roots were first roughly cleaned and later on washed and then dried. Fibrous roots and barks were removed by threshing. The remaining roots were at first cut roughly into pieces of about 10 cm in length and then milled into a powder.

Alternative plant species to produce red include: Dyer's Woodruff (*Asperula tinctoria*), Lady's Bedstraw (*Galium verum*), Hedge Bedstraw (*Galium mollugo*)

Woad (*Isatis tinctoria*)

Distribution: Woad is spread throughout Middle and South-West Europe. In the 16th century Thuringia was one of the most famous regions for woad cultivation and processing in Germany.

Biology: The biennial plant species belongs to the cruciferae. In the first season plants form a very strong rosette with numerous, unserrated, elongated leaves and develop umbellate panicles with yellow flowers producing single seeded, black-violett coloured silicula in the following season.

Dye stuff: In temperate regions, woad was the most important source for natural blue indigo. Instead of indigo itself, the woad leaves contain preliminary stages which have been described as isatan-B (indoxyl-5-ketogluconat) and indican (indoxyl-ß-D-glucosid) respectively (3, 8). Fresh woad leaves, however, produce much less indigo than indigo plants (*Indigofera tinctoria*) from tropical and subtropical regions (7).

Environmental conditions: Woad is widely tolerant of a variety of climatic and soil conditions. To produce dyes with more brightness and gloss warm, dry, fertile, chalky soils were recommended (5).

Aspects of the cultivation, harvesting and processing are descirbed below as they relate to the medieval practices. Finally modern prospects are described.

Cultivation: The sowing time was of great importance for the yield of leaves. At first it was described that woad should be sown around Christmas time even on snow. Later it was recommended to sow either in autumn - from the middle of September up to the middle of October - or in the spring - from the middle of February up to April and even in May. Broadcast sowing needed a seed quantity of 150 l/ha and for drilling the instructions ranged from 70-80 l up to 100-120 l/ha. Dependent on soil quality, row spacing of 25-35 cm was recommended. Plants of the five leaves stage should be singled to 15-25 cm, with respect to soil quality.

Harvest: In the first year of cultivation, when the oldest leaves became senescent, they were cut off above ground. Due to the strong capability of regeneration, leaves were harvested 2-3 times in the first year and up to the development of flower stalks in the second year.

Processing: Harvest was followed by washing and wilting leaves. Then leaves were mashed by woad mills while adding water. This process resulted in a mush which was heaped up. Later balls were formed by hand and dried on special darres. The dried woad balls were sold on to the market, which was the end of farmers work. Further treatment was done by woad dealers. The woad balls were moistened and fermented again. After drying and grinding up to a powder, the material was ready for sale.

The medieval procedure described above was very laborious and time consuming. Nowadays, however, the basic research for the application of modern biotechnology is done in the following way: On the surface of woad leaves specific bacteria have been observed and isolated. They produce an enzyme responsible for the splitting of the indigo-preliminary-stage indoxyl-ß-D-glucosid into indoxyl and glucose. Whereas glucose is the substrate for bacteria, two indoxyl molecules join spontaneously to form indigo under the influence of oxygen. Using cultures of these specialized bacteria, biotechnological processing methods for the transformation of woad mush ingredients into indigo could be developed for an effective production of natural indigo from woad (3).

Alternative plant species to produce blue include: Dyer's Knotweed (*Polygonum tinctorum*); Wild Indigo (*Baptisia tinctoria*)

Weld (*Reseda luteola*)

Distribution: Weld is spread throughout Middle and South Europe. It is one of the oldest dye plants and until the 19th century it was cultivated in all countries of our continent.

Italy, the south of France and warmer regions of Germany have been the main cultivation centres for weld.

Biology: Weld belongs to the resedaceae and is a winter annual species. Before winter it grows into flat rosettes with lanceolate, undivided leaves developing flower stalks in the following season, being 100-150 cm hight with long, slender, erect spikes, with numerous tiny, inconspicuous, yellowish flowers, forming spherical, open capsules with numerous, black, kidney-shaped seeds.

Dye stuff: Under European climatical conditions, weld is of greater importance than any other yellow dye delivering plant, because it produces a brilliant colour of extreme fastness to light and of great stability. Most of the yellow dye plants contain hydroxyflavones belonging to the class of flavonoides. The combination of flavonoid components is specific for each plant species (6). The yellow colour of weld consists of luteolin, isorhamnetin, kaempferol, apigenin and luteolinglucoside (2, 6).

Environmental conditions: Weld is a so-called pioneer plant and therefore almost independent from specific environmental conditions. Plants grown under light, medium soil and hot climates, however, had a higher staining capacity than those from fertile soil (4).

Cultivation: Winter and spring cultivation are described for weld. Informations on sowing time for winter weld range from the end of July/middle of August up to September, whereas spring weld is sown in March/April. Recommendations for seed quantity are large scaled from 4, 8, 12 or 16 kg up to 20-24 kg/ha. After rosettes are 3-5 cm in diameter, plants should be singled up to a distance of 12-16 cm.

Harvest: The whole plants were either pulled out or cut off above ground when they became yellow, just before maturity of seeds. For winter weld harvest time was July/August and for spring weld August/September. The data on yield range form 1,5-5 or 38 dt dry matter weight per hectar up to 2-3 t/ha.

Processing: The plant material was dried in the shade and later on bundles of whole weld plants were sold.

Alternative plant species to produce yellow include: Sawwort (*Serratula tinctoria*); Dyer's Chamomile (*Anthemis tinctoria*); Dyer's Broom (*Genista tinctoria*)

3. INDUSTRIAL USE

Traditional use of plant dyes

In ancient times, before the industrial production of synthetic dyes a wide range of colorants of plant and animal origin was used to dye natural fibres such as wool, cotton, linen and silk as well as fur and leather goods. This material also served to colour cosmetic products and to produce inks, water-colours and artistic paints.

Modern use of plant dyes

Nowadays, plant dyes are also suitable for a wide range of industrial applications:

-textile dyeing for top clothes (e.g. wool, silk)
-textile dyeing for interior decorating (e.g. floor coverings)
-dyeing leather and pelts
-indoor paints and lacquers
-paper industry
-printing inks, water colours and artist dyes
-artistic paints for children and coloration of children's toys
-decorative cosmetics (e.g. hair)
-colouring foodstuffs and semi-luxury foods

Competition

The main competition as far as natural dyes are concerned comes from the synthetically-produced dye stuffs. Amongst the natural dyes there is a competition between domestically produced products and dye plants or dye plant products imported from tropical and sub-tropical regions. In particular turmeric (*Curcuma longa*), indigo plant (*Indigofera tinctoria*), logwood (*Haematoxylum campechianum*), redwood (*Caesalpinia echinata*) and annatto (*Bixa orellana*) are traded throughout the world.

4. MARKET POTENTIAL

At present about 50% of all dye stuffs are processed in the textile industry. For the commercial demand of textiles coloured with natural dyes considerable growth rates are expected. The demand will be influenced both by the extent of the use of natural fibres and by corresponding marketing concepts. According to preliminary market studies carried out by the KATALYSE Institute for Applied Environmental Research, Cologne, the market is already showing very encouraging growth. Some internationally active textile manufacturers have brought out what they are calling "Ecological Collections". Even the "Paris haute couture" presented collections coloured with natural dyes. Specialized dyehouses are fully booked out and are reporting an unusual brisk market demand. In some countries the supply cannot keep pace with the demand. Many textile manufacturers are eager to include plant-dyed collections in their fashion cards but the specialized dyehouses do not have the capacity to accept this additional business.

Other promising outlets are the indoor paints and lacquers market, as well as floor coverings in natural fibres. The extent of this product pallet is growing and it seems to be realistic to expect a growing market potential in these segments for the next years.

As far as food applications are concerned it seems safe to assume that natural dyes will replace synthetic dye stuffs on an increasing scale. The colouring matter used in food products is mainly obtained from fruits of lignifying plants. These dyes are of only minor importance in all other application sectors, where almost exclusive preference is given to herbaceous plants (e.g. the above described).

5. DISCUSSION OF FUTURE ASPECTS

Ecological aspects

Some of the dye delivering plant species, such as weld, can be described as "low-input types" because of their very modest nutrient requirements. Practical experience has shown that the dyeing capacity can be increased with a reduced nutrient supply and without the use of any fertilizers.

Most of the dye plant species are not related to other important crops. An incorporation of such plant species will thus improve the traditional rotation systems.

Dye plants are marketed as dried plant material. The drying and dye extraction processes are very modest with regard to energy and chemical inputs. The plant residues remaining after dye extraction can be composted. The waste water burden can be described as relatively marginal.

Economical aspects

At present, agriculture is confronted with a number of problems such as closing farms, rising subsidies and intensifying production systems. In such a time a booming market is opening up for the cultivation of dye plants, because there is still no significant cultivation of dye plants within the EC at the moment.

For many years, the EC has had to rely almost exclusively on imports from non-member countries to satisfy its market demand for natural dye stuff. According to the processing industry, the imported raw materials are often of inferior and non-uniform quality. At the moment, however, the processing industry has no option but to continue with its practice of relying on imports from non-member countries to supply its needs.

Predictions regarding the economic outlook for a cultivation of dye plants can be made on the basis of a market willing to pay cost-covering prices. The conversion of parts of the present agricultural production capacity to meet the market demands in this special sector would thus guarantee cost-covering agricultural production.

Textile dyeing as well as pigment production from plants does not require complex industrial machinery and therefore it would seem to be a good niche for the small and medium-sized undertakings. Although still to be optimized, there are various techniques and processes available for the production of pigments and textile dyeing purposes.

The booming market for natural coloured products would encourage the establishment and ensure the existence of small and medium-sized businesses, promoting an ecologically compatible form of agricultural production and processing base.

Despite the fact that the economic and political prerequisites for the cultivation and processing of dye plants on a wider scale are favourable, so far there have been no moves to encourage the adoption of these crops to optimise the domestic production of natural dyes and their products.

Scientific aspects

The information reviewed herein on the cultivation of the most important dye delivering plant species is based on obsolete empirical observations. Scientific experiments are urgently needed to fill up the significant lag in applied research in order to develop modern agricultural production systems.

At present dye delivering plant species are still typical wild types or useful plants respectively. An extended industrial use and agricultural cultivation would require that cultivars of the most important plant species are available. Accordingly, the first step was initiated by the Federal Ministry of Food, Agriculture and Forestry in Germany. Within the scope of the research project entitled "Screening of dye delivering plants" evaluation and selection of a number of species and strains in order to determine adaptability to climatical conditions, yield of fresh and dry matter, as well as dye stuff content were carried out (4). A selection of idiotypes could lead to the development of strains "tailor-made" for the dye stuffs industry. Various species are wild or useful plant populations and therefore early success can be expected via this selection process.

The development of modern agricultural production systems and the selection of varieties or strains, however, will be successful only by application of modern extraction methods as well as ecologically acceptable and technologically simplified dyeing recipes suitable for industrial-scale production purposes.

Therefore some intensive research has to be initiated:
-Evaluation of the genetic variation in certain species
-Development of simple methods for the quantitative and qualitative analysis of dyes in individual plants
-Selection of types which demonstrate significant value as dye plants and the development of cultivars or improved strains in certain species
-Optimizing plant cultivation parameters (e.g. sowing time, row and plant distance, harvest time and method)
-Development of mechanization for cultivation, harvest and processing
-Optimizing techniques and processes for production of pigments and dyeing

Research in the field of dye plants and plant dyes should create significant opportunities to substitute a more environmentally-acceptable alternative to traditional petro-chemical-based dye stuffs. At the same time this research should encourage small and medium-sized businesses as well as promoting sustainable methods of agricultural production which are both environmentally friendly and economically profitable.

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