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An investigation of dye plants and their colourant substances in the eastern Mediterranean region of Turkey

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Plants traditionally used to dye carpets and woven matting in the eastern Mediterranean region were investigated. The survey was carried out in Kadirli, Feke, Aladağ, the surrounding villages of Adana, and in Osmaniye (Turkey). According to the survey results, 37 species of plants belonging to 29 families were used in natural dye production. The total dye contents of collected plants ranged from 1.5% to 10.0%. Mordants and dyes obtained from some of these plants were used to treat wool yarn and the yarn's dyed properties were tested. Some of the plants were also examined in terms of cultivation and fifteen were transferred to a Dye Plants Collection Garden. They were *Alnus glutinosa* (L.) Gaertn. ssp. *antitaurica* Yalt., *Arctium minus* ssp. *pubens* (Bab.) Arènes, *Chrysanthemum segetum* L., *Cistus creticus* L., *Cotinus coggygria* Scop., *Datisca cannabina* L., *Galium verum* ssp. *glabrescens* Ehrend., *Isatis tinctoria* ssp. *tomentella* (Boiss. & Balansa) P.H.Davis, *Melissa officinalis* ssp. *inodora* Bornm., *Mentha longifolia* (L.) Huds. ssp. *longifolia*, *Reseda lutea* var. *lutea* L., *Rhamnus oleoides* ssp. *graecus* (Boiss. & Reut.) Holmboe, *Rhus coriaria* L., *Rubia tinctorum* L., and *Rumex patientia* L. © 2004 The Linnean Society of London, *Botanical Journal of the Linnean Society*, 2004, **146**, 71–77.

ADDITIONAL KEYWORDS: colour sensitivity to light – conservation – cultivation.

INTRODUCTION

Today, synthetic chemicals used in dyes for the textile industry are known to be a principal source of environmental pollution. Synthetic dye substances also have several carcinogenic properties and cause allergies in humans. During the last few years there has been a resurgence of interest in natural dyes to replace synthetics. Natural dyes not only cause far less environmental pollution and health difficulties, but also have been reported to have distinctive washing and sunlight fade-resistant properties (Mert, Doğan & Başlar, 1992; Angelini *et al*., 1997).

Plant colourants are used in colouring foods, textiles, cosmetics and pharmaceutical preparations. To promote the marketing of these colourants, it is necessary to develop the cultivation of the dye plants from which they are extracted, extraction techniques and analytical methods for separating, identifying and quantifying the components of different classes of pigments (Piccaglia & Venturi, 1998).

Unfortunately, natural dyes are rarely used in modern dyeing, except by specialist companies and craft dyers (Gilbert & Cooke, 2001). For the production of eco-textiles based on natural dyes, an evaluation of the economic and ecological sources for natural dyes is of growing interest. Yellow, red brown, green and dark grey colours can be obtained from various sources of plant material (Bechtold *et al*., 2002). These are the most popular colours among various people.

Common madder (*Rubia tinctorum* L.) produces several anthraquinone pigments in its roots, one of which is alizarin (1,2 dihydroxy anthraquinone), that has been used for dyeing textiles since 2000 BC. (Angelini *et al*., 1997). Alizarin is the active ingredient of the famous Turkey red dye, which for centuries was the most resistant to being lost through washing/exposure to sunlight and most brilliant red dye known. After the synthesis of alizarin in 1868, the production of the

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natural dye decreased rapidly, eventually ceasing altogether (Gallop, 1987; Başlar & Oflas, 1990).

Anatolia has a large variety of plants available for dyeing purposes and the craft of dyeing has been improved through centuries of experience. In Turkey, there are approximately 150 species of plants used in natural dye production (Mert *et al.*, 1992). In this study, we aimed to determine which dye plants are already in use, potential examples of new plants that could be used for dyeing, and the total content of dye plants in Adana and its surrounding regions, in the eastern Mediterranean Region of Turkey. Plants containing dye stuff and colourant substances used in carpet and woven matting were identified. They were evaluated for their potential cultivation and need for conservation, as many of these extensively used plants face extinction.

MATERIAL AND METHODS

The survey was carried out in Adana and the surrounding districts of the eastern Mediterranean Region of Turkey during March 1999 and August 2001. In this study, dye plants were gathered and ethnobotanical information obtained from women over 35 years of age inhabiting the 26 districts. They were interviewed about dye plants, local names, and how to use these plants in dyeing. Species of the dye plants known by the villagers and the wild plants commonly grown in the districts were collected for identification, determination of total colourant content and mode of propagation (seed, cuttings of branch and root). The plants were collected at an altitude of approximately 300–1500 m a.s.l., from mostly mountainous areas.

Collected plants were conserved in a garden under *ex-situ* conditions in the experimental fields of the Field Crops Department, Agriculture Faculty, Çukurova University and in the wild at Adana (altitude: 23 m a.s.l.) to be used in agronomic research and also for gene preservation. Herbarium specimens were stored in the Biology Department of Çukurova University, Adana. All of the specimens were identified according to the *Flora of Turkey* (Webster, 1980; Davis, 1965–85). The authorities are cited using *Authors of Plant Names* (Brummitt & Powell, 1992).

DYEING PROCESSES

Total dye stuff contents were analysed according to Harborne (1973). Three grams of dried plant tissue was immersed in 2 M HCl and heated in a test tube for 30–40 min at 100°C. The cooled extract was then filtered and extracted using ethyl acetate. The ethyl acetate extract was concentrated until dry, and then weighed.

A premordant method in the colouring process was applied by using mordant at a ratio of 3% w/w wool carpet yarns. First, wool carpet yarns were mordanted separately with potassium di-chromate ($K_2Cr_2O_7$), copper sulphate ($CuSO_4.5H_2O$), ferrous sulphate ($FeSO_4.7H_2O$) and potassium aluminium sulphate ($KAl(SO4)_2.12H_2O$). Each of these four mordants was dissolved in one litre of tepid water (1/40 w/v). Secondly, the previously dampened wool yarn was boiled with the mordanted water for an hour. Subsequently the mordanted wool yarn that was taken out of the water was squeezed and prepared for dyeing. Dyes were prepared by boiling 25 g air-dried or 100 g fresh plant part (except *Isatis tinctoria* ssp. *tomentella*) for an hour and straining after cooling. As soon as the wool had cooled after mordanting, it was put into the cool dye bath and gently boiled for approximately an hour until the desired colour was obtained. The next day, it was washed in water and soap, rinsed and dried in a shady and airy place. *Isatis tinctoria* ssp. *tomentella* required fermentation for a blue colour. *Isatis* leaves were crushed in a mortar and made into balls, which were allowed to dry over a period of 5 weeks; they were then crushed, heaped into piles, sprayed with water and allowed to ferment aerobically over a period of nine weeks. The dyeing method mentioned above was then followed (Gilbert & Cooke, 2001). Colours obtained by this method were coded according to Küppers (1977). Dyed wool yarn samples were spread on a white background with the sunlight shining from one side and were coded according to their colours and tone differences (Y, Yellow; M, Red; C, Cyan blue).

Colour sensitivity to light was determined on the wool for the colours obtained from these plants. Light sensitivity was determined according to TS 867 (Anonymous, 1984) and 423–2 (Anonymous, 1996) prepared by TSE (For dyed or Pressed Textiles Colour Sensitivity Testing Methods-Colour Sensitivity Determination Methods Facing Sunlight). The samples were exposed to light in a digital light tester instrument for 72 h. A grey scale ranging from 1 (weak light sensitivity) to 5 (good light sensitivity) values was utilized for the assessment of change in colour.

RESULTS AND DISCUSSION

During the study, 26 plant species were recorded as dye plants in Adana and Osmaniye districts. An additional 11 plants from the research area were reported in the literature as dye plants elsewhere, but, it was found that they were not used for dyeing purposes in the study area. Of the total of 37, 36 species belong to Spermatophyta and one (*Morchella conica* Pers. ex Fr.) to Cryptogamae. Taxonomically identified plants obtained from field surveys are given in Table 1, along

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Table 1. Wild dye plants gathered from the around Adana and Osmaniye villages, their species and local names, dye content and part used for dyeing

Family	Species	Local name	Dye stuff content[1]	Used part
Anacardiaceae	*Cotinus coggygria* Scop.[2]	Peruk ağacı	4.5	Branches with fruit
	Rhus coriaria L.[2]	Sumak	2.5	Branches with leaves
	Pistacia terebinthus ssp. *palaestina* (Boiss.) Engl.	Sakız, Melengiç	1.5	Branches with leaves
Betulaceae	*Alnus glutinosa* (L.) Gaertn. ssp. *antitaurica* Yalt.	Karacan, Zıvar	2.5	Branches with leaves
Boraginaceae	*Alkanna cappadocica* Boiss. & Balansa[2]	Havaciva	4.0	Aerial part
Cistaceae	*Cistus creticus* L.	Laden otu	5.0	Branches with leaves
	Cistus laurifolius L.	Karahan	5.0	Branches with leaves
Compositae (Asteraceae)	*Arctium minus* ssp. *pubens* (Bab.) Arènes	Dulavrat otu	1.5	Leaves
	Chrysanthemum segetum L.	Sarı papatya	1.6	Aerial part with flower
	Xanthium spinosum L.	Pıtrak	1.0	Aerial part
Cruciferae (Brassicaceae)	*Isatis tinctoria* ssp. *tomentella* (Boiss. & Balansa) P.H.Davis[2]	Çivitotu	5.5	Leaves
Datiscaceae	*Datisca cannabina* L.	Haçkırık	6.0	Aerial part with flower
Euphorbiaceae	*Euphorbia rigida* M.Bieb.	Sütleğen	2.0	Aerial part with flower
Fagaceae	*Quercus infectoria* Olivier ssp. *boissieri* (Reut.) O.Schwarz	Mese mazısı	8.0	Branches
Juglandaceae	*Juglans regia* L.	Ceviz	4.0	Husk of fruit
Labiatae (Lamiaceae)	*Melissa officinalis* ssp. *inodora* Bornm.[2]	Oğulotu	2.0	Aerial part
	Mentha longifolia (L.) Huds. ssp. *longifolia*	Yarpuz, Narpız	3.0	Aerial part
Lauraceae	*Laurus nobilis* L.	Defne, Har agacı	1.5	Branches with flower
Liliaceae	*Allium cepa* L.	Soğan	2.0	Scale leaves of bulb
Morchellaceae	*Morchella conica* Pers. ex Fr.	Mantar, göbelek	3.0	Aerial part
Myrtaceae	*Myrtus communis* L. ssp. *communis*	Mersin, Murt	1.0	Aerial part
Oleaceae	*Fraxinus ornus* L. ssp. *cilicica* (Lingelsh.) Yalt.	Karadal	10.0	Branches
Papaveraceae	*Papaver rhoeas* L.	Gelincik, Pampal	9.0	Aerial part
Phytolaccaceae	*Phytolacca pruinosa* Fenzl[2]	Sekerciboyası	2.0	Aerial part
Pinaceae	*Pinus bruita* Ten.	Çam	1.75	Bark
Polygonaceae	*Rumex patientia* L.[2]	Büyüklabada, Ebelek	3.5	Aerial part
Punicaceae	*Punica granatum* L.	Nar	2.75	Pericarp
Ranunculaceae	*Helleborus vesicarius* Aucher ex Boiss.[2]	Patlakot	1.5	Aerial part
Resedaceae	*Reseda lutea* var. *lutea* L.v	Sarı muhabbet çiçeği	5.0	Aerial part with flower
Rhamnaceae	*Rhamnus oleoides* ssp. *graecus* (Boiss. & Reut.) Holmboe	Cehri	7.5	Branches with leaves
Rosaceae	*Eriolobus trilobatus* (Poir.) M.Roem.	At elması, Geyik elması	4.5	Branches with leaves
	Prunus spinosa L. ssp. *dasyphylla* (Schur) Domin	Çakal erigi, Keçi eriği	2.5	Root
Rubiaceae	*Galium verum* ssp. *glabrescens* Ehrend.[2]	Yoğurt otu	1.5	Aerial part
	Rubia tinctorum L.	Kökboya, Kınacıotu	7.0	Root
Solanaceae	*Solanum alatum* Moench	ğt üzümü	1.25	Aerial part
Thymelaeaceae	*Daphne sericea* Vahl	Dafne kabuğu, Develik	4.0	Branches with leaves
Umbelliferae (Apiaceae)	*Sium sisarum* var. *lancifolium* (M.Bieb.) Thell.	Su kazayağı, Kazayağı	1.5	Aerial part

[1]Values given as % dried total weight.
[2]Plants were reported in the literature as dye plants in other areas, but were not used for dye in the study areas.

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with their vernacular names and total dye stuff contents (% dried), under their respective families and arranged in alphabetical order.

Plant parts used for dyeing and colourants varied according to species, e.g. *Rubia* root, *Isatis* leaves, *Quercus* bark, *Euphorbia* aerial parts, *Alnus* leaves and branches. Total dye stuff content of plants ranged from 1.5 to 10%. The main natural colours except blue from the plants were excellent according to local people. They used different materials such as mud and ash with plant matter in order to obtain light and dark shades of colours. For example, *Datisca cannabina* gave a bright yellow colour on its own but when mud (clay) was added during the dyeing, it gave brown, greenish brown or khaki.

Although *Arctium minus* ssp. *pubens*, *Helleborus vesicarius* Aucher ex Boiss. and *Melissa officinalis* ssp. *inodora* existed in the study areas, it was not appreciated that they could be used in dyeing. We obtained different colours (light brown, yellow to khaki and yellow shades) from these plants using mordants (potassium aluminium sulphate, copper sulphate, ferrous sulphate, potassium dichromate). The colour sensitivity to light on wool and colours obtained from certain plants by using different mordants are given in Table 2. The colour sensitivity to light was usually good.

Isatis tinctoria ssp. *tomentella* existed in these areas, but was not used by local people for dyeing in the study areas. Unfortunately, we have not yet been able to obtain blue colour from *Isatis tinctoria* ssp. *tomentella*. There is a considerable lack of knowledge on obtaining indigo from plants in spite of numerous studies dealing with the production of indigo from *Isatis* species (Gilbert & Cooke, 2001). Another plant, *Phytolacca pruinosa* Fenzl (known in Turkish as 'şekerci boyası'), meaning sugar-merchant dye according to Baytop (1984), is used in food dyeing. However, local people believe it is poisonous and have never used it.

Seeds collected from the natural flora often failed to germinate (e.g. *Alkanna cappadocica* Boiss. & Balansa, *Alnus glutinosa* ssp. *antitaurica*, *Phytolacca pruinosa*, *Rhamnus oleoides* ssp. graecus) or the germination rate was low. Some plants germinated easily, e.g. *Arctium minus* ssp. *pubens*, *Chrysanthemum segetum*, *Datisca cannabina*, *Galium verum* ssp. *glabrescens*, *Melissa officinalis* ssp. *inodora*, *Reseda lutea* var. *lutea* and *Rumex patientia*.

Several taxa were propagated vegetatively (*Alnus glutinosa* ssp. *antitaurica*, *Cistus creticus*, *C. laurifolius* L., *Cotinus coggygria*, *Mentha longifolia* ssp. *longifolia* and *Rhus coriaria*). Fifteen plants (*Alnus glutinosa* ssp. *antitaurica*, *Arctium minus* ssp. *pubens*, *Chrysanthemum segetum*, *Cistus creticus*, *Cotinus coggygria*, *Datisca cannabina*, *Galium verum* ssp. *glabrescens*, *Isatis tinctoria* ssp. *tomentella*, *Melissa officinalis* ssp. *inodora*, *Mentha longifolia* ssp. *longifolia*, *Reseda lutea* var. *lutea*, *Rhamnus oleoides* ssp. *graecus*, *Rhus coriaria*, *Rubia tinctorum* and *Rumex patientia*) were transferred into the Dye Plants Collection Garden. Natural plants known as weeds were not cultivated [*Euphorbia rigida* M.Bieb., *Papaver rhoeas* L., *Sium sisarum* var. *lancifolium* (M.Bieb.) Thell., *Solanum alatum* Moench, *Xanthium spinosum* L.] because they were widespread in the region. Also several woody species [*Eriolobus trilobatus* (Poir.) M.Roem., *Daphne sericea* Vahl, *Fraxinus ornus* L. ssp. *cilicica* (Lingelsh.) Yalt., *Juglans regia* L., *Laurus nobilis* L., *Pinus bruita* Ten., *Pistacia terebinthus* ssp. palaestina (Boiss.) Engl., *Prunus spinosa* L. ssp. *dasyphylla* (Schur) Domin, *Punica granatum* L., *Quercus infectoria* Olivier ssp. *boissieri* (Reut.) O.Schwarz] and cultivated species (*Allium cepa* L.) were excluded from cultivation or transferral.

The tasks of gathering plants, dyeing and weaving are almost exclusively women's work in the villages in the study region and across Turkey. A few men take part in gathering and dyeing, especially in the main commercial hand-made carpet-weaving regions. When women dye and weave carpets, their incomes are increased. The red-dyed wool used in weaving the famous Taşpınar carpets was dyed with *Rubia tinctorum*, and plants such as *Pistacia lentiscus* L., *Plumbago europaea* L. and *Verbascum lasianthum* Boiss. ex Benth. provided dye for the various colours associated with the red. Many of these plants were gathered and processed by women (Ertuğ, 2000). Women continue to be the weavers, and in many villages carpet-weaving has social, practical and economic dimensions. Daughters are taught to weave from a very early age in the hope of making them more marriageable. Different weaving designs and use of different colours have traditionally been passed down from mother to daughter. Local knowledge is important as the characteristics of plant dyes depend on what part of the plant is used, where the plant grew (e.g. growth conditions), its age and what time of year it is reaped. Thus, different individuals of the same plant species may give different colours and intensities (Hancock, 1997).

Light intensity plays a vital role in the production of indigo precursors and, subsequently, indigo yield. From these findings, the timing of *Isatis tinctoria* ssp. *tomentella* harvesting could have a significant effect on the indigo yield from the crop, particularly when harvested earlier in the season (Gilbert & Cooke, 2001). Light, nutrient stress and low temperature stimulates the production of anthocyanins (Hancock, 1997). The indican content of *Polygonum tinctorium* Aiton increased with the maturity of the leaves (Minami *et al*., 2000).

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Table 2. Colour sensitivity to light and colour of some plants

Plant name	Mordant	Sensitivity to light	Colour
Alkanna cappadocica Boiss. & Balansa[1]	Potassium dichromate	3.5	$Y_{99}M_{50}C_{50}$
	Copper sulphate	3.5	$Y_{70}M_{40}C_{50}$
	Ferrous sulphate	4.0	$Y_{70}M_{50}C_{40}$
	Potassium aluminium sulphate	4.0	$Y_{80}M_{30}C_{30}$
	None	3.5	$Y_{50}M_{30}C_{30}$
Arctium minus ssp. *pubens* (Bab.) Arènes	Potassium dichromate	4.0	$Y_{80}M_{30}C_{40}$
	Copper sulphate	3.0	$Y_{60}M_{30}C_{30}$
	Ferrous sulphate	3.5	$Y_{70}M_{20}C_{20}$
	Potassium aluminium sulphate	4.5	$Y_{70}M_{40}C_{40}$
	None	4.5	$Y_{99}M_{40}C_{10}$
Cotinus coggyria Scop.	Potassium dichromate	3.5	$Y_{99}M_{50}C_{40}$
	Copper sulphate	4.5	$Y_{99}M_{60}C_{70}$
	Ferrous sulphate	4.5	$Y_{60}M_{40}C_{50}$
	Potassium aluminium sulphate	4.0	$Y_{99}M_{30}C_{30}$
	None	3.5	$Y_{70}M_{50}C_{40}$
Datisca cannabina L.	Potassium dichromate	4.0	$Y_{90}M_{40}C_{00}$
	Copper sulphate	4.5	$Y_{99}M_{50}C_{40}$
	Ferrous sulphate	4.5	$Y_{99}M_{60}C_{70}$
	Potassium aluminium sulphate	5.0	$Y_{99}M_{20}C_{10}$
	None	4.5	$Y_{99}M_{20}C_{20}$
Eriolobus trilobatus (Poir.) M.Roem.	Potassium dichromate	4.5	$Y_{99}M_{50}C_{10}$
	Copper sulphate	4.5	$Y_{90}M_{40}C_{20}$
	Ferrous sulphate	2.0	$Y_{99}M_{40}C_{20}$
	Potassium aluminium sulphate	2.0	$Y_{70}M_{20}C_{00}$
	None	2.0	$Y_{50}M_{40}C_{00}$
Helleborus vesicarius Aucher ex Boiss.	Potassium dichromate	3.5	$Y_{50}M_{10}C_{20}$
	Copper sulphate	4.5	$Y_{50}M_{20}C_{30}$
	Ferrous sulphate	3.0	$Y_{50}M_{30}C_{30}$
	Potassium aluminium sulphate	2.5	$Y_{60}M_{20}C_{20}$
	None	2.0	$Y_{60}M_{30}C_{40}$
Isatis tinctoria ssp. *tomentella* (Boiss. Balansa) P.H.Davis[1]	Potassium dichromate	2.5	$Y_{50}M_{10}C_{00}$
	Copper sulphate	3.0	$Y_{60}M_{20}C_{30}$
	Ferrous sulphate	4.5	$Y_{60}M_{30}C_{20}$
	Potassium aluminium sulphate	2.5	$Y_{20}M_{00}C_{00}$
	None	2.5	$Y_{40}M_{10}C_{00}$
Melissa officinalis ssp. *inodora* Bornm.[1]	Potassium dichromate	4.0	$Y_{99}M_{50}C_{50}$
	Copper sulphate	4.0	$Y_{99}M_{60}C_{70}$
	Ferrous sulphate	3.0	$Y_{60}M_{40}C_{40}$
	Potassium aluminium sulphate	2.5	$Y_{60}M_{20}C_{10}$
	None	3.5	$Y_{60}M_{30}C_{20}$
Prunus spinosa L. ssp. *dasyphylla* (Schur) Domin	Potassium dichromate	4.0	$Y_{80}M_{70}C_{70}$
	Copper sulphate	4.0	$Y_{80}M_{60}C_{60}$
	Ferrous sulphate	3.0	$Y_{50}M_{50}C_{50}$
	Potassium aluminium sulphate	3.5	$Y_{60}M_{50}C_{00}$
	None	4.0	$Y_{50}M_{50}C_{40}$
Reseda lutea var. *lutea* L.[1]	Potassium dichromate	4.0	$Y_{50}M_{30}C_{30}$
	Copper sulphate	4.0	$Y_{80}M_{30}C_{40}$
	Ferrous sulphate	3.5	$Y_{80}M_{10}C_{10}$
	Potassium aluminium sulphate	3.5	$Y_{50}M_{10}C_{10}$
	None	3.0	$Y_{30}M_{00}C_{00}$

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Table 2. *Continued*

Plant name	Mordant	Sensitivity to light	Colour
Rhamnus oleoides ssp. *graecus* (Boiss. & Reut.) Holmboe	Potassium dichromate	4.0	$Y_{99}M_{50}C_{30}$
	Copper sulphate	4.5	$Y_{90}M_{40}C_{40}$
	Ferrous sulphate	4.5	$Y_{90}M_{50}C_{50}$
	Potassium aluminium sulphate	4.5	$Y_{60}M_{20}C_{20}$
	None	4.0	$Y_{70}M_{20}C_{10}$
Rubia tinctorum L.	Potassium dichromate	4.5	$Y_{80}M_{99}C_{80}$
	Copper sulphate	4.5	$Y_{90}M_{90}C_{70}$
	Ferrous sulphate	4.5	$Y_{90}M_{99}C_{99}$
	Potassium aluminium sulphate	4.5	$Y_{90}M_{70}C_{20}$
	None	2.0	$Y_{50}M_{10}C_{30}$

[1]Plants were reported in the literature as dye plants in other areas, but were not used for dye in the study areas.

standard dye products are more readily obtained from growing these plants in fields due to the reasons mentioned above.

The dye plants examined in this study are mostly native to the Mediterranean region. In our research, we have concentrated on those plants that have already been used and have a potential as dye plants. We have also tried to test the domestication potential of these plants in the eastern Mediterranean region. In the future, these plants will be investigated for the cultivation and extraction of natural dyes for industrial uses. Coloured foods, textiles, cosmetics and pharmaceutical preparations are economically important for this region and research into the commercial production of natural dye stuff is essential. Therefore, it is necessary to study both the dye contents and their suitability for agricultural production.

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