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ORIGINAL ARTICLE

New archaeobotanical finds of *Isatis tinctoria* L. (woad) from Iron Age Gaul and a discussion of the importance of woad in ancient time

Véronique Zech-Matterne · Luc Leconte

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Abstract Although chemical analyses of textile remains have traced the use of *Isatis tinctoria* L. (woad) back to the Neolithic period, archaeobotanical remains of the plant are scarce in north-western Europe, especially in France. A new discovery in the rural settlement of Roissy, north of Paris, raises the question of local cultivation of woad from at least the fifth–fourth century B.C. (La Tène A/B1) in northern Gaul. The plant assemblage comes from the filling of a storage pit, which also included a wide variety of cultivated plants. These data represent a valuable contribution to the study of the circumstances of the adoption of woad as a new crop.

Keywords Archaeobotany · Northern France · Woad · *Isatis tinctoria* · Dyestuff

Introduction

Isatis tinctoria L. (woad), in French *guède*, *wède*, *waide*, *vouède*, *pastel des teinturiers*, *bleu de Picardie*, is a well-known crop, which was cultivated to produce a blue dyestuff. A new find of *Isatis* has been encountered on the site of Roissy "Zac Demi Lune", département of Val d'Oise, north of Paris. This rural settlement, excavated under the direction of L. Leconte, INRAP (*Institut National de Recherches Archéologiques Préventives*), is dated to the La Tène period (fifth–first century B.C.).

The site is located on deep loamy soils lying on a calcareous substratum. The thickness of loam varies from 2 to 12 m, giving the relief a flattened aspect. The pedological map of Paris shows a mosaic of brown soils around this location (Horemans 1984). The present day arable cover appears to be very suitable for crop cultivation of any kind. Archaeobotanical data from Iron Age sites near Roissy identify emmer and hulled barley as the main crops, followed by spelt, einkorn, naked wheat, broomcorn millet, celtic bean, lentil, pea and bitter vetch.

Several periods of occupation have been recognized on the Iron Age site under examination here. Our material originates from the transition La Tène A/B1 phase (430–380 B.C.). Although previous finds of *Isatis* have been reported from settlements or burials of high status, the related archaeological material and structures do not show any luxurious character for this occupation layer. However, a regional survey of "aristocratic" sites located in Île-de-France (meaning sites connected with "aristocratic" burials) presents the same absence of display.

Materials and methods

About 10 l of sediment from an early/middle La Tène storage pit (Str. 48) with the characteristic bottle-shaped profile were taken, sieved and the (only) charred botanical remains sorted out. Seeds identified as *I. tinctoria* have been measured and compared to recent specimens.

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V. Zech-Matterne (✉)
CNRS, UMR 7209, National Museum of Natural History, 55 rue Buffon, 75005 Paris, France
e-mail: veronique.zechmatterne@mnhn.fr

L. Leconte
INRAP CIF/Conservare, 21 rue des Cordeliers, 60200 Compiègne, France
e-mail: luc.leconte@inrap.fr

Results

The archaeobotanical material considered here was dispersed in the intermediate filling of the storage pit (layer U.S. 4) and mixed with other rubbish. Among many other taxa present in the sample, 104 carbonized seeds of *I. tinctoria* (woad) have been identified (Fig. 1b–e). All of them show an oval shape, with a round/pointed apex. A long groove marks the surface, as is usually the case with members of the Brassicaceae (Fig. 1a). The slightly reticulate epidermis pattern is clearly visible on some specimens (Fig. 1e). The pointed radicle is easily observed both on carbonized and fresh material. It appears to be a distinct character, which is clearly present on the analysed material, as it is in the drawing published by Stika (1999, Figs. 2 and 3). The dimensions in mm of 10 seeds from Roissy have been measured: ($L_{max} = 2.6$; average $= 2.4$; $L_{min} = 2.2$/ $W_{max} = 1.1$; average $= 0.9$; $W_{min} = 0.8$) as well as 10 modern seeds, from our reference collection ($L = 2.9$; 2.7; 2.5/$W = 1.5$; 1.3; 1.2) (Table 1). These measurements are somewhat smaller than those reported for three charred/or mineralized seeds found in Hochdorf ($2.8 \times 1.1 \times 1.0$ mm) (Stika 1999). However, the material from Roissy also looks shrivelled or immature. The width of the carbonized seeds is shortened by the lateral wrinkling of the epidermis, which is also observable, to a lesser extent, in the material published by Rösch (2008, Figs. 3–13).

Gold of pleasure, flax, barley, emmer, undetermined wheat, bitter vetch, undetermined pulses, broomcorn millet and possibly oat represent the cultivated plants in the archaeobotanical assemblage of Roissy. The range of wild plants represents cultivated fields and meadows, with an unexpected high percentage of *Leucanthemum vulgare*, a very good competitor component of “bad” pastures (Table 2).

Interpretation of the plant assemblage

The wide range of taxa (28), combined with the small number of remains of each of them and the nature of the context itself leads to an interpretation of the plant assemblage from Roissy as that of mixed rubbish. Consequently, it is difficult to determine whether it corresponds to the waste of food, fodder or craft by-products.

The number of food plants (9 taxa) among the cultivated taxa seems too high to result from the preparation of a single meal. Moreover, the percentage of chaff components is rather high, and includes isolated embryos, emmer glume bases and rachis internodes of hulled barley. This would rather indicate the by-products obtained by the cleaning of harvested crops. However, this hypothesis is not supported by the weed assemblage, which does not indicate cultivated fields, with the exception of *Papaver dubium/rhoeas* and *Vicia hirsuta/tetrasperma*. The spectrum also comprises

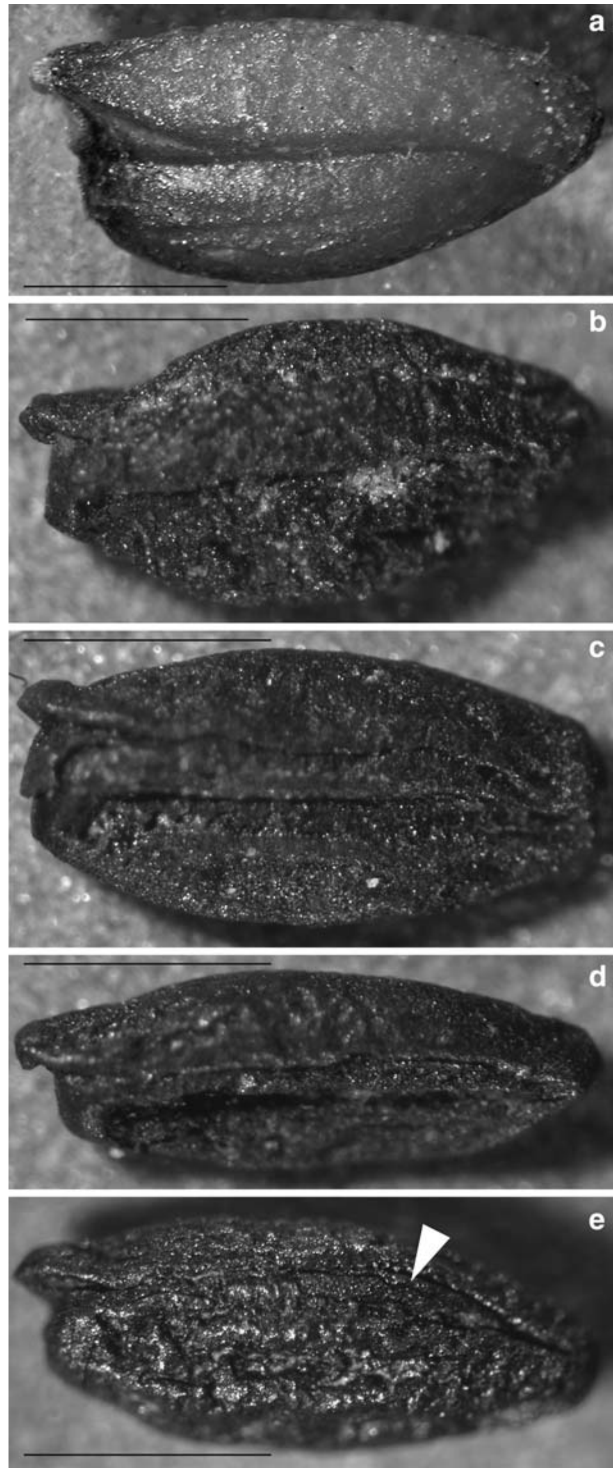

Fig. 1 View of the seeds of *Isatis tinctoria* L.: **a** modern; **b–d** carbonised remains from Roissy; **e** reticulate pattern of the **d** specimen (the *arrow*); scale 1 mm, photos by V. Matterne

plants of waste-land and pasture, such as *Alchemilla*, *Daucus carota*, *Leucanthemum vulgare* and undetermined Asteraceae.

Although the number of wild taxa appears to be rather high (75% of the assemblage; $n = 995$), in comparison

Table 1 Measurements in mm of 10 seeds from Roissy "Zac Demi Lune"

Modern seeds (uncharred)		Charred seeds from Roissy	
Length	Width	Length	Width
2.8	1.4	2.6	1.1
2.8	1.3	2.5	1.0
2.6	1.3	2.4	0.9
2.9	1.5	2.5	0.9
2.5	1.3	2.5	0.8
2.8	1.2	2.4	0.8
2.9	1.3	2.3	0.8
2.9	1.3	2.2	0.9
2.5	1.2	2.2	0.9
2.6	1.3	2.5	0.9

Table 2 Plant assemblage of Roissy "Zac Demi Lune", structure 48, layer 4, storage pit LT A/B1 (430–380 B.C.) including the *Isatis* find (R.O. Luc Leconte, INRAP)

Taxa	Vol: 10 l
Cultivated taxa	
Avena sp.	4 + 57 f.
Camelina sativa	6 + 27 f.
Cerealia	120 f.
Isolated embryo	114
Fabaceae dom.	5 f.
Hordeum vulgare, rachis internode	6 f.
Isatis tinctoria (seeds only)	104
Linum usitatissimum	1
Panicum miliaceum	7
Triticum dicoccum	2
Triticum dicoccum, glume fragment	349 f.
Triticum sp.	28 f.
Vicia ervilia	4 cotyl.
Stem fragment	3
Number of remains (without chaff)	245
Wild taxa	
Alchemilla sp.	1
Asteraceae	184 + 171 f.
Brassicaceae	1
Bromus sp.	2 + 32 f.
Caryophyllaceae	1
Chenopodium sp.	2
Cirsium sp.	1
Daucus carota	1 f.
Galium aparine/spurium	1 + 2 f.
cf. *Glyceria fluitans*	1
Leucanthemum vulgare	339 + 15 f.
Papaver dubium/rhoeas	2
Poa annua	32
cf. *Polycnemum arvense*	1
Rumex sp.	1
Setaria verticillata/viridis	4
Stellaria type	9
Vicia hirsuta/tetrasperma	22 + 71 cotyl.
Number of remains of wild taxa	750
Total number of remains	995

with cultivated taxa ($n = 245$), this assemblage cannot be interpreted as evidence of hay, grazing, or litter. The over-representation of *L. vulgare* (ox-eye daisy), for example, does not match this interpretation. This is considered to be a weedy component of pastures and meadows, not only because it is little consumed when green, but also because the fodder from it is not relished and of low food value.

This list of taxa does not give an idea of the composition of the surrounding flora. Nevertheless, and whatever this mixture could reflect, the hundreds of seeds of *I. tinctoria* can be interpreted as a strong indication of local cultivation of woad. If dyed cloth or dye were imported, only pigments or fragments of leaves would have been preserved, as the seeds are not used for dyeing. The only reason for finding seeds is the necessity of storing them for sowing in the next season. Woad was most probably cultivated, as the occurrence of *Isatis* in protohistoric and early historic weed assemblages from northern France is unknown, even in waterlogged conditions.

Considering the scarcity of woad records, these data represent a valuable contribution towards plotting the ancient geographical distribution of the plant in Gaul, and to determining if medieval and modern cultivation areas were based on earlier ones in the protohistoric period. With the extension of the archaeobotanical as well as textile analysis dataset, the precise circumstances of the adoption of woad as a new crop will start to be clarified.

The plant, its use and the dyeing process

Molecular markers used to distinguish species in the *Isatis* genus as well as landraces of *I. tinctoria* reveal a high genetic diversity in this group (Gilbert et al. 2002, cited by Spataro et al. 2007). Twenty-two species are given in *Flora Europaea* (Tutin et al. 1968–80). The species *I. tinctoria* is a biennial, glabrous member of the Brassicaceae, up to 1 m high, with yellow flowers clustered in dense racemes and seeds contained in pendulous flattened siliquae. Nowadays it is a common ruderal plant of dry and sunny locations such as waste ground, fallow land, cliffs and rocks and is also considered a noxious weed in cereal fields. According to *Flora Europaea*, *I. tinctoria* L. is thought to be native in south-west Asia and possibly in some parts of south-eastern Europe. The centre of origin in central Asia has been confirmed by genetic analyses (Spataro and Negri 2008).

Possible *Isatis* sp. occurs as a wild component of the flora identified from the seed material at the Neolithic site of Çatalhöyük, in central Anatolia (Fairbairn et al. 2002). The plant is naturalised in many places of ancient cultivation in Europe (Blamey and Grey-Wilson 1991) and cited as an alien/established species for France and Germany in the plants list of DAISIE (Delivering Alien Invasive Species Inventories for Europe). Although woad has been mainly used as a dyestuff for textiles and for the production of pigments used in hand painted books (like the Lindisfarne Gospels, seventh–eighth centuries), it is also known as a medicinal plant (Hamburger 2002), and a fodder plant cited by Dioscorides in the preface of his books II and III (Verhille, personal communication), with properties comparable to those of cabbage (Hullot 1997).

Woad cultivation requires deep, rich and well-drained soils. Although the yield is genetically controlled, the soil qualities and even light conditions have an influence on the individual production capacity of the plant (Gilbert and Cooke 2001). Dry and sunny conditions seem to improve the yield (Stoker et al. 1998). Manure must be added to the land because the crop is quite demanding in organic substances (Guarino et al. 2000).

The active substance for dyeing is not directly synthesised by the plant. It derives from a recombination of indoxyl molecules, derived from two precursors: isatan B and indican. This form of indigo is practically insoluble in water and has to be reduced to another form which is absorbable by the fibres to be dyed (Gilbert and Cooke 2001). The bacterium responsible for this reduction has been recently identified as *Clostridium isatidis* (Nicholson and John 2005). Once fixed to the cloth, after re-oxidation, indigo is quite stable and the brightness of the colour is preserved for centuries. A description of the main chemical structures and reactions leading to the obtaining of indigotine can be read in Rosenberg (2008).

The dyeing powder is extracted from the leaves after a long and complicated treatment. The leaves are harvested at maturity from the basal rosette and are subsequently smashed or ground in mills in order to extract the pulp. The crushed leaves are sprinkled with water, and the first fermentation takes place. After this, they are rolled into small balls, named *cocagnes* or *coques* in France, which can be stored and transported in this form. The desiccated balls of woad are thereafter ground with a quern or crushed with a mallet, then dampened with water and a second fermentation takes place. When dried, this paste called *agranat* represents the concentrated dyeing stuff, or *pastel*, which is ready for use.

The main transformation, or couching, takes place in anaerobic conditions and requires an alkaline environment. The dyeing vats are prepared and ashes or lime are usually added in order to assist the reduction process. After soaking, the cloth is exposed to the open air and the blue colour emerges as by magic.

A very detailed description of the extraction process and the preparation of the dyeing vats can be found in Guarino et al. (2000). The pigments used for painting were obtained, as a by-product, from the dyeing bath. They were collected from the foam floating on the surface and further concentrated (Vaissière and Félix 2006). Plant fibres retrieved from a waterlogged deposit at the Coppergate excavation at York (ninth–tenth centuries A.D.) have been assumed to be from a dye bath consisting of *Isatis* leaves. The plant could be identified due to the presence of the siliquae (Tomlinson 1985).

The chemical process corresponding to these steps is as follows: an enzymatic hydrolysis of the glycoside precursors indican B and isatan unblocks the indoxyl molecules. A dimerisation process splits the indoxyl into two molecules, indigotine (the main one) and indirubine. The couching corresponds to a reduction process, in which the indigo is transformed to leuco-indigo which is soluble in water. The colour of the dyeing bath is a pale yellow. After exposure to the air and thus re-oxidation, the leuco-indigo becomes insoluble indigo again and a blue *grand teint* is obtained. In order to improve the deepness of the colour, several immersions are made (Cardon 2003).

Previous archaeobotanical evidence of woad in France

Despite numerous identifications of the colouring agent through chemical analyses of archaeological textiles, occurrences of *Isatis* in archaeobotanical assemblages remain very scarce. The rare finds from French archaeological deposits are mainly the result of the use of leaves, not seeds, in the preparation process of the dyestuff. However, the cultivation of the plant on a large scale would normally have led to the preservation of seeds in storage contexts, at least for re-sowing.

Pradat and Marinval have published the discovery of three woad seeds in a rubbish pit dating to the fifth–fourth century B.C. on the site "Le Grand Jaunet" at Liniez, in the Indre département (Marinval and Pradat 2004). Pradat suggests that the local cultivation of the plant is not certain, considering the established status of the plant and the probability of its spontaneous occurrence as a weed in field flora of the Berry region.

Another find consisting of eighteen carbonized seeds, identified by A. Bouchette, comes from the fifth century B.C. site of "La Combe Fages" at Loupiac, Lot département (Zech-Matterne et al. 2009).

The next occurrence of woad is reported from the medieval farm site of Dury "Le Moulin" in the Somme region, northern France, where Bakels (1999) identified sixteen seeds of woad, from a mid ninth–tenth century A.D. storage pit.

The importance of woad in ancient times: a short review and a discussion

Archaeological contexts for dyeing activities are not easy to bring to light. In archaeobotanical assemblages as well, woad is only represented by a small number of specimens, at least in France. This raises the question of the dating of the beginning of local cultivation of the plant and the exact importance of this cultivated dyeplant in Gaul. The situation is rather similar in other parts of Europe.

Colours obtained from vegetable dyestuffs comprise mainly yellow, orange and brown. Only woad could add blue to this range and was the unique source of blue clothing. Other materials provide blue colours, like "Egyptian Blue", but in northern France in the Iron Age period it has been only used for colouring plaster. Such blue pigment has been regularly identified in the form of small pellets, for example at Braines in the Aisne département and at Varennes-sur-Seine in Seine-et-Marne (Auxiette et al. 2008; Cavassa 2008).

On a wider scale, the importance of woad cultivation during protohistoric and antique periods is not easy to determine. Despite the difficult process of extraction, the dyeing properties of *Isatis* were probably already used in the Neolithic, as shown by the discoveries of fibres dyed in blue at the site of l'Adaouste cave (Bouches-du-Rhône, France) (Cardon 2003, p. 288). This occurrence remains unique and does not automatically imply the local cultivation of the plant, as it is not confirmed by archaeobotanical remains.

Wool textile fragments dyed with woad have been recovered from Bronze Age and Hallstatt period salt-mines in Hallstatt, Austria (Joosten et al. 2006). The use of woad's properties has been widely identified through the discoveries of siliquae, seeds or pigments preserved in various contexts dating to the Iron Age, at Eberdingen-Hochdorf, Germany (Stika 1999), Heuneburg, Germany (Körber-Grohne 1981), Ginderup, Denmark (Jessen 1933) and at Feddersen Wierde, Germany (Körber-Grohne 1967). Woad has been found on the late Iron Age site of Dragonby, England (Van der Veen et al. 1993), flourishing during the last and first centuries B.C. and A.D., where 18 remains of woad, pod fragments and seeds were discovered in the bottom layer of a waterlogged pit.

Textile analyses have also supported the evidence of woad, including among others the items from Lonne Hede (Denmark), Dürrnberg (Austria), Hohmichele (Germany), Sainte-Geneviève-des-Bois and Estissac (France) (Cardon 2003).

Historical sources report the curiosity provoked among Roman authors by the use of woad by Celtic and Germanic people for body and hair painting, for prophylactic or ritual purposes (Caesar, B.G. V, 14, 2; Pliny the Elder H.N. XXII, 2, 1). This suggested that the plant could have been used both for textile and body art. However, archaeological evidence and artefacts connected with such a practice are lacking (Carr 2002).

Despite the often mentioned preference for non-blue colour in Roman society, the cultivation of woad in Italy became of some importance during the Roman Empire. The remains of large dye works in the city of Pompeii illustrate the craft specialisation of some localities in southern and central Italy (Guarino et al. 2000).

Later on, woad was widely used, especially in medieval time. It was of great importance to several countries (Germany, Italy, France) where it was cultivated up until *Indigofera tinctoria* L. (indigo), probably originating from India, reached Europe at the start of the 17th century A.D. In France, woad cultivation started to be of some importance in the 12th century A.D., when the blue colour became more and more appreciated as the official ornament of nobles. This new attitude contrasted with the lack of appreciation of blue in the early medieval period (Pastoureau 1997). From the 13th century A.D., woad was cultivated on an industrial scale in Picardy and Normandy (Pastoureau 1997). Previously, only the dyeplant *Rubia tinctorum* L. (madder) reached such an importance. This is, for example, shown by the illustration of a *waidier* (woad merchant) and his wife on the outer wall of the Assumption chapel, on the southern frontage of Amiens cathedral, as a grant for his generous donation in order to finance this major architectural work. Later on, in the middle of the 14th century, woad started to be grown in the so-called "triangle d'or" (Toulouse-Albi-Carcassone, southwestern France), named after the bright yellow colour of the plant when flowering. It remains nowadays a living symbol of this region.

Conclusion

Questions linked to the origins of woad cultivation can be discussed within a broader framework: the prehistoric production of dyestuffs and pigments and the evolution of the preference for the colour, according to social status, fashions and cultural habits. In this sense, the discovery of 104 seeds of woad at Roissy, interpreted as evidence for local cultivation, is significant. During the Iron Age of northern France, the tastes of fashion or symbolic values associated with the colour blue could be expressed in the way people dressed themselves as well in the way they decorated dwellings, at least in some privileged settlements.

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