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Two alien *Solanum* species new to the Spanish flora, and their characterization within the *Solanum nigrum* complex (*Solanaceae*)

Abstract

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The distribution of *Solanum physalifolium* var. *nitidibaccatum* and *Solanum sarrachoides* in Spain is described. These alien species are not included in any Spanish Flora and are not mentioned in any European or Mediterranean Flora as occurring in Spain. Both species show marked similarities and were long considered to belong to a single species, *S. sarrachoides;* however there are clear and precise differences between them.
Useful differential characters, here studied, are found among morphological (size and form of cotyledons, size and form of calyx, pubescence, etc.), micromorphological (microstructure of the berry, of the episperm, of the types of hairs, etc), physiological (band patterns obtained by electrophoresis) and ecological features.

Introduction

Solanum sect. *Solanum*, also known as *S.* sect. *Maurella* Nees or sect. *Morella* (Dunal) Bitter, mainly consists of weedy and cosmopolitan species.
The great morphological, ecological and genetic variability found in the genus as a whole is well expressed in this section, which has led to numerous problems of identification and denomination. All species belonging here are usually grouped together in the "*Solanum nigrum* complex". Within this complex, the specific limits are blurred due to the great vegetative plasticity resulting from the interaction of the environment with a variable genome, evidenced i. a. by a wide range of chromosome numbers (2n = 24, 48, 72, 96). Dunal (1852) recognized 53 species within the group, Bitter (1912, 1913) an even larger number, while other authors reduced the complex to a single species, *S. nigrum* L. According to Edmonds (1972) 300 "variants" have been recognized at specific and subspecific levels. Currently it is accepted that the "*Solanum nigrum* complex" comprises some 30 species (Schilling 1981).

In this paper two alien species of the "*Solanum nigrun* complex" new to the Spanish flora, both native of South America, are studied. Their nomenclature is confused, as for

other taxa of the complex. *S. sarrachoides* has been misnamed "S. nigrum var. *villosum*" or "*S. villosum*" (Stebbins & Paddock 1949), and *S. physalifolium* has been misidentified as "*S. villosum*", "*S. luteum*" and "S. nigrum var. *villosum*" (Edmonds 1986). The confusion may be due to the fact that both, as also the true *S. villosum* Mill. (= *S. luteum* Mill.), have hairy stems and leaves.

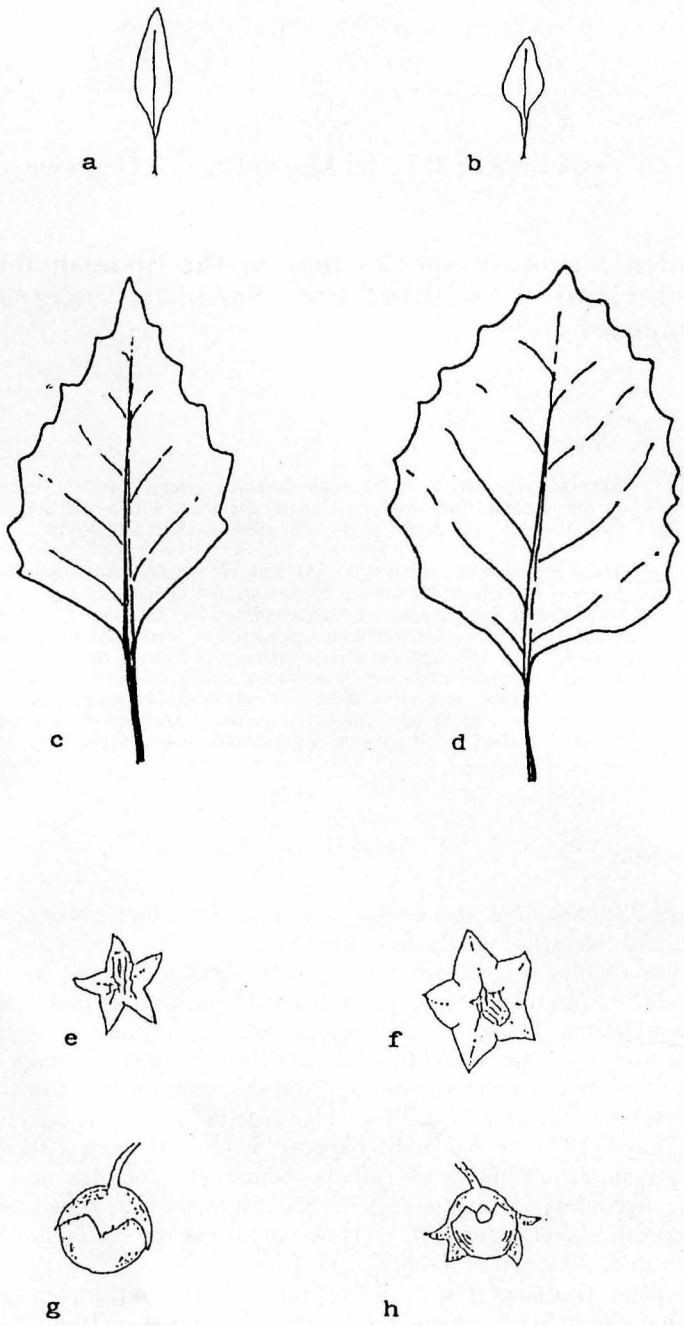

Fig. 1. Cotyledon, leaf, flower and berry shape of: *Solanum physalifolium* var. *nitidibaccatum* (a, c, e, g) and *S. sarrachoides* (b, d, f, h).

Table 1. Average (of 30 measures) and range of lenght-width ratio of cotyledons of *Solanum sarrachoides* and *S. physalifolium* var. *nitidibaccatum*.

	Origin	L/W
S. sarrachoides	Toledo	2.14 (1.75 - 2.34)
S. physalifolium	Navarra	3.42 (3.25 - 3.75)
	Palencia	3.86 (3.33 - 4.70)
	Soria	3.50 (3.30 - 3.82)

Table 2. Ranges of dimensions (of 30 measures) of berries, seed and granule numbers per berry of *Solanum sarrachoides* and *S. physalifolium* var. *nitidibaccatum*. (a = length; b = largest width; c = smallest width)

	Berry dimensions mm	Seeds per berry	Granules per berry
S. sarrachoides	a = 6.4 - 7.2 b = 6.3 - 7.2 c = 5.9 - 6.9	30 - 53	six
S. physalifolium	a = 4.3 - 6.7 b = 4.9 - 6.7 c = 4.6 - 6.3	15 - 26	two or none

Table 3. Seed dimensions (average of 80 measures), weight (average of 15 measures) and colour of *Solanum sarrachoides* and *S. physalifolium* var. *nitidibaccatum*.

	Lenght mm	Width mm	Index L/W	mg/100 seeds	Colour
S. sarrachoides	1.4	1.1	0.79	21.4	white
S. physalifolium	1.8	1.4	0.78	70.4	beige

Solanum sarrachoides Sendt. was described in 1846. Bitter (1912) split off *S. nitidibaccatum* from it, which Edmonds (1986) treated as a variety of *S. physalifolium* Rusby, var. *nitidibaccatum* (Bitter) Edmonds, said to differ from var. *physalifolium* in the number of flowers per inflorescence, pedicel length, sepal shape, berry size, and number and size of sclerotic granules.

In this paper some morphological, micro-morphological and physiological features of the two taxa found in Spain are compared, and data on their ecology and chorology in Spain are given. Their detailed characterization will permit their correct identification in their different phenological states.

Up to now only a few scattered Spanish records of these taxa have been published, and neither is mentioned in any of the current works devoted to the Spanish flora, probably due to their being mistaken for *Solanum nigrum* L.

In fact, *S. physalifolium* is widely distributed in the northern half of Spain. The first known Spanish collection dates from 1976, but its present wide distribution makes us think that it must have been introduced into Spain much earlier. The first collection of *S. sarrachoides* in Spain was made by Laorga (1983).

At present both taxa are widely distributed throughout Europe. Both have been recorded from Belgium, Czechoslovakia, England, France, Finland, Germany, Netherlands, Spain, Sweden, and Switzerland; and *Solanum physalifolium* var. *nitidibaccatum* alone, from Hungary and Norway.

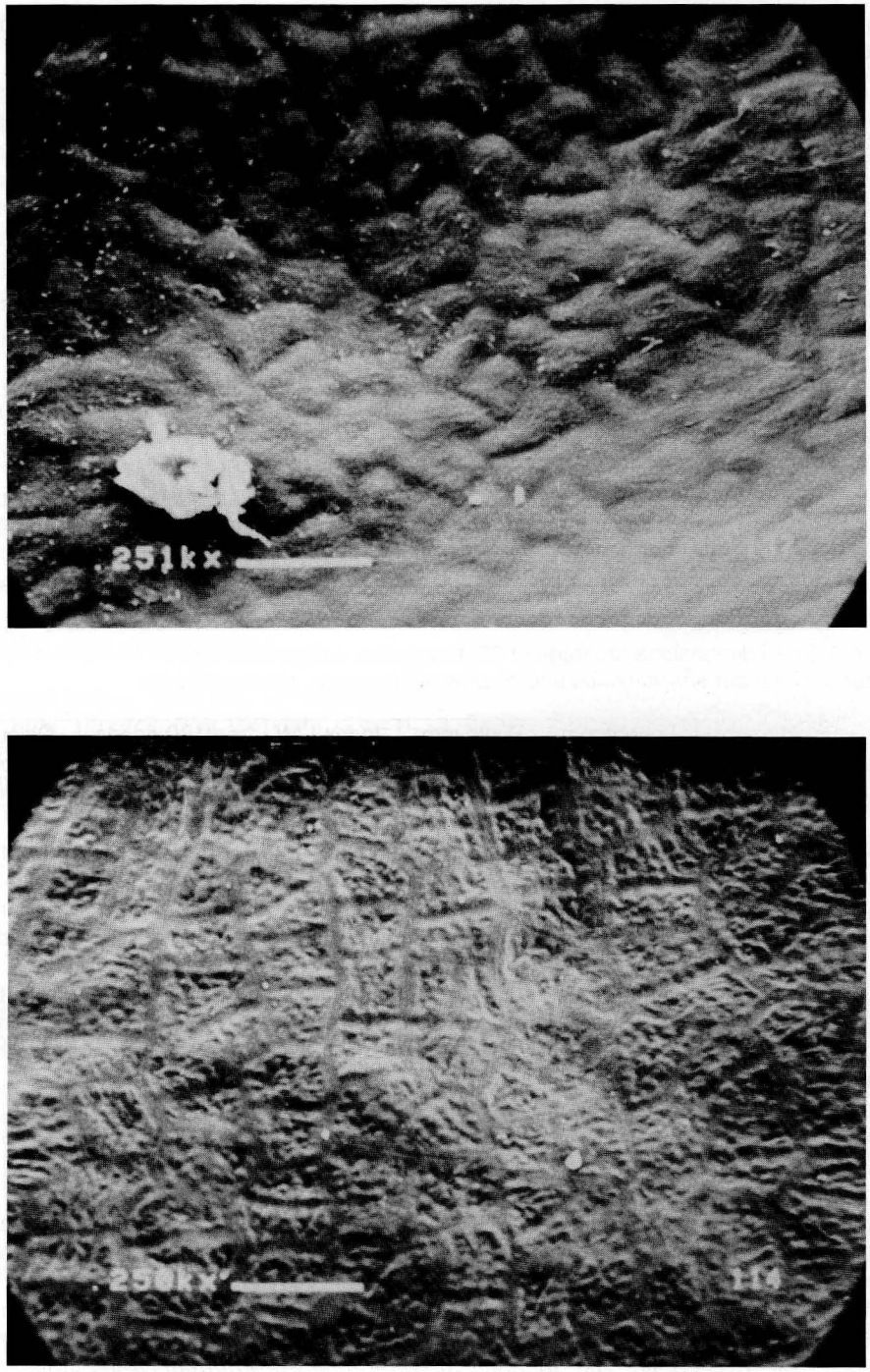

Fig. 2. Surface of the berries of *Solanum physalifolium* var. *nitidibaccatum* (above) and *S. sarrachoides* (below). Scale bar = 5.6 µm.

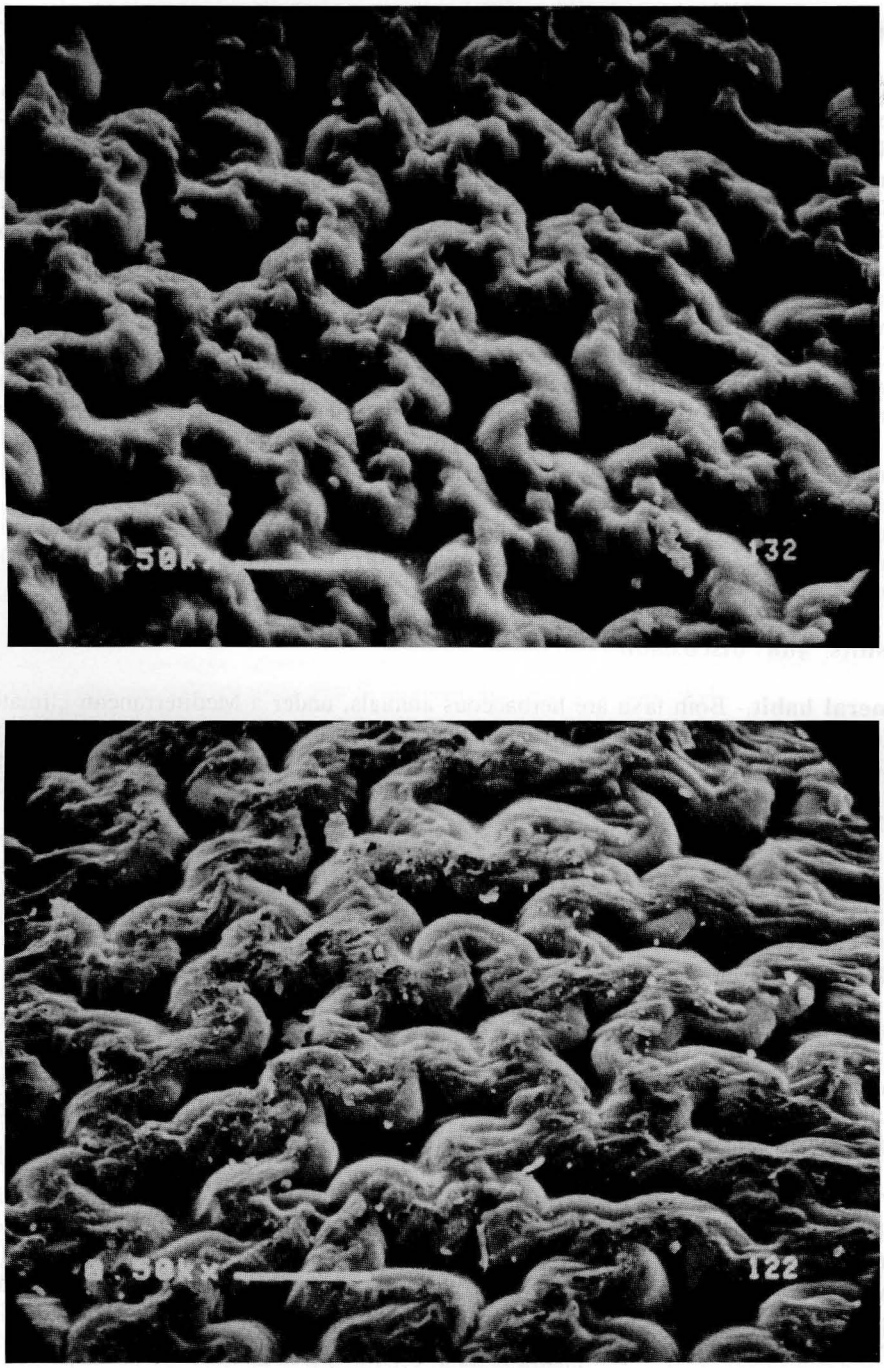

Fig. 3. Ornamentation of the seed testa in *Solanum physalifolium* var. *nitidibaccatum* (above) and *S. sarrachoides* (below). Scale bar = 2.8 μm.

Material and methods

Specimens collected in the wild in 1987, 1988, 1989 were used. In addition, the herbaria of the Royal Botanical Garden of Madrid (MA) and of the Faculty of Pharmacy of the Universidad Complutense of Madrid (MAF) were consulted.

In order to eliminate modification by the environment, some plants grown from seeds of *Solanum sarrachoides* collected in Malpica de Tajo (Toledo), and from *S. physalifolium* seeds collected in Mendavia (Navarra), San Esteban de Gormaz (Soria) and Palencia, were, in addition, cultivated in a glasshouse under identical conditions. Seed germination was enhanced by a treatment with 1000 ppm. of gibberellic acid. Seeds of each provenance were sown three times in succession into pots of 24 cm diameter.

Cotyledons were sampled at maximum development while being still green. Adult leaves were taken randomly from the middle stem portion (5th to 8th node). Sugar content was determined six times for each sample of completely mature fruits, using a high-contrast hand refractometer (0-32 %). Micromorphological observations were made by scanning electron microscopy, on gold-palladium coated preparations. Seed size was determined under a binocular stereo-microscope by means of an ocular micrometer, and seed weight with a precision scale. Polyacrylamide gel electrophoresis of the denaturated total seed proteins was effected in accordance with the methods of Laemmli (1970) and Payne & al. (1980).

Results and discussion

General habit.- Both taxa are herbaceous annuals, under a Mediterranean climate. In *Solanum sarrachoides* the stem is erect, or slightly prostrate as a result of abundant branching. In *S. physalifolium* var. *nitidibaccatum* the stem is mostly prostrate or decumbent, but can also be erect. Both species are up to 40-60 cm tall, villous and covered with glandular hairs.

Cotyledons.- In *Solanum sarrachoides* they are ovate-lanceolate (Fig. 1b), with a length/width index (il) of 1.75-2.34. In *S. physalifolium* var. *nitidibaccatum* they are lanceolate (Fig. 1a), with an il value always >3 (Table 1). Cotyledon shape is thus diagnostic for these two weedy species, at an early stage of their life cycle.

Leaves.- The leaf blades of *Solanum sarrachoides* are light green, elliptic-rhombic with a maximum width in the middle, and with sinuate-dentate margins (Fig. 1d). In *S. physalifolium* var. *nitidibaccatum* they are dark green, ovate-rhombic with a maximum width in the proximal third, and with sinuate-lobulate margins (Fig. 1c). Differences in leaf shape are slight, and unsuited for separating the two taxa.

The three trichome types defined by Edmonds (1982) in *Solanum* sect. *Solanum* - stalked glands, multicellular hairs and uniseriate hairs, glandular or eglandular - all occur in the two studied taxa, although the indumentum is denser in *S. sarrachoides* than in *S. physalifolium* var. *nitidibaccatum*. The former also shows a lower density of stomata than the latter. Probably both characters are influenced by the habitat, with *S. physalifolium* var. *nitidibaccatum* growing under cooler and moister conditions.

Flower.- The corollas in *Solanum sarrachoides* are white with a central light yellow star, small and rotate, with petals coalescent for half their length (Fig. 1f). The flowers are grouped in umbel-like inflorescences. In *S. physalifolium* var. *nitidibaccatum* the corollas are white with a purple central zone, stellate (Fig. 1e). The flowers are arranged in raceme-

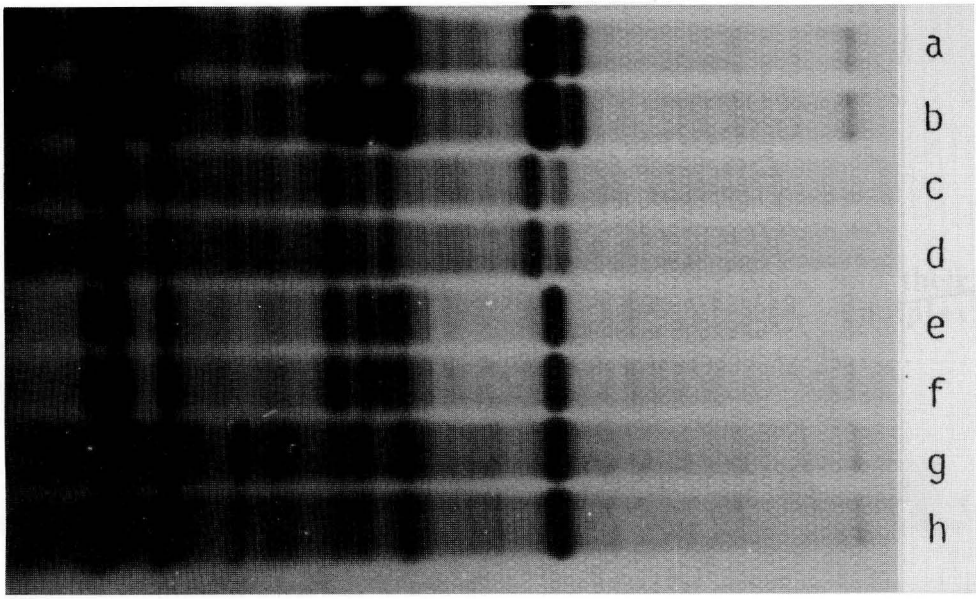

Fig. 4. Protein bands pattern of *Solanum nigrum* (a, b); *S. physalifolium* var. *nitidibaccatum* (c, d); *S. sarrachoides* (e, f); and *S. villosum* (g, h).

like inflorescences. These descriptions do not agree with those of Edmonds (1986), which may be due to geographical variation of corolla features.

Calix.- The calyx is strongly accrescent in both taxa, which is a good character for distinguishing them from their relatives. In *Solanum_sarrachoides* it encloses at least the lower half of the berry, being the sepals united in their inferior half or third, and with acuminate tips, whereas in *S. physalifolium* var. *nitidibaccatum* it encloses at most the lower half of berry, and the sepals are fused more than halfway to their blunt tips (Fig. 1h, g).

Micromorphological differences between the two taxa include the following: (1) In *Solanum sarrachoides* no stomata occur on the inner face of the sepals, whereas they do occur in *S. physalifolium* var. *nitidibaccatum*. (2) Whereas in both taxa the calix segments bear the same multicellular glandular and uniseriate hairs inside, the surface they occupy extends over more than half the total sepal length in *S. sarrachoides* but over only one fifth in *S. physalifolium* var. *nitidibaccatum*.

Fruit.- The berry in both taxa is almost exactly spherical, usually green when ripe, with a whitish cross at the apex and an irregular whitish net. That of *Solanum sarrachoides* is larger. The size range of the berries of both species is shown in Table 2. The fruits of both taxa also show significant differences in numbers of seeds and sclerotic granules (Table 2). The sugar content of the mature berry is lower in *S. physalifolium* var. *nitidibaccatum* (6.5 %) than in *S. sarrachoides* (11.2 %).

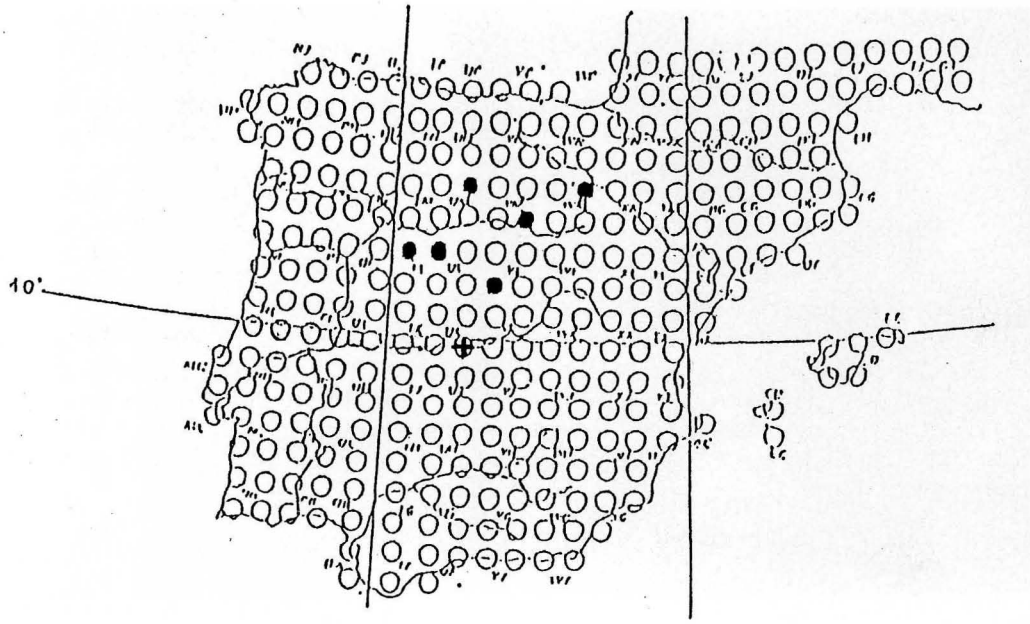

Fig. 5. Distribution in Spain of *Solanum physalifolium* var. *nitidibaccatum* (dots) and *S. sarrachoides* (cross).

The microstructure of the epicarp is shown in Fig. 2. In *Solanum physalifolium* var. *nitidibaccatum* the ornamentation of the berry consists of a network of grooves which delimit slightly granular raised areas, while in *S. sarrachoides* the netted grooves are shallower and areas in between are much rougher. Perhaps due to these morphological differences, the berry of *S. physalifolium* var. *nitidibaccatum* shows greater resistance to rupture of its epidermis.

Seed.- The seeds of *Solanum sarrachoides* are smaller than those of *S. physalifolium* var. *nitidibaccatum*, and have a different colour (Table 3). The micro-ornamentation of the testa is of the same type in both taxa but the raised bands are wider and denser in *S. sarrachoides* (Fig. 3).

The gel electrophorethic analysis of the total seed proteins shows a clear qualitative difference between the two species, and also between them, *S. nigrum* and *S. villosum* (Fig. 4).

Ecology and distribution in Spain.- The distribution in Spain of the two taxa does not overlap. *Solanum physalifolium* var. *nitidibaccatum* is found in the northern half of Spain, most frequently along the Duero river valley where it is a locally successful summer weed of irrigated areas (Fig. 5), whereas *S. sarrachoides* is confined to a very restricted area in the central part of the Tajo river valley and is also a summer weed on irrigated ground.

Average yearly summer temperatures are lower in northern Spain than in the central region, a meseta at an altitude of c. 700-800 m. The Central System mountain range also separates the Spanish areas of the two taxa.

Solanum sarrachoides grew without problems under experimental cultivation at Malpica de Tajo (Toledo), on the central meseta, and produced flowers and fruits throughout summer. This was not the case of *S. physalifolium* var. *nitidibaccatum* which in the hot season (with maximum day temperatures of 35-40°C) did not produce flowers or fruits despite of irrigation. The climate of the areas of Spain in which the two taxa are found corroborates these observations. Certain morphological characteristics of *S. physalifolium* var. *nitidibaccatum*, such as its less dense indumentum, possibly explain its being better adapted to mild summer temperatures.

Dispersal strategy is the same in both taxa: at the slightest shock, ripe berries fall to the ground together with the calyx and peduncle, and remain there without drying out for a long period of time, particularly those of *Solanum physalifolium* var. *nitidibaccatum* due to their harder epicarp. Thus, dispersal is very limited, except for carriage by birds. Water appears to be the main agent of dispersal, which accounts for the occurrence of both species in important river valleys and in irrigated areas, in Spain.

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