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Fruit and Seed Morphology of Some Species of Solanaceae

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Abstract

The fruit and seed morphology of 24 species, representing seven genera of Solanaceae were investigated by using a binocular stereomicroscope and scanning electron microscopy (SEM), to determine the significance of fruit and seed coat features as taxonomic characters. Morphological characters, including color, texture, shape, fruit type, hilum position, anticlinal shape and periclinal shape. There were three major patterns of seed ornamentation: irregular reticulate, regular reticulate and verrucate reticulate. The dendrogram showed that species could be grouped into two major clusters, the first cluster (I) contains 15 species and divided into two groups, while the second cluster (II) contains nine species that can be divided into two groups. The data proved useful in the construction of a dichotomous indented key to the studied species. Twenty characters were used to create systematic Key using DELTA key-generating programs. The results indicate that the morphological characteristics of fruits and seeds would be helpful for the identification of Solanaceae species.

***Key words*:** *Morphology, Seed, Fruit, SEM, Solanaceae*

Introduction

The Solanaceae is one of the most important and large families of flowering plants. The family is widely distributed in a diversity range of ecological habitats in both tropical and temperate regions. It consists of about 98 genera and 2700 species (Olmstead and Bohs 2007).

In Egypt Solanaceae is a well-represented family, about 30-33 wild species belonging to eight genera according to (Tãckholm 1974 and Boulos 2002; 2009). Moreover (Hepper 1998) reported that the family is represented by 25 genera and about 91 species including cultivated species.

The first systematic classification of the Solanaceae was proposed by (Dunal 1852) and consisted of a division of the 61 genera known at the time, into two tribes and 11 subtribes, while (Wettstein 1895) divided the Solanaceae into two series A and B which comprise three and two tribes respectively. Recently, Hunziker (2001) classified the family into 6 subfamilies and about 21 tribes.

Several workers (Dachyshyn 1965, Srivastava 1969, Nha & Danert 1973, Dave *et al.,* 1980, Symon 1979 & 1984, Chiarini & Barboza 2007 and Zhigila *et al.,* 2014) described the morphological characters of fruit in some species of Solanaceae.

Seed micro and macromorphology have been shown to provide useful characters for taxonomic relationship of plant families (Esau 1953, Mohana 1974, Corner 1976, Barthlott 1981 & 1984 and Shetler 1986). Recent studies on Solanaceae have shown that seed morphology characters are of considerable systematic significance, both at the generic and specific levels. Several previous studies have examined seed morphology of various members of some species of Solanaceae using both light and scanning electron microscopy. (Bahadur & Farooqui 1986, Axelius 1992; Zhang & Wen 1996 Hoare & Knapp 1997; Carvalho *et al*., 1999, Zhang & Lu 1999; Kong *et al.,* 2011; Ghimire *et al.,* 2011; Zhang *et al.,* 2005, Kaya *et al.,* 2016 and Ahmed & Fadl 2016).

The aim of the present study is to describe the diagnostic characters of fruit and seed of the studied species as important tools in the delimitation of clade within Solanaceae.

Materials and Methods

The present study included 24 species of Solanaceae belonging to two subfamilies and five tribes according to the classification of Hunziker (2001). The study was based on fresh materials collected from different

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localities in Egypt in addition to Herbarium specimens, in few cases, kept in Cairo University Herbarium (CAI) and the Herbarium of the Desert Research Center (CAIH). Specimens of studied taxa were prepared and kept in the herbarium of Botany and Microbiology Department, Faculty of Science (Boys branch) Al-Azhar University, Cairo, Egypt. Data of the collected materials are shown in Table 1. (N.B. specimens of *S. sinaicum* collected from cultivated specimen grown in Agricultural Museum).

The collected materials were identified by means of comparison with specimens kept in different Herbaria. In addition, keys of Tãckholm (1974) and Boulos (2002) were also used.

Fruit and seed details were examined with the aid of binocular stereo microscope under incident light and photographs. Also for the study of seed using SEM, three seed were mounted on metal stubs, coated, golden, examined and photographed by JEOL Scanning electron microscope at the accelerating voltage of 18kv, at the Electron Microscope at The Regional Center for Mycology and Biotechnology, Al Azhar University, Cairo, Egypt.

All the examined species were used as operational taxonomic units (OUT's). The 20 character states which resulted from morphological data were analyzed by means of Hierarchical Cluster analysis used distance and similarity measure Bray-Curtis Sorensen.

The relationships between the studied species of Solanaceae have been demonstrated as dendrograms (Fig. 1-A and 1-B) by using statistical programs PC-ORD (Software, version 5) and Primer (Software, version 6.0). A total of 20 comparative morphological characters for studied species were scored and coded for creating data matrix used for numerical analysis. The relationships between the studied species have been demonstrated as generating Key by using the statistical program DELTA software of programs (Dallwitz 2010).

Results and Discussion

1. Fruit morphology

Fruit is very variable in shape, type, texture, color, size and dehiscence (Table 2 and Plate 1).

The fruit color varied from black in *L. schweinfurthii* var. *aschersonii* and *S. nigrum* var. *nigrum*, black-red in *L. europaeum*, yellow-orange in *S. coagulans*, *S. elaeagnifolium*, *S. forsskaolii* and *S. incanum,* orange in *L. shawii, P. peruviana*, *S. sinaicum* and *S. villosum* subsp. *villosum*, grey in *P. ixocarpa*, bright red in *W. somnifera*, yellowish green in *P. angulata*, orange red in *W. obtusifolia* to brown in the rest.

The fruit types of the studied species ranged between capsule in *D. innoxia, D. stramonium, H. albus*, *H. boveanus*, *H. desertorum, H. muticus*, *H. pusillus*, *N. glauca* and *N. rustica* and berry in all the rest of the studied taxa. Fruit dehiscence by valves in *D. innoxia, D. stramonium*, *N. glauca* and *N. rustica*, circumscissile in *H. albus*, *H. boveanus*, *H. desertorum, H. muticus* and *H. pusillus* and indehiscence in the rest.

The shape of fruit ranged between globose in most studied species, spheroidal in *D. innoxia, S. coagulans, S. elaeagnifolium*, *S. forsskaolii, S.incanum, S. nigrum* var. *nigrum*, *S. sinaicum* and *S. villosum* subsp. *villosum*, ovoid in *D. stramonium, N. glauca* and *N. rustica* and oblong in *H. albus, H. boveanus, H. desertorum, H. muticus* and *H. pusillus.* The length of the fruits ranged between; 0.4-1.5 cm. in most studied species and 1.7-2.5 cm. in *S. incanum* while 3.2-3.9 cm in *D. innoxia* and *D. stramonium.* On the other hand, the width recorded 1.7-3.6 cm. in *D. innoxia*, *D. stramonium* and *S. incanum* while 0.4-1.5 cm. in the remainders.

The fruit included in opened calyx in all studied species of *Hyoscyamus* and *Nicotiana*, it was included in closed calyx in studied species of *Physalis* and *Withania* and exposed in the rest of the studied taxa.

The texture of the fruit ranged between spiny in *D. innoxia* and *D. stramonium,* Glabrescent in *S. elaeagnifolium*, tuberculate in *H. albus*, *H. boveanus*, *H. desertorum, H. muticus* and *H. pusillus* and glabrous in the remainders.

Table 1: List of the collected species for the present study

Species	According to Hunziker, 2001		Collection data
	Subfamily	Tribe	
1- *Datura innoxia* Mill.	Solanoideae	Datureae	Al-Azhar University Cairo, 5/11/2016; Osama Ragab (Al Azhar Univ.)
2- *Datura stramonium* L.			Al-Azhar University Cairo, 23/5/2017 and Kafr El-Dwar, 29/6/2017; Osama Ragab, (Al Azhar Univ.)
3- *Hyoscyamus albus* L.		Hyoscyameae	Burg El Arab- El Hammam Coastal road, 15/5/2017; O.N. Ghaly, (Al Azhar Univ.)
4- *Hyoscyamus boveanus* (Dunal) Asch. & Schweinf.			Wadi El Messerdy, Saint Katherine, South Sinai , 2/5/2010; O.N. Ghaly, (CAIH)
5- *Hyoscyamus desertorum* (Asch. & Boiss.) Täckh.			Wadi El-Arish, 14/9 /1965; L. Boulos, (CAI)
6- *Hyoscyamus muticus* L.			Cairo-Alexandria road, 100km, 13/ 12/ 2016; Osama Ragab, (Al Azhar Univ.) Shalateen-Abu Ramad road, 60 km, 7/4/2017; O.N. Ghaly (Al Azhar Univ.)
7- *Hyoscyamus pusillus* L.			Wadi Tiniya, Saint Katherine Protectorate, 20/4/2008; H. Shabana, (CAIH)
8- *Lycium europaeum* L.		Lycieae	Alexandria - Matruh Coastal road, 237 km, 12/3/2017; Osama Ragab, (Al Azhar Univ.)
9- *Lycium schweinfurthii* Dammer var. *aschersonii* (Dammer) Feinbrun			Alkom Alakhdar island, El Brullus, 20/3/2017; Osama Ragab, (Al Azhar Univ.)
10- *Lycium shawii* Roem & Schult.			Wadi Hagul, 26/12/2017; Osama Ragab, (Al Azhar Univ.)
11- *Physalis angulata* L.		Solaneae	Pajour, Minufiyah, 7/11/2017; Osama Ragab, (Al Azhar Univ.)
12- *Physalis ixocarpa* Brot. ex Hornem.			Kafr El-Dwar, 27/10/2016; Osama Ragab, (Al Azhar Univ.)
13- **Physalis peruviana* L.			Nasr City- Cairo, 14/3/2018; Osama Ragab, (Al Azhar Univ.)
14- *Solanum coagulans* Forssk.			Wadi Darweena, Gabel Elba, 1/4/ 2000; Iman Al- Gohary, (CAIH)
15- *Solanum elaeagnifolium* Cav.			Burg El Arab City, 15/5/2017; O.N. Ghaly, (Al Azhar Univ.)
16- *Solanum forsskaolii* Dunal			Wadi Maarafaii,Gebel Elba, 8/4/2017; O.N. Ghaly, (Al Azhar Univ.)
17- *Solanum incanum* L.			Wadi Kanthesrob, Gebel Elba, 9/4/2017; O.N. Ghaly, (Al Azhar Univ.)
18- *Solanum nigrum* L. var. *nigrum*			Kafr El-Dwar, 27/10/2016; Osama Ragab, (Al Azhar Univ.)
19- *Solanum sinaicum* Boiss.			Agriculture Museum Garden, Giza, 10/1/2018; Osama Ragab, (Al Azhar Univ.),
20- *Solanum villosum* Mill. subsp. *villosum*			Minufiyah, 5/4/2017 and Burg El Arab City, 15/5/2017; Osama Ragab (Al Azhar Univ.)
21- *Withania obtusifolia* Täckh.			Wadi Akaw, Gebel Elba, 26/4/2013; O.N. Ghaly and M. Abutaha, (CAIH)
22- *Withania somnifera* (L.) Dunal			Cairo University, 10/4/2017; Minufiyah, 4/2017 and Nasr City- Cairo, 3/4/2018; Osama Ragab, (Al Azhar Univ.),
23- *Nicotiana glauca* R.C. Graham	Cestroideae	Nicotianeae	Alexandria-Matrouh road, 237 km, 12/3/ 2017; Osama Ragab, (Al Azhar Univ.)
24- *Nicotiana rustica* L.			Agriculture Museum Garden, 4/1988; S. Khalifa, (CAIH)

*****Cultivated species

Table 2: Morphological characters of fruit

Character / Species	Fruit mean length/ cm	Fruit mean width/ cm	fruit color	Fruit type	Fruit dehiscence	Fruit shape	Fruit calyx	Fruit texture
Datura innoxia	3-3.9	2.6-3.6	1	1	1	1	1	1
Datura stramonium	3.2-4	2.2-3	1	1	1	2	1	1
Hyoscyamus albus	1-1.3	0.6-0.7	1	1	2	3	2	4
Hyoscyamus boveanus	1.1-1.3	0.5-0.6	1	1	2	3	2	4
Hyoscyamus desertorum	0.8-0.9	0.5-0.6	1	1	2	3	2	4
Hyoscyamus muticus	0.7-1.3	0.5-0.7	1	1	2	3	2	4
Hyoscyamus pusillus	0.9-1	0.3-0.4	1	1	2	3	2	4
Lycium europaeum	0.4-0.5	0.4-0.5	3	2	3	4	1	2
Lycium schweinfurthii* var. *aschersonii	0.4-0.45	0.4-0.45	2	2	3	4	1	2
Lycium shawii	0.4-0.45	0.35-0.45	5	2	3	4	1	2
Nicotiana glauca	0.55-1.3	0.6-0.85	1	1	1	2	2	2
Nicotiana rustica	0.9-1	0.7-0.8	1	1	1	2	2	2
Physalis angulata	1.2-1.5	1.2-1.5	8	2	3	4	3	2
Physalis ixocarpa	1.2-1.4	1.2-1.4	6	2	3	4	3	2
Physalis peruviana	1-1.3	1-1.2	5	2	3	4	3	2
Solanum coagulans	0.6-1	0.6-1	4	2	3	1	1	2
Solanum elaeagnifolium	0.8-1.2	0.8-1.2	4	2	3	1	1	3
Solanum forsskaolii	0.5-.0.6	0.5-0.6	4	2	3	1	1	2
Solanum incanum	1.7-2.5	1.7-2.5	4	2	3	1	1	2
Solanum nigrum* var. *nigrum	0.6-0.7	0.6-0.7	2	2	3	1	1	2
Solanum sinaicum	0.58-0.62	0.58-0.62	5	2	3	1	1	2
Solanum villosum* subsp. *villosum	0.5-0.9	0.5-0.9	5	2	3	1	1	2
Withania obtusifolia	0.5-0.7	0.5-0.7	9	2	3	4	3	2
Withania somnifera	0.6-0.7	0.6-0.7	7	2	3	4	3	2

Fruit color: 1= brown / 2= black / 3=black – red/ 4=yellow-orange / 5=orange / 6=grey / 7=bright red / 8= yellowish green / 9=orange red
Fruit type: 1= capsule /2= berry
Fruit dehiscence: 1=valve /2=circumscissile /3=indehiscence
Fruit shape: 1= spherical /2= ovoid /3=oblong /4=globose
Fruit calyx: 1= exposed /2= included in opened calyx /3=included in closed calyx
Fruit texture: 1= spiny /2= glabrous /3=glabrescent /4=tuberculate


1

Datura innoxia


2

Datura stramonium


3

Hyoscyamus albus


4

Hyoscyamus boveanus


5

Hyoscyamus muticus


6

Hyoscyamus desertorum


7

Hyoscyamus pusillus


8

Lycium europaeum


9

Lycium schweinfurthii* var. *aschersonii


10

Lycium shawii


11

Nicotiana glauca


12

Nicotiana rustica

Plate 1 (Figs. 1-12): Fruit morphology in studied species.

13

Physalis angulata

14

Physalis ixocarpa

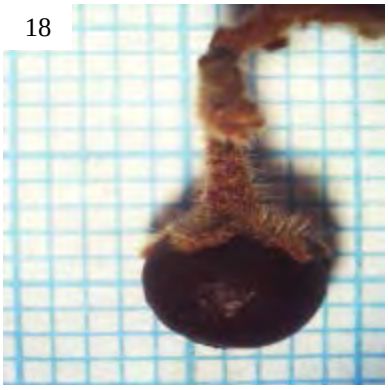
15

Physalis peruviana

17

Solanum elaeagnifolium

18

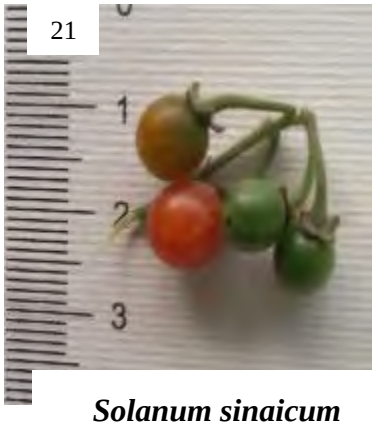


Solanum forsskaolii

16

Solanum coagulans

21



Solanum sinaicum

19

Solanum incanum

20

Solanum nigrum* var. *nigrum

22

Solanum villosum* subsp. *villosum

23

Withania somnifera

24

Withania obtusifolia

Plate 1 (Figs. 13-24): Fruit morphology in studied species.

2. Seed morphology

The morphology of mature seed showed some variation in size, shape, color, texture, measurement, ornamentation and hilum position (Table 3 and plate 2 and 3).

The number of seed / fruit is many, more than 8 seeds in most studied species but few (4-8 seeds) in *L. europaeum*, *L. schweinfurthii* var. *aschersonii*, *L. shawii, S. coagulans* and *S. forsskaolii*. Seed shape ranged between reniform in *D. innoxia*, *D. stramonium*, *H. boveanus*, *L. europaeum*, *L. schweinfurthii* var. *aschersonii*, *L. shawii, S. forsskaolii* and *W. obtusifolia,* oblong- obovate in *N. glauca,* broadly ovoid in *H. desertorum, S. coagulans, S. elaeagnifolium, S. incanum* and *S. sinaicum* and obovoid in the remainders. Seed is flattened in *D. innoxia*, *P. ixocarpa, P. peruviana*, *S. forsskaolii, S. sinaicum*, *S. villosum* subsp. *villosum* and *W. somnifera,* slightly convex in *H. albus*, *H. boveanus*, *L. shawii*, *P. angulata*, *S. elaeagnifolium, S. incanum*, *S. nigrum* var. *nigrum* and *W. obtusifolia* and convex in the remainders.

The color of seed: varied from light brown, black, brown, yellow to brown, yellow, yellowish brown and dark brown. The yellowish brown in most studied species, light brown in *D. innoxia* and *W. obtusifolia,* black in *D. stramonium*, brown in *L. europaeum, L. schweinfurthii* var. *aschersonii, L. shawii* and *N. glauca,* yellow to brown in *S. incanum,* yellow in *P. angulata, P. ixocarpa*, *P. peruviana*, *S. sinaicum* and *W. somnifera* and dark brown in *N. rustica, S. coagulans, S. elaeagnifolium* and *S. forsskaolii*. Seed texture smooth in *S. elaeagnifolium*, rough in *D. innoxia* and *D. stramonium*, slightly tuberculate in *P. angulata, Ph. ixocarpa*, *Ph. peruviana, S. coagulans, S. incanum, S. nigrum* var. *nigrum*, *S. sinaicum* and *S. villosum* subsp. *villosum*, striate in *N. glauca* and tuberculate in the rest.

The length of seeds ranged between; 0.6-1.3 mm. in *H. albus, H. boveanus, H. desertorum, H. pusillus, N. glauca* and *N. rustica* while it was 2.8 mm. in *D. innoxia*, *D. stramonium*, *S. coagulans*, *S. elaeagnifolium* and *S. forsskaolii* and 1.4-2.8 mm. in the remainders.

The width of seed was less than 2 mm. in most studied species and 2 mm or more in *D. innoxia*, *D. stramonium, L. europaeum*, *L. schweinfurthii* var. *aschersonii*, *L. shawii, S. coagulans*, *S. elaeagnifolium* and *S. forsskaolii*.

The hilum position: is usually terminal while it was subterminal in *D. innoxia*, *D. stramonium, S. coagulans, S. elaeagnifolium, S. sinaicum* and *W. obtusifolia* and lateral in *H. albus, H. desertorum, L. europaeum, N. glauca, N. rustica, P. angulata, P. ixocarpa* and *P. peruviana.* Hilum shape inconspicuous in most studied species and conspicuous in *D. innoxia*, *D. stramonium, H. desertorum, L. europaeum*, *L. shawii, N. glauca, N. rustica, P. angulata, S. coagulans*, *S. elaeagnifolium* and *S. forsskaolii*.

Seeds were shiny in *S. coagulans* and *S. elaeagnifolium* and dull in the remainders.

Seed ornamentation

There were three major patterns of seed ornamentation: Irregular reticulate in most studied species (Plate 3); regular reticulate in *S. forsskaolii* (Plate 3; Fig. 18) and verrucate reticulate in *D. innoxia* and *D. stramonium* (Plate 3; Figs. 1-2)

Anticlinal wall shape: was usually undulate, slightly undulate in *D. stramonium, D. innoxia, H. muticus, L. shawii, S. elaeagnifolium, S. sinaicum* and *S. villosum* subsp. *villosum,* slightly straight in *L. europaeum* and *L. schweinfurthii* var. *aschersonii* and straight in *S. forsskaolii.*

Anticlinal thickness: is thin in *H. muticus, N. glauca*, *N. rustica*, *S. forsskaolii* and *W. obtusifolia*, thick in *H. albus*, *H. boveanus*, *H. desertorum*, *S. coagulans*, *S. elaeagnifolium* and *S. villosum* subsp. *villosum* and very thick in the rest.

Anticlinal level: was raised in most of the studied species, slightly raised in *D. innoxia*, *D. stramonium*, *H. desertorum, H. muticus*, *L. shawii*, *N. glauca, S. elaeagnifolium*, *S. incanum*, *S. nigrum* var. *nigrum*, *S. villosum* subsp. *villosum* and *W. obtusifolia* and grooved in *P. angulata, P. ixocarpa* and *P. peruviana*.

Periclinal wall: may be flat, slightly concave and concave. The slightly concave in *D.*

innoxia, *S. elaeagnifolium* and *S. forsskaolii*, concave in *H. albus*, *H. boveanus*, *H. desertorum, H. muticus, L. shawii, S. incanum* and *W. obtusifolia* and flat in the reminders.

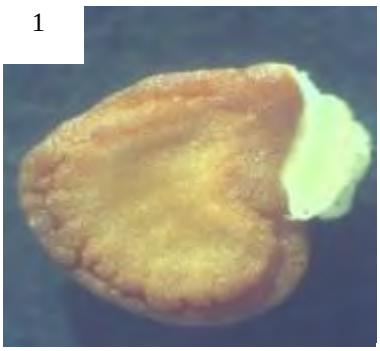
Also the cells are usually wide, narrow in *D. innoxia, D. stramonium, H. pusillus, L. europaeum*, *L. schweinfurthii* var. *aschersonii*, *S. elaeagnifolium*, *S. incanum, S. nigrum* var. *nigrum*, *S. villosum* subsp. *villosum* and *W. somnifera* and very wide in *H. muticus*, *N. glauca* and *N. rustica*.

From the SEM data, it was noticed that the seed surface sculpture, aspects of the anticlinal and periclinal walls could serve as good diagnostic parameters at the generic and specific level in the studied Solanaceae.

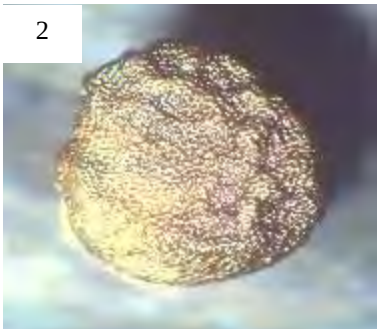
Table 3: Morphological characters of seed

Character / Species	Number of seeds in fruit	Seed shape	Seed	Seed color	Seed texture	Seed length (mm)	Seed width (mm)	Hilum position	Hilum shape	Seed shines	Seed ornamentation	Anticlinal			Periclina l shape	Cells
												Shape	Thickness	Level		
Datura innoxia	2	1	1	1	2	4.1-5	3-3.5-4	2	1	2	3	1	3	1	2	1
Datura stramonium	2	1	3	2	2	3-3.5	2.3-2.8	2	1	2	3	1	3	1	1	1
Hyoscyamus albus	2	2	2	6	3	1-1.3	1-1.1	3	2	2	2	2	2	2	3	2
Hyoscyamus boveanus	2	1	2	6	3	0.9-1.1	0.5-0.8	1	2	2	2	2	2	2	3	2
Hyoscyamus desertorum	2	4	3	6	3	0.9-1	0.8-0.9	3	1	2	2	2	2	1	3	2
Hyoscyamus muticus	2	2	3	3	3	1.7-1.9	1.6-1.7	1	2	2	2	1	1	1	3	3
Hyoscyamus pusillus	2	2	3	6	3	1.1-1.3	1-1.1	1	2	2	2	2	3	2	1	1
Lycium europaeum	1	1	3	3	3	2.3-2.6	2-2.5	3	1	2	2	3	3	2	1	1
Lycium schweinfurthii* var. *aschersonii	1	1	3	3	3	2-2.6	1.7-2.3	1	2	2	2	3	3	2	1	1
Lycium shawii	1	1	2	3	3	1.9-2.8	1.8-2.8	1	1	2	2	1	3	1	3	2
Nicotiana glauca	2	3	3	3	5	0.6-0.8	0.4-0.6	3	1	2	2	2	1	1	1	3
Nicotiana rustica	2	2	3	7	3	1-1.2	0.8-0.9	3	1	2	2	2	1	2	1	3
Physalis angulata	2	2	2	5	4	1.4-1.8	1.1-1.2	3	1	2	2	2	3	3	1	2
Physalis ixocarpa	2	2	1	5	4	2-2.1	1.7-1.9	3	2	2	2	2	3	3	1	2
Physalis peruviana	2	2	1	5	4	2-2.1	1.7-1.8	3	2	2	2	2	3	3	1	2
Solanum coagulans	1	4	3	7	4	3-3.2	2.8-3	2	1	1	2	2	2	2	1	2
Solanum elaeagnifolium	2	4	2	7	1	2.8-3.5	2.5-3	2	1	1	2	1	2	1	2	1
Solanum forsskaolii	1	1	1	7	3	3.4-4	2.6-3.5	1	1	2	1	4	1	2	2	2
Solanum incanum	2	4	2	4	4	2-2.6	1.8-2.1	1	2	2	2	2	3	1	3	1
Solanum nigrum* var. *nigrum	2	2	2	6	4	2-2.1	1.2-1.8	1	2	2	2	2	3	1	1	1
Solanum sinaicum	2	4	1	5	4	1.8-2	1.5-17	2	2	2	2	1	3	2	1	2
Solanum villosum* subsp. *villosum	2	2	1	6	4	1.7-2	1.2-1.5	1	2	2	2	1	2	1	1	1
Withania obtusifolia	2	1	2	1	3	1.9-2.1	1.8-1.9	2	2	2	2	3	1	1	3	2
Withania somnifera	2	2	1	5	3	1.8-1.9	1.8-1.9	1	2	2	2	2	3	2	1	1

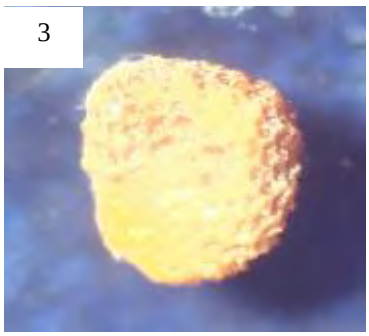
Number of seeds in fruit: 1= (4-8 seeds) few /2=many more than 8 seeds
Seed shape: 1=reniform /2=obovoid /3=oblong obovate /4= broad ovate
Seed: 1=flattened /2=slightly convex /3=convex
Seed color: 1=light brown / 2= black /3=brown /4= yellow to brown /5=yellow /6=yellowish brown / 7= dark brown
Seed texture: 1= smooth/2=rough/3=tuberculate /4= slightly tuberculate/5=striate
Hilum position: 1= terminal /2=subterminal /3= lateral
Hilum shape: 1=conspicuous /2=inconspicuous
Seed shines: 1=shiny /2=dull
Seed ornamentation: 1= regular reticulate / 2=irregular reticulate / 3=verrucate reticulate
Anticlinal shape: 1=slightly undulate / 2= undulate / 3= slightly straight / 4=straight
Anticlinal thickness: 1=thin / 2=thick/ 3= very thick
Anticlinal level: 1= slightly raised /2= raised / 3= grooved
Periclinal shape: 1=flat / 2=slightly concave / 3=concave
Cells: 1=narrow / 2=wide / 3=very wide



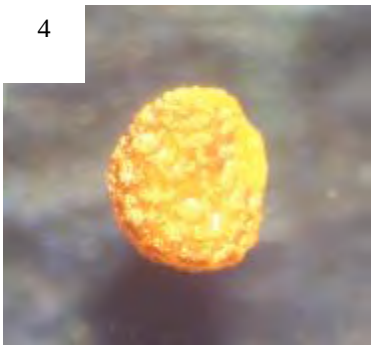
Datura innoxia



Datura stramonium

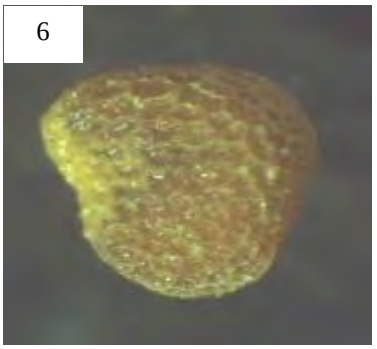


Hyoscyamus albus

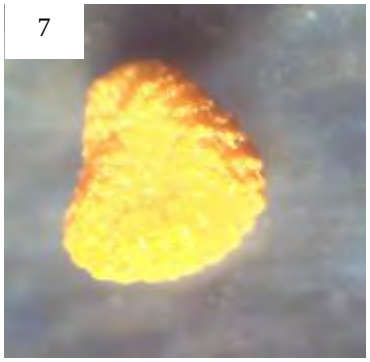


Hyoscyamus boveanus

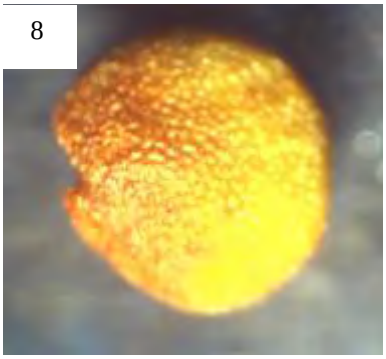
Hyoscyamus desertorum



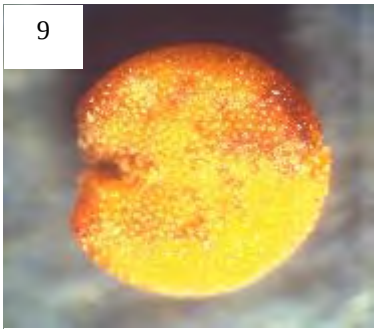
Hyoscyamus muticus



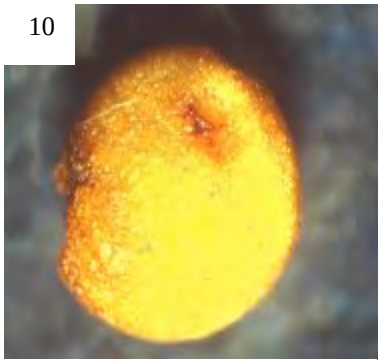
Hyoscyamus pusillus



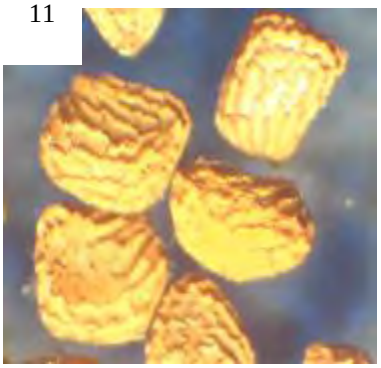
Lycium europaeum



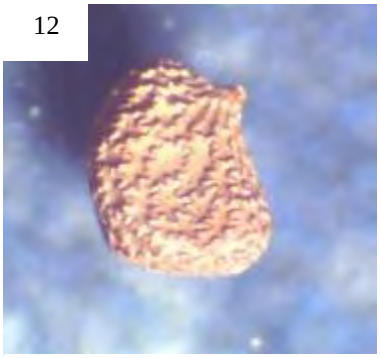
Lycium schweinfurthii* var. *aschersonii



Lycium shawii



Nicotiana glauca



Nicotiana rustica

Plate 2 (Figs. 1-12): LM micrographs of the seed morphology in studied species.

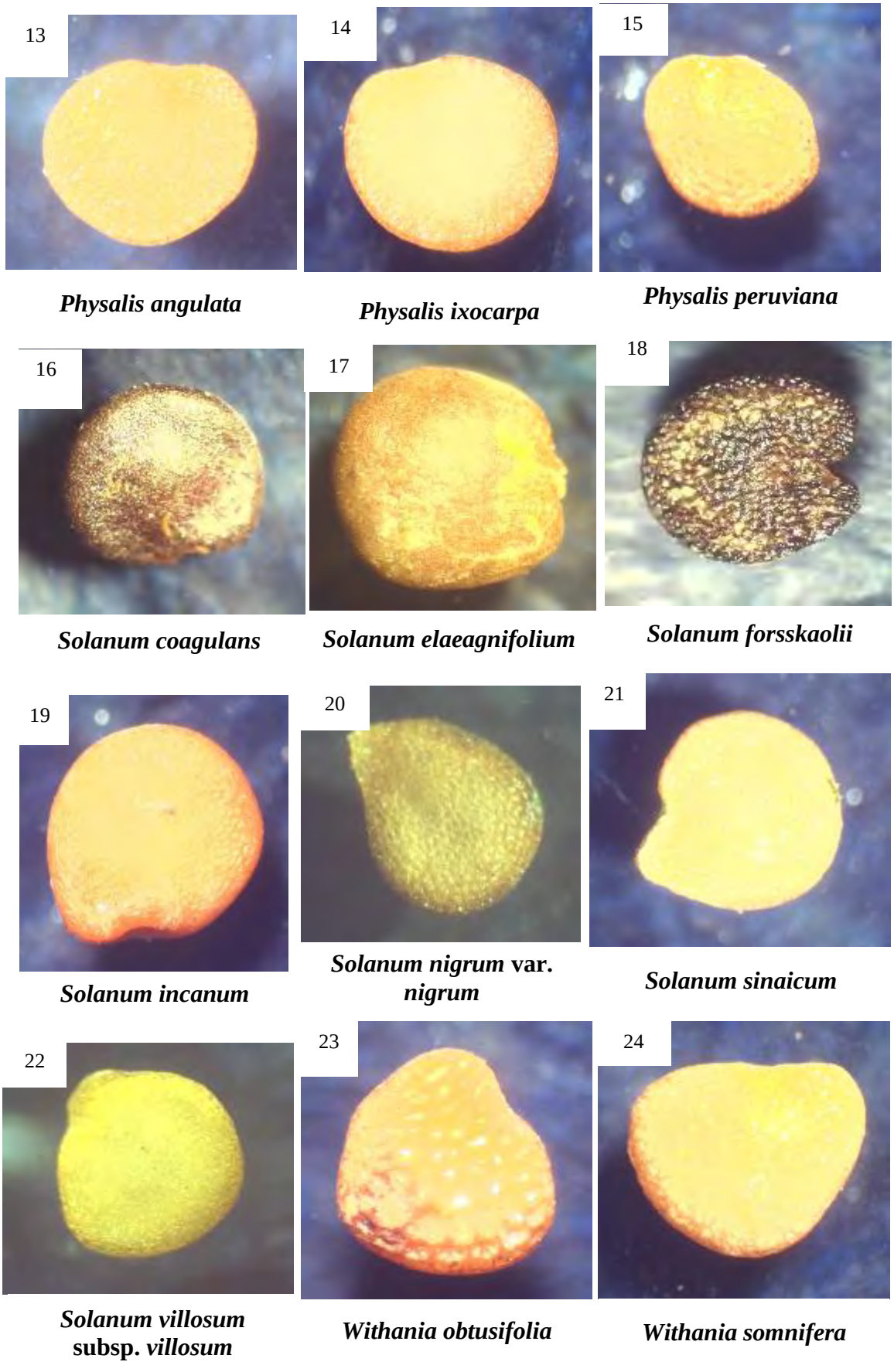
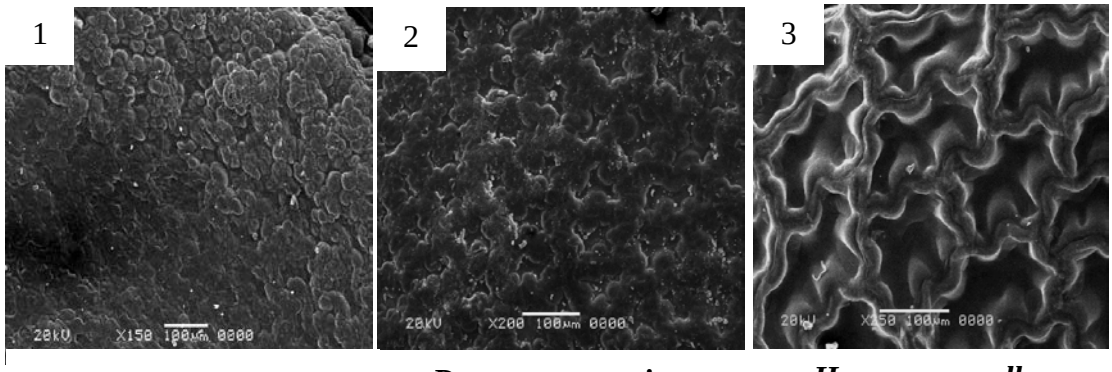
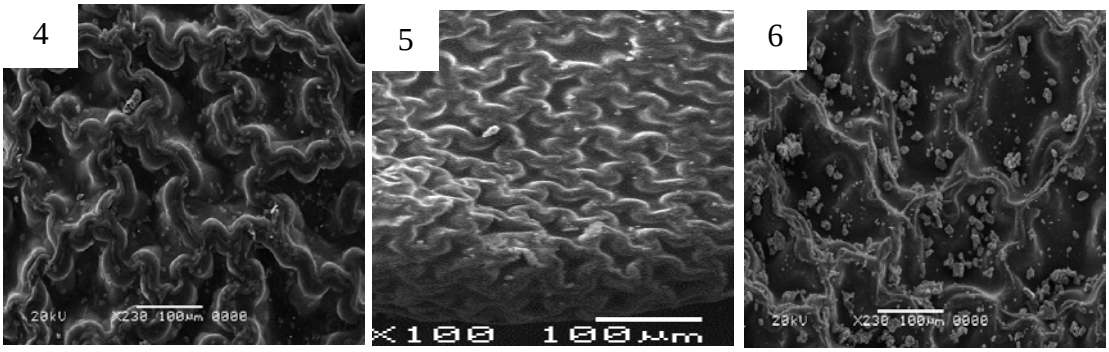


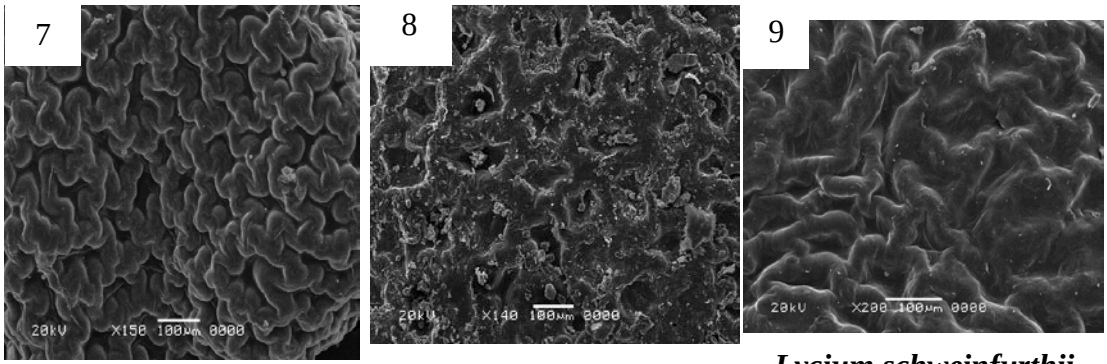
Plate 2 (Figs. 13-24): LM micrographs of the seed morphology in studied species.



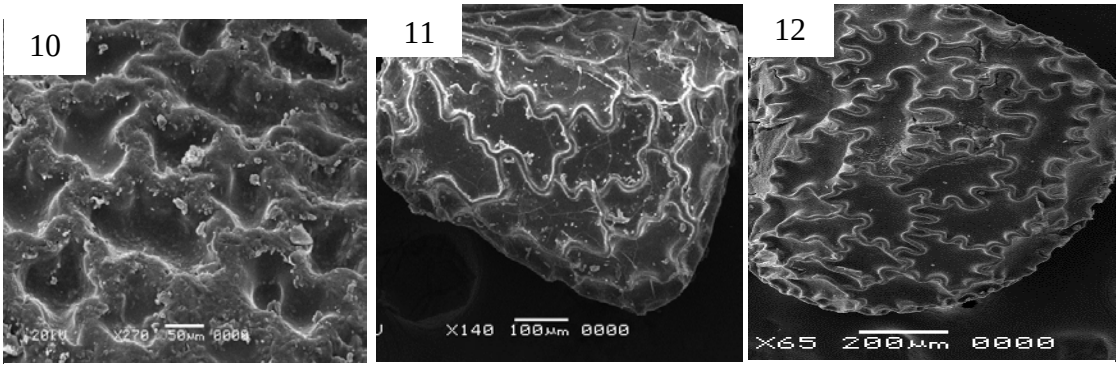
Datura innoxia ***Datura stramonium*** ***Hyoscyamus albus***



Hyoscyamus boveanus ***Hyoscyamus desertorum*** ***Hyoscyamus muticus***



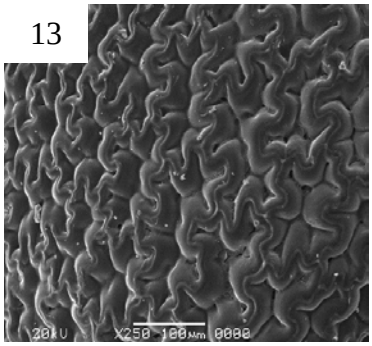
Hyoscyamus pusillus ***Lycium europaeum*** ***Lycium schweinfurthii*** **var.** ***aschersonii***



Lycium shawii ***Nicotiana glauca*** ***Nicotiana rustica***

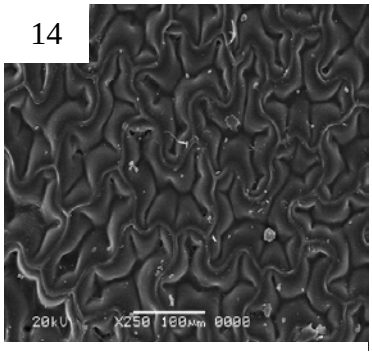
Plate 3 (Figs. 1-12): SEM micrographs of seed surface in studied species

13



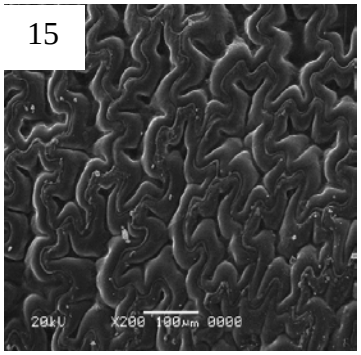
Physalis angulata

14



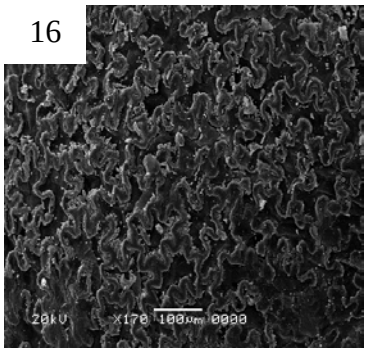
Physalis ixocarpa

15



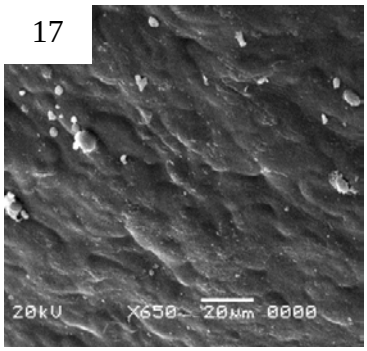
Physalis peruviana

16



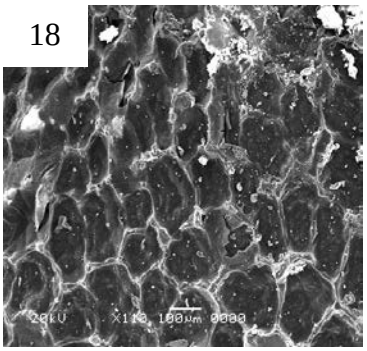
Solanum coagulans

17



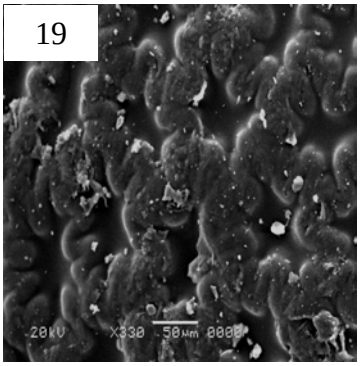
Solanum elaeagnifolium

18



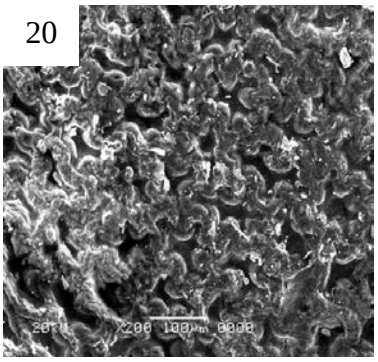
Solanum forsskaolii

19



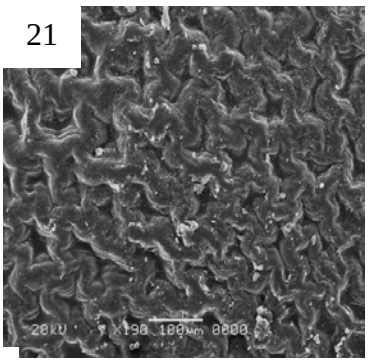
Solanum incanum

20



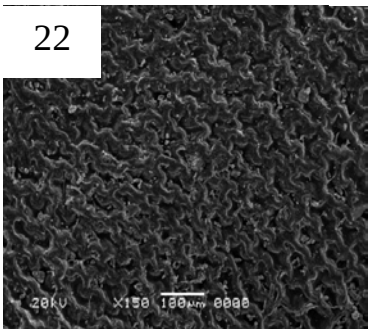
Solanum nigrum* var. *nigrum

21



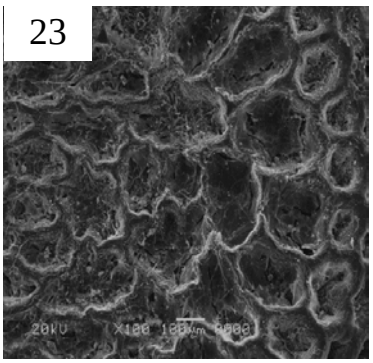
Solanum sinaicum

22



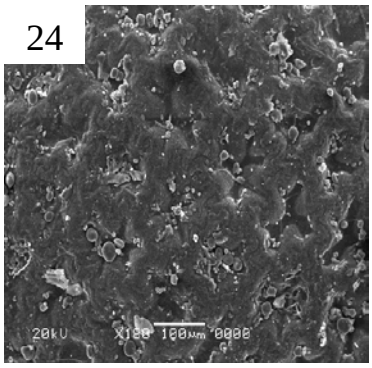
Solanum villosum* subsp. *villosum

23



Withania obtusifolia

24



Withania somnifera

Plate 3 (Figs. 13-24): SEM micrographs of seed surface in studied species

3. Numerical analysis:

3. A. Cluster analysis

The 20 morphological characters of fruit and seed used in cluster analysis are included in data matrix occupy in operational taxonomic units OUT's to analyse the relationships between the 24 studied species by means of Hierarchical Cluster analysis using the PC-ORD software, version 5 and PRIMER software, version 6.0 analysis used similarity and distance measure Bray Curtis.

In the dendrogram produced from using PC-ORD program used distance measure Bray Curtis (Fig. 1-A) showed that twenty four species were grouped into two major clusters**.**

The first cluster (I) consisted of (15 species) and divided into two groups: group "1" consisted of eight species, and subdivided into two subgroups: subgroup "a" contains three species *L. europaeum*, *L. schweinfurthii* var. *aschersonii* and *L. shawii*. At the same time, the subgroup "b" consists of five species *P. angulata, P. ixocarpa*, *P. peruviana*, *W. obtusifolia* and *W. somnifera*. The group "2" which subdivided into two subgroups: subgroup "2a" incorporated; *S. coagulans, S. incanum, S. sinaicum, S. nigrum* var. *nigrum, S. villosum* subsp. *villosum* and *S. elaeagnifolium* and the subgroup "2b" consists of only one species *S. forsskaolii.*

The second cluster (II) comprises the remainders (9 species) and divided into two groups: group "3" consisted of two species, *D. innoxia* and *D. stramonium*. The group "4" consisted of seven species and subdivided into two subgroups: subgroup "3a" contains five species *H. albus, H. desertorum, H. boveanus, H. pusillus* and *H. muticus* and subgroup "3b" comprises two species *N. glauca* and *N. rustica*.

In the dendrogram produced from using PRIMER program used similarity measure Bray Curtis (Fig. 1-B) showed that twenty four species were grouped into two major clusters.

The first cluster (I) consisted of two species *D. innoxia* and *D. stramonium* and the second cluster (II) comprises the rest.

The results of cluster analysis using PCORD program Fig. 1-A agreed with that produced by PRIMER program Fig. 1-B.

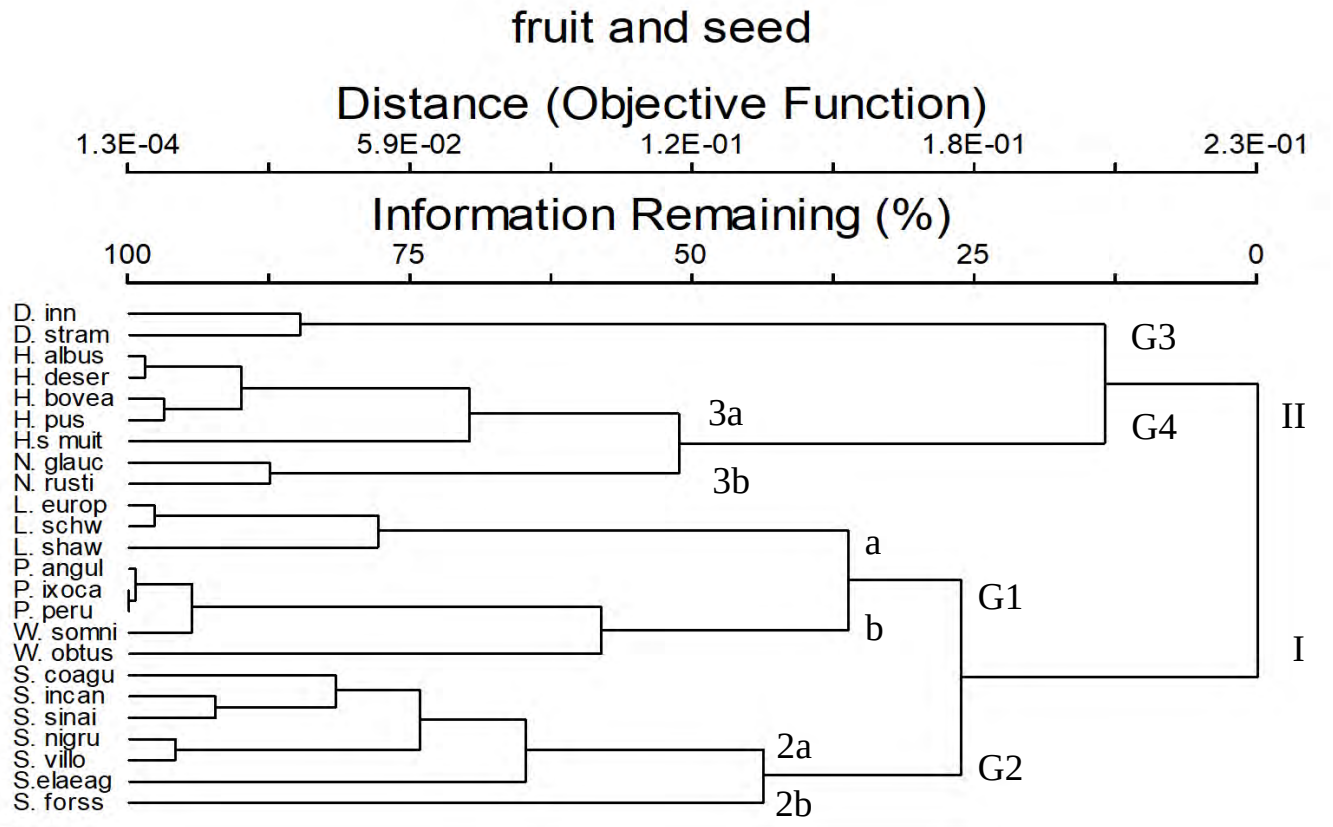


Fig. 1-A: Dendrogram showing the interrelationships between 24 species of Solanaceae based on fruit and seed characters by using PC-ORD Program.

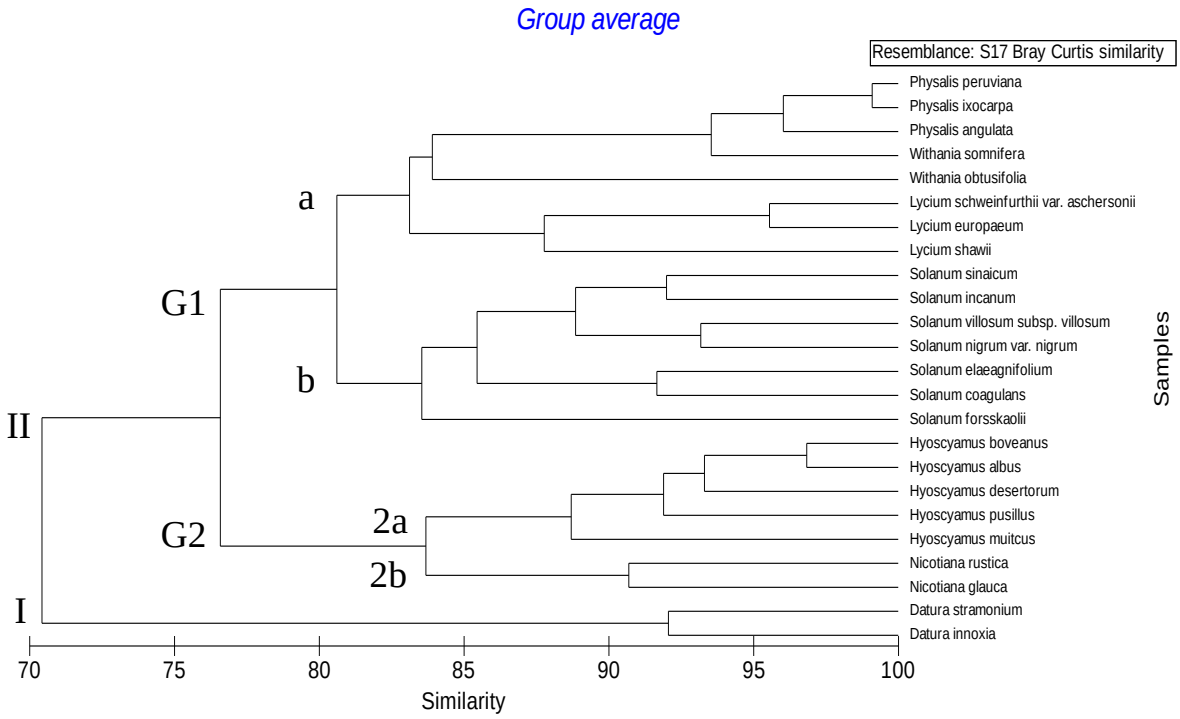


Fig. 1-B: Dendrogram showing the interrelationships between 24 species of Solanaceae based on fruit and seed characters by using PRIMER Program.

3. B. Computer generating Key:

In the present study, 24 species were used as the Operational Taxonomic Units. A total of selected 20 attribute. These attribute representing the morphology aspects. The construction of the key was carried by using DELTA (Description Language for Taxonomy).

Characters: 20 in data, 20 included, 15 in key.
Items: 24 in data, 24 included, 24 in key.
Characters included: 1–20
Character reliabilities: 1–20, 5

1. Fruit color brown……**2**
Fruit color black……**6**
Fruit color black – red……***Lycium europaeum***
Fruit color yellow-orange……**7**
Fruit color orange……**9**
Fruit color grey……***Physalis ixocarpa***
Fruit color bright red…… ***Withania somnifera***
Fruit color yellowish green…….. ***Physalis angulata***
Fruit color orange red…….. ***Withania obtusifolia***

2(1). Seed color light brown…… ***Datura innoxia***
Seed colorblack……***Datura stramonium***
Seed color brown……**3**
Seed color yellowish brown……**4**
Seed color dark brown…….. ***Nicotiana rustica***

3(2). Fruit dehiscence valve; Fruit shape ovoid; Fruit texture glabrous; Seed shape oblong obovat....
…….. ***Nicotiana glauca***
Fruit dehiscence circumscissile; Fruit shape oblong; Fruit Texture tuberculate; Seed shape obovoid……. ***Hyoscyamus muticus***

4(2). Seed shape reniform…… ***Hyoscyamus boveanus***
Seed shape obovoid……..**5**
Seed shape broad ovate……. ***Hyoscyamus desertorum***

5(4). Hilum position terminal; Seed convex; Anticlinal thickness very thick; Periclinal shape flat….
……..***Hyoscamus pusillus***
Hilum position lateral; Seed slightly convex; Anticlinal thickness thick; Periclinal shape concave……***Hyoscyamus albus***

6(1). Seed color brown; Fruit shape globose; Number of seeds in fruit few; Seed shape reinform…...
…… ***Lycium schweinfurthii* var. *aschersonii***
Seed color yellowish brown; Fruit shape spherical; Number of seeds in fruit many; Seed shape obovoid…….***Solanum nigrum* var. *nigrum***

7(1). Seed texture smooth; Anticlinal shape slightly undulate……...***Solanum elaeagnifolium***
Seed texture tuberculate; Anticlinal shape straight……...***Solanum forsskaolii***
Seed texture slightly tuberculate; Anticlinal shape undulate……...**8**

8(7). Seed color yellow to brown; Hilum position terminal; Number of seeds in fruit many; Hilum inconspicuous…….....…***Solanum incanum***
Seed color dark brown; Hilum position subterminal; Number of seeds in fruit few; Hilum conspicuous…….. ***Solanum coagulans***

9(1). Seed color brown……***Lycium shawii***
Seed color yellow……...**10**
Seed color yellowish brown…….. ***Solanum villosum* subsp. *villosum***

10(9). Hilum position subterminal; Fruit shape spherical; Fruit exposed; Seed shape broad ovate…..…
…… ***Solanum sinaicum***
Hilum position lateral; Fruit shape globose; Fruit included in closed calyx; Seed shape obovoid
……...… ***Physalis peruviana***

3. C. Artificial Key to the studied species of family Solanaceae

1.a. Fruit capsule……..……..……..……**2**
1.b. Fruit berry……..……..……..…… **10**
2.a. Fruit dehiscence by valves……..……..……**3**
2.b. Fruit dehiscence by circumscissile…….…….……**6**
3.a. Fruit exposed, Fruit texture spiny, Seed ornamentation verrucate reticulate……..…….**4**
3.b Fruit included in opened calyx, Fruit texture glabrous, Seed ornamentation…….
irregular reticulate …… ……**5**
4.a. Fruit spheroidal, Seed light brown, flattened; periclinal wall slightly concave
……. ……..…… …….. ***Datura innoxia***
4.b. Fruit ovoid; seed black, convex; periclinal wall flat ……..… ***Datura stramonium***
5.a. Seed oblong - obovoid, brown, striate; anticlinal wall slightly raised …..***Nicotiana glauca***
5.b. Seed obovoid, dark brown, tuberculate; anticlinal wall raised……. ***Nicotiana rustica***
6.a. Seed reniform……...……...…… ***Hyoscyamus boveanus***
6.b. Seed broadly ovoid-obovate…….....…… **7**
7.a. Seed ovoid…… ***Hyoscyamus desertorum***
7.b. Seed obovate …… **8**
8.a. Seed brown; anticlinal wall slightly undulate……....….……...***Hyoscyamus muticus***
8.b. Seed yellowish brown; anticlinal shape undulate……..…….…….**9**
9.a. Hilum lateral; anticlinal wall thick; periclinal wall concave……. ***Hyoscyamus albus***
9.b. Hilum terminal; anticlinal wall very thick; periclinal wall flat…….. ***Hyoscyamus pusillus***
10.a. Fruit spheroid…….. **11**
10.b. Fruit globose…….... **17**
11.a. Seed ornamentation regulary reticulate ……...……. ***Solanum forsskaolii***

11.b. Seed ornamentation irregularly reticulate ……..…….…..…… **12**
12.a. Seed shiny……... **13**
12.b. Seed dull…….. **14**
13.a. Number of seeds in fruit few; seed slightly tuberculate, convex; anticlinal wall undulate, raised; periclinal wall flat, cells wide……. ***Solanum coagulans***
13.b. Number of seeds in fruit many, seed smooth, slightly convex; anticlinal wall slightly undulate, slightly raised; periclinal wall concave, cells narrow..***Solanum elaeagnifolium***
14.a. Seed slightly convex; anticlinal wall undulated…..…..……..……**15**
14.b. Seed flattened; anticlinal shape slightly undulated…….**16**
15.a. Fruit yellow-orange, Seed broadly ovoid; periclinal wall concave.....***Solanum incanum***
15.b. Fruit black, seed obovoid, periclinal wall flat…….. ***Solanum nigrum* var. *nigrum***
16.a. Seed yellow; anticlinal wall raised; cells wide……....… ***Solanum sinaicum***
16.b. Seed yellowish brown; anticlinal level slightly raised, cells narrow……...…… …… ……..……...… ***Solanum villosum* subsp. *villosum***
17.a. Fruit exposed……..……. **18**
17.b. Fruit included in closed calyx ……...……. **20**
18.a. Seed slightly convex, Anticlinal shape slightly undulate, Anticlinal level slightly raised, Periclinal shape concave, Cells wide…….…….. ***Lycium shawii***
18.b. Seed convex, Anticlinal shape slightly straight, Anticlinal level raised, Periclinal shape flat, Cells narrow...…….……..…….…….…….. **19**
19.a. Fruit color black-red, Hilum position lateral…...……... ***Lycium europaeum***
19.b. Fruit color black, Hilum position terminal.....***Lycium schweinfurthii* var. *aschersonii***
20.a. Hilum position terminal or sub terminal, Anticlinal level raised…….…….…….**21**
20.b. Hilum position lateral, Anticlinal level grooved……..…**22**
21.a. Fruit orange red, Hilum sub terminal, Anticlinal slightly raised…...***Withania obtusifolia***
21.b. Fruit bright red, Hilum terminal, Anticlinal raised ……..…. ***Withania somnifera***
22.a. Seed convex, Seed length < 2mm, Hilum conspicuous..…….……. ***Physalis angulata***
22.b. Seed flattened, Seed length >2mm, Hilum inconspicuous…….…….....….**23**
23.a. Fruit grey……....….... ***Physalis ixocarpa***
23.b. Fruit orange …….……..…. ***Physalis peruviana***

The main results of the numerical analysis are: *D. innoxia* and *D. stramonium* to be separated from the rest of the genera as a distinct tribe Datureae. This result agrees and supports the view of Wettestein, (1895) and Hunziker (2001). *N. glauca* and *N. rustica* (Nicotianeae – Cestroideae) are deeply immersed in group 4 together with *Hyoscyamus* species (Hyoscyameae – Solanoideae). This result agrees and supports the view of Dunal classification, (1852). *L. europaeum, L. schweinfurthii* var. *aschersonii* and *L. shawii* (Lycieae) are deeply seated in group1 among an assortment of genera belonging to Solaneae this result agrees and support the view of Dunal, (l.c.).

The variability in seed surface patterns is seemingly very useful in the recognition of all species studied. This agrees with the results reported by Kong *et al*., (2011). They showed that the finer details of the seed surface appear useful for delimitation at generic level and also species level among the species investigated of Solanaceae.

In conclusion, it could be confirmed that valuable taxonomic evidence has been obtained from studying fruit and seed characteristics in some species of Solanaceae. Many of these characteristics are diagnostic at both the generic and specific levels.

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