Impossible to press? – Succulents in Renaissance herbaria

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Several Renaissance herbaria, including the herbarium by Caspar Bauhin, contain preserved specimens of different succulent plants, such as cacti, stonecrops, palm lilies or aloes. In view of the difficulties experienced even today when preparing succulents for the herbarium, the efforts of the Renaissance botanists to meet this challenge is remarkable. The view that succulents by definition are unsuitable for pressing for the herbarium, as for instance expressed by Richard Bradley in his 1716 book, prevails to these days. We first provide a condensed overview of standard preparation techniques for succulents advocated in the literature of the past forty years. Then, a selection of specimens of succulents in early herbaria, from several plant families, is discussed and the preparation methods used at that time, and possible solutions of the difficulties involved, are outlined.

„So, do not be afraid of the spines. With a bit of patience, anyone can produce good-quality herbarium specimens of cacti" (De Groot 2011: 989)

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Today, if botanists are asked about their experience in preparing succulents in the conventional manner for the herbarium by pressing and drying, most will likely confess that they never preserved succulent plants in this way – too difficult or outright impossible, time consuming, and with little-pleasing results is the general attitude in the field. Indeed, succulent plant species are under-represented in most herbaria, at least as conventional pressed sheet specimens. The English gardener-naturalist Richard Bradley (1688–1732) even employed this purported impossibility to define succulents in his famous book „The history of succulent plants, containing the Aloes, Ficoids …, Torch Thistles, Melon Thistles, and such other as are not capable of an Hortus-siccus" (Fig. 1) (Bradley 1716; see Eggli and Nyffeler 2009 for a discussion of the definitions of the term succulence).

Notwithstanding the alleged impossibility to press and dry succulents, there are thousands of specimens of succulent plants conserved in the herbaria of the world – alone the small specialized herbarium at the Sukkulenten-Sammlung Zürich (ZSS) counts some 8000 sheet specimens amongst its 29300 accessions of preserved plants (data from December 2021).

In this paper, we first summarize different methodologies advocated over time for preparing succulents for the herbarium. Then we showcase four different lineages of succulents *(Aloe, Opuntia, Yucca, Sedum)* for which we surveyed a selection of Renaissance herbaria to establish when the first specimens of these taxa were pressed, and how Renaissance botanists tackled the difficulties involved in pressing and drying these plants for the herbarium.

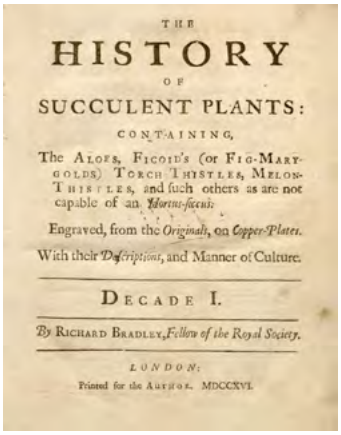
THE
HISTORY
OF
SUCCULENT PLANTS:
CONTAINING,
The Aloes, Ficoid's (or Fig-Marygolds) Torch Thistles, Melon-Thistles, and such others as are not capable of an Hortus-siccus:
Engraved, from the Originals, on Copper-Plates.
With their Descriptions, and Manner of Culture.
DECADE I.
By Richard Bradley, Fellow of the Royal Society.
LONDON:
Printed for the Author. MDCCXVI.

Fig. 1. Title page of Bradley (1716). (Biodiversity Heritage Library / Missouri Botanical Garden; http://www.biodiversitylibrary.org/item/14649#page/1/mode/1up)

Fig. 2. Herbarium press placed on a gas stove to benefit from passive convectional heating.
Photograph F. F. Merklinger

Table 1. List (ascending by date of making) of the herbaria cited in the text, with details on the dates of making, holding institutions, specimens cited, and digital accessibility

Herbarium	*Period*	*Holding Institution*	*Specimens cited in the text*	*Digital access*
Mendoza herbarium	1539–1554	Real Biblioteca del Monasterio de San Lorenzo de El Escorial, Spain	*Aloe*	none
Francesco Petrollini (Vols. 1–4 , formerly known as „Cibo", and „Rome Herbarium")	c. 1550–1553	Biblioteca Angelica, Rome	*Aloe*	none
Erbario A	c. 1550–1553?	Biblioteca Angelica, Rome	*Opuntia*	none
Ulisse Aldrovandi	c. 1551–1586	Herbarium BOLO, Orto Botanico & Herbario, Università di Bologna	*Aloe, Opuntia*	http://137.204.21.141/aldrovandi/Explore
Felix Platter	c. 1552–1614	Burgerbibliothek Bern	*Sedum, Hylotelephium*	http://www.burgerbib.ch/de/bestaende/privat-archive/platter-herbarium
Caspar Ratzenberger	1556–1592	Naturkundemuseum Ottoneum, Kassel	*Aloe*	none
Leonhard Rauwolf (Vols. 1–3)	1560–1563	Herbarium L, Naturalis Biodiversity Center, Leiden	*Opuntia*	none
Hieronymus Harder	1576–1594	„Herbarium Vivum", Bayerische Staats-biblitothek München	*Sedum, Hylotelephium*	München: https://bild-suche.digitale-sammlungen.de/index.html?c=viewer&bandnummer=bsb00011834&pimage=00001&v=150&nav=&l=de
Caspar Bauhin	(1577?–) 1579–1624	University of Basel, Basel	*Opuntia, Sedum, Yucca*	none

Fig. 3. Flowering *Aloe vera* in the herbarium of Ulisse Aldrovandi (volume 3, fol. 21). (http://137.204.21.141/aldrovandi/Explore, Università degli Studi di Bologna, Sistema Museale di Ateneo, permission granted for educational use).

Fig. 4. Contemporaneous specimen of a flowering *Aloe* in the herbarium of the Sukkulenten-Sammlung Zürich (ZSS 312: *Aloe* sp. aff. *officinalis*, Collenette 5481: Saudi Arabia, Jabal Radhwa, 1950 m, prepared from cultivated material ZSS 85 3914 /0, 9. June 1989).

Standard preparation techniques for succulents

Clearly, drying the voluminous leaves, stems and/or roots of succulent plants with their extensive water-storage tissue needs careful preparation techniques – over the past forty years a number of publications have described specific approaches and methods, and herbarium management manuals (e.g., Bridson and Forman 1998, Victor et al. 2004) usually have at least a short section on handling succulents. Two main problems in preparing conventional dry pressed specimens have to be addressed: **a** The plant tissue should be killed quickly to enable rapid desiccation – succulent plants have evolved numerous adaptations to cope with water stress, and to conserve stored water over prolonged periods of time, and can survive for months in herbarium presses. **b** Drying of the killed pressed material should be quick and thorough to prevent microbial decay, which can start within 48 hours especially in warm and humid climates.

Fig. 5. Sterile *Aloe vera* in the herbarium of Caspar Ratzenberger, with added lumps of dried *Aloe* exudate (Volume 3, fol. 401). (Courtesy Naturkundemuseum Kassel)

Baker et al. (1985) and De Groot (2011) provided short summaries of the techniques advocated in the literature for rapidly killing the plant tissue, focusing on stem succulents: After

Fig. 6. *Opuntia ficus-indica* with immature fruits from the herbarium of Ulisse Aldrovandi (volume 5, fol. 201). (http://137.204.21.141/aldrovandi/Explore, Università degli Studi di Bologna, Sistema Museale di Ateneo, permission granted for educational use)

Fig. 7. *Opuntia ficus-indica* with a separated flower from the Herbarium Rauwolf, Vol. 1. (Courtesy Naturalis Biodiversity Centre)

slicing specimens vertically and horizontally, and possible removal of the bulk of the succulent tissue, the material can be immersed into an ethanol bath for 24–48 hours, or frozen, thawed and then blotted, boiled and then blotted, or ordinary salt or borax can be liberally applied to the cut surfaces which is then blotted before conventional pressing. A further approach to kill plant tissues rapidly is the use of a microwave oven [first briefly mentioned by Fuller and Barbe (1981), then described in more detail by Leuenberger (1982)]. For stem succulent Euphorbias, Leach (1995) advocates first boiling the material, pressing it, and to „paint" it with petrol to control decay, while for the stem succulent Asclepiads and leaf-succulent Aloes, he suggests to first immerse the material in a petrol bath. Burgoyne and Smith (1999) suggest a combination of freezing the freshly collected material with subsequent thawing using the „defrost mode" of a microwave oven. Reyes-Agüero et al. (2008) advocate to spray the cut surfaces of *Opuntia* cladodes with 70 % formaldehyde and leaving them to dry exposed to direct sun for two to three hours prior to conventional pressing.

For pressing and drying of the specimens, conventional herbarium presses are universally suggested, with ample use of blotters and cardboard or plywood layers; Eggli and Leuenberger (1996) and De Groot (2011) in addition suggest interspersing sheets of perforated or corrugated aluminium sheets. Presses can then be placed in the sun or another warm and dry place (including on gas stoves, Fig. 2, only recommended with great care), with frequent change of humid blotters and cardboards. De Groot (2011) advocates using „a conventional herbarium specimen dryer" without further details, while Reyes-Agüero et al. (2008) use a „forced-air furnace at 85–90°C". Eggli and Leuenberger (1996) described an easily portable method that provides forced warm air circulation using a small hair dryer and a semi-air-tight bag. With this latter method, specimens can be dried within 24 hours in dry climates, without any pretreatments apart from cutting the plants into manageable parts and removing the bulk of succulent tissue, and without need to change blotters or papers. For processing larger numbers of specimens, a comparative setup using room or industrial electric heaters is a good option.

Apart from conventional pressed specimens, succulents can also be successfully preserved as spirit specimens or „carpological" specimens, such as voluminous dried plant bodies or part of bodies. Most herbaria prefer conventional sheet specimens, however, because of volume considerations and ease of handling and preservation.

Succulents in Renaissance Herbaria

Renaissance botanists had none of these commodities, as just described, available. Nonetheless, they were not afraid of handling native juicy stonecrops, or exotic leaf succulents and spiny cacti, as witnessed by the specimens in the surviving early herbaria (see Baldini et al. 2022 for a list of extant 16th century herbaria). We carried out a non-exhaustive search for succulents present in these precious collections as far as available in digital form, or on the base of published inventories. Here, we discuss a few selected examples to highlight how Renaissance botanists met the challenge of making informative herbarium specimens that allow us today to reconstruct early gain of succulent plant knowledge (see table 1 for list of Herbaria).

Aloe vera (Asphodelaceae; syn. Aloaceae; a cultivar not known from the wild; the closely related *A. officinalis* is native to Saudi Arabia and the Yemen): Specimens of flowering *Aloe* are present in the herbaria of Ulisse Aldrovandi (Fig. 3), Francesco Petrollini (formerly known as „Herbario Cibo" or „Rome Herbarium", cf. Stefanaki et al. 2019, Baldini et al. 2022) and in the so called Mendoza herbarium, and a sterile specimen is present in the herbarium of Caspar Ratzenberger (Fig. 5) (Urs Eggli et al., pers. comm.). *Aloe vera* was used medicinally since at least the Greco-Roman period and is described and illustrated in very numerous medieval manuscripts as well as Renaissance books. It was cultivated in Europe at least since the 1530s, likely having been introduced from the Arabian Peninsula or the Near East (Grace et al. 2015). The flowering specimens in the herbaria of Aldrovandi and Petrollini were preserved in the period between 1551 and 1553, and that in the Mendoza herbarium at some unknown time between 1539 and 1554. Surprisingly, it took at least some 10 years before illustrations of flowering *Aloe* were published independently but almost simultaneously by Marini (1562) and Mattioli (1562). The specimen in the Mendoza herbarium is broken and fragmentary, but the specimens of Aldrovandi and Petrollini give a good idea of the plants then cultivated. Their quality compares favourably with modern herbarium specimens (Fig. 4), testifying the ability of their makers to deal with the juicy mucilaginous leaves. The available illustrations of the specimens do not permit a judgement whether complete leaves were pressed, or whether the lower face and the water-storage tissue was cut away before pressing.

The specimen in the Ratzenberger herbarium (Fig. 5) is notable for two reasons: Firstly, an entire young plant (judged by the size), including stem and roots was pressed and mounted. Secondly, Ratzenberger added two samples of dried *Aloe* exudate (the form in which *Aloe* was traded for medical applications), together with a long note excerpted from Garcia de Orta (1567) or a later edition of that work.

Fig. 8. *Opuntia ficus-indica* from the Herbarium Bauhin, BAS B05-015. This specimen is notable since part of the vascular system has been prepared and mounted separately. (University of Basel, Herbaria Basel (BAS), CC BY 4.0)

Fig. 9. *Yucca gloriosa* cf. with flowers from the herbarium of Caspar Bauhin (BAS-B02-111), ex cult. London (without date) & Paris (1614). (University of Basel, Herbaria Basel (BAS), CC BY 4.0)

Fig. 10. *Sedum album* from the herbarium of Caspar Bauhin (BAS-B08-047), collected from roofs in Basel, without date. (University of Basel, Herbaria Basel (BAS), CC BY 4.0)

Fig. 11. *Sedum album* on a page from the „Herbarium Vivum" of Hieronymus Harder with several specimens of Crassulaceae: *Sedum album* top row middle and right, *S. acre* bottom left and *Hylotelephium telephium* (bottom right) plus *Saxifraga paniculata* cf. (top row left). (Bayerische Staatsbibliothek, Cod. Icon 3, fol. 11v (scan 45), https://www.digitale-sammlungen.de/de/view/bsb00011834; Creative Commons BY-NC-SA 4.0)

Opuntia ficus-indica (Cactaceae; since ancient times widely cultivated as crop in Mexico, and now an invasive neophyte elsewhere): The prickly pear cactus was observed growing in Rome as early as 1549 by Johannes Kentmann (Eggli et al. 2018), and Ulisse Aldrovandi observed it, also in Rome, in 1550 and 1553 near Pisa (Soldano 2000, Soldano and Borgi 2007, Stefanaki et al. 2021). North of the Alps, Conrad Gessner was likely the first who cultivated this species; he received his material in 1558 from Italy (Eggli 2019). Material in the herbarium of Aldrovandi (Vol. 5, p. 200.1 and 200.2, sterile specimens; p. 201, specimen with 4 immature fruits; Fig. 6), is dated to 1553 by Soldano and Borgi (2007: 8) and Stefanaki et al. (2021: 454). A sterile specimen is also present in the „Erbario A" (Stefanaki et al. 2021: 455), and a specimen with a flower, prepared in southern France between 1560 and 1562, is conserved in the herbarium of Leonhard Rauwolf (Stefanaki et al. 2021; Fig. 7). A further sterile specimen is present in the Bauhin herbarium, is

without provenance details, and was prepared at some unknown time between 1577 and 1624. This specimen is notable because part of the vasculature was pressed separately (Fig. 8).

The specimen in the Ulisse Aldrovandi herbarium appears to be the oldest extant specimen of *Opuntia ficus-indica*. Aldrovandi described the difficulties of preparing *Opuntia* for the herbarium in a letter in 1553 to Pietro Andrea Mattioli (Soldano 2002: 62–63), which roughly translates as follows: „… these leaves are more juicy than those of the terrestrial *Aloe*. I cut the leaf in half … and cut out the juice, but the quantity of humidity was such that I could not preserve its natural colour, despite I worked with great care and changed the paper in which they were placed every day for 7 or 8 times". Whether these remarks apply to the very specimens present in his herbarium (Fig. 6) is unclear, but they are a vivid description of the necessary pretreatment of the stem segments and the difficulties to dry the material quickly without artificial heat.

Yucca species (Agavaceae / Asparagaceae: Agavoideae): A very well prepared specimen of a *Yucca* species (determined as *Y. gloriosa* by an unknown hand; *Y. gloriosa* is widespread in the E USA) is present in the Bauhin herbarium. According to the labels, it is a composite specimen, partly from the garden of „D. Cargillus", London (James Cargill (c.1565–1616), a student of Caspar Bauhin in Basel), and the longer leaf supplied 1614 by „D. Burserus" (likely Joachim Burser, who was a student of Caspar Bauhin in Basel) from Paris („Lutetia") (Fig. 9). We know from Ewald (1995, citing Thacker 1979) that *Yucca gloriosa* was first introduced to England in 1593. Gerard (1596) mentions that he cultivated material in his garden, and later (Gerard 1597) gave a more detailed account including a woodcut of a sterile plant. The first illustrations of a flowering *Yucca* cf. *gloriosa* were published by L'Obel (1605), Aldini (1625) and Parkinson (1629: 435). No other specimens of *Yucca* have been located in Renaissance herbaria (A. Stefanaki, pers. comm. November 2022), and the specimen in the Bauhin herbarium is thus the earliest extant *Yucca* specimen.

Sedum album (Crassulaceae; widespread throughout Europe): Species of the genera *Crassula, Hylotelephium, Sedum, Sempervivum* and *Umbilicus* (all Crassulaceae) are native to Europe, and accordingly, specimens of these appear frequently in Renaissance herbaria. By way of example, and to show the particular difficulties of pressing herbs with relatively small succulent leaves, we refer to the various approaches favored by different botanists with the help of specimens of *Sedum album:* The specimen from the Bauhin herbarium (Fig.10) shows the common condition that the succulent leaves in their majority fall off in the pressing and drying process. One way of overcoming the problem is to add an illustration cut from a printed book, as Bauhin commonly did (Fig.10). Another and rather innovative solution was implemented by Hieronymus Harder, who added the missing leaves of *Sedum album* in

Fig. 12. *Hylotelephium telephium* from the herbarium of Felix Platter (Vol. 6, page 373). (Burgerbibliothek Bern, https://www.burgerbib.ch/de/bestaende/privatarchive/einzelstuecke/platter-herbarium; Public Domain Mark 1.0)

the form of colour drawings (Fig. 11, upper right). The same herbarium page also has a specimen of *Hylotelephium telephium* with similarly added leaves and tuberous roots, but the stem and inflorescence now missing (Fig. 11, lower right), as well as a depauperate specimen devoid of leaves of *Sedum* cf. *acre* (Fig. 11, lower left). On the other hand, the herbarium of Felix Platter includes some very diligently prepared specimens with part or all of the leaves present (Fig. 12) – one wonders how Felix Platter achieved this quality with the equipment available at his time: Producing such quality of specimens is only possible by killing the tissues rapidly before abscission layers form. But whether Felix Platter killed his plants by using hot water, or perhaps placed the tightened herbarium press on a well-heated tiled stove, remains unknown.

Conclusions

Specimens of the exotic succulents *Aloe vera* and *Opuntia ficus-indica* appeared almost concurrently in the 1550s in several of the 16th century herbaria. In contrast, the first specimen of *Yucca gloriosa* cf. is some 50 years younger, in parallel to its supposed later introduction into cultivation. The early specimens of these exotic succulents together with those of the native European *Sedum album* show the ability of Renaissance botanists to successfully deal with plants difficult to press for the herbarium. At the same time, these renaissance specimens provide an interesting possibility to learn more about the introduction of hitherto unknown succulents into European horticulture.

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Jurriaan de Vos kindly provided a list of specimens of succulent plants in the Bauhin herbarium Basel. Anastasia Stefanaki (University of Utrecht) kindly checked for specimens of *Opuntia* and *Yucca* in numerous Renaissance herbaria. We further gladly acknowledge the help of Adriano Soldano with details of the correspondence between Aldrovandi and Mattioli on *Opuntia*.

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