Botanical and ethnobotanical studies in *Peucedanum ostruthium* (Apiaceae) from the upper Saastal: Variability of morphology and coumarin components, and use as a medicinal plant

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In memory of my Father

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Cover picture: Herbarium specimen of *Peucedanum ostruthium*

Abstract

Peucedanum ostruthium (L.) W.D.J. KOCH is a widely used medicinal plant in the Alpine region. Preparations are usually made from the rhizomes and are applied for a broad number of diseases like gastrointestinal complaints, diseases of respiratory organs as well as internal and external infections, wounds and skin problems. The use of this medicinal plant can be traced back to medieval times according to literature. The therapeutic effect is attributed to the coumarins occurring in the essential oil, which are of interest in modern pharmacy. The white flowering umbellifer is native to the subalpine and alpine regions and prefers rather fresh, shady and nutrient-rich places and can form herds through offshoot propagation.

In this study, the effect of environmental factor like altitudinal levels, soil and health conditions on morphological traits of *Peucedanum ostruthium* and its coumarin contents were quantitatively analyzed. In this respect, aboveground and belowground organs were measured at different altitudes and locations. The soil conditions were defined using indicator values. Rhizomes were collected for a quantitative HPTLC analysis regarding coumarin concentrations. Furthermore, the local medicinal plant knowledge about *Peucedanum ostruthium* in the upper Saastal was examined by informal interviews with local herbalists. The relevance of *Peucedanum ostruthium* as a medicinal plant was investigated by comparing historical records with recent ethnobotanical studies and the currently held knowledge from Saastal.

A tendency of larger organs, particularly rhizomes, can be determined at lower altitudinal levels with good soil and health conditions, whereas the coumarin contents appear in similar concentrations in all investigated populations. Overall, no subpopulations could be identified concerning the variability of morphological traits or coumarin contents. This leads to the assumption that the investigated individuals of *Peucedanum ostruthium* belongs to a large metapopulation with close genetic relationships. Although the local people in the Saastal know and use different medicinal plants, *Peucedanum ostruthium* plays only a subordinate role. Leaves are used to support wound healing, however, the use of rhizomes is not present, whereas in other Alpine regions the plant is considered a panacea. A wide use of the *Peucedanum ostruthium* has remained constant since the medieval times including apotropaic uses and fumigation with its rhizomes. While it became an integral part in herbal books in the past and was cultivated over large parts of Europe, today *Peucedanum ostruthium* is rather forgotten in popular medicine.

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1. Introduction

> Peucedanum ostruthium *(L.) W.D.J. KOCH is a white flowering umbellifer. Growing in cool and shady places in the mountains, it can cover several square meters and gives off an aromatic but indescribable scent. The strongest smell is of its rhizome, which grows horizontally under the earth's surface. These rhizomes have a long history in the traditional medicine of central Europe.*

1.1 *Peucedanum ostruthium*: A traditional medicinal plant in Europe

Many species of the family Apiaceae have been used as traditional medicinal plants (Dal Cero, 2016). The Genus *Peucedanum* includes about 120 species distributed in Europe, West Asia and Africa (Hess *et al*., 1977). Around 12 species are known to be used in traditional medicine and are reported in Europe, Iran, India, Japan and China. In Chinese medicine, some species are highly valued like *P. praeruptorum* DUNN and *P. japonicum* THUMB (Sarkhail, 2014). *Peucedanum ostruthium* is native in Europe and has primarily been used in the Alpine regions. Common preparations usually made of the rhizomes are infusions, tinctures, bitters or pulps and are applied for a broad number of diseases, like gastrointestinal complaints, diseases of respiratory organs as well as fever reducing, internal and external infections, wounds and skin problems or toothache (Vogl-Lukasser *et al.*, 2006; Brüschweiler, 2008; Pieroni *et al.*, 2009; Poretti, 2009; Grabowski, 2010; Grasser,*et al.*, 2012; Wegmann, 2013; Abbet, 2014; Dal Cero *et al.*, 2015). Therefore, it has the reputation of a panacea in some regions. Other important applications can be found in veterinary medicine or in the defense against misfortune and illness (apotropaic). They are well recorded since the first ethnobotanical studies about Alpine regions in the 19th century and are summarized in Marzell (1922), Flamm and Kröber (1935) and Hoffmann-Krayer and Bächtold-Stäubli (1935). The rhizomes are usually collected in autumn, when essential oils are accumulated in order for the plant to properly overwinter (Brüschweiler, 2008; Künzle and Opplinger, 2018).

Etymology

The medicinal use can be traced back to the 11th Century, when it was literary mentioned for the first time in the herbal book Macer Floridus under the name *Ostrution* (Tschirch, 1917; Mayer, 2001). Since then, the plant was given many different names whether in medicinal books or in the vernacular dialect. It is assumed that *Ostruthium* is derived from the Greek (gr.:

"Struthos/Struthion" = sparrow/bird) due to the leaf shape. In medieval times, *Peucedanum ostruthium* was also called *Astrenze* or *Meisterwurz* (Tschirch, 1917). Translated from German into Latin resulted in the name *Magistrantia* (lat.: "Magister" = master) and later in Renaissance *Imperatoria* (lat.: "Imperatoria" = imperial; Marzell, 1922). *Imperatoria ostruthium* L. is still an accepted synonym for *Peucedanum ostruthium (*Gygax e*t al.,* 2018). The medicinal drug is available under the name *Radix Imperatoriae* or *Rhizoma Imperatoriae* (Vogl *et al.*, 2011). *Astrenze* is still a common name in the German-speaking part of Switzerland. Further vernacular names are *Kaiserwurz, Wohlstand, Hoorstrenz*. In English: *masterwort*, French: *Impératoire*, Italian: *erba renna* and Swedish: *mästerrot* (GBIF, 2019). The designation «master» or «imperial» indicate how much the plant has been appreciated. In the past, it was planted in gardens all over Europe and even reached North America (Hess *et al*., 1977; Fremstad, 2004; Keser *et al.*, 2014). Besides from the native habitat in the Alps and the Pyrenees, today the plant is also abundant in central and northern Europe (**Figure 1**).

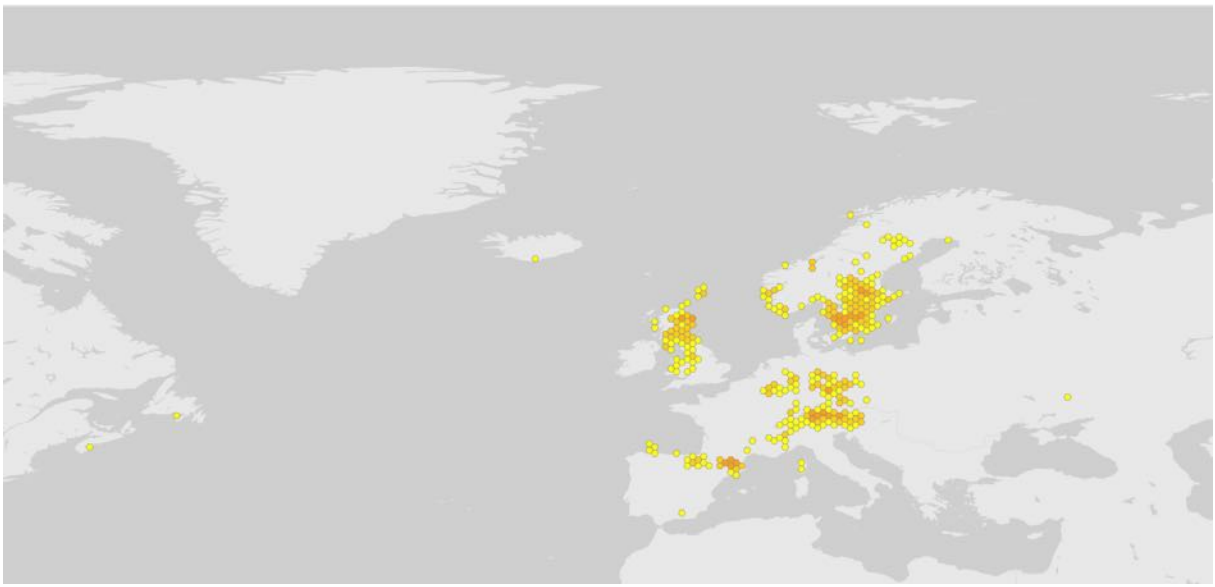


Figure 1: Global distribution of *Peucedanum ostruthium*. Source: GBIF, 2019

1.2 The botany of *Peucedanum ostruthium*

Peucedanum ostruthium can grow to a height of 100 cm and have white or reddish flowering umbels. The dentated leaves are divided in 3 sub-leaves (detailed description in **Table 1**). The species is primarily found on the subalpine and alpine level (Gygax *et al.*, 2018). Since it can grow on silicicolous as well as on calcicolous substrate it is widely abundant in the whole Alpine region (Alvarez *et al.*, 2009). The species is most prevalent in the tall herbaceous plant

community (Adenostylion), but it also occurs in other communities such as the nutrient-rich alpine meadow Rumicion alpini, the green alder shrubs Alnenion viridis and along the banks of streams (Hess *et al.*, 1977; Delarze *et al.*, 2015; Gygax *et al.*, 2018). Considering the ecological indicator values of Landolt *et al.* (2010), *Peucedanum ostruthium* prefers nitrogen-rich soils in moderately acidic areas (N = 4, R = 3) and in rather fresh and shady places (F = 3, L = 3). As mentioned above, it is found mainly in subalpine regions as a cool indicator (T = 2). The species can reproductively disperse by generating seeds annually with up to 50 umbels (Hess *et al*., 1977). The ability of vegetative propagation allows an individual to form that many reproductive organs by forming clonal rhizomes with horizontal growth. Its frequently dominant occurrence in plant communities is made possible by the advantages of horizontal propagation. On one hand, it is enabled to cover a larger area in competition with other plants for more light and nutrients, thereby nutrient-rich hotspots can be selected. On the other hand, proliferation is multiplied by vegetative and reproductive propagation. The plant is also more robust against disturbance since rhizomes are protected in the underground and can store reserves (Klimešová *et al.*, 2018). The rhizome is divided in a front thick storage shoot with a sprout and a rear migrating shoot with long internodes (**Figure 2**). The organ is rich in starch and resin and has essential oils in large balsamic channels crossing the bark and medulla. The essential oil consists mainly of terpenes (95%) but also of phenolic compounds such as coumarins and furanocoumarins (Tschirch, 1917). They play a crucial role in plant defense against herbivores by having phototoxic and postingestive effects on insects (Berenbaum, 1981; Hadaček *et al*., 1994). The simple coumarins are toxic to generalized feeders but have no effect on umbellifer specialists. There, the furanocoumarins are used (Berenbaum, 1981). Among the specialists are the leaf beetles of the genus *Oreina* spp., which have been competing with *Peucedanum ostruthium* in a species interaction spanned several glacial cycles (Dobler *et al.*, 1996; Borer *et al.*, 2012).

Table 1: Botanical description of *Peucedanum ostruthium*

Botany of *Peucedanum ostruthium*[1]	
40-100 cm high. **Leaves** with 3 large, stemmed sub-leaves, these are 3-lobed varying in depth, often going down to the base, unevenly sharp-dentated. Hollow **stem**. **Umbels** in two compounds. Bracts 0-1, small bracts few. **Flowers** white or reddish. **Fruits** flat, round, 4-5 mm in diameter, with broadly winged marginal ribs. Can form herds through offshoots, Perennial hemicryptophyte Indicator values: 334-323.h.2n=22	

1: Info Flora (2017); Image source: Hess et al. (1977)

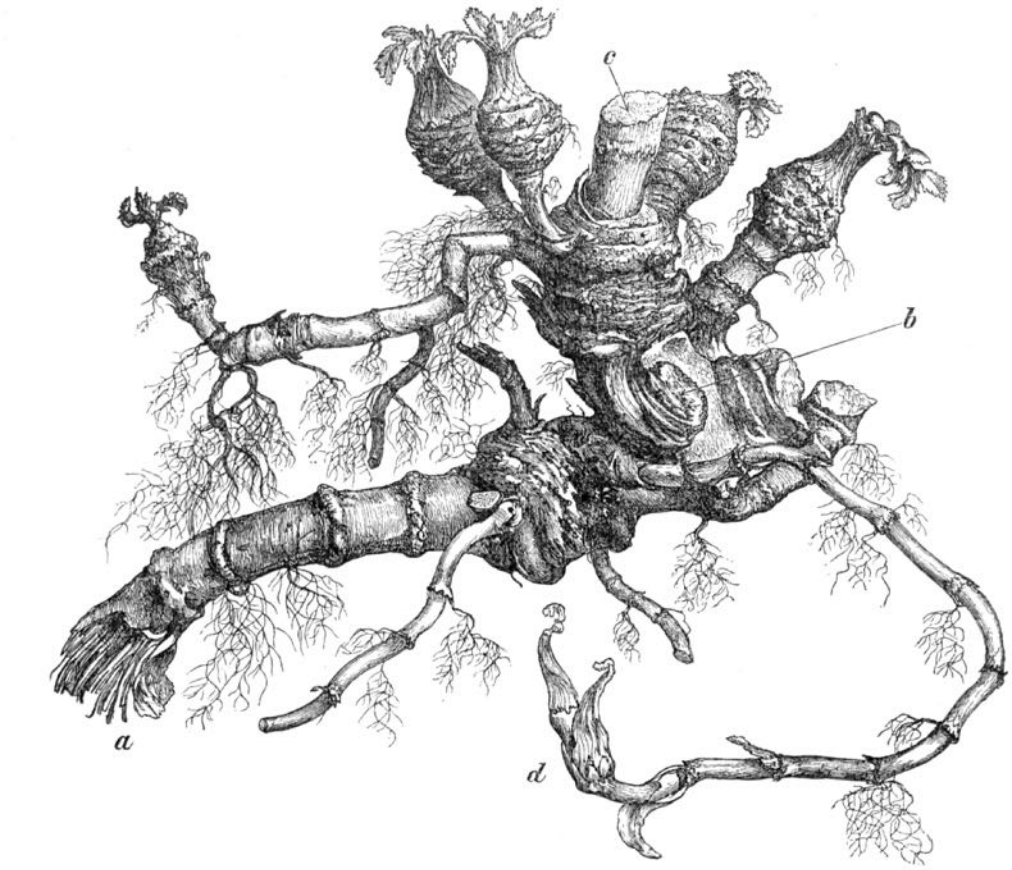


Figure 2: Rhizome of *Peucedanum ostruthium*, **a**: dying end, **b**: remainder of a sprout expelled in an earlier year, **c:** remainder of the sprout from last year, **d**: migratory part of rhizome. Source: Tschirch (1917), p. 906

1.3 Morphological traits as a benchmark for environment-species interaction

Morphological trait measurements of plants are well established in the research based on the assumption that the intraspecific variability of morphological shapes determines the response of plants to abiotic and biotic environmental factors (Körner and Renhardt, 1987; de Kroons and Hutchings, 1995; Albert *et al.*, 2010; Grassein *et al.*, 2010; Pellissier *et al.*, 2010; Keser *et al.*, 2014; E.-Vojtkó *et al.*, 2017). It is also important to include belowground organs (roots and storage organs), as they can play an important role in explaining plant distribution and abundance especially in cases of perennial plants (de Kroons and Hutchings, 1995; Keser *et al.*, 2014; Klimešová *et al.*,2016; E.-Vojtkó *et al.*, 2017). Abiotic environmental factors like soil condition, climate or water supply have an effect on morphological plant traits and are generally accepted in science. Each species shows different degrees of adaptation to environmental factors. For example, the total biomass of two different grass species can increase in different proportion while treating them with water and nutrients (Grassein *et al.*, 2010). This phenomenon is defined as plasticity, whereby plants with little morphological variability follow a more conservative growth strategy than plants with a high intraspecific variability. The conservative growth is characterized by slow growth rate and propagation (de Kroons and Hutchings, 1995; Albert *et al.*, 2010; Grassein *et al.*, 2010). The effect of environmental factor on traits is most obvious when plants are growing under stressful conditions (Körner and Renhardt, 1987; Pellissier *et al.*, 2010). Stress factors can be low-nutrient soils, increased infestation of herbivores or diseases and, with regard to alpine regions, lower temperatures, shorter seasons for growth and higher UV radiation (Rodriguez-Hernandez, 2019). In the case of altitudinal factor, plants are renowned to be smaller at higher altitudinal levels in an interspecific point of view but also at an intraspecies level between populations (Körner and Renhardt, 1987; Pellissier *et al.*, 2010). Due to the numerous abiotic and biotic factors involved in an ecosystem, it is often difficult to determine which factor leads to which adaptation in a single species, since unknown factors in the field studies could also have an influence.

1.4 Phytochemical components in the rhizomes of *Peucedanum ostruthium*

Species of the family Apiaceae are all rich in essential oils and coumarins. More than 300 molecules could be identified from the aromatic Genus *Peucedanum* so far (Sarkhail, 2014). The main components of the plant extracts are flavonoid glycosides, aglycones, coumarins, furanocoumarins and phenolic acids (Cieśla *et al.*, 2009). The essential oil of *Peucedanum*

ostruthium contains 39 components according to the study of Cisowski *et al.* (2001). The main components are Sabinene (35.2% of essential oil) and 4-Terpineol (27.2%), both belonging to the Monoterpenes. In lower compounds the sesquiterpenes α-phellandrene (3.7%), γ-Terpinene (3.0%) and Germacrene D (2.8%) could be detected. High concentration of terpene derivates are typical in essential oil and are attributed to have anti-microbiotic activity (Hänsel *et al.*, 2015). The components in the leaves are similar to the rhizomes but are present in other concentrations (Cisowski *et al.*, 2001).

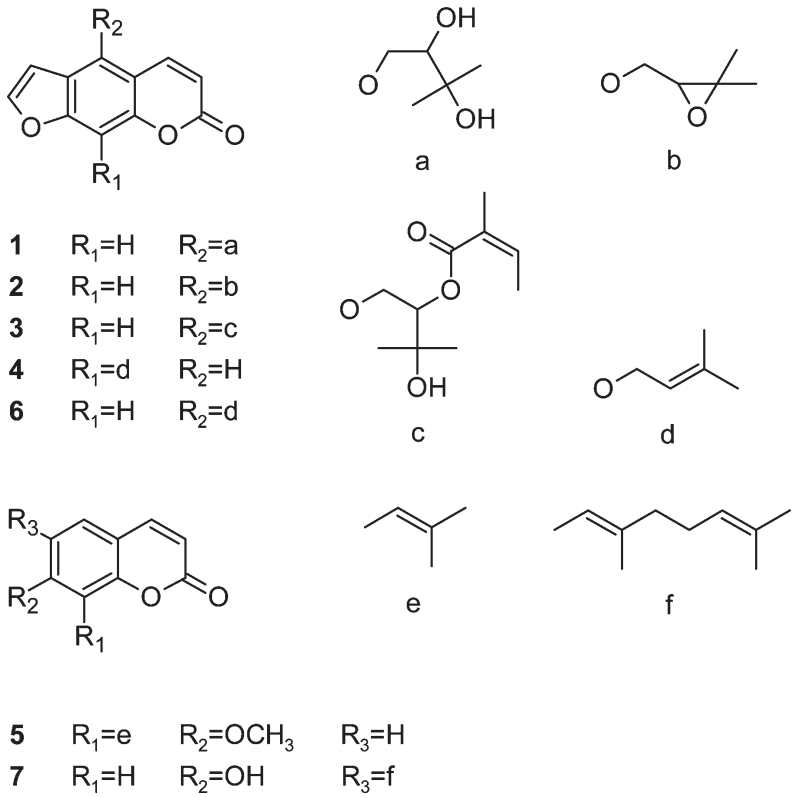


Figure 3: Coumarins identified in *Peucedanum ostruthium.* **1:** oxypeucedanin hydrate, **2:** oxypeucedanin, **3:** ostruthol, **4:** imperatorin, **5:** osthol, **6:** isoimperatorin, **7:** ostruthin. 1-4 & 6 = linear furanocoumarins, 5&7 = simple coumarins. Source: Joa *et al.* (2011)

The coumarin content is about 6% and include 8 simple and linear coumarin derivates: ostruthin (41% of total coumarin content), oxypeucedanin (18%), ostruthol (13%), imperatorin (9%), isoimperatorin (9%), oxypeucedanin hydrate (6%) and osthol (1%; **Figure 3**; Joa *et al.,* 2011). Additionally, the dihydroxy furanocoumarin glycoside Apterin and the Chromone Peucenin were detected (Vogl *et al.*, 2011; Palmioli *et al.*, 2019). The major glycosylated flavonoid is Hesperidin (Hörhammer *et al.*, 1969). Coumarins are phenolic acids and represent lactones of an *o*-hydroxycarbamide. They are lipophile and many of them show a fluorescence behavior. Furanocoumarins got their name from an additional furan ring. Furthermore, some coumarins

contain a substitute isoprene and are common in Apiaceae species, like ostruthin or imperatorin in *Peucedanum ostruthium.* Besides the pharmacological potential, coumarins can also be hepatoxic or carcinogenic (Hänsel *et al.*, 2015). The toxicity of the coumarins in *Peucedanum ostruthium* has yet to be examined.

1. 5 Recent pharmacological studies of coumarins in Peucedanum ostruthium

Modern pharmacological investigations support the power of *Peucedanum ostruthium* rhizomes, as claimed in traditional medicine, with observations of therapeutic activities of several coumarins (**Table 2**). Therefore, ostruthin is claimed to have an impact on vascular smooth cell proliferation and could help with cardiovascular diseases (Rauwald *et al*., 1994; Joa *et al.*, 2011). Furthermore, ostruthin shows an antimycotic activity against Mycobacteria (Schinkovitz *et al.*, 2003a). Antibacterial activities are attributed to the coumarin oxypeucedanin hydrate (Gökay *et al.*, 2010). Osthol shows immune-modulatory and anti-inflammatory activity (Zimecki *et al.*, 2009a). Furthermore, it could be an effective treatment for Alzheimer disease, epilepsy and other neurodegenerative diseases (Urbain *et al.*, 2005; Du *et al.*, 2019). These studies all extract osthol from *Peucedanum ostruthium*. More investigations have focused on osthol as it is also present in other medicinal plants of the Apiaceae, where additionally anti-proliferative, anti-convulsant, anti-cancer and anti-allergic properties have been observed (Jarząb *et al.*, 2017). Other studies about *Peucedanum ostruthium* additionally found antipyretic, anti-inflammatory as well as anti-oxidant activities (Hiermann and Schantl, 1998; Palmioli *et al.*, 2019).

Table 2: Therapeutic effects and treatments of diseases according to traditional medicine in the Alpine region and to modern pharmacological studies

According to traditional Medicine[1]	**According to modern pharmacological studies**
Cardiovascular	*Cardiovascular*
Activate blood circulation	impact on vascular smooth cell proliferation: Cardiovascular diseases (Joa *et al.*, 2011) Calcium antagonistic activity: Cardiovascular diseases (Rauwald *et al.*, 1994)
Dermatological	
support wound healing, anti-inflammatory, disinfectant	
Tonic	*Tonic*
Strengthening immune system, diaphoretic	Immunomodulatory and anti-inflammatory activity (Zimecki *et al.*, 2009a) Anti-inflammatory, antiphlogistic and antipyretic (Hiermann and Schantl, 1998)
Nervous system	*Nervous system*
Calmative, general strengthening, headache	Reduction of acetylcholine level in the brain: treatment for Alzheimer disease (Urbain, Marston and Hostettmann, 2005) Treatment of epilepsy and other neurodegenerative diseases characterized by overexpression of PI3K/Akt/mTOR (Du *et al.*, 2019) Antioxidant and treatment for Alzheimer diseases (Palmioli *et al.*, 2019)
Gastrointestinal	*Other*
digestion, heartburn, colic	antibiotic activity (Gökay *et al.*, 2010) antimycotic activity (Schinkovitz *et al.*, 2003a)
Respiratory	
cold, cough, bronchitis, lung diseases	

1: Most important treatments in traditional medicine according to the evaluation of this study in chapter 4.3, details of traditional uses in Appendix D table 3

1.5 Aim of the study

A group of research questions addressed the variability of morphological traits among subpopulations along a gradient of altitudinal levels and between different localities into distant villages. Furthermore, investigations of their interdependences and the effect of environmental conditions to the morphological patterns of *Peucedanum ostruthium* were performed:

- How do morphological traits vary?
- Is *Peucedanum ostruthium* in upper Saastal structured in subpopulations based on their morphological variability and on distinct environmental conditions?
- Does altitudinal level, soil condition or herbivory have an effect on the morphological variability of *Peucedanum ostruthium*?

A second group of research questions addressed the kinds and concentrations of coumarin components in the belowground parts (rhizome) and the possible influence that environmental factors at the different sites have.

- Which coumarins can be identified in rhizomes of *Peucedanum ostruthium* and what is their concentration?
- Do coumarin components depend on certain morphological traits?
- Does altitudinal level, soil condition or herbivory have an effect on the coumarin components in the rhizomes of *Peucedanum ostruthium*?

Finally, ethnobotanical research questions dealt with how *Peucedanum ostruthium* is used by the locals in the upper Saastal and how their knowledge about the medicinal plant can be interpreted in comparison with historical records and other ethnobotanically researched Alpine regions.

- Which application of *Peucedanum ostruthium* is used in the Saastal?
- Do the locals of Saastal prefer other plants for medicinal applications that could also be treated with *Peucedanum ostruthium*?
- Which preferred applications of *Peucedanum ostruthium* have been historically recorded and are still used in the Alpine regions?
- What importance did *Peucedanum ostruthium* have in the past and still has today?

2. Methods

2.1 Study site

The Saastal is located in the canton Valais in Switzerland (**Figure 4**). The high mountain valley in the central Alps lies on 800 – 2200 m a. s. l. This study only considers the upper Saastal, which includes the municipalities Saas-Balen (1450-1550 a. s. l), Saas-Grund (1500-1600 a. s. l.), Saas-Fee (1750-1850 a. s. l.) and Saas-Almagell (1600-1700 a. s. l.) with 3281 inhabitant in total (effective 31.12.2018; BFS, 2019; **Figure 5**). The valley belongs to the region with the most mountaintops in the Alps reaching 4000 m. The valley itself is flat and ascending from Saas-Balen to the Mattmark reservoir. Saas-Fee is the only municipality not to lie in the basic valley but on a raised side valley instead. The substrate consists of silicate rocks and offers a lime poor habitat except in the region around Mattmark reservoir which are basaltic deposits. The valley is part of the inner-Alpine region with only low annual precipitation and thus, belongs to the dry warm areas in the Alps (Eggenberg and Möhl, 2013). The valley has a high biodiversity with about 1300 plant species (Info Flora, 2017). The landscape is characterized by larch-pine and blueberry-spruce forests. On the alpine level (>2000m), meadows are mainly managed with sheep. The ground of the valley is shaped by rich pastures which are cultivated in small plots (*Parzellenwirtschaft*). A further characteristic element in the valley is the tourist infrastructure for winter sports, which is particularly present in Saas-Fee and Saas-Grund. Tourism began at the end of the 19th century, when botany enthusiasts from Zurich explored the region. Until then local people were self-sufficient and lived under very simple conditions with neither doctors nor schools (Wyder, 2018). Today the tourism sector is the most important employer in the valley.

2.2 Fieldwork

Botanical fieldwork

The botanical field study was performed from July until August and in October 2020. Data and samples were collected from 120 individuals on 4 sites in the region Saas-Balen (SB) and Saas-Almagell (SA). Each site involves 30 samples and is linked to a certain altitudinal range on the western slope of the mountain chain. Three sites are located in Saas-Balen at 1450-1550m, 1750-1850m and 2000-2100m a. s. l. and one site in Saas-Almagell at 1750-1850 m a. s. l. (**Figure 5**).

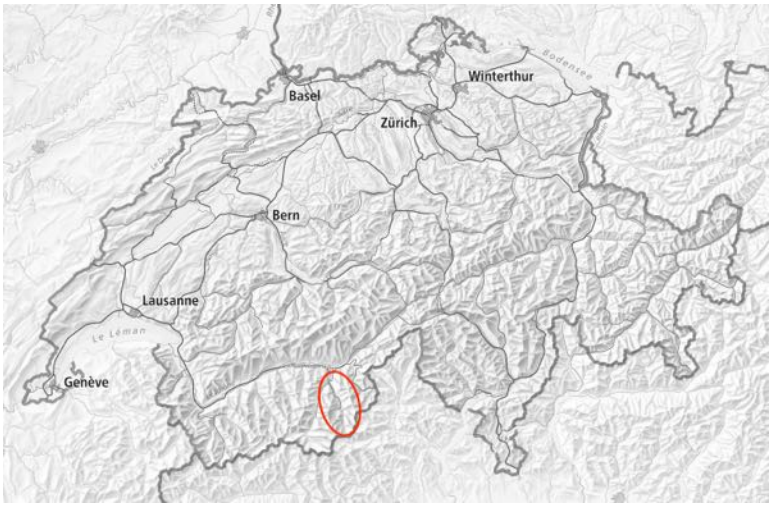


Figure 4: Relief map of Switzerland. Red: Saastal. Adapted from: geo.admin.ch, geodata © swisstopo

Figure 5: 1: Saas-Balen, **2:** Saas-Grund, **3:** Saas-Fee, **4:** Saas-Almagell, **yellow:** 1450-1550m SB, **pink**: 1750-1850m SB, **green**: 2000-2100m SB, **blue**: 1750-1850m SA. Adapted from: geo.admin.ch, © ESA/Eurimage/swisstopo, NPOC

Peucedanum ostruthium was only collected in the tall herbaceous mountain plant community Adenostylion (**Figure 7.1**). The plant community was determined by the bottom-up method according to Delarze *et al.* (2015). For this purpose, at least 15 species of the plant community were identified at each collection site (plots) from July until August (protocol in Appendix A Table 5). The number of plots varies between the sites due to the occurrence of *Peucedanum ostruthium* and the Adenostylion. At the same time data about umbel and leaf traits were collected with 3 measurements per individual from the largest organs (illustration of the measured traits in **Figure 6**). Additionally, the number of lobes per measured leaf were counted.

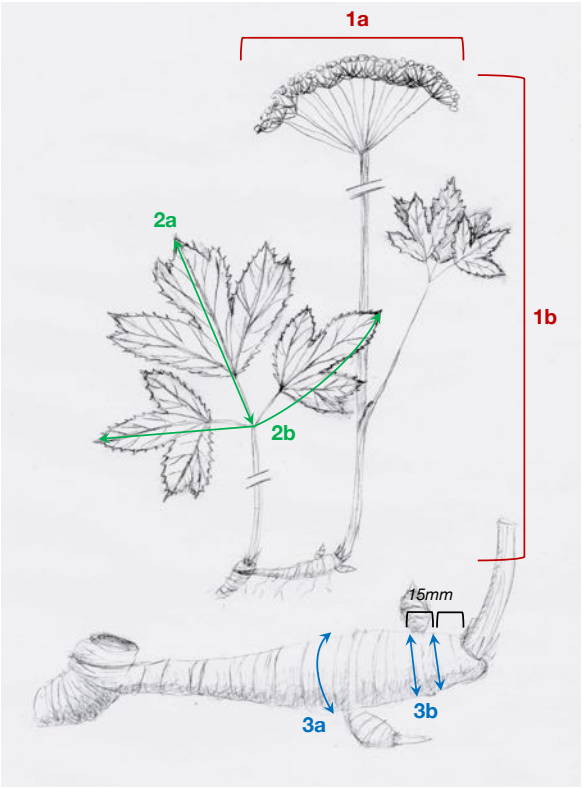


Figure 6: Morphological traits of *Peucedanum ostruthium*. **1a:** umbel width, **1b:** umbel height, **2a**: leaf length, **2b:** leaf width, **3a**: rhizome circumference at thickest point, **3b**: rhizome diameter, 15 mm away from sprout

The health condition and herbivory of the individuals was assessed by estimating certain disease characteristics and the strength of the infestation. Finally, an overall impression of the individuals and the plots has been noted (sampling protocol in Appendix A Table 3). A minimum distance of 5m between two sampled individuals should prevent that only one clonally propagated individual is recorded.

In October, the same individuals were revisited to collect data about rhizome traits and harvest pieces of rhizomes for the later HPTLC analysis. For each individual, data and samples of three different rhizomes were collected. The rhizome circumference was always measured at the thickest position of the rhizome, whereas the rhizome diameter was measured at the harvested pieces. The pieces have a length of 15mm and are cut 15mm away from the sprout shoot. They were weighed on the harvest day (harvest weight) and after the drying process (dry weight). For the drying process, the pieces were cut into slices and dried at 45° C for 12 hours in a food dehydrator. The three rhizome pieces of one individual were mixed together to one sample and were stored for the HPTLC analysis (**Figure 7.2**).

The samples were collected in a certain order to obtain similar seasonal conditions at the different altitudinal levels. The umbels and leaf traits were collected from bottom to top and in

summer, attention was paid that the plant was between flowering and seed formation. The rhizomes were collected in autumn in reverse order.

Ethnobotanical fieldwork

From September until October, a total of 20 informal interviews were conducted in the upper Saastal. Interview partners were selected who are known for their knowledge and use of medicinal plants and can therefore be regarded as herbalists. To find these herbalists in the valley the snowball method was used (Russell, 2017). For this purpose, initial advices were asked from a tourism employee. Additionally, passersby in Saas-Balen were shortly interviewed about their knowledge of *Peucedanum ostruthium* and whether they knew someone with a great medicinal plant knowledge. The interviewees themselves were also asked about other herbalists (snowball tree in Appendix C Figure 1). During the interviews, the questions were based on a guideline. First, the interviewees were asked if they know and use *Peucedanum ostruthium* while showing them pictures in its typical habitat and an herbarium specimen (**Figure 7.1**). If they did not know it as a medicinal plant, their experience and relationship with *Peucedanum ostruthium* in general was discussed. Furthermore, the interviewees were asked about their general medicinal plant knowledge and uses. Besides the questions about the plant parts, application and preparations, they were also asked where they gather them. The interviews were conducted until everything was said, which could range from half an hour to 2 hours. The 20 interviewees (17 female, 3 male) have an average age of 76.6 years ranging from 60 to 93. Half of the 20 interviewed persons worked or still work in the tourist business in hotels, six called themselves housekeeper and 5 are farmers. Overall, 17 interviewees stated that they got the training in medicinal plants from their mothers. Only 9 people consult a herbal book or the internet for information. Three of them sell their products to customers (Detailed information in Appendix C Table 1)

The medicinal plant knowledge was presented in form of use-reports in a table, including vernacular names, collection places, application, preparation and treatments (Appendix C Table 3). Since *Peucedanum ostruthium* plays a subordinate role in the Saastal, a study of historical records and other recent ethnobotanical studies was conducted. The use of *Peucedanum ostruthium* from the literature was then listed as citation-reports in a similar order as the use-reports (Appendix D Table 3). Use-reports as well as citation-reports were counted together by species, plant parts used, form of application and use category.

2.3 Plant Material

For each site, 10 umbel specimens of *Peucedanum ostruthium* were collected (in total 40 specimens). Furthermore, 3 x 120 leaves specimens, which traits were measured and 72 specimens of species from the plant community were collected. They are deposited at the herbarium of the Department of Systematic and Evolutionary Botany, University of Zürich. The nomenclature follows *Flora Helvetica* (Gygax *et al.,*2018). 3x120 samples of rhizomes were harvested for HPTLC analysis, their remains were deposited in CAMAG AG, Switzerland, where the HPTLC analysis was conducted.

2.4 HPTLC Analysis

The HPTLC analysis was performed in the laboratory of the CAMAG AG headquarter in Muttenz Switzerland. The preparation and analysis procedure was carried out according to the method of Frommenwiler *et al.* (2018). They performed this method on samples of *Angelica gigas* NAKAI and *A. sinensis* (OLIV.) DIELS roots, which have similar coumarin compositions. In this study, all 120 samples were processed in the following way. The rhizome slices were chopped at 25'000 rpm for 1 min to a fine powder. The powder then was passed through a sieve of 355µm pore size (**Figure 7.4**). The unsieved remains was separately stored and later processed in the same way as the sieved sample. 1g (±0.05) of the sieved sample powder was added to 5ml Methanol. The solution was shaken for 10 min at 300rpm and then centrifuged for 5 min at 5000rpm. The reference substances imperatorin, isoimperatorin, osthol, oxypeucedanin and ostruthin were dissolved 1:1 with Methanol and shortly sonificated. By using the TLC sampler (ATS4, CAMAG) 4µl of reference and sample solutions were applied on the chromatography plate. Then the plates were developed with the developing chamber (ADC2, CAMAG). The chambers were set to a relative humidity of 33% ($MgCl_2$) and were saturated for 20 min with the developing solvent; a mixture of toluene, ethyl acetate and acetic acid with a ratio of 90:10:1. The developing distance was set to 80 mm. The plates were evaluated by densitometry analysis at UV 244nm and UV 320 nm (Deuterium and Tungsten lamp, TLC Scanner, CAMAG). The spectra were chosen as a compromise in absorbance quality of the evaluated coumarins. Images of the plates were made under UV 254nm and UV366nm. Then the plates were derivatized by dipping them in a solution of 10% sulfuric acid in methanol (CAMAG Chromatogram Immersion Device III; speed: 3; time:0) and heated for 3 minutes at 100°C degree. The derivatized plates were scanned under UV 478 nm (Tungsten lamp, TLC)

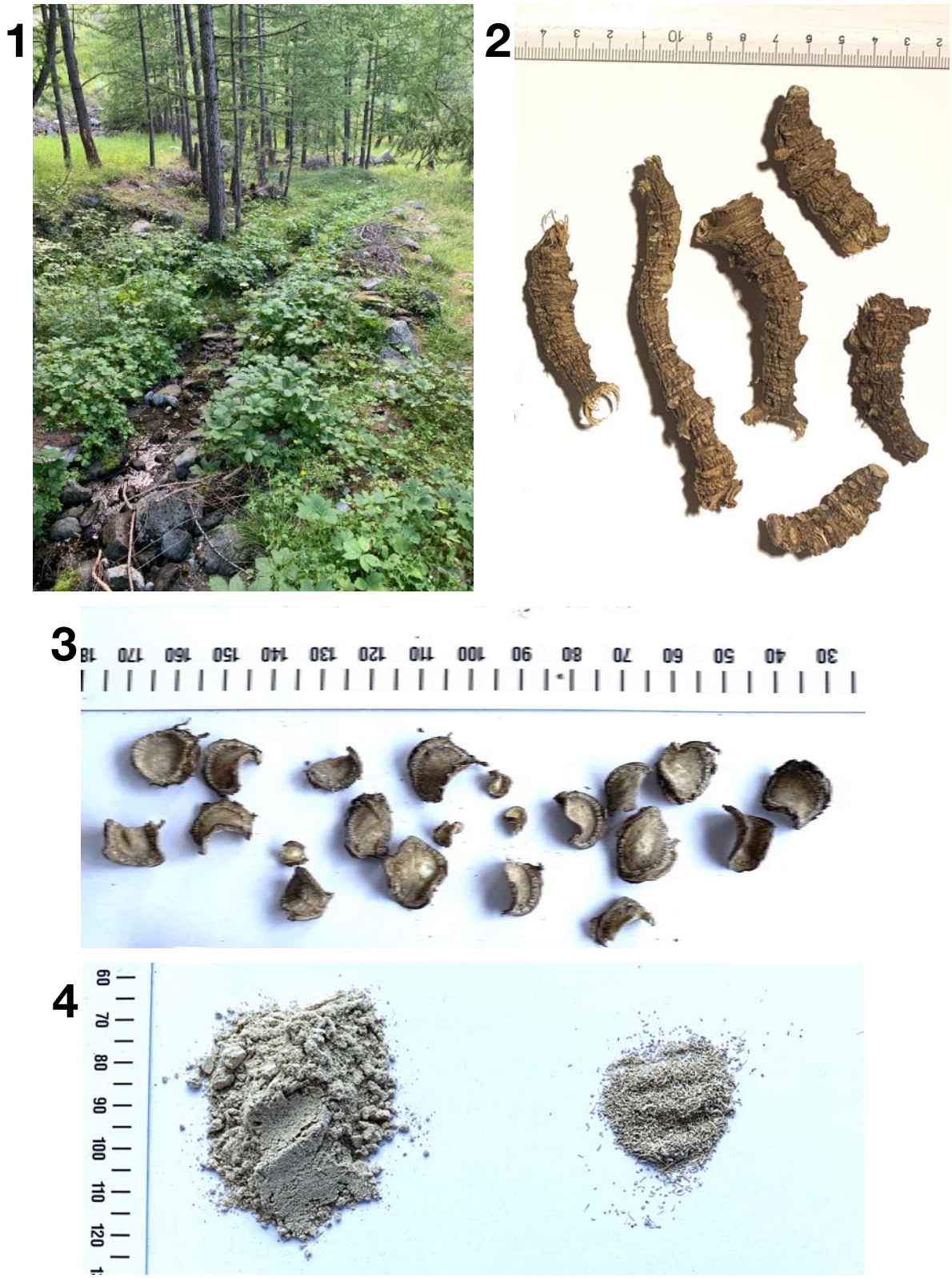


Figure 7: 1: typical habitat of *Peucedanum ostruthium* and other tall herbaceous plants along a water channel, **2:** dried rhizomes, **3:** dried and cut rhizome sample, **4:** sieved powder of a rhizome sample and unsieved remains (>355µm)

and visualized with images of RT White (R=remission, T=transmission) and UV 366nm. The same procedure was made with a 1:5 dilution of the sample solution in Methanol to obtain a more differentiated distribution of the single peaks and was taken for further analysis. The unsieved powder was compared to the sieved, but no anomalies were observed. Furthermore, samples of tincture (1:1 in Methanol, prepared in a spirit with 40% EtOH by the author) and infusion (one teaspoon of sieved powder in a cup with hot water (> 95° C) stirred for 1 min and passed through a filter paper) freshly prepared and after 3 days were analyzed according to the same procedure. The profiles of the samples and standards were generated from the TLC scan under 244 nm using the visionCATS software (CAMAG, version 2.0). The concentration of coumarins in µg/ml for the quantitative analysis was evaluated by calibrating the peak absorption of the coumarins comparing with the reference substance isoimperatorin, whose concentration is known.

2.5 Data Analysis

Statistical analyses and graphs were performed on RStudio (Version 1.2.5033, © 2009-2019 RStudio Inc.). The values of the morphological trait variables are the average of the 3 measured traits per individual. Since not all variables were normally distributed (tested with Shapiro Wilk Test and graphical display) the non-parametric Kruskal-Wallis test by ranks and Mann-Whitney U test were used to compare the variables. Differences were considered significant at p-value < 0.05. Outliers were checked for by using graphical display and linear relationships between variables were verified with linear models including an analysis of variance (ANOVA). Then a principal component analysis (PCA) was performed. Attention was paid that the first and second PC do not fall below a value of 70% in explanation of variance to ensure convincing results while comparing with environmental factors.

3. Results

3.1 Morphological trait measurements of *Peucedanum ostruthium*

Overview of traits measurements

A summary of the *Peucedanum ostruthium* trait measurements are given in **Table 3**. The maxima are in many cases at least twice as large as the minima. The most drastic difference can be noticed in the rhizome length, where the longest measured rhizome is more than 5 times longer than the shortest. Other major differences can be found in the umbel height and the size of leaves (leaf length and leaf width). However, smaller differences in maxima and minima are found in rhizome circumference and the width of umbel inflorescence.

As shown in **Figure 8**, the number of lobes of the basal leaves increases with their size of the leaves. A regression analysis further indicates a linear relationship between number of leaf lobes and leaf surface but with a high variance (p-value < 0.001, $R^2 = 0.15$, leaf surface is calculated with the area of an equilateral triangle based on leaf width and length.) The average circumference measured at the thickest point of the rhizomes has a converted diameter of 18.7 mm. This is only slightly larger than the diameter (15.0 mm) which was always measured 15 mm away from the shoot base. On average, the rhizomes lost 65.4 % of their weight during the drying process. This leads to a weight reduction of 1.7 g or a water loss of about 1.7 ml of a piece of rhizome with an average diameter of 15 mm and a length of 15 mm (measured at the harvested pieces).

Correlations between traits

Strong correlation between the single measured traits are rare cases. In particular, traits measured from the same organs usually indicate a relationship to each other. (Scatterplot of traits in Appendix A Figure 1)

The variability of umbel height and width of the inflorescence surface are in a linear relationship, but with a high variance (linear model: p-value < 0.001, $R^2 = 0.23$). The three sub-leaves measures 190-209 mm and are about equal in length (leaf width includes two leaf parts and must be divided by two for this calculation). Leaf length and leaf width are also in a strong linear relationship with a very low variance (linear model: p-value < 0.05, $R^2 = 0.89$).

Table 3: Means, medians, minima and maxima of measured traits of all *Peucedanum ostruthium* samples

Traits	Mean	Unit	Standart deviation	Minimum	Median	Maximum	Sample size
umbel height	1028.0	mm	± 160.6	623.3	1020.0	1470.0	3x120
umbel width	175.0	mm	± 22.0	123.3	176.7	230.0	3x120
leaf lobes	9.0		± 2.1	4.0	8.7	13.7	3x120
leaf width	379.4	mm	± 61.1	126.7	209.2	293.3	3x120
leaf length	208.7	mm	± 33.1	188.3	375.0	530.0	3x120
rhizome length	60.9	mm	± 23.1	29.3	56.7	158.3	3x120
rhizome circumference	58.8	mm	± 6.3	41.8	58.3	75.0	3x120
rhizome diameter	15.0	mm	± 1.8	10.8	14.8	19.3	3x119
harvest weight	2.6	g	± 0.7	1.4	2.5	4.8	3x120
dry weight	0.9	g	± 0.2	0.5	0.9	1.6	3x120

Figure 8: Pictures of *Peucedanum ostruthium* leaves from collected herbarium specimens, sorted by leaf size (smallest at the bottom)

A distinct linear relationship is found between rhizome circumferences, their diameters, harvest- and dry weights, but not in combination with rhizome length. Moderate positive correlations are identified between the aboveground organs including the traits umbel height, umbel width, leaf length, leaf width and leaf lobes.

The relationships among the investigated trait measurement are evident in the biplot of principal component analysis (PCA) in **Figure 9**. The arrows (eigenvectors) are divided into two groups, the aboveground organ traits together with the rhizome length and the remaining belowground organ traits. Within the group an evident correlation is present, but not between the two groups. The individual samples (grey points in **Figure 9**) do not show any distinct pattern or trends.

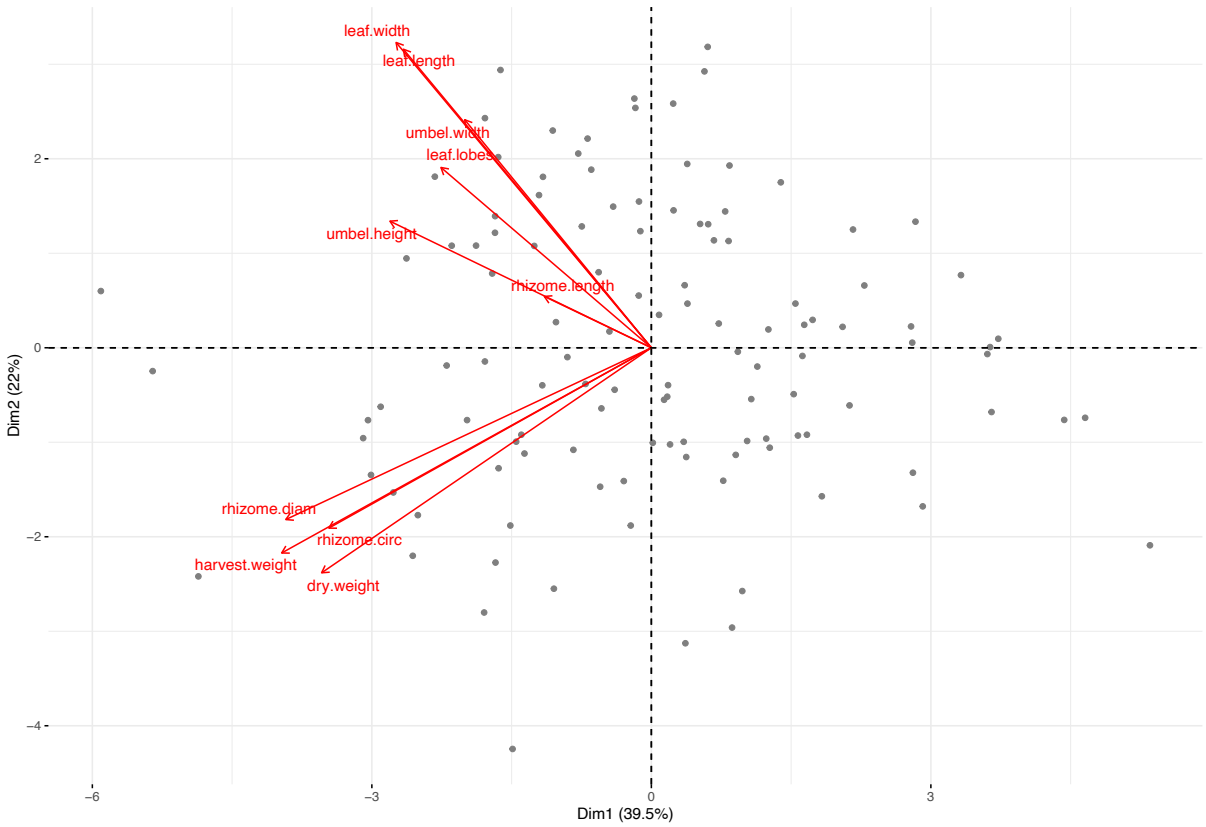


Figure 9: Biplot of PCA illustrate the correlation between all measured traits (sample size = 120)

The principal component 1 and 2 (PC1, PC2) in the biplot of **Figure 9** explain together only 61.2% of the variance (PC1 = 39.5%, PC2 = 22%). The limited explanation of PC1 and 2 result from a high variance of traits and is too low to provide clear results. For this reason, aboveground and belowground organ traits are considered separately in the following PCA analysis. The PC1 and PC2 of the above organ traits explain together 75% of the variance. The

PC1 and PC2 of the belowground organ traits, however, explain together 85% of variance (the percentage may vary depending on the number of data points). Histogram of eigenvalues in Appendix A Figure 2.

Morphological trait measurements and environmental factors

Altitudinal levels

The samples in the biplots of **Figure 10** are structured in subpopulations of three altitudes in the community of Saas-Balen (SB), differentiated here as the lowest at 1450-1550m, as the middle at 1750-1850m and as the highest at 2000-2100m a. s. l.

The aboveground organ traits show a rather homogenous morphological variability on all three altitudinal subpopulations (**Figure 10A**). Only the observation of smaller umbel organs (height and width) in the middle altitude is obvious, which is also significantly smaller in the Kruskal-Wallis-Test (p-value < 0.05). Kruskal-Wallis (KW) and Mann-Whitney-U-Test (U-Test) of all single values are provided in Appendix A Table 2.

The traits of the belowground organs show far greater variability between the altitudinal subpopulations (**Figure 10B**). Overall, the rhizome traits are largest at the lowest altitude. A reduction of the rhizome thickness (and the associated weight sizes) can be observed at the middle altitude. The rhizome length and thickness are clearly smaller at the highest altitude. In KW analyses, certain values are significant lower at highest altitude (rhizome length: p-value < 0.05, rhizome diameter: p-value < 0.01; harvest weight: p-value < 0.001; dry weight: p-value < 0.05).

Distance of subpopulations and their localities to settlements

In **Figure 11** samples are differentiated in subpopulation with two classes of localities. Two subpopulations belong to Saas-Balen (SB) and one to Saas-Almagell (SA). 1750-1850 SB and 1750-1850 SA are located on the same altitudinal level, whereas 1450-1550 SB and 1750-1850 SA are situated in a similar habitat surrounding. Both subpopulations grow near the settlement area, and hence, are expected to receive a larger share of nutrients from the cattle kept in the villages. (whereas 1750-1850 SB is situated in a region of alpine pastures and forest). Finally, 1750-1850 SB and 1750-1850 SA are located at the same altitudinal level. This comparison is needed to understand whether location, habitat or altitude have an influence on the morphological variability of the traits of *P. ostruthium* in upper Saastal.

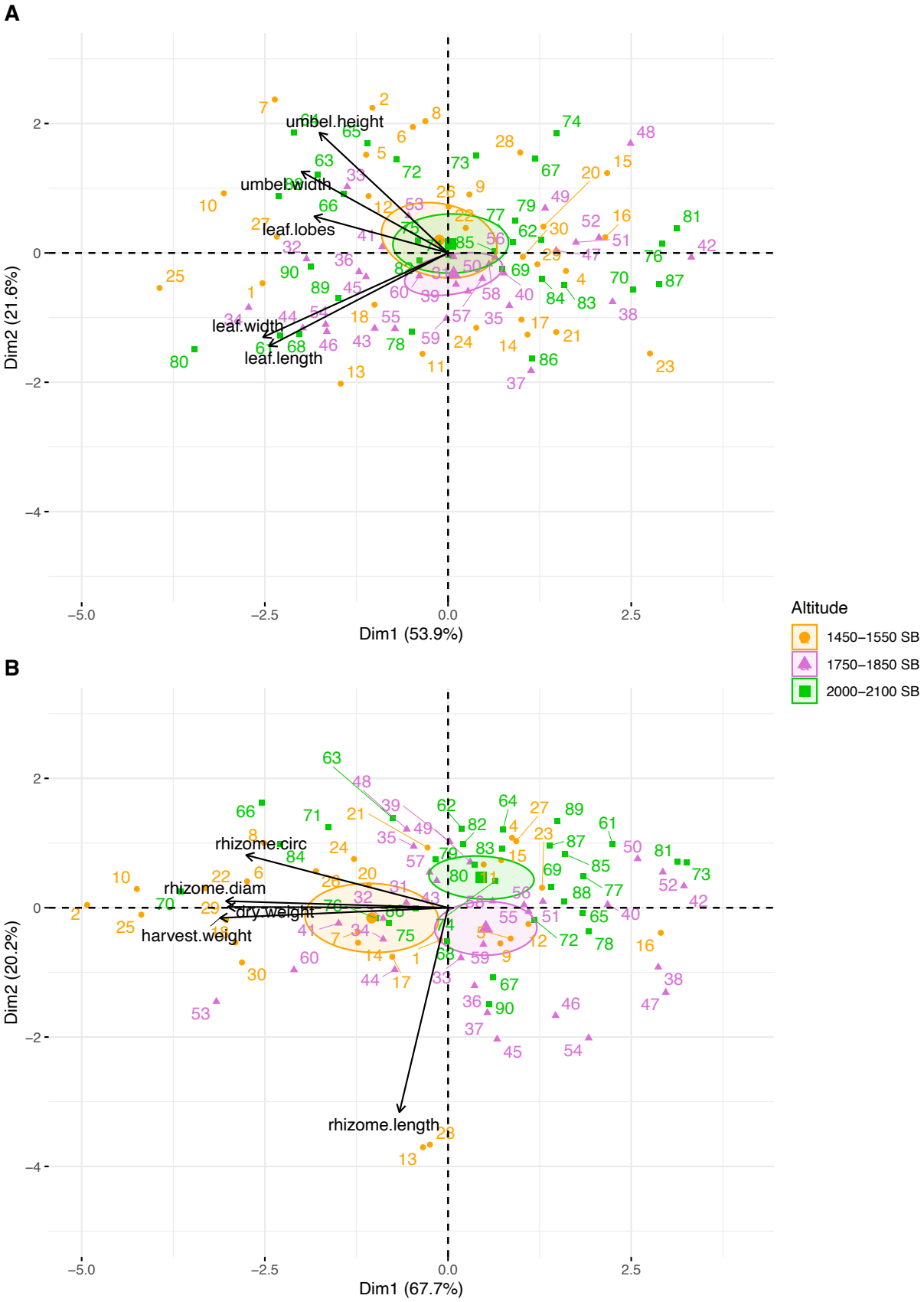


Figure 10: Biplot of **A**: aboveground organ traits and **B**: belowground organ traits. Samples are divided in subpopulations of the three different altitudinal levels in Saas-Balen (SB). (sample size = 90, 30 samples per category)

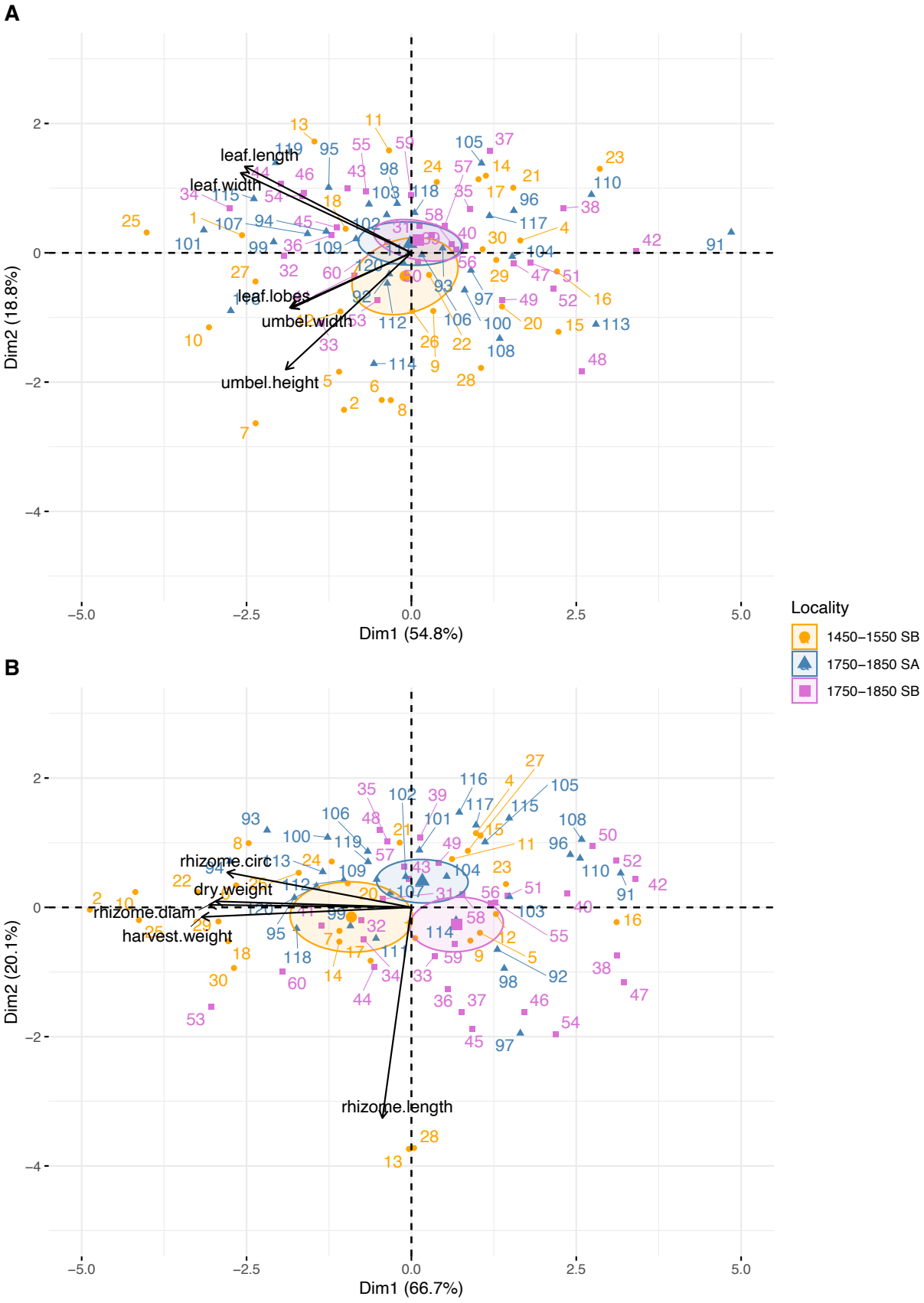


Figure 11: Biplot of **A**: aboveground organ traits and **B**: belowground organ traits. Samples are divided in subpopulations. 1450-1550 SB: near the settlement in Saas-Balen, 1750-1850 SB: same altitude as 1750-1850 SA: near the settlement in Saas-Almagell. (sample size = 90, 30 samples per category)

In both biplots (aboveground and belowground organ traits), the subpopulation on the lowest altitude (1450-1550 SB) is distinct from the other two subpopulations. The umbels and rhizomes tend to be larger. Analysis with KW shows a significant difference in rhizome length (p-value < 0.01) and harvest weight (p-value < 0.001) at the lowest altitude compared to the other two subpopulations. Umbel height, rhizome diameter and dry weight are only significant between the lower and middle altitude in Saas-Balen (U-Test). Average trait values for all 4 sites are listed in Appendix A Table 1.

Association of Peucedanum ostruthium *with plant communities*

Samples of *Peucedanum ostruthium* were always collected in the tall herbaceous plant communities (Adenostylion, Delarze *et al.*, 2015). On average 16 species were documented per plot and a total of 471 species at 29 plots on 4 sites (sites: three different altitudinal levels in Saas-Balen and one site in Saas-Almagell; species are listed in Appendix A Table 3).

The most common species besides *Peucedanum ostruthium* were *Alchemilla vulgaris* agg., *Chaerophyllum villarsii*, *Dactylis glomerate, Epilobium angustifolium*, *Geranium sylvaticum*, *Rumex alpestris*, and *Veratrum album*. Nutrient indicator as *Rumex alpinus* and *Urtica dioica* occur in a similar abundance at all 4 sites. Species characteristic of the Adenostylion plant community, which have appeared in the survey, are: *Aconitum variegatum* agg, *Chaerophyllum villarsii, Geranium sylvaticum*, *Rumex alpestris* and *Viola biflora*. and of course, *Peucedanum ostruthium*. The main dominant species in the Adenostylion plant community is *Adenostyles alliariae*, which was only encountered at the lowest site of Saas-Balen (site 1) and at the side in Saas-Almagell (site 4). Some further species of Adenostylion were also only documented at these two sites. At site 1: *Heracleum sphondyllum* subsp. *elegans*, at site 4: *Thalictrum aquilegiifolium* and *Valeriana versifolia*.

Species of the similar plant community Filipendulion are abundant, such as *Agrostis gigantea*, *Angelica sylvestris* and *Geum rivale*. Many species are characteristic to other plant communities and are interlinked with the Adenostylion. All four sites are interlinked with the alpine rich pasture (Polygono-Trisetion), where following species can be considered: *Dactylis glomerata*, *Pimpinella major* and *Trollius europaeus*. Another interlinked habitat is the Rumicion alpini with *Rumex alpina, Veratrum album* and *Urtica dioica*. Further habitats are the Alnenion viridis with *Alnus viridis* and *Streptopus amplexifolius* and the forest habitat (a mix of Vaccinio-Piceion and Larici-Pinetum cembrae) with *Homogyne alpina*, *Luzula nivea*, *Melampyrum sylcaticum*, *Oxalis acetosella, Rhododendron ferrugineum*, and *Sorbus aucuparia*.

Soil Condition

The average indicator values of all 29 plots are: nutrient content (N) = 3.3 ± 0.3, humidity (F) = 3.2 ± 0.2, reaction rate (R) = 2.9 ± 0.2, light (L) = 3.1 ± 0.2 and temperature (T) = 2.5 ± 0.2. In further analyses, the indicator values N, F and R are considered to represent the soil condition. The range of indicator values in **Figure 13** gives an estimation in which range the soil conditions prevail in the Adenostylion. The nutrient lies in the range from 2.8 to 3.7, humidity in the range from 2.8 to 3.5 and the reaction rate is from 2.5 to 3.2.

Values of the morphological traits remain constant in relation with the nutrient content in soil (**Figure 13.1).** A minimal increase of the traits is indicated in **Figure 13.3** at the indicator value of reaction rate = 3.0. No clear significance could be determined in KW tests for single traits values (Appendix A Table 2)

Herbivory

The main herbivores of *Peucedanum ostruthium* are beetles of the genus *Oreina* (**Figure 12**). The beetles may feed the leaves up to a large extent. The intensity of this feeding damage was classified into four categories and is illustrated in **Figure 14**. In both biplots it is evident that the samples with the most extensive herbivory also have the largest organ traits. Especially the samples with large leaves are more frequently attacked by herbivores. These results must be handled with care, because the sample size of the category "strong" is rather small and could bias the results. Samples in the category "moderate" tend to appear with smaller organ traits compared with the traits in other categories. Finally, samples with no or up to a moderate feeding damage are not influenced by the herbivore from a short-term perspective.

Figure 12: Herbivores of genus *Oreina* sitting on *Peucedanum ostruthium. Pictures taken by the author in summer 2019 at fieldwork in Saas-Balen*

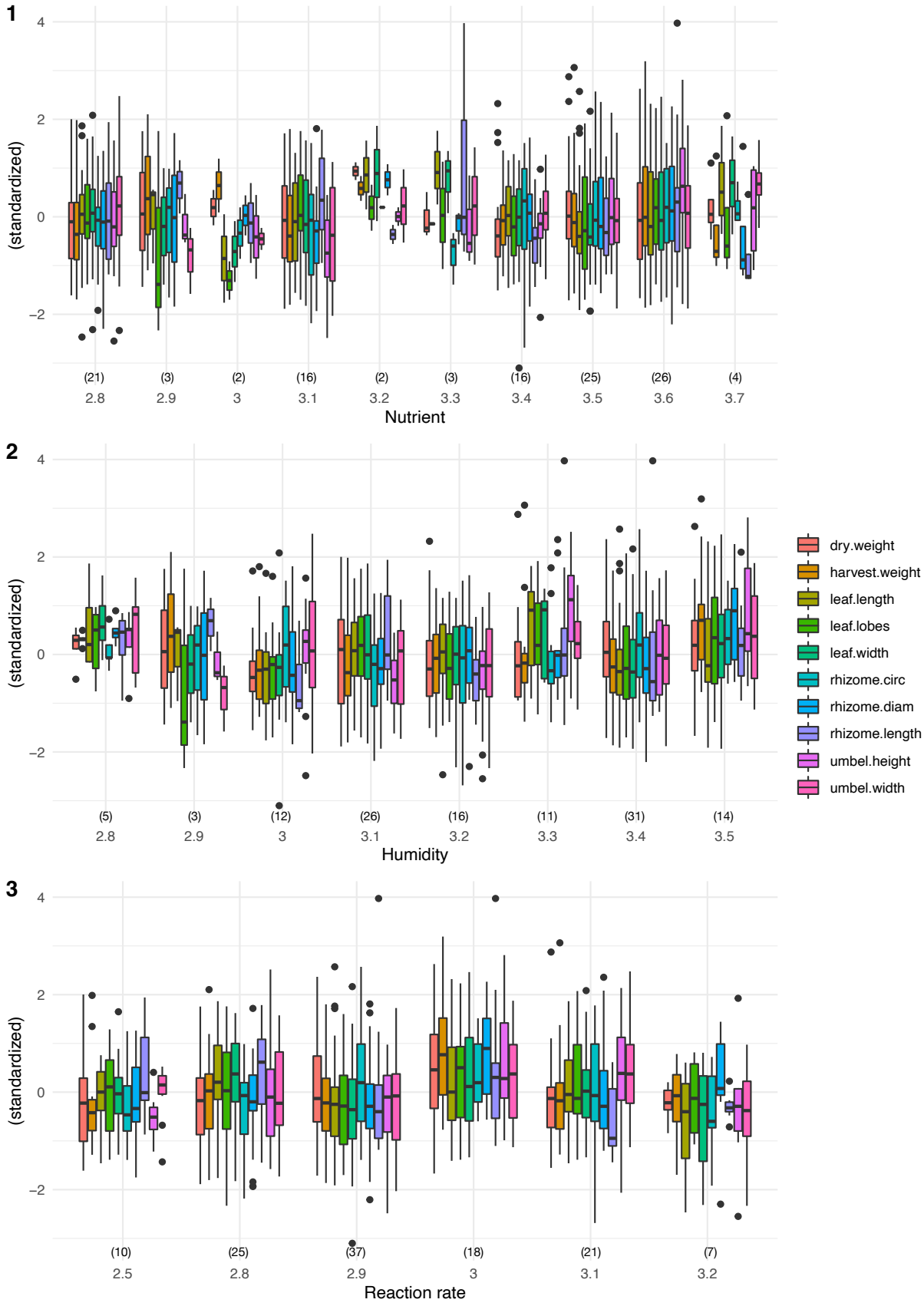


Figure 13: Values of traits (presented as colored boxplots) are grouped by indicator values. **1:** nutrient content (N), **2:** humidity (F), **3:** reaction rate (R). Values in brackets show number of samples taken at that particular indicator value. Values of traits are standardized (mean = 0, standard deviation = 1). Sample size = 120, for particular values in brackets

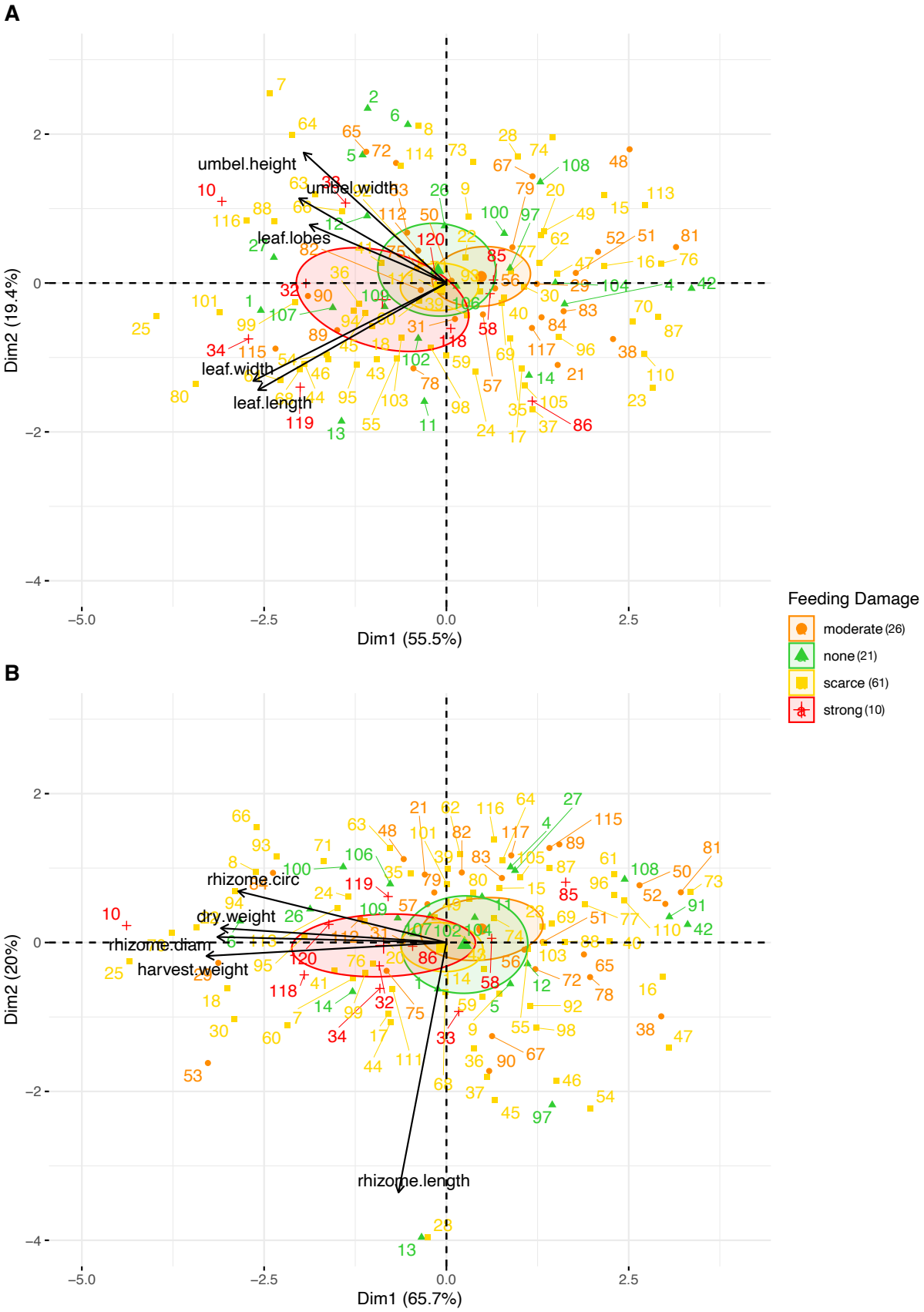


Figure 14: Biplot of **A**: aboveground organ traits and **B**: belowground organ traits. Samples are distinguished in in four categories of herbivory (sample size = 120, samples per category in brackets in the legend)

Comparing the 4 sites with the other environmental factors

Table 4 gives an overview of the environmental factors on the 4 different sites respectively on the 3 altitudinal levels in Saas-Balen and separately located site in Saas-Almagell. These relationships are important to consider as single sites were treated as one subpopulation in the field survey (same altitudinal level ranges and plots close to each other).

The health of the individuals (estimating of the aboveground organs for disease, herbivory and other visible damage) at the sites 2000-2100 SB and 1750-1850 SA are worse than at the other sites. If herbivory is considered individually, the more affected individuals are found at 1750-1850 SB and 2000-2100 SB. All three indicator values are lower at 1750-1850 SB compared to the other sites. This trend is most extreme for nutrient content with N = 3.0, whereas the other sites have at least a value of N = 3.4.

Table 4: Average of environmental factors at the 4 sites. SB: Saas-Balen, SA: Saas-Almagell. Condition: higher average value means a worse condition of the individuals. Herbivory values: number of individuals in a category. Sample size: 120, per site: 30

site	**health**	**herbivory**			
altidutinal level		*none*	*scarce*	*moderate*	*strong*
1450-1550 SB	2.3	11	14	2	1
1750-1850 SB	2.5	1	16	9	4
2000-2100 SB	3.4	0	16	12	2
1750-1850 SA	3.2	9	15	3	3
site (plots)	**indicator values of soil condition**				
altidutinal level	*F*	*R*	*N*	*T*	*L*
1450-1550 SB (11)	3.3	3.0	3.4	2.6	3.1
1750-1850 SB (4)	3.1	2.7	3.0	2.6	2.9
2000-2100 SB (5)	3.3	2.9	3.4	2.4	3.3
1750-1850 SA (9)	3.3	3.1	3.5	2.6	3.2

3.2 Qualitative and Quantitative Components of Coumarins in *P. ostruthium*

Qualitative Components of Coumarins

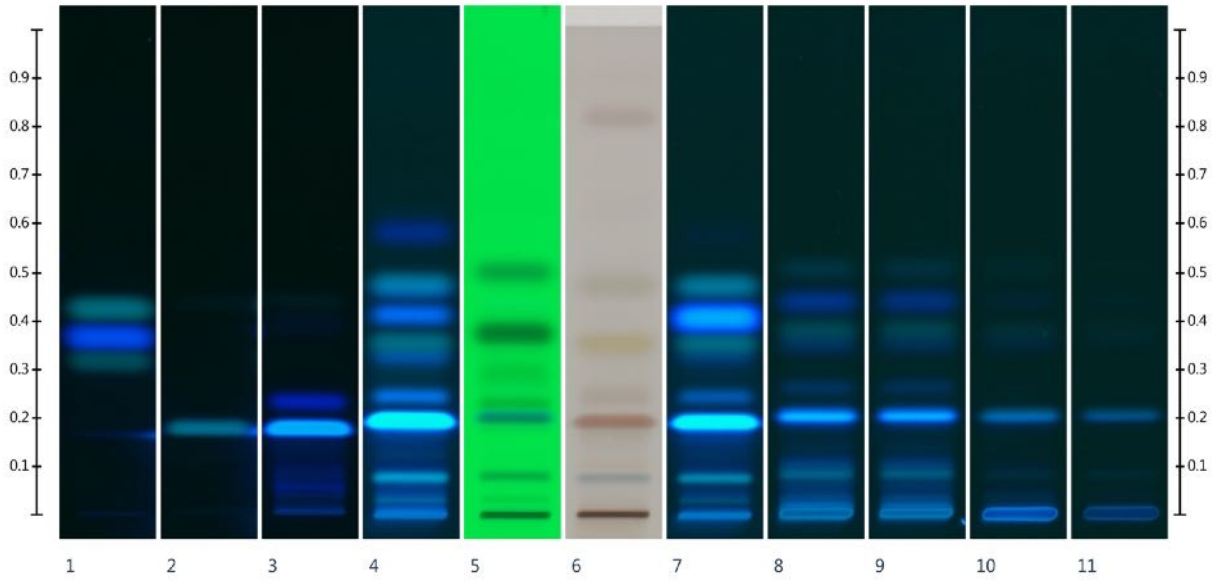


Figure 15: HPTLC fingerprints of *Peucedanum ostruthium*. Reference substances at absorptions spectrum (AS) = 366nm with **1:** isoimperatorin (RF > 0.3), osthol (RF < 0.4), imperatorin (RF > 0.4). **2:** oxypeucedanin. **3:** ostruthin. **4:** sample at AS = 366nm, **5:** sample at AS = 254 nm, **6:** derivatized sample at AS = RT White, **7**: sample with high osthol concentration (AS = 366nm). **8 & 9**: tincture (rhizome in 40‰ Ethanol). **10:** freshly prepared infusion, **11:** infusion after 3 days.

The following coumarins are identified in the rhizomes of *Peucedanum ostruthium* by reference substances on the HPTLC plate: the simple coumarins ostruthin and osthol and the linear coumarins oxypeucedanin, isoimperatorin and imperatorin (**Figure 15**, overview of all samples in Appendix B Figure 1-3). Oxypeucedanin and ostruthin ran equally under these conditions and share a band on the chromatography plate or peak in the spectrum analysis. They are counted together as one group for further analysis. Only one sample could be identified containing osthol in higher concentrations. The absorptions at spectrum 244nm of all 120 samples are represented in **Figure 16**, where a higher variability in concentration can be observed in peak 2, isoimperatorin and imperatorin. While the coumarins in the tincture are well extracted but in lower concentrations, the coumarins were only low concentrated in the infusion samples (**Figure 15**). The blue discoloration of the infusion after 3 days is not visible on the HPTLC fingerprint (picture of discoloration in Appendix B Figure 4).

One gram rhizome powder (dissolved in 5 ml methanol and in dilution of 1:5) contains an estimated 7.6 mg of coumarin components. This value is taken from the sum of coumarins listed

in **Table 5.** Other possible coumarin absorptions weakly expressed in spectrum analysis were neglected in this calculation and also not included in the total coumarin content values.

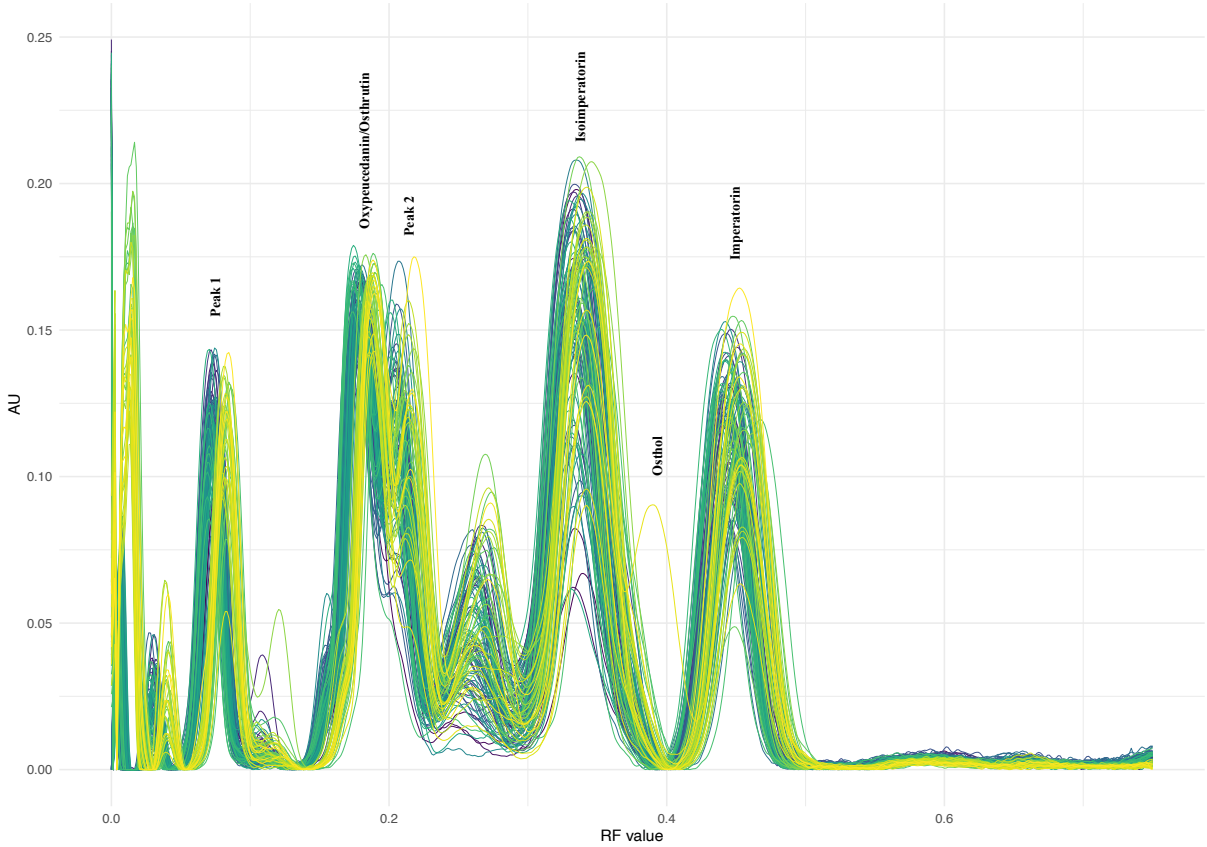


Figure 16: Absorptions of all 120 samples. Absorption spectrum = 244nm. AU = arbitrary units, RF value = retardation factor

Table 5: Average of calibrated coumarin compounds from 3x120 samples.

Coumarins	mean (µg/ml)	Standard deviation	Sample Size
Peak 1	522.80	± 98.11	3x120
Ostruthin/Oxy-peucedanin	876.34	± 42.03	3x120
Peak 2	377.06	± 109.40	3x120
Isoimperatorin	517.74	± 107.93	3x120
Imperatorin	747.41	± 167.17	3x120
Total[1]	3038.21	± 75.61	3x120

1: The above mentioned single coumarins are summed up in Total

Quantitative Components of Coumarins and Environmental factors

Correlation with morphological traits

The ratio of coumarin content to 1g rhizome powder mainly remains constant in relation to the morphological traits of *P. ostruthium* organs. However, it can be added that there is a very small linear relationship with the rhizome diameter (scatterplot in Appendix Figure 1). They are directly correlated through the harvesting process for the later HPTLC analysis.

Altitudinal levels, distance of subpopulations and their localities to settlements

The differences in coumarin contents of rhizomes between altitudinal levels and localities are negligible. The calibrated value of total coumarins content shows no significant changes between altitudinal levels in rank test of Kruskal-Wallis (Appendix A Table 2). Nevertheless, small differences can be noticed in **Figure 17**. It is noticeable that the subpopulation at the lowest altitudinal level in Saas-Balen and the subpopulation in Saas-Almagell have a slightly higher coumarin content than the other two. The subpopulation at the highest altitudinal level in Saas-Balen has an even smaller content of coumarins than the other subpopulations, which is most evident at peak 1 and the peak of ostruthin and oxypeucedanin. Average coumarin content for all 4 sites are listed in Appendix A Table 1.

Soil Condition

The three indicator values nutrient, humidity and reaction rate have no significant influence on the total coumarin content based on a rank test of Kruskal-Wallis (Appendix A Table 2). The distribution of coumarin content in relation with indicator values are illustrated in **Figure 18**. Although there is no significance, some differences between the values of all three indicators can be observed. On one hand, the variance of ostruthin and oxypeucedanin compounds are equally distributed over the values. Isoimperatorin and imperatorin on the other hand appear with a higher variance and both in similar proportions. It is hardly possible to identify a trend when considering the total coumarin content.

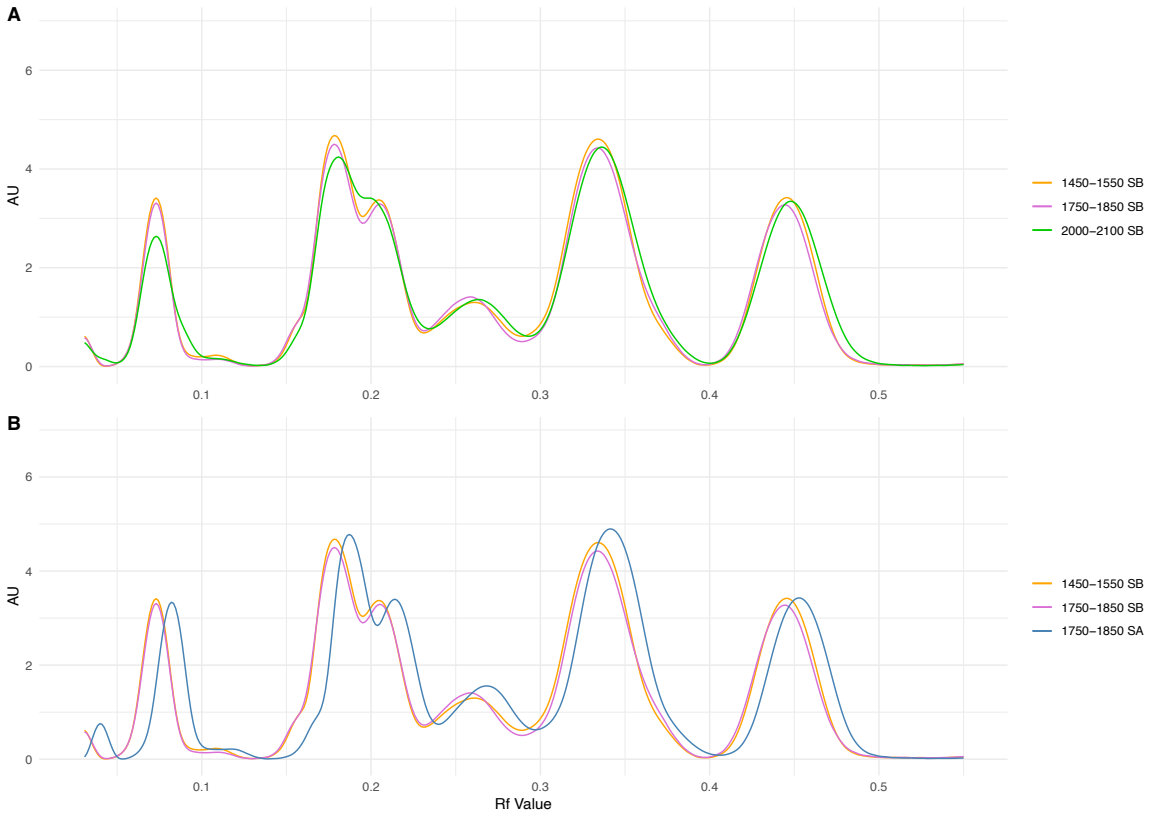


Figure 17: Means of sample absorptions divided in subpopulations at **A**: different altitudinal levels in Saas-Balen (sample size = 3x30) and **B**: different localities (Saas-Balen and Saas-Almagell, sample size = 3x30). Absorption spectrum = 244nm. AU = arbitrary units, RF value = retardation factor

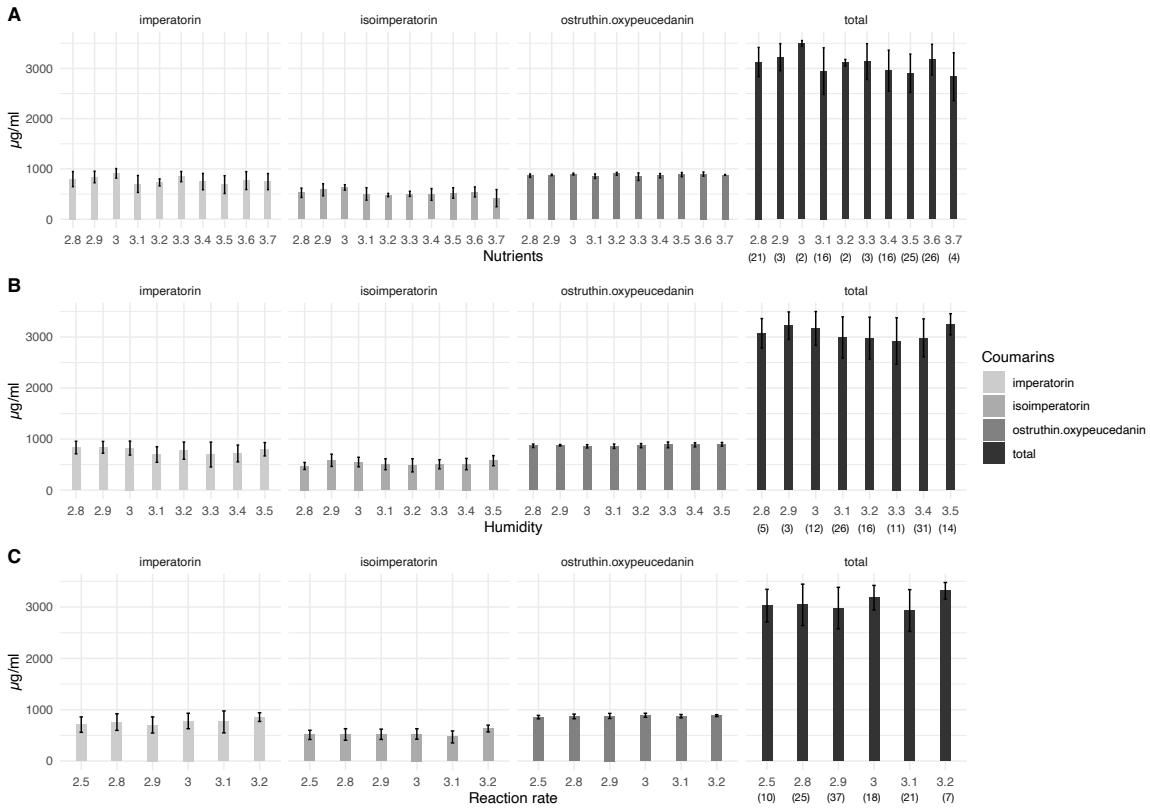


Figure 18: Average amount of particular coumarins (grey) and in total (black) at indicator values of **A**: nutrient content, **B**: humidity, **C**: reaction rate. Sample size = 120, for single values in brackets

Herbivory

The extent of feeding damage to leaves caused by herbivores has no significant influence on the coumarin contents (Kruskal-Wallis-Test, Appendix A Table 2). However, differences in coumarin contents can still be recognized in **Figure 19**. Imperatorin and the total amount of coumarins show the same distribution pattern. Samples with no or strong herbivory contain a higher concentration of coumarins. The lowest amount of coumarins is observed in the category "moderate". Imperatorin and isoimperatorin show no variation of concentration overall.

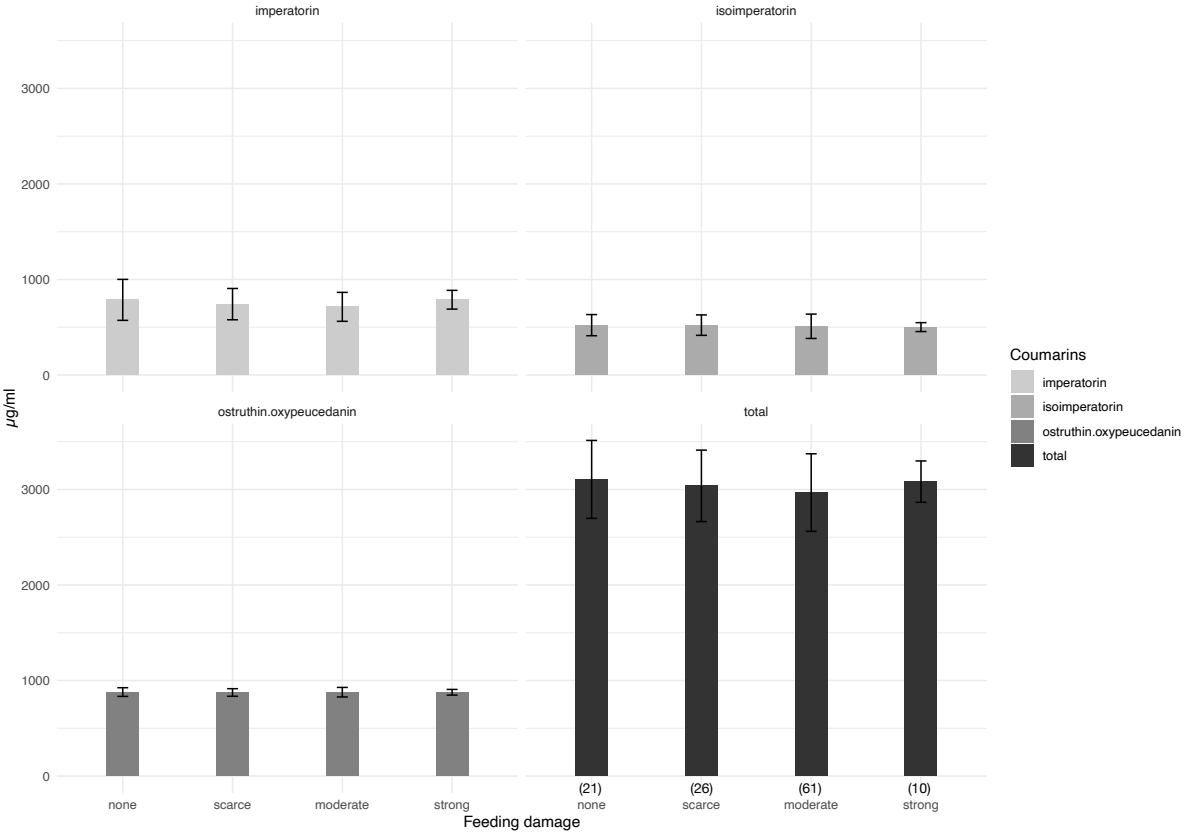


Figure 19: Average amount of particular coumarins (grey) and in total (black) in relation with Herbivory extent. Sample size = 120, for single values in brackets

3.3 Use and knowledge of *Peucedanum ostruthium* as a medicinal plant

Knowledge of *Peucedanum ostruthium* and other medicinal plants in the Saastal

Overview of medicinal plant knowledge

A total of 64 plant species with 272 use reports (UR) in the medicinal category were mentioned in the semi-structured interviews (**Figure 20**, details of species and use-reports in Appendix C Table 3). The use-reports were classified by plant parts used, form of application and medicinal category. The most popular medicinal plants are *Arnica montana* (28 UR), *Thymus* spp. (15 UR), *Calendula officinalis* (16 UR), *Achillea millefolium* (13 UR) and *Urtica dioica* (15 UR). *Calendula officinalis* is very popular and can be seen in almost every garden. Nearly all species grow in the Saastal and many are typical Alpine plants like *Arnica montana*, *Alchemilla alpina*, *Achillea moschata* or *Vaccinium vitis-vidaea*. They are usually collected in the wild. Species that do not grow in the valley are bought on the market, cultivated in the garden or collected at lower altitudinal level in the Vispertal. *Peucedanum ostruthium* was mentioned by 4 interviewees as a medicinal plant.

Altogether, 33 families were reported (Appendix C Figure 2) with highest species numbers for Asteraceae (13 spp.), Rosaceae (6 spp.) and Lamiaceae (5 spp.). The most important medicinal categories are respiratory (51 UR), dermatological (50 UR), skeleton-muscular (39 UR) and gastrointestinal (36 UR, Appendix C Figure 4 and Table 2 for medicinal categories). Typically, flowers (87 UR), leaves (70 UR) and herba (entire aboveground plant, 46 UR) are most often used for medicinal preparations. The use of belowground plant parts is not common in the Saastal (red in **Figure 21**). The most common preparations are infusions (115 UR), alcoholic extractions (63 UR) and oil extractions (51 UR, Appendix C Figure 3), which are mostly applied systemic (61% of UR) and topically (30%).

Knowledge about Peucedanum ostruthium *in the Saastal*

Some of the interviewees, but also many other people who were spoken to during the fieldwork did not know *Peucedanum ostruthium* or mistook it with other similarly looking Apiaceae. For example, some mentioned that they were taught (mostly by their mother) to keep their hands off it because the plant is toxic. They probably did not mean *Peucedanum ostruthium* but *Heracleum sphondylum* subsp. *elegans*, which grows in the same habitat and looks very similar to *Peucedanum ostruthium* to the untrained eye. Other local people called the plant *Gärbele* after being shown pictures of *Peucedanum ostruthium*. However, this name is usually used for the species *Chaerophyllum villarsii* (Bergkerbel), which often grows next to *Peucedanum*

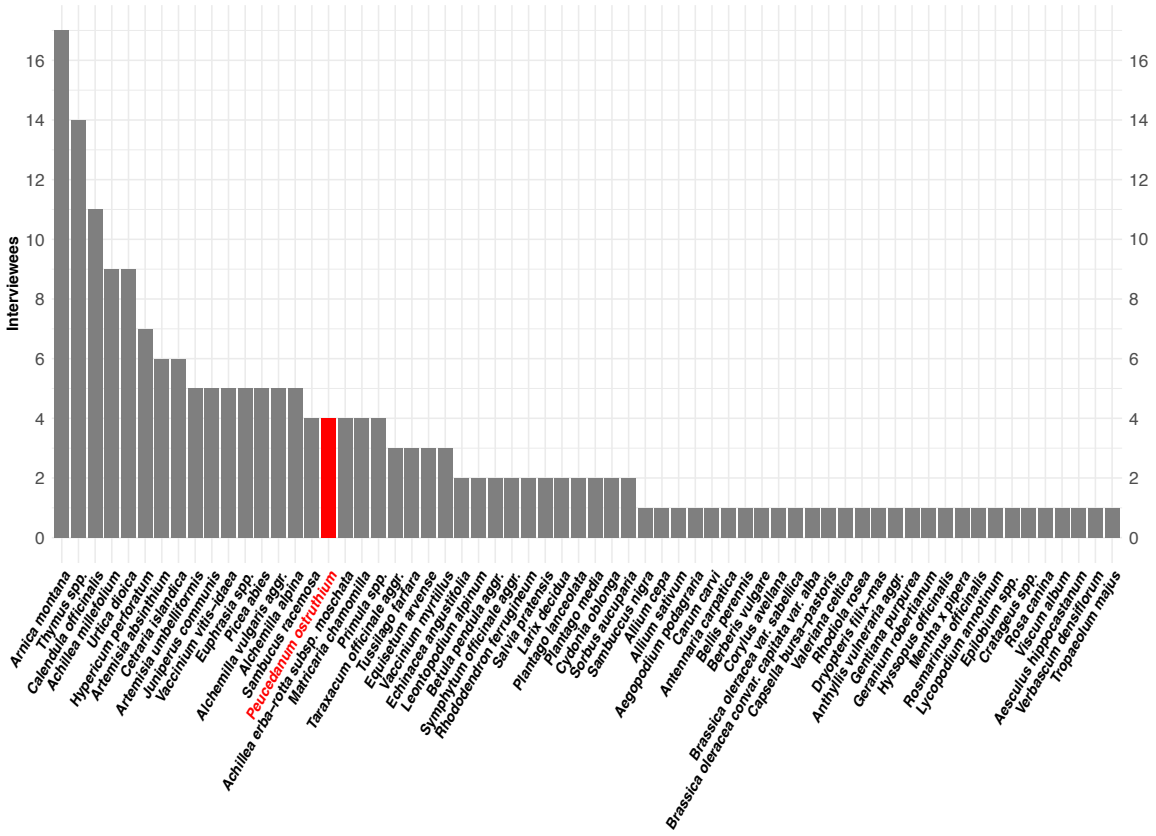


Figure 20: Plant species mentioned ($n_{species}$=64; n_{Int}= 20); 29 were mentioned only once.

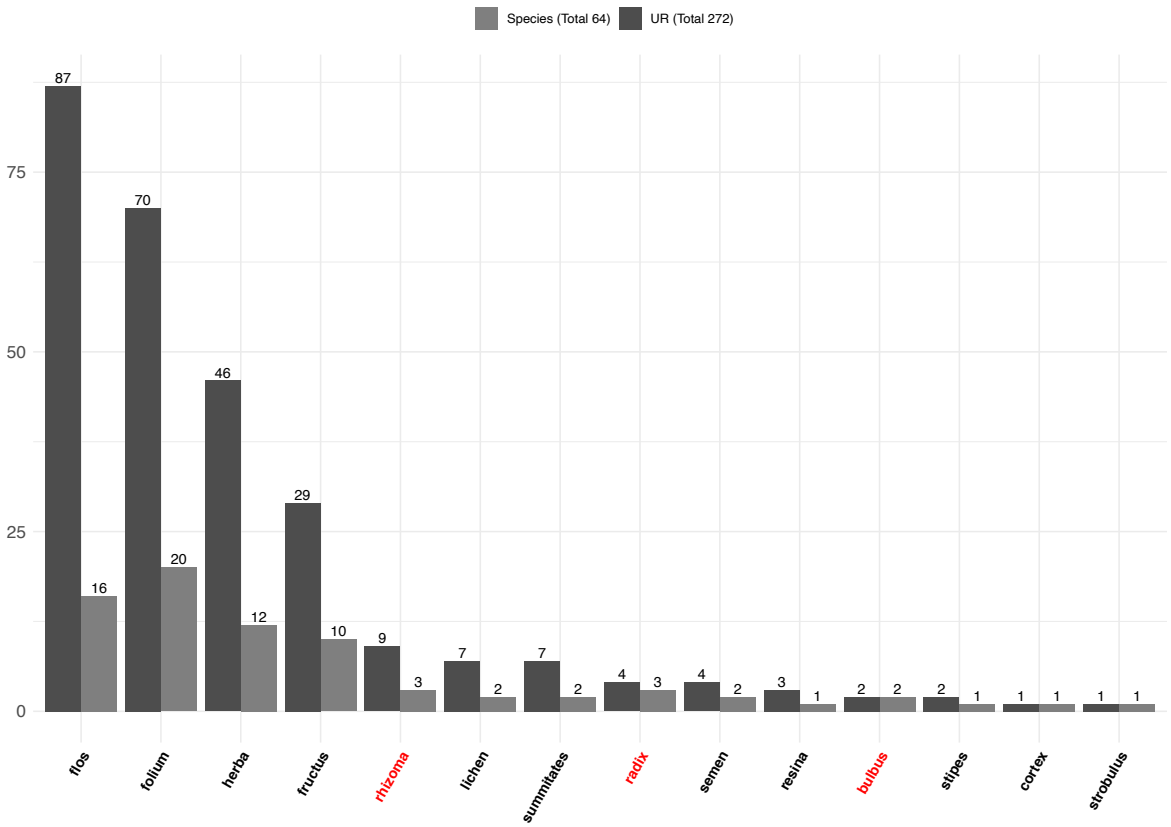


Figure 21: Plant parts used (n_{UR}=272; $n_{species}$=64; n_{Int}= 20). Red: belowground parts of plants

ostruthium. Furthermore, it was called *Sturrobenju*, which means large stem. After a long discussion it became clear that this was the name of the *Angelica sylvestris*, which can grow up to 2 meters and also grows near *Peucedanum ostruthium*. The actual vernacular name for *Peucedanum ostruthium* is *Aschtränze*.

Only the half of the interviewees knew the plant. Three of them described it as a harmless weed in the hey. One interviewee, a pharmacist, knows *Peucedanum ostruthium* in homeopathy but not in the traditional medicine.

Reports of interviewees about Peucedanum ostruthium

In her childhood, Anni A. fed the cows every evening with *Peucedanum ostruthium* and *Rumex alpinus*. She and her brothers collected the plants fresh every day and gave them to the livestock as supplementary food. It was called *Sürele*.

Trudy S. collects *Peucedanum ostruthium* on the way from Saas-Fee to Saas-Almagell or she goes quickly to the near forest next to her house. She said: «Look out for a "Wasserleitung" (typical water channel in Valais) and you will find *Peucedanum ostruthium*. […] It should be collected in autumn or spring, when the power is not in the leaves but in the rhizomes.» She makes an ointment with the rhizomes for wounds and a tincture or tea for gastrointestinal complaints. Eating a piece of rhizome has the same effect. Trudy S. is the only informant in the Saastal who uses the root. She learned about it from her sister, who is educated in herbal medicine and lives in Canton Schwyz.

In the past, when Maria B. and her daughter Ulrika B. worked in the Alps, they used the leaves of the plant to heal wounds and cuts. They bandaged the spot with a leaf. This should help to stop the wound from bleeding and prevent an infection. Maria B. told that it pulls out the poison and the pain.

> «*We mier uf der alpu üs gschnettet (cut) hei, heimmer die Blätter drufgetah und eingebunde. Damit das nimme blietet oder kei vergiftig git.* […] *Das hets eifach usgezoge. Isch zu där Ziet uf de Alp sBeste gsi* » (Maria B.)

The sister of Maria used it as an ointment. She cooked the leaves up with milking grease and used it for joint pain or rheumatism. Maria and her sister both learned the use of *Peucedanum ostruthium* from her mother.

«*D'aschtränze isch fürd Gländ und alles.* […] *Die (sister) het sie uberall gsammlut, hie uf der Wiese, det wos Brünneli het, wüsster, det hets viel! Wenn grad am Wasser verbii gloffe bisch…* » (Ulrika B.)

Ulrika B.'s godmother, who was also present during the interview, only knew *Peucedanum ostruthium* as a weed:

«*Die hemmer hie scho, aber die hemmer immer für Unchrüt ghalte. Ich kenne sie scho, aber ned als Heilchrüt* […] *Die Astränze düemmer zwenig nutze hie. Die blüie eifach und lat schie la kaputt ga...* »

First, Helene B. could not remember *Peucedanum ostruthium*, but after she saw the pictures, she told a story from her childhood: When she was 5 to 6 years old, she had a heavy accident. She cut her leg open down to the bone and had to go to the hospital, but this was very difficult to do in this time (75 years ago). There was only a small unprepared road out of the Saastal and so they needed several days until reaching the next hospital. Her mother put leaves of *Peucedanum ostruthium* on the open wound to avoid an infection. She said, if she had gotten an infection, she would have had to amputate her leg. Fortunately, her leg could be saved.

Hedwig B. also put the leaves on wounds. Further, she talked about a friend of her husband who collected the green beetles (*Oreina* sp.) from *P. ostruthium*. She was a farmer and has the knowledge about medicinal plants from her mother.

A shop assistant (around 30 years old) from Saas-Fee mentioned that he smoked the dried stems of *Peucedanum ostruthium* with his friends in his childhood. (He was not part of the interview survey.)

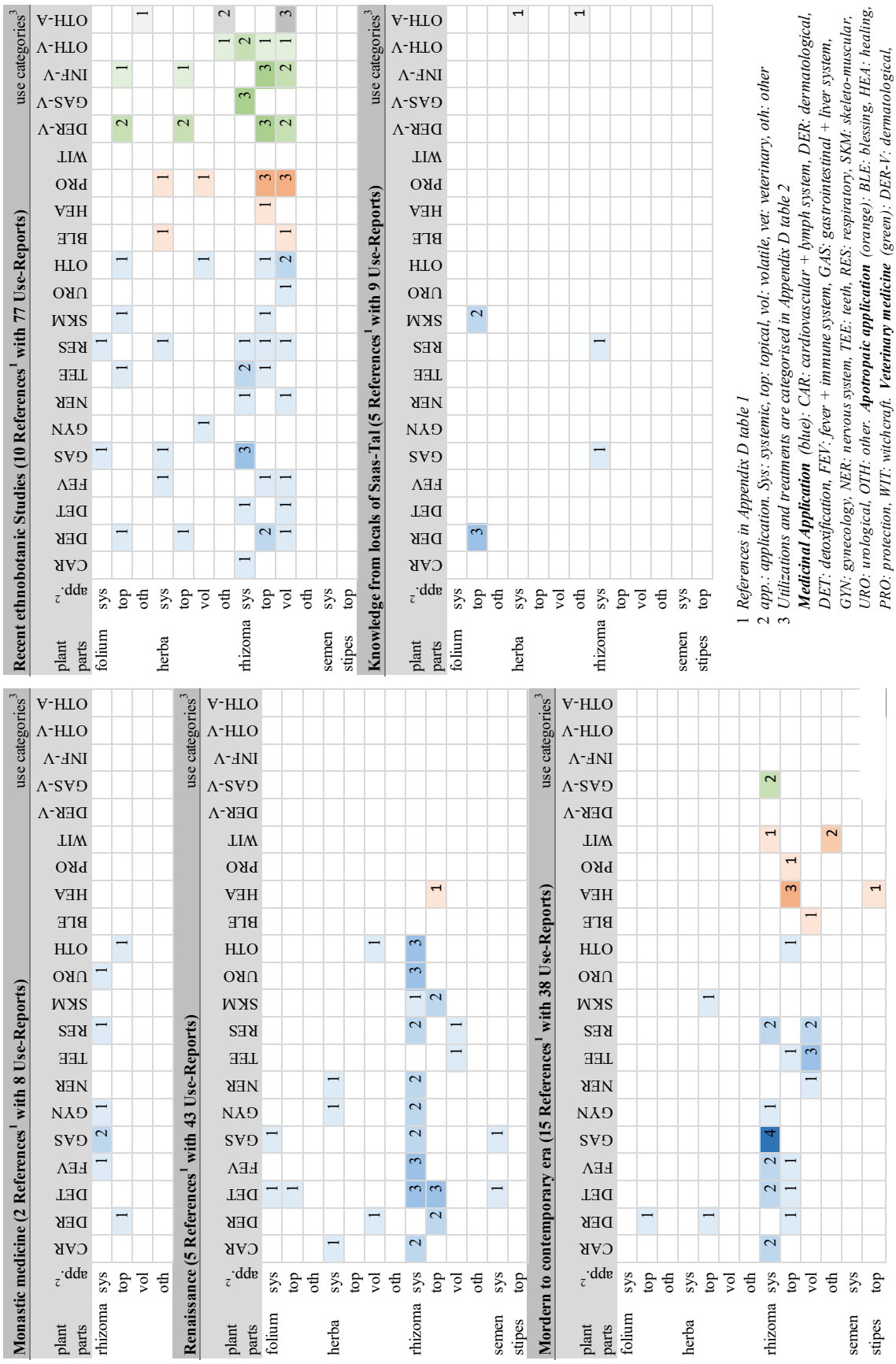
Knowledge and use of about *Peucedanum ostruthium* in different time periods

Table 6 illustrates the use of *Peucedanum ostruthium*. It is divided into three time categories: Monastic medicine (8^{th}-12^{th} Century), Renaissance (16^{th}-18^{th} Century) and modern to contemporary era (19^{th}-21^{th} Century) as historical references. It also includes recent ethnobotanical studies and the survey in Saastal as references of current uses in the Alpine regions (all references are given in Appendix D Table 1). There are three main use categories where *P. ostruthium* has played an important role since the medieval times: as medicine, as apotropaic and protective treatment, and as veterinary medicine.

A total of 175 citation-reports (CR) were recorded from the literature and classified by plant part used, form of application and use category. The reports are distributed over time as follows: Monastic medicine 8 CR, Renaissance 43 CR, modern to contemporary era 38 CR, recent ethnobotanical studies 77 CR and survey in Saastal 9 CR.

Rhizomes are in all time categories and for all use categories the most frequently used plant parts of *Peucedanum ostruthium* with 129 CR (74% of all CR). The use of rhizomes is followed by herba (24 CR), leaves 1(9 CR), seeds (2CR) and stems (1 CR). Systemic (76 CR) and topical applications (58 CR) are the most common. Volatile application of rhizomes (and less common of leaves) also occurs for all use categories (34 CR). It is most widely documented in recent ethnobotanical studies with 23 CR, compared to systemic application with 21 CR and topical applications with 29 CR. Overall, highest amount of citation-reports is cited for the medicinal categories: Gastrointestinal (16 CR), detoxification (14 UR), respiratory (14 CR), dermatological (13 CR) as well as fever and immune system (10 CR), which all belongs to the medicinal utilizations. Considering all time categories together apotropaic and veterinary medicine uses are less frequently. Apotropaic uses are mainly documented in protection (9 CR), healing (6 CR), blessing (3 CR) and witchcraft (3CR). Veterinary medicine uses are cited in dermatological (9CR), infections (7CR), gastrointestinal (5 CR) and other uses (5 CR). However, the preferences of uses differ when looking at single time categories. Recent ethnobotanical studies document an importance of veterinary medicine use for dermatological (9 CR) and infection (7 CR) treatments and of protective uses (8 CR) in the apotropaic category. Apotropaic uses play also a relevant role in modern to contemporary utilization with healing (4 CR) and witchcraft (3 CR). Teeth treatments are reported in both time categories more often with 4 and 5 CR than in other. The most important utilization in Renaissance is found in the category dermatology with 9 CR. The local people of Saastal do not use *Peucedanum ostruthium* in an apotropaic function nor in veterinary medicine. Citation-reports in detail are listed in Appendix D Table 3.

Table 6: Use categories of *Peucedanum ostruthium* in different time periods (monastic medicine, Renaissance, modern to contemporary era), recent ethnobotanical studies and the survey in Saastal.



4. Discussion

4.1 Morphological variability of *Peucedanum ostruthium* in upper Saastal

Variability of morphological traits and their influence on organ shapes

The range of measured trait values corresponds approximately to the description of Peucedanum ostruthium in Hess *et al.* (1977). Although the leaves and umbels are generally larger than in the literature, the proportions of the leaves (1-1½ as long as wide) and the general height of growth are consistent with the traits studied. The diverse appearance of the leaves is also described: Their shape may be round or oval and the lobes vary in depth. In this study, shapes and sizes of umbels, leaves, and rhizomes can all vary considerably. However, a more uniform size can be observed in the surfaces of umbels and the circumferences of rhizomes.

Within the organs, linear relationships between the trait values can be found. Many of them are weak due to a high level of variance. This implies that the proportions of organs are not completely fixed but vary within a certain range. This is the case with the height of umbel and its inflorescence diameter, with the number of lobes in and the size of leaf and with the length and thickness of rhizomes. In contrast, strong linear relationships are evident in rhizome thickness and the related harvest and dry weights and in length and width of the leaf. Although some organ proportion ranges seem to be to be under genetic control, the remaining variability can be explained with a certain morphological plasticity of the plant. Similar occurrences of morphological plasticity of species in several populations have been described by Grassein *et al.* (2010). Albert *et al.* (2010) postulates that this intraspecific variability enables adaptation to certain environmental conditions. The distribution of eigenvalues vectors in the PCA biplot (see **Figure 9** in results section) show that aboveground and belowground organs are correlated within the group but not with each other, indicating the groups mainly act independently in terms of morphological shapes. In the study of Keser *et al.* (2014) on the effect of the biomass of aboveground and belowground organ groups in soils with different nutrient contents, the plants (including *Peucedanum ostruthium*) show a slightly different reaction of the two organ groups, which supports the observed independence. An interesting exception is the length of rhizomes, which correlate only weakly with other rhizome traits and with aboveground organs. The length of the rhizome therefore depends on other factors. A possible factor could be the soil texture. Impressions during the fieldwork indicates that rhizomes were longer in soft and dry forest soils and appeared rather short but highly branched in stony and humid soils. In the

study of de Kroons and Hutchings (1995), plant species showed a morphological response with spacer (stolon or rhizome internodes) length and branching to light and nutrient availability indicating a morphological plasticity as an effective exploitation of local resources. It can therefore be assumed, that *Peucedanum ostruthium* prefers stony and humid soil. This soil is presumably rich in nutrients, because of the availability of water.

Overall, the above-mentioned relationships of morphological traits, which are clearly visible within the organs and weakly distinct between aboveground or belowground organs, contribute to the overall appearance of *Peucedanum ostruthium.* Nevertheless, the existing morphological variability could be a result of its plasticity and adaptability to environmental conditions.

Effects of environmental conditions on the morphological variability

Indeed, all environmental factors can have simultaneously effects on *Peucedanum ostruthium*, including the influence by other plants in the communities. Therefore, it is worth to state that *Peucedanum ostruthium* has usually been the dominant species in the investigated plant communities. This dominance can be explained through the clonal growth habit of *Peucedanum ostruthium*, which provides many advantages in proliferation. The clonal propagation enables the plant to cover a larger area in competition with other plants and therefore hotspots with good conditions (nutrient-rich, humid or light) can be selected. Proliferation is multiplied by vegetative and reproductive propagation. The plant is also more resistant against disturbance through the reshooting rhizomes with a storage purpose (Klimešová *et al.* 2018).

Environmental conditions on the 4 sites

Environmental factors, which have a considerable effect on certain morphological traits are mainly the altitudinal levels (and, hence, subsequent changes in temperature average, UV radiation, length of growing season as well as temperature fluctuation), the presence of nitrogen in soil and the general health condition of the individuals.

On site 2 (1750-1850 SB) the environmental situation is supposed to be more stressful than on the other sites. *Peucedanum ostruthium* is mowed there 1-2 times a year. The indicator values indicate slightly drier (F = 3.1) and less nutrient content in soil (N = 3.0), whereas on the other site humidity is 3.3 and the nutrient content from 3.4 to 3.5. The more stressful condition on site 2 affects the umbel size and rhizome thickness. The poorer nutrient supply is assumed to be the main factor here, since the other three sites with higher nutrient content in soil do not show this combined reduction of umbel size and rhizome thickness. Nutrient acquisition obviously plays an important role in accumulation of biomass in aboveground and belowground

biomass as also shown in previous studies (de Kroons and Hutchings, 1995; Grassein *et al.*, 2010; Keser *et al.*, 2014). On site 3 with the highest altitudinal level (2000-2100 SB), the health condition of the individuals is worse (value of health condition = 3.4). Furthermore, the indicator value shows an expected minimal decrease in temperature (T = 2.4; on the other sites: T = 2.6). These two factors have an effect on the rhizome as a whole (length and thickness). The high altitudinal level means more stressful conditions with lower temperature average, more extreme temperature fluctuation and higher UV radiation. These factors in combination with a shorter growing season lead to a trend of decreasing plant size as also shown in the study of Pellissier *et al.* (2010). The same decrease in rhizome length can also be found at the lower site 4 (1750-1850 SA), which has similarly bad health condition values as site 3 (value of health condition = 3.2, value on site 1 = 2.3, on site 2 = 2.5). Overall, it can be stated that the size of rhizomes and umbels, is largest on site 1 at the lowest altitudinal level (1450-1550 SB) with nitrogen content, milder temperatures and good health conditions and thus under best conditions.

Effects of environmental factors in the entire population

If soil conditions and herbivory are considered including all individuals without dividing in site subpopulations, only slight trends can be observed. This implies that single factors only play a subordinate role in affecting the morphological variability.

The alpine leaf beetle *Oreina* spp. is highly specific to feed on *Peucedanum ostruthium.* It occurs rather abundantly in the Saastal, wherefore, the collected leaf samples were usually encountered with feeding damage (see **Figure 9** in the Results section; see also Dobler *et al.*, 1996; Borer *et al.*, 2012). The moderately damaged individuals have smaller organs (aboveground and belowground). That could be interpreted as a consequence of a continuously attack of herbivores over years but cannot be confirmed in this study. It should be noted that herbivory is the only environmental factor that has a visible effect on the leaf size.

If the samples are evaluated according to their indicator values, no effect of nutrient content or humidity were found. Only a small trend of increased trait values can be observed at the reaction rate with a value R of 3.0. An explanation of seeing only a trend within this indicator value is that the reaction rate is one of the main factors for the intraspecific diversity of alpine plants (Alvarez *et al.*, 2009). The estimated reaction rate is also the optimal value for *Peucedanum ostruthium* in the reference literature (Landolt *et al.*, 2010). The value of nutrient content lies between 2.8 and 3.7 and is, indeed, rather low compared to the assigned indicator value N of 4.0 for *Peucedanum ostruthium* in the literature. Additionally, *Peucedanum ostruthium* was

rarely observed in the nutrient-rich plant community Rumicion alpini, as indicated by Delarze *et al.* (2015). Therefore, further investigations may be necessary, as *Peucedanum ostruthium* can also be frequently found under less nutrient-rich conditions than indicated in the literature.

An approximation to the conditions prevailing on the different sites can be obtained through the combination of certain environmental factors. These analyses reveal their effect on the morphology of *Peucedanum ostruthium.* This support the assumption that the alpine plant *Peucedanum ostruthium* has a morphological plasticity (i.e., intraspecific variability), which is in response to environmental conditions and indeed to other unknown factors (Albert *et al. 2010;* Grassein *et al.* 2010). In the biplots, however, it is clearly visible that the morphology of rhizomes is more affected by environmental conditions and thus has a greater plasticity than the aboveground organs. This could also be observed in the study of E.-Vojtkó et al. (2017). Therefore, it is important to do more investigations on the variability of rhizomes, which has been rather underestimated in functional trait studies. This conclusion is also reported by other recent studies (e.g., Klimešová *et al.* 2018; E.-Vojtkó *et al.* 2017).
Nevertheless, considering the pattern of samples in the biplot (see **Figure 9** in the Result section) it becomes clear that the individuals of *Peucedanum ostruthium* in the Saastal should be viewed as one metapopulation, which per se cannot really be differentiated into subpopulations by its morphological variability. Alvarez *et al.* (2009) supports this assumption with a large genome-screening of *Peucedanum ostruthium* among others in the entire Alpine region and compared the genetic diversity with the indicator values. The genetic kinship was significantly correlated with the reaction rate. Since the Saas-Tal consist mainly of silicate rocks, it is very likely that individuals of *Peucedanum ostruthium* are genetically close related.

4.2 Coumarin components of *Peucedanum ostruthium* rhizomes

Kinds and concentration of coumarin components

The coumarins identified in *Peucedanum ostruthium* with HPTLC analysis are also documented so far in the studies (Joa *et al.*, 2011; Vogl *et al.*, 2011; Palmioli *et al.*, 2019). Furthermore, they have identified oxypeucedanin hydrates, ostruthol and the chromone peucenin. The total content of coumarins in one gram rhizome powder is 6% in Joa *et al.* (2011) and is close to the estimated 7.5% in this study, although different methods were used (HPLC-DAD-MS vs. HPTLC and CH_2CL_2 vs. Met-OH extraction). Ostruthin and oxypeucedanin constitute the major proportion of total coumarin content.

Although Osthol is one of the highly investigated coumarin of *Peucedanum ostruthium* in phytopharmacological studies (Zimecki *et al.*, 2009b; Jarząb *et al.*, 2017; Du *et al.*, 2019), it occurred only in low concentrations in the Saastal and in other analysis (Joa *et al.*, 2011; Vogl *et al.*, 2011) or even was not identified at all (Palmioli *et al.*, 2019). But among the 120 analyzed samples in this study was one exception with a rather high concentration of osthol. The sample was collected on site 4 (1750-1850 SA) and besides of the high osthol concentration, it is an average sample considering the morphological traits (with tending to have larger organs). Interestingly, Vogl *et al.* (2011) and Cisowski *et al.* (2001) also documented samples with a significantly higher content of osthol.

It is well known that coumarins dissolve better in tinctures than in infusions because of their lipophile behavior. Hence, all the coumarins are present in the tincture even if in smaller concentrations and are almost not dissolved at all in the infusion samples. Vogl *et al.* (2011) had similar results with an HPLC analysis. If preparing an infusion of the rhizomes, it can be observed that the infusion begins to turn blue after about half an hour. A secondary metabolite obviously reacts with hot water. On HPTLC plates no change of running coumarins were identified and can therefore be excluded to be responsible for the discoloration. This phenomenon has only been described once in the literature so far (Tschirch, 1917).

Effects of environmental factors on the concentration of coumarin components

Overall, no significant differences were found between the subpopulation of the four sites. However, the lowest coumarin concentrations are observed in the population at the highest altitudinal level (2000-2100 SB). It is assumed that several environmental factors in combination have an effect on the coumarin concentrations. On site 3 the vegetation period is shorter; the health of the plants is worse; and the rhizomes are generally smaller. By contrast, site 1 (1450-1550 SB) and site 4 (1750-1850 SA), which have lower stress factor levels and larger rhizomes, the coumarin concentrations are higher. A reason for the lower concentrations on site 3 could be that the protection from the more extreme climatic conditions could be selectively more important on the highest altitudinal level than the investments in defense against herbivores (Rodriguez-Hernandez, 2019). But the differences are too small to confirm these assumptions. The small differences in coumarin concentrations over altitudinal levels could also be due to the reason that coumarins are not responsible for protection against abiotic stress, but in the defense against herbivores (Berenbaum, 1981; Hadaček, Greger and Proksch, 1994). Nevertheless, *Peucedanum ostruthium* is confronted with stressful conditions in high

mountain habitats as already described above. In his review Rodriguez-Hernandez (2019) summarizes responsible secondary metabolites for protection against harsher conditions in higher mountain regions. These molecules mainly belong to flavonoids, anthocyanins, phenolic acids or carotenes and are found in increased concentrations on higher altitudinal levels. As shown in the study of Palmioli *et al.* (2019), *Peucedanum ostruthium* also contains a large number of flavonoids and phenolic acids. They are presumably responsible for this protection and could rather vary in concentrations over the altitudinal levels than the coumarins. Supplementary, the total content of essential oil may vary between subpopulations of the genus *Peucedanum* within different environmental conditions, as shown in a study about *Peucedanum membranacea* in Iran (Ghasemi Pirbalouti, Hossayni and Shirmardi, 2013). All this leads to the conclusion that certain substances of *Peucedanum ostruthium* could vary over altitudinal levels but not in coumarin concentrations.

Considering the intensiveness of herbivory in comparison with the coumarin concentrations, no significant differences can be observed. Single and linear coumarins as investigated in this study are toxic for generalized herbivores, but not for the highly adapted leaf beetles *Oreina* spp. (Berenbaum, 1981). In the field study almost no generalist herbivores were observed, but many beetles of the genus *Oreina*. Furthermore, coumarins such as ostruthin or oxypeucedanin shows a clear anti-microbiotic activity (Schinkovitz *et al.*, 2003b; Gökay *et al.*, 2010). As the feeding damage is mainly caused by *Oreina* spp. and the investigated coumarins are not active in this specific defense supports the observation of a mostly constant occurrence of coumarin concentration compared to herbivory. However, a minimal decrease in the concentrations of imperatorin and the total coumarin content is still visible in samples with none to moderate feeding damage. The same decreasing effect appears in relation with the size of leaves. The reduction of coumarin concentration could be the reason of an increased utilization in the defense against pathogens or generalized herbivores, where imperatorin being considered as highly effective (Hadaček *et al.*, 1994). Another possible reason is, that an increased active plant defense over years could lead to a reduced production of coumarins and smaller leaves.
Coumarins occur in different degree of variability. This can be noticed in the absorption spectrum (see **Figure 16** in result section) and in comparing with environmental factors. The phenomenon could be explained by different purposes of particular coumarins in plant defense to ensure fast adaptations by maintaining a high level of diversity in secondary metabolites (Jones and Firn, 1991). The investigated coumarins isoimperatorin, imperatorin, and oxypeucedanin are highly active in the herbivory defense according to the study of Hadaček *et*

al., (1994), but they also observed different levels of activity. Overall, the high level of active coumarins in *Peucedanum ostruthium* ensures a potent defense against herbivores.

Finally, no significant differences in coumarin concentrations were found in this study. A reason could be that all individuals belong to a large metapopulation with a close genetic relationship, as the variability of the morphological traits also suggests. Vogl *et al.* (2011) also noticed a rather small variation in coumarin concentrations in her study with samples from different sites in Austria and from companies in Austria and Germany. Thus, the coumarin concentrations could also be stable within the whole species.

HPTLC is rarely used today in pharmaceutical studies as a method to perform accurate quantitative analyses (Loos *et al*., 2016). However, it should not be underestimated as a fast and cost-effective method for quantitative analysis of secondary metabolite contents in plants. Giacomelli et al. (2015) also came to this conclusion in a similar study. In this study the results of all 120 samples do not show unexpected deviations.

4.3 Ethnobotanical relevance of *Peucedanum ostruthium* as a medicinal plant

Relevance of *Peucedanum ostruthium* in upper Saas Valley

The relationship of local people with Peucedanum ostruthium

Most of the interviewed people of Saastal know *Peucedanum ostruthium* as a harmless weed growing in the meadows and along the water channels. Others mistook the plant with similar looking species of the family Apiaceae, which also flower white and occur in the same plant community. One person uses the plant as supplementary fodder for the cows. Only 5 of the 20 interviewees knew *Peucedanum ostruthium* as a medicinal plant, although half of the interviewees were herbalists, and known throughout the valley for their medicinal plants' knowledge. They are representative for today's medicinal plants knowledge in the Saastal.

Peucedanum ostruthium does not belong to the popular medicinal plants in the Saastal. Furthermore, it is assumed that if the plant had not been specifically mentioned by the interviewer, perhaps not everyone would have remembered it. The interviewees used *Peucedanum ostruthium* mainly in young years while working in the Alps. If one got an injury, the first best remedy was to make a compress with its leaves to support healing and avoid infections. Marzell (1922) reported this use as a common application in Alpine regions. It has

also been documented in the Val d'Anniviers located in the French part of Valais (Brüschweiler, 2008). The interviewees or their parents have been farmers. This could be the reason that *Peucedanum ostruthium* was mainly used while working in the Alps. All interviewees got their knowledge about *Peucedanum ostruthium* from their mother. Helping on the alp and gathering plants was often assigned to women in the past (Christanell *et al.*, no date; Grasser *et al.*, 2012; Wyder, 2018). The role of the mother is for transmission of medicinal plants knowledge is generally known to be important (Soldati *et al.*, 2015).

Role of underground plant parts in the Saastal

Interestingly, the use of *Peucedanum ostruthium* rhizomes has not been mentioned in the Saastal, although its use has been widespread according to recent ethnobotanical studies in the French part of Valais including Val d'Anniviers, Ticino, Prättigau, Walsertal, Tirol and among swiss herbalist as well as historical records (**Table 6**). One interviewee said that roots (and rhizomes) are generally not well known for medicinal uses among people of the Saastal. This statement is supported by the few use reports collected for belowground organs in this study (for 7 species; **Figure 21**). Four of these species are cultivated in gardens (*Allium cepa, Allium sativum, Echinacea* spp. and *Symphytum officinale*). Only the belowground plant parts of *Gentiana purpurea* and *Urtica dioica* are wild gathered. One interviewee mentioned to use rhizomes of *Peucedanum ostruthium* and *Rhodiola rosea* but emphasized that she got this knowledge from outside the valley. In other Alpine regions as Prättigau, Walsertal or Ticino underground organs are widely used (Poretti, 2009; Grasser *et al.*, 2012; Wegmann, 2013). Worldwide, underground organs are an integral part of collected and cultivated plants for medicinal use (Schippmann *et al.*, 2006).

Socioeconomic changes in the Saastal

In the past, *Peucedanum ostruthium* was probably well known among farmers in the Saastal. The local plant name *Aschtränze* is a common vernacular name for *Peucedanum ostruthium* in many German-speaking parts of Switzerland. The name can be traced back to the 11th Century (Tschirch, 1917). The knowledge about *Peucedanum ostruthium* was probably exchanged with its name Astrenze in the past. Similar looking medicinal plants of the family Apiaceae have other vernacular names like *Pimpinella* spp. (*Bibernelle)*, *Angelica* spp. (*Sturrobenju, Engelwurz*) or *Aegopodium podograria* L. (*Giersch*) in the Saastal as well as in other Alpine regions (Grasser *et al*., 2012b; Wegmann, 2013). The name *Aschtränze* can therefore be explicitly attributed to *Peucedanum ostruthium*. Whether local people in the Saastal ever used

the rhizomes is unknown. Socioeconomic changes through tourism probably had a major influence on the local plant knowledge and use. At the 19th Century, many of the self-sufficient farmers started to work in the tourism and hotel sector (Wyder, 2018). Nowadays tourism is the most income source and half of the interviewees are working in this sector. As *Peucedanum ostruthium* is supposed to be generally used by the farmers in the Saastal, these changes could be a main reason why knowledge about *Peucedanum ostruthium* is almost forgotten. Similar processes have been reported for other parts of Valais as well as Tirol (Christanell *et al.*, 2010; Abbet, 2014). Also, *Peucedanum ostruthium* is not described in the preferred herbal books used by the interviewees such as Künzle (1914) and Treben (1970). In *Natürlich Gesund mit Heilpflanzen* (Vonarburg, 2001), which was also mentioned as source, it is mainly presented as a treatment for hay fever.

Local people of Saastal, however, know different medicinal plants, which they may prepare for self-medication. This can be traced back to the need for self-sufficiency until the 19th century, when there was no doctor in the valley and people lived in poverty (Wyder, 2018). Certain species are highly appreciated for particular medical treatments and are therefore well known among the interviewees. The most often mentioned species was *Arnica montana*. It is used for joint pain and muscle aches and is well-known for this in the Alpine regions (Brüschweiler, 2008). *Thymus* spp. is used for coughs and colds, *Calendula officinalis* for dermatological applications, *Achillea millefolium* for digestion and *Urtica dioica* for detoxification. They also belong to the most important medicinal plants and are generally known for these uses in other Alpine regions (Grasser *et al.*, 2012; Wegmann, 2013). While *Peucedanum ostruthium* could also be used as substitute for all these treatments, local people of the Saastal rely on the above-mentioned medicinal plants.

Relevance in historical records compared to current uses in Alpine regions

Peucedanum ostruthium has been described as a medicinal plant since the medieval times, for example by Hildegard von Bingen and Macer Floridus (Berendes, 1897; Mayer, 2001). Until today the rhizome is the most often cited plant part in literature, other parts are less frequently documented. Besides systemic and topical applications, fumigation of rhizomes plays an important role. Overall, *Peucedanum ostruthium* was used in a wide range of applications for medical, apotropaic and veterinary medical treatments throughout all time periods since the medieval time. Therefore, it is not surprising that the plant received names such as *Meisterwurz*, *Kaiserwurz* with the derived Latinizations *Magistrantia* or *Imperatoria* (Marzell, 1922). In

some regions of the Alps, *Peucedanum ostruthium* is still considered as a panacea like in the Austrian Walsertal (Grabowski, 2010). The Walser even took the knowledge about *Peucedanum ostruthium* while migrating to Bosco Gurin in late Middle Ages; otherwise the use of this plant is largely forgotten in Ticino (Poretti, 2009). In Val d'Anniviers, *Peucedanum ostruthium* is worshipped as a sacred plant (Brüschweiler, 2008).

Medicinal Uses

There is a general agreement in the citations of historical records and in recent ethnobotanical studies that *Peucedanum ostruthium* may have healing effects on the digestive and respiratory system. Furthermore, it has been used to cure external as well as internal infections and poisoning, to lower fever and to strengthen the immune system. Therefore a constant use since medieval times can be postulated as it was also concluded about other medicinal plant species from Dal Cero (2016). It has often been documented to have "pull-out" abilities. Preparations should be able to pull disease-causing substances out of the body, such as mucus in the lung and nose, toothache, and poison in wounds or in the body (Fuchs, 1543; Bock, 1546; Wartmann, 1874; Brüschweiler, 2008). In the humoral pathology during monastic medicine and Renaissance, *Peucedanum ostruthium* has been classified as a warm and dry plant due to its bitterness and hot pungency. Therefore, it is able to pull the cold and viscous fluid out of the body (Fuchs, 1543; Bock, 1546; Berendes, 1897; Mayer, 2001). Preparations have been applied systemically or topically and as volatiles. Fumigating wounds of humans and animals or inflamed parts of the body such as ears, urinary infection or throat is documented since the Renaissance (Bock, 1546; Brüschweiler, 2008; Pohl-Sennhauser, 2008). *Peucedanum ostruthium* has also been snuffed as a sternutatory (Bock, 1546; Mayer, 2001; Künzle and Opplinger, 2018). It is widely used as a treatment for toothache (Poretti, 2009; Bock, 1546; Wartmann, 1874; Stoll, 1909; Wegmann, 2013; Dal Cero *et al.*, 2015; Grasser *et al*., 2016).

In pharmacological studies, contents of essential oils (especially coumarins) of *Peucedanum ostruthium* have been suggested to have the following activities: Anti-inflammatory (Hiermann and Schantl, 1998; Zimecki *et al.*, 2009b; Joa *et al.*, 2011), anti-biotic (Schinkovitz *et al.*, 2003b; Gökay *et al.*, 2010), anti-pyretic (Hiermann and Schantl, 1998) or against cardiovascular diseases (Joa *et al.*, 2011). These is in accordance with the documented uses in the historical records and ethnobotanical studies. Some authors even claim that compounds of *Peucedanum ostruthium* have anti-cancer (Zimecki *et al.*, 2009b) or neuroprotective properties and may be used for diseases such as Alzheimer's or epilepsy (Urbain *et al*., 2005; Du *et al.*, 2019; Palmioli

et al., 2019). Similarly, such treatments were documented during Renaissance. Marzell (1922) citates a record from Wolff (1690) about treatments with rhizomes of *Peucedanum ostruthium* against epilepsy. Paracelsus used it for spleen and uterus tumors (Flamm and Kröber, 1935).

Apotropaic and veterinary medicinal uses

The documented "pull-out" abilities of *Peucedanum ostruthium* have also been relevant in apotropaic applications since the Renaissance. Carrying rhizomes in a pocket or as an amulet around the neck should protect against diseases or infections and is still common nowadays (Wartmann, 1874; Marzell, 1922; Zimmermann, 1927; Poretti, 2009; Grasser *et al.*, 2012; Wegmann, 2013). Rhizomes were also fixed on special parts of the body to cure diseases like epilepsy and tuberculosis (Marzell, 1922; Hoffmann-Krayer and Bächtold-Stäubli, 1935). The number of used rhizome pieces or treatment repetitions are partially relevant and should mostly be an odd number (Wartmann, 1874; Hoffmann-Krayer and Bächtold-Stäubli, 1935; Vogl-Lukasser *et al.*, 2006). Other apotropaic applications are related to a blessing of *Peucedanum ostruthium* and subsequent fumigation of rooms and stables. This should prevent human and livestock from misfortune, diseases and even lightning strikes and is usually performed on holy days like Christmas, Epiphany or Assumption Day (Weinhold, 1894; von Andrian, 1905; Pohl-Sennhauser, 2008; Grabowski, 2010; Wegmann, 2013). Apotropaic fumigation is still practiced today in Alpine regions. Interestingly, the highest use of fumigation is reported and is wide spread in French part of Valais (Brüschweiler, 2008; Abbet, 2014). In Saastal, local people do not fumigate the plant or use it as apotropaic.

Peucedanum ostruthium is also widely used in veterinary medicine since the Renaissance. The uses cannot clearly be differentiated from apotropaic or similar medicinal treatments for humans. For example, fumigation of stables and feeding livestock with blessed plants are used to keep misfortune and disease away as well as for disinfection and strengthen the animals. For Westböhmen (Czech Republic) it was reported that bewitched cows which gave no milk were feed with rhizomes of *Peucedanum ostruthium*, garlic and salted bread (John, 1905). Medically, *Peucedanum ostruthium* is mainly used to treat infections such as the dreaded claw disease or infected wounds and gastrointestinal complaints. The overlap of veterinary and human medical treatments is a common phenomenon and, e.g. also discussed for traditional veterinary medicine in Italy (Viegi *et al.*, 2003).

Relevance of Peucedanum ostruthium *in the past and today*

As already mentioned above, the names of *Peucedanum ostruthium* like *Imperatoria* indicate a great relevance in the monastic medicine and the Renaissance. Treatments with its rhizomes of diseases incurable for this time like plague, leprosy and tumors also demonstrate the relevance of the plant (Fuchs, 1543; Bock, 1546; Herzog, 1871; Flamm and Kröber, 1935). *Peucedanum ostruthium* has most likely not been described in *De Materia Medica* by Dioscorides (40-90 CE), since the plant does not occur at all in Mediterranean regions. In Renaissance many medicinal plants were adopted from *De Materia Medica* by herbalists like Hieronymus Bock and Leonhart Fuchs (Dal Cero, 2016). Both speculated about possible plants from *De Materia Medica* which could fit on *Peucedanum ostruthium*, like the *smyrnion* or *silphion* (Fuchs, 1543; Bock, 1546). Nevertheless, *Peucedanum ostruthium*, with its wide range of applications, became an integral part of their herbal books. Since the plant is native in higher areas of the Alps, it has been cultivated in gardens to have it close by. First records of it are found in the herbal book of Bock (1546). The cultivated plant was probably spread over large parts of Europe including Germany, the Crimea and Russia (Tschirch, 1917; Hess *et al*.,1977). Presumably, it was also introduced to Scandinavia and the USA, where small, non-invasive populations can still be found today, usually in the near of old pastures and gardens (Fremstad, 2004; Keser *et al.*, 2014). *Peucedanum ostruthium* is still cultivated today as documented in Walsertal (Grabowski, 2010). Instructions can be found in the herbal book of Vonarburg (2001). Today, *Peucedanum ostruthium* is listed in popular herbal books, such as in a new edition of *Chrut und Unchrut* by Johann Künzle (2018) or *Natürlich Gesund mit Heilpflanzen* by Bruno Vonarburg (2001). In the internet, the plant is sold by drugstores and is primarily merchandised in Austria (18.07.2020). But, *Peucedanum ostruthium* slowly fell into oblivion in biomedicine and pharmacology. It was last published as a monograph in the Pharmakopoea germanica II (1882) and in the Pharmakopoea helvetica III (1893; Waldbauer, 2011). Since then, it does not occur as a monograph any longer in the well-known European institutions ESCOP, Commission E. and HMPC and it is therefore not listed in the standard work Wichtl – Teedrogen und Phytopharmaka (Bauer *et al.*, 2016). However, since the 1990s interest in contents of its essential oils has been increasing and it is subject of many pharmaceutical studies. Maybe it will occur again in the pharmacopoeia in the future.

5. Conclusions and Outlook

This study has provided a detailed overview of the variability in morphological traits and coumarin concentrations of *Peucedanum ostruthium* based on a population in Saastal. Differences in morphology but not in coumarin concentrations could be observed compared to environmental factors such as altitudinal levels, soil and health condition. Additionally, milder climate and nutrient-rich soils enable the growth of larger organs. The highest variability is found in the rhizomes, which has already been confirmed in other studies and could explained by a plasticity of the clonal growth strategy. In this context, tendencies towards higher concentrations in coumarin contents can also be observed. Nevertheless, the concentration of coumarins remains very uniform, considering the entire population. In this case, HPTLC analysis turned out to be a valid tool for the quantitative analysis of coumarin concentrations. Nevertheless, the variability of morphological traits and coumarin concentrations cannot be divided into subpopulations, it is most likely one metapopulation with close genetic relationships. In conclusion, the study suggests that rhizomes should be collected on lower altitudinal levels from large and healthy individuals to obtain well developed rhizomes with high coumarin content. However, better understanding of the interaction between *Peucedanum ostruthium* and its environment could be provided in comparing the traits and coumarin content with other populations in different locations and habitats. Furthermore, it would be interesting to observe the health condition and herbivory activities over a longer time period for a better understanding of the role of coumarins in plant defense.

This study further provided the first ethnobotanical insight into the German-speaking part of Valais based on research in the Saastal. The local people have a broad knowledge of medicinal plants, which is typical for Alpine regions. Nevertheless, *Peucedanum ostruthium* is only little known as a medicinal plant and the otherwise observed important use of its rhizomes is missing completely. It should be noted that the use of underground plant parts is generally not very common. In contrast, *Peucedanum ostruthium*, its rhizome and underground plant parts are frequently used in other Alpine regions. This knowledge might have been lost due to socioeconomic changes in the Saastal. Further investigation in the German-speaking part of Valais could help to understand how established the use of *Peucedanum ostruthium* and its rhizomes are in this Alpine region. It would also be interesting to do a more elaborated ethnobotanical research of the general use of plants in the Saastal, since the focus in this study heavily relied on the knowledge about *Peucedanum ostruthium*.

The study in history of *Peucedanum ostruthium* revealed a long and exciting record of its use dating back to medieval times. The plant has always been appreciated and is still regarded as a panacea in certain Alpine regions. The wide range of applications for many diseases that have survived since medieval times indicates its relevance. Certain medical treatments have also been important in veterinary medicine or are partly inseparable from apotropaic uses, where fumigation of rhizomes play a crucial role. It would be interesting to investigate the history of *Peucedanum ostruthium* in other parts of the world. Furthermore, it could also be investigated where it is still being used today outside the Alpine region. The growing interest of pharmacological research in its therapeutic properties shows the worth of *Peucedanum ostruthium* and should therefore be used more for medical purposes

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Appendix A: Botany

Table 1: Average morphological trait values and coumarin concentrations at the four sites

site	**aboveground organ traits**				
	leaf lobes	*umbel height (mm)*	*umbel width (mm)*	*leaf width (mm)*	*leaf length (mm)*
1450-1550 SB	9.4	1088.2	171.8	376.3	206.5
1750-1850 SB	9.1	963.9	174.4	382.4	208.5
2000-2100 SB	8.6	1057.0	177.1	373.2	205.3
1750-1850 SA	8.7	998.8	176.7	382.9	212.7
site	**belowground organ traits**				
	rhizome length (mm)	*rhizome circ. (mm)*	*rhizome diam. (mm)*	*harvest weight (g)*	*dry weight (g)*
1450-1550 SB	67.3	60.7	16.0	3.1	1.0
1750-1850 SB	67.8	56.6	14.5	2.5	0.9
2000-2100 SB	52.5	59.7	14.4	2.3	0.9
1750-1850 SA	53.8	58.3	15.3	2.6	0.9
site	**coumarins**				
	total (µg/ml)	*peak 1 (µg/ml)*	*Ost/Oxy (µg/ml)*	*peak 2 (µg/ml)*	*isoimperatorin (µg/ml)*	*imperatorin (µg/ml)*
1450-1550 SB	3094.4	558.9	874.3	395.2	520.2	745.8
1750-1850 SB	2952.1	519.2	851.5	375.1	495.3	711.1
2000-2100 SB	3074.0	503.1	893.9	385.7	545.0	746.4
1750-1850 SA	3062.5	524.2	884.4	351.7	517.3	784.9

Figure 1: Scatterplot, distribution and correlation-value of morphological traits and the total coumarin content

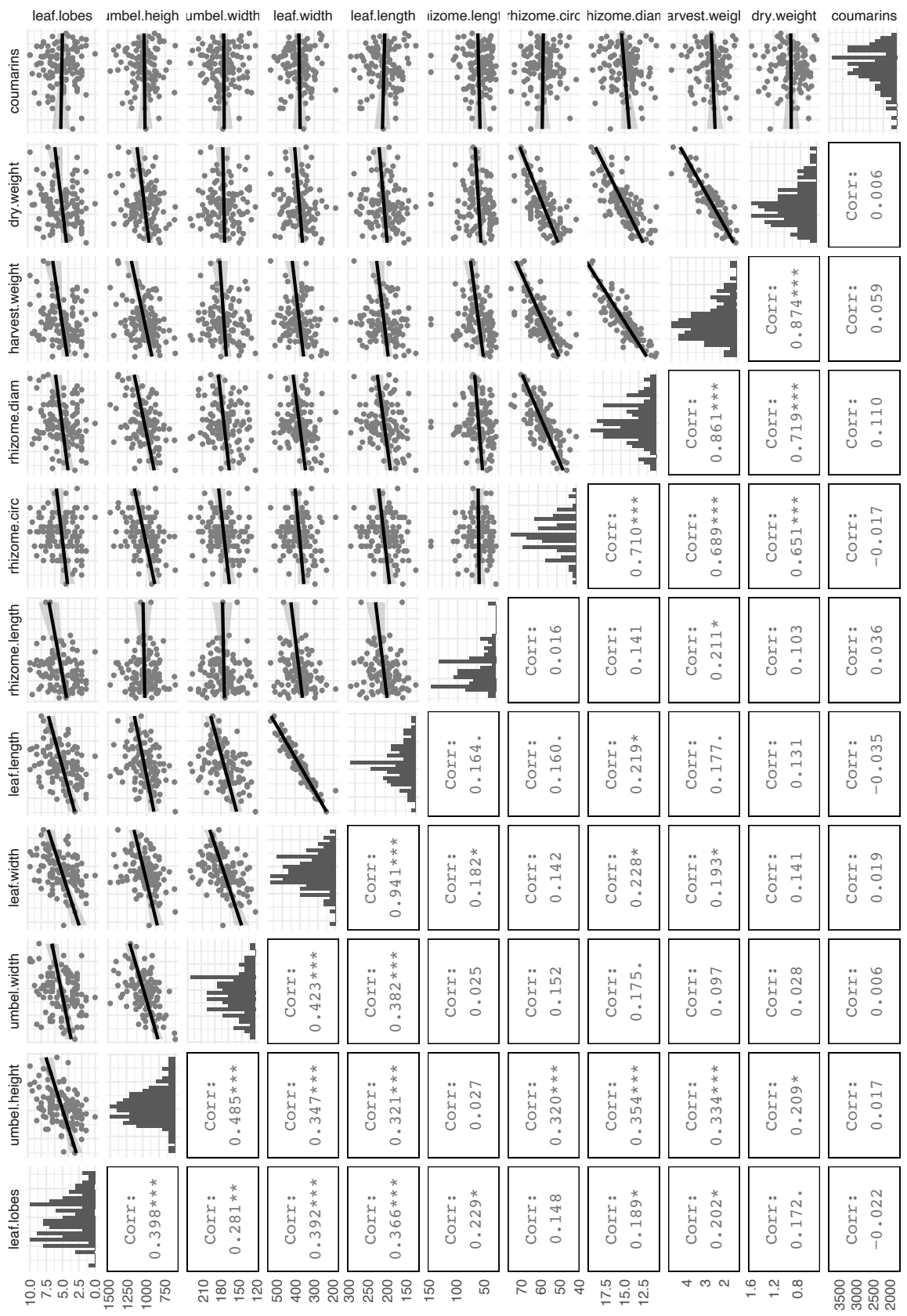

Figure 2: Histogram of eigenvalues (PC's) **A:** of all morphological traits, **B**: of aboveground organ traits, **C**: of belowground organ traits

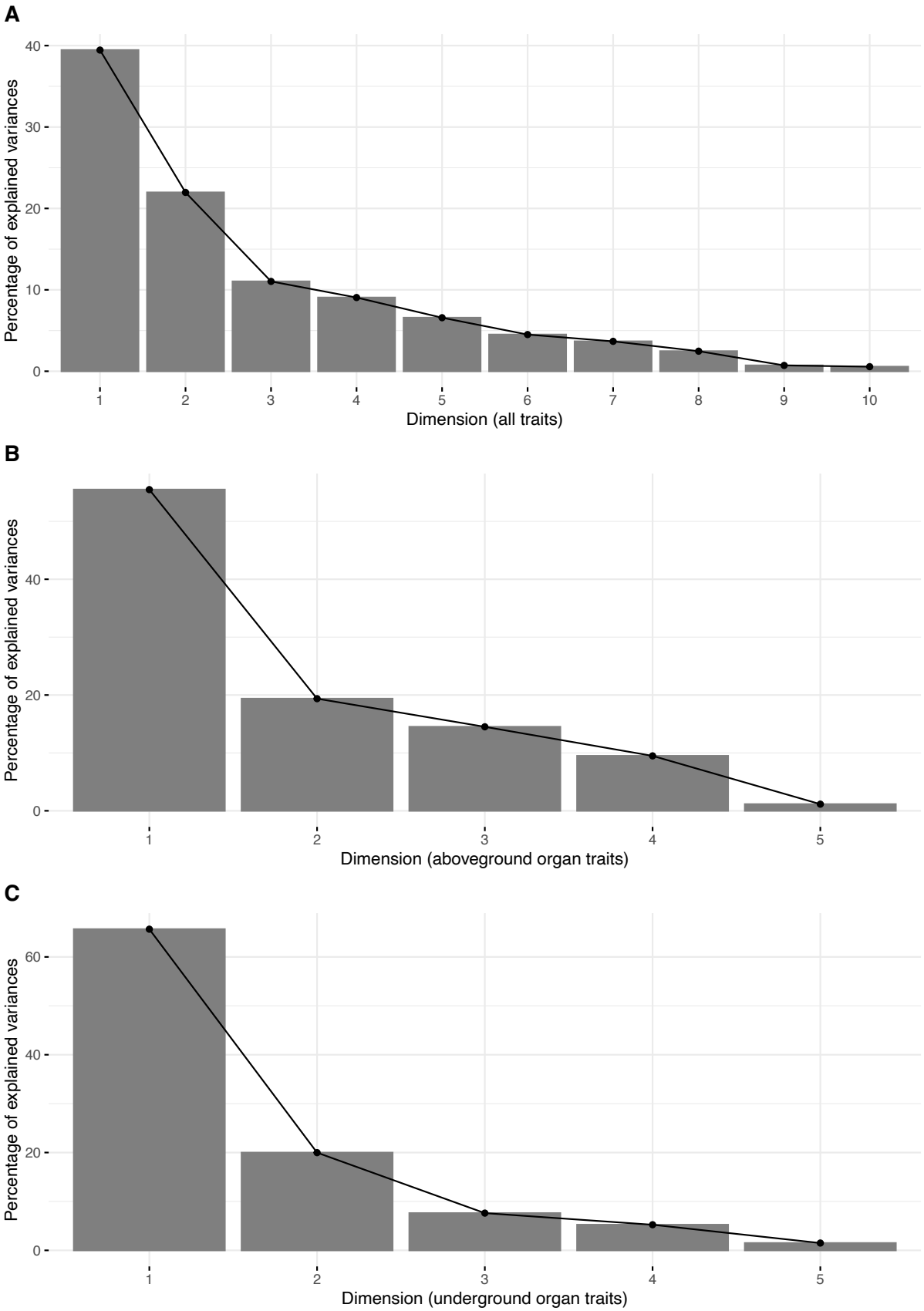

Table 2: Rank Tests of Kruskal-Wallis including all 4 sites and Mann-Whitney-U comparing single variables. Test differences in ranks of morphological traits and total coumarin content in relation to environmental factors.

	altitude/locality			
	Kruskal-Wallis-Test	*between single variables (Mann-Whitney-U test)*	*abbr.*	
leaf lobes	0.4505	n. s.	b1:	1450-1550 Saas-Balen
umbel height	0.01684	b1-b2; b2-b3	b2:	1750-1850 Saas-Balen
umbel width	0.842	n. s.	b3:	2000-2100 Saas-Balen
leaf length	0.6259	n. s.	b4:	1750-1850 Saas-Almagell
leaf width	0.6527	n. s.		
rhizome length	0.002098	b1-b4, b1-b3, b2-b4,b2-b4		
rhizome circ	0.1445	n. s.		
rhizome diam	0.004228	b1-b2, b1-b3		
harvest weight	0.0002936	b1-b4, b1-b2, b1-b3		
dry weight	0.04397	b1-b2, b1-b3		
coumarins	0.3138	n. s.		

	nutrient		**humidity**	
	Kruskal-Wallis-Test	*between single variables (Mann-Whitney-U test)*	*Kruskal-Wallis-Test*	*between single variables (Mann-Whitney-U test)*
leaf lobes	0.7322	n. s.	0.3422	n. s.
umbel height	0.02587	3.1-3.6	0.0003445	3.1-3.3, 3.1-3.4, 3.1-3.5, 3.3-3.4
umbel width	0.4128	n. s.	0.3844	n. s.
leaf length	0.3704	n. s.	0.2385	n. s.
leaf width	0.8945	n. s.	0.227	n. s.
rhizome length	0.04914	n. s.	0.005969	3.0-3.1
rhizome circ	0.6181	n. s.	0.3424	n. s.
rhizome diam	0.583	n. s.	0.0722	n. s.
harvest weight	0.6954	n. s.	0.1744	n. s.
dry weight	0.7869	n. s.	0.7588	n. s.
coumarins	0.1213	n. s.	0.2243	n. s.

	reaction rate		**herbivory**	
	Kruskal-Wallis-Test	*between single variables (Mann-Whitney-U test)*	*Kruskal-Wallis-Test*	*between single variables (Mann-Whitney-U test)*
leaf lobes	0.4234	n. s.	0.5372	n. s.
umbel height	0.02008	2.5-3.0, 2.9-3.0, 2.5-3.1	0.8192	n. s.
umbel width	0.192	n. s.	0.3457	n. s.
leaf length	0.2307	n. s.	0.1525	n. s.
leaf width	0.1841	n. s.	0.057	n. s.
rhizome length	0.001168	2.5-3.1, 2.8-2.9, 2.8-3.1	0.4921	n. s.
rhizome circ	0.07721	n. s.	0.9065	n. s.
rhizome diam	0.01301	2.5-3.0, 2.8-3.0, 2.9-3.0, 3.0-3.1	0.1716	n. s.
harvest weight	0.04014	2.8-3.0, 2.9-3.0, 3.0-3.1	0.04593	moderate-strong
dry weight	0.3423	n. s.	0.1262	n. s.
coumarins	0.09979	n. s.	0.6318	n. s.

Table 3: Documented species at the four sites and their occurrence added up from the plots

plant communities at 1450-1550m a.s.l Saas-Balen			
16.7 species per plot (11), species total 46			
Species	**occur-ence**	**Species**	**occur-ence**
Chaerophyllum villarsii W.D.J. Koch	11	*Epilobiom montanum* L.	1
Peucedanum ostruthium (L.) W.D.J. Koch	11	*Equisetum sylvaticum* L.	1
Epilobium angustifolium L.	10	*Melampyrum sylvaticum* L.	1
Geranium sylvaticum L.	8	*Phyteuma betonicifolium* Vill.	1
Dactylis glomerata L.	7	*Pimpinella major* (L.) Huds.	1
Alchemilla vulgaris agg.	6	*Polypodium vulgare* L.	1
Rumex alpestris Jacq.	6	*Ranunculus montanus* Willd.	1
Adenostyles alliariae (Gouan) A. Kern.	5	*Streptopus amplexifolius* (L.) DC.	1
Angelica sylvestris L.	5	*Taraxacum officinale* agg.	1
Dryopteris filix-mas (L.) Schott	5	*Trifolium pratense* L.	1
Heracleum sphondyllum subsp. elegans (Crantz) Schübl. & G. Martens	5	*Trifolium repens* L.	1
Luzula nivea (L.) DC	5		
Oxalis acetosella L.	5		
Ranunculus acris L.	5		
Rubus idaeus L.	5		
Rumex acetosella L.	5		
Rumex alpinus L.	5		
Urtica dioica L.	5		
Aconitum variegatum agg.	4		
Cirsium helenioides (L.) Hill	4		
Deschampsia cespitosa (L.) P. Beauv.	4		
Hieracium murorum agg.	4		
Viola biflora L.	4		
Aconitum lycoctonum subsp. *vulparia* (Rchb.) Nyman	3		
Alnus viridis (Chaix) DC.	3		
Athyrium filix-femina (L.) Roth	3		
Equisetum arvense L.	3		
Geum rivale L.	3		
Silene dioica (L.) Clairv.	3		
Silene vulgaris (Moench) Garcke	3		
Veratrum album L.	3		
Bromus inermis Leyss.	2		
Helictotrichon pubescens (Huds.) Pilg.	2		
Hieracium pictum Pers.	2		
Hieracium prenanthoides agg.	2		
Phleum pratense L.	2		
Achillea millefolium L.	1		
Arabis nova Vill.	1		
Avenella flexuosa (L.) Drejer	1		
Crepis paludosa (L.) Moench	1		
Dactylorhiza maculata (L.) Soó	1		

Plant communities at 1750-1850m a.s.l. Saas-Balen	
15.3 species per plot (4), species total 27	
Species	**occur-ence**
Chaerophyllum villarsii	4
Epilobium angustifolium	4
Luzula nivea	4
Peucedanum ostruthium	4
Geranium sylvaticum	3
Phleum pratense	3
Solidago virgaurea L. subsp. v*irgaurea*	3
Veratrum album	3
Agrostis capillaris L.	2
Hieracium prenanthoides agg.	2
Homogyne alpina (L.) Cass.	2
Oxalis acetosella	2
Rhododendron ferrugineum L.	2
Rubus idaeus	2
Rumex alpestris	2
Rumex alpinus	2
Achillea millefolium	1
Alchemilla vulgaris agg.	1
Alnus viridis	1
Arrhenatherum elatius (L.) J. Presl & C. Presl	1
Avenella flexuosa	1
Calamagrostis varia (Schrad.) Host	1
Cirsium palustre (L.) Scop.	1
Deschampsia cespitosa	1
Dryopteris dilatata agg.	1
Hieracium murorum agg.	1
Hieracium pictum	1
Leucanthemum vulgare agg.	1
Poa nemoralis L.	1
Ranunculus acris	1
Ranunculus montanus	1
Silene vulgaris	1
Sorbus aucuparia L.	1

Plant communities at 2000-2100m a.s.l. Saas-Balen			
16.4 species per plot (5), species total 34			
Species	**occur-ence**	**Species**	**occur-ence**
Chaerophyllum villarsii	5	*Senecio ovatus* subsp. *alpestris* (Gaudin) Herborg	1
Peucedanum ostruthium	5	*Silene vulgaris*	1
Epilobium angustifolium	4	*Viola biflora*	1
Rumex alpestris	4		
Urtica dioica	4		
Veratrum album	4		
Achillea millefolium	3		
Alnus viridis	3		
Dactylis glomerata	3		
Geranium sylvaticum	3		
Rubus idaeus	3		
Rumex alpinus	3		
Aconitum variegatum subsp. *valesiacum* (Gáyer) Greuter & Burdet	2		
Alchemilla vulgaris agg.	2		
Alopecurus pratensis L.	2		
Calamagrostis varia	2		
Centaurea nervosa Willd.	2		
Cirsium palustre	2		
Gentiana purpurea L.	2		
Rhodiola rosea L.	2		
Trollius europaeus L.	2		
Aconitum lycoctonum subsp. *neapolitanum* (Ten.) Nyman	1		
Aconitum variegatum subsp. *paniculatum* (Arcang.) Negodi	1		
Agrostis schraderiana Bech.	1		
Athyrium filix-femina	1		
Cerastium arvense subsp. strictum	1		
Cystoperis fragilis Bech.	1		
Deschampsia cespitosa	1		
Epilobiom montanum	1		
Festuca spp.	1		
Hieracium pictum	1		
Hieracium prenanthoides agg.	1		
Juncus jacquinii L.	1		
Leucanthemum vulgare agg.	1		
Oxalis acetosella	1		
Ranunculus montanus	1		
Rumex acetosella	1		
Saxifraga stellaris L.	1		

Plant communities at 1750-1850m a.s.l. Saas-Almagell			
16 species per plot (9), total species 48			
Species	**occur-ence**	**Species**	**occur-ence**
Peucedanum ostruthium	9	*Juncus alpinoarticulatus* Chaix	1
Chaerophyllum villarsii	7	*Oxalis acetosella*	1
Geranium sylvaticum	7	*Phalaris arundinacea* L.	1
Alchemilla vulgaris agg.	6	*Poa nemoralis*	1
Epilobium angustifolium	6	*Ranunculus acris*	1
Rumex alpestris	6	*Ranunculus montanus*	1
Dactylis glomerata	5	*Salix myrsinifolia* Salisb.	1
Epilobium montanum	5	*Saxifraga stellaris*	1
Hieracium prenanthoides agg.	5	*Stellaria nemorum* L. subsp. *nemorum*	1
Rumex acetosella	5	*Taraxacum officinale* agg.	1
Tussilago farfara L.	5	*Trollius europaeus*	1
Veratrum album	5	*Valeriana versifolia* Brügger	1
Viola biflora	5		
Cirsium palustre	4		
Silene vulgaris	4		
Urtica dioica	4		
Adenostyles alliariae	3		
Cirsium helenioides	3		
Rubus idaeus	3		
Rumex alpinus	3		
Achillea millefolium	2		
Aconitum variegatum agg.	2		
Alnus viridis	2		
Deschampsia cespitosa	2		
Elymus repens (L.) Gould	2		
Galium pumilum agg.	2		
Phleum pratense	2		
Solidago virgaurea L. subsp. v*irgaurea*	2		
Thalictrum aquilegiifolium L.	2		
Aconitum lycoctonum agg.	1		
Aconitum variegatum subsp. paniculatum	1		
Agrostis gigantea Roth	1		
Alopecurus pratensis	1		
Angelica sylvestris	1		
Athyrium filix-femina	1		
Briza media L.	1		
Bromus inermis	1		
Calamagrostis varia	1		
Carex frigida All.	1		
Cirsium arvense (L.) Scop.	1		
Dactylorhiza maculata	1		
Festuca spp.	1		
Gentiana purpurea	1		

Table 4: Protocol of morphological traits during fieldwork

Protokoll *Peucedanum ostruthium* (L.) Koch – Apiaceae

Beobachterin: Camille Brioschi, Elisenstrasse 4, 8953 Dietikon
Gemeinde: 3908 Saas-Balen, Wallis
Lebensraum: *Hochstauden der Gebirge*

Datum		**Koordinaten**	
Standort		**Höhe**	
Individuum		**ID**	*Band.Standort-Höhe-Individuum*

Vermessung

Leaf-ID	*Blattbreite (mm)*	*Blattlänge*	*Blatteinschnitt*
-L.1			
-L.2			
-L.3			

Reproduction-ID	*Wuchshöhe (mm)*	*Doldenlänge*	*Doldenbreite*
-R.1			
-R.2			
-R.3			

Gesamtgrösse (m^2)	
Zustand	
Eindruck Individuum	
Eindruck Standort	

ID Herbarbeleg: *CB-Band.Standort-Höhe-H.Individuum*
Weiteres:

Rhizom von *Peucedanum ostruthium* (L.) Koch – Apiaceae

Datum		**ID**	*Standort-Höhe-Individuum*
Standort		**Individuum**	

Samples HPTLC

Dry Weight			
Harvest Weight			
Cut: diameter			
Circumference			
Total Length			
Sample-ID	*-rhi.ind.1*	*-rhi.ind.2*	*-rhi.ind.3*

Sample GC

Sample-ID	*-GC.Individuum*
Total Length	
Circumference thick	
Circumference thin	

Table 5: Protocol of species in plant community per plot

Begleitflora

Beobachterin: Camille Brioschi, Elisenstrasse 4, 8953 Dietikon
Gemeinde: 3908 Saas-Balen, Wallis

Standort-ID		**Koordinaten**		**Höhe**	
Nr.	Wissenschaftlicher Artname				Häufigkeit (Deckung %)
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					
11					
12					
13					
14					
15					

Standort-ID		**Koordinaten**		**Höhe**	
Nr.	Wissenschaftlicher Artname				Häufigkeit (Deckung %)
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					
11					
12					
13					
14					
15					

Appendix B: Coumarins

Figure 1: Images of HPTLC plates under UV 254nm, **1**: 1450-1550 Saas-Balen, **2:** 1750-1850m Saas-Balen, **3:** 2000-2100m Saas-Balen, **4**: 1750-1850 Saas-Almagell. 1:5 Dilution, reference substances: oxypeucedanin and isoimperatorin

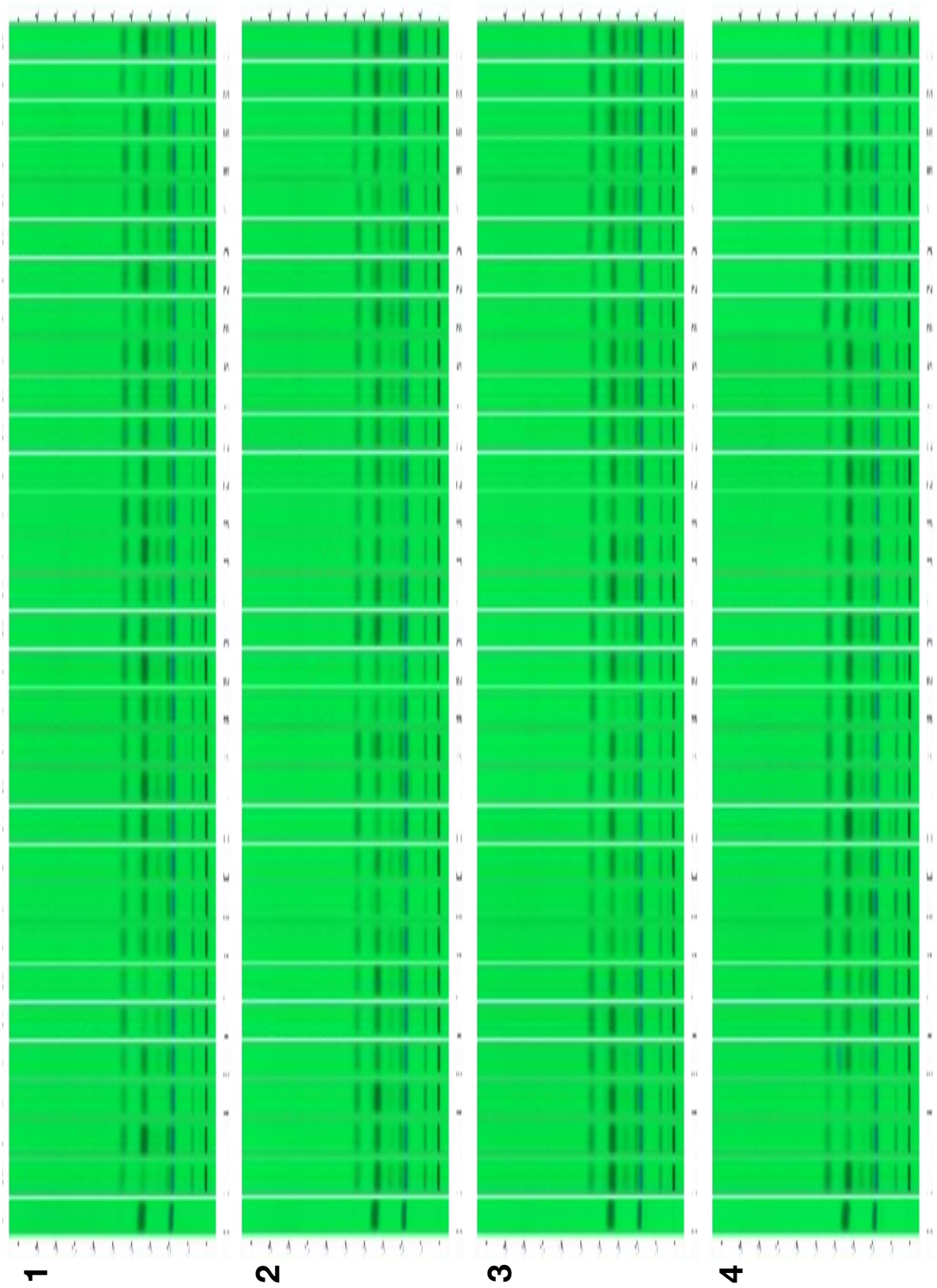

Figure 2: Images of HPTLC plates under UV 366nm, **1**: 1450-1550 Saas-Balen, **2:** 1750-1850m Saas-Balen, **3:** 2000-2100m Saas-Balen, **4**: 1750-1850 Saas-Almagell. 1:5 Dilution, reference substances: oxypeucedanin and isoimperatorin

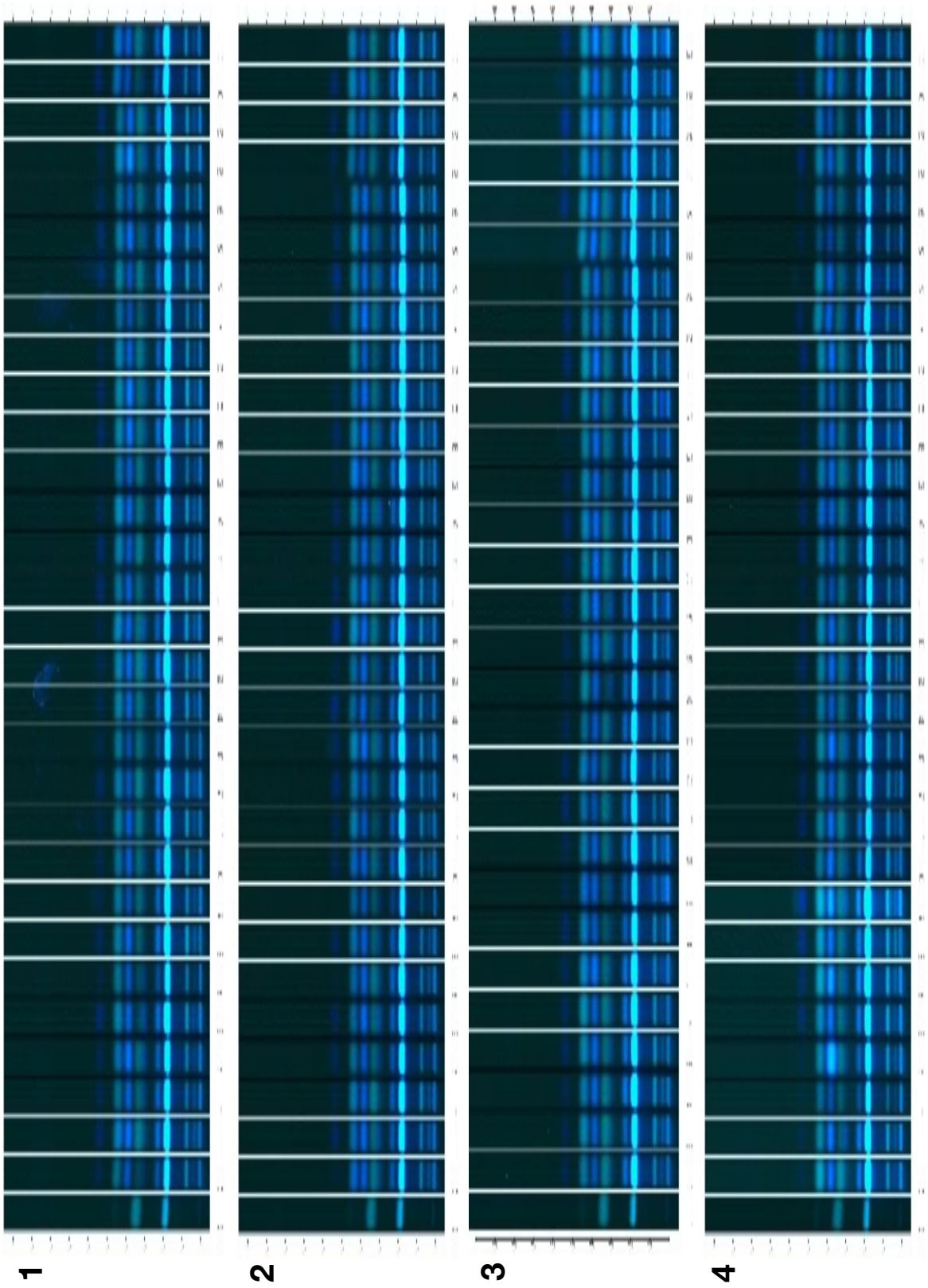

Figure 3: Images of derivate HPTLC plates under RT White (R = remission, T = transmission), **1**: 1450-1550 Saas-Balen, **2:** 1750-1850m Saas-Balen, **3:** 2000-2100m Saas-Balen, **4**: 1750-1850 Saas-Almagell. 1:5 Dilution, reference substances: oxypeucedanin and isoimperatorin

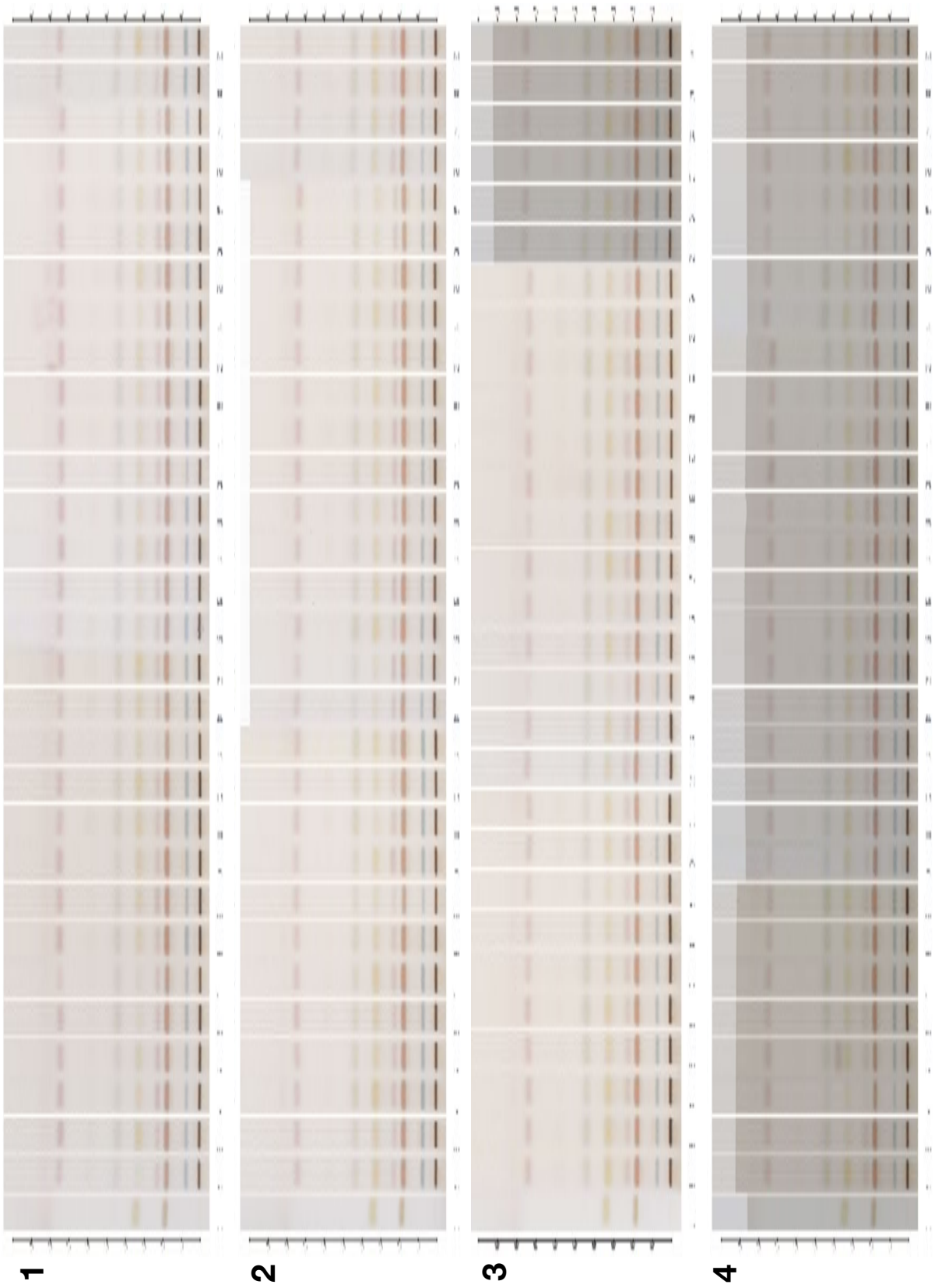

Figure 4: Right: Infusion of rhizome powder after 3 days, left: freshly prepared infusion

Appendix C: Ethnobotany in the Saastal

Table 1: Information about the interviewees from the Saastal. In total 20 persons

Residence	**Occupations**
	(can have several per person)
7 Saas-Almagell	10 Hotel business
6 Saas-Balen	6 Housekeeper
6 Saas-Grund	5 Farmer (1 male)
1 Saas-Fee	2 Teacher
	2 Seamstress
Knowledge about P. ostruthium	2 Cook
	1 Hunter (male)
10 None	1 Pharmacist (male)
5 Medicinal plant	1 Cheesery
3 weed	1 Ski teacher
1 feed for livestock	
1 homeopathy	

Medicinal Knowledge from :	
(can have several per person)	
17 Mother	1 Female cousin
3 Grandmother	1 Parents
2 Aunt	1 Herbal book
2 Mother-in-law	1 Education
2 Sister	1 grandparents
2 Capuchin monks (one is an uncle)	

Herbal books	
mentioned by 9 interviewees	
3 Gesundheit aus der Apotheke Gottes – Maria Treben (1970)	1 Was ist Hildegard Medizin? – Helmut Posch (1983)
2 natürlich gesund mit Heilpflanzen – Bruno Vonarburg (2001)	1 Pflanzliche Urtinkturen – H & H Kalbermatten (2011)
2 Kräuterbuch – Johann Künzle (2014)	1 Die Breuss-Kur – Rudolf Breuss (2013)
2 Internet	1 records from her sister (herbalist)
1 Flora Helvetica (Gygax et al., 2018)	11 N/D
1 Johanisskraut – Kraft und Leben aus der Natur (Geiss, 1998)	

Figure 1: Snowball tree of interviewees, lines = recommendations, orange frame = No interview because of age-related memory loss

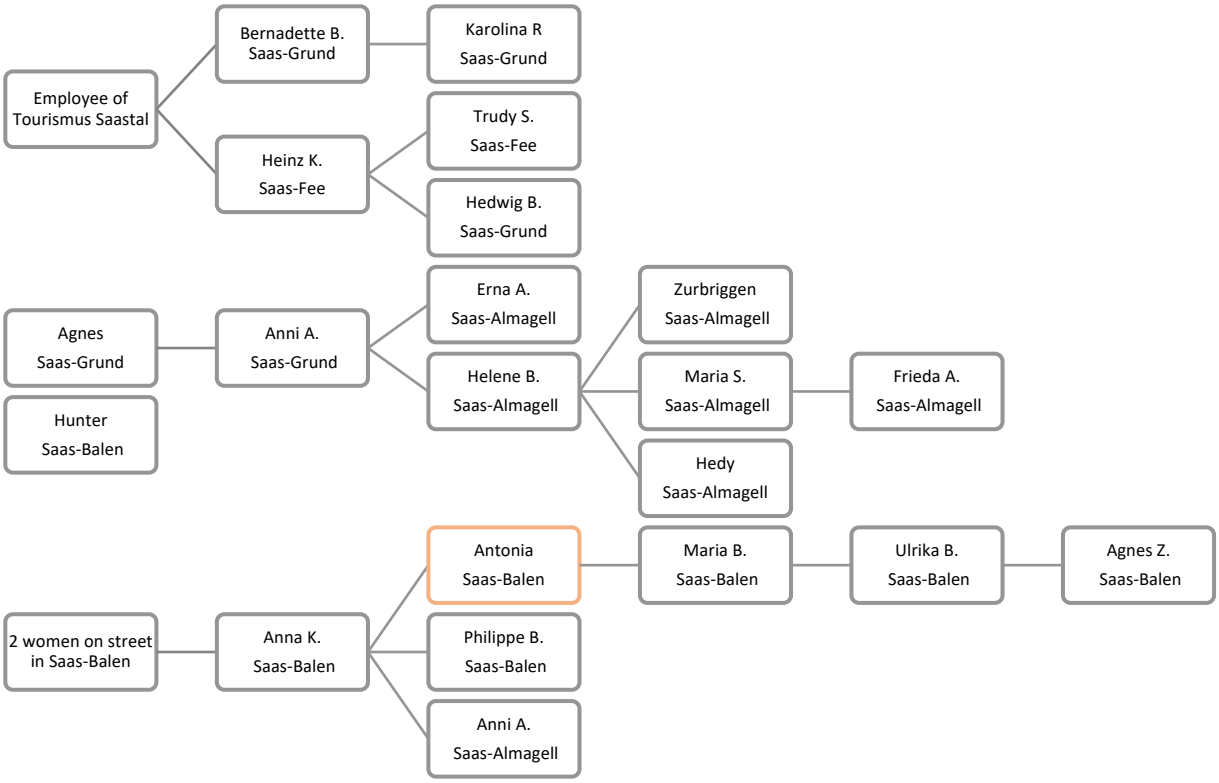

Figure 2: Families of mentioned species in use-reports ($n_{species}$=64; n_{family}=33; n_{Int}= 20)

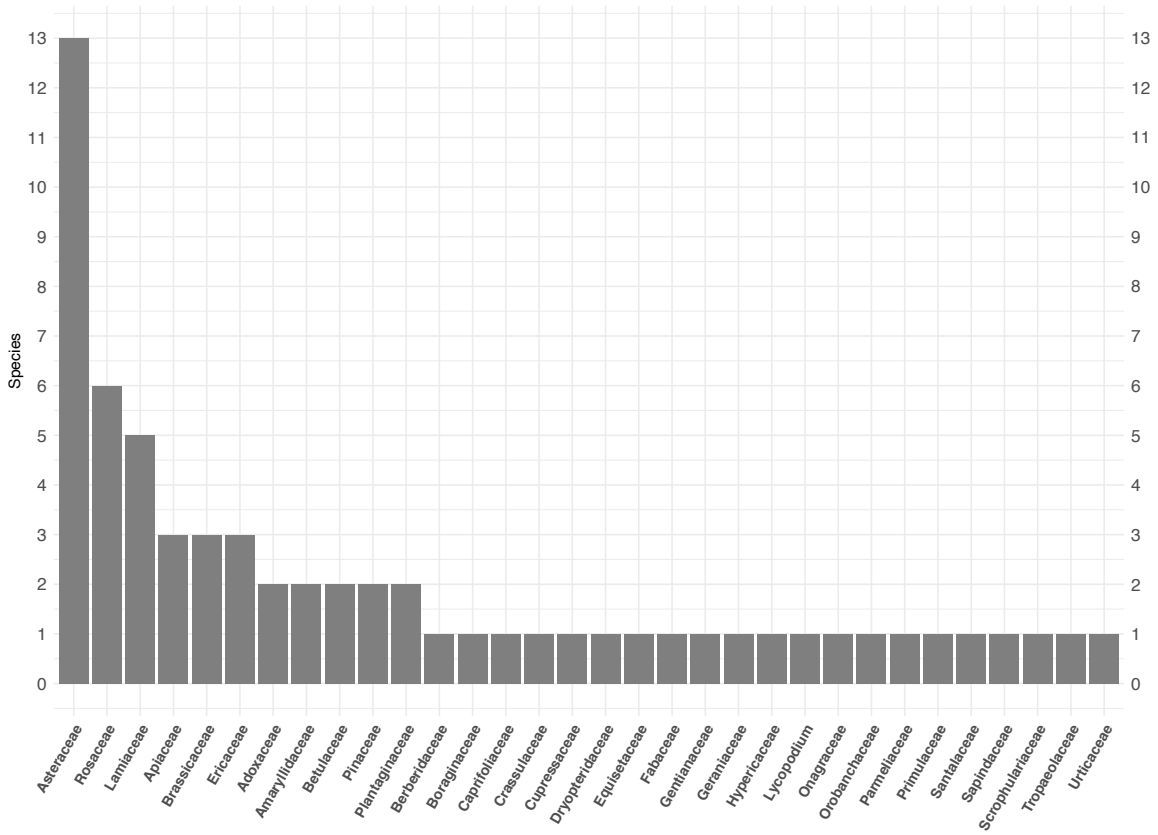

Figure 3: Preparations of use-reports (n_{UR}=272; $n_{species}$=64; n_{Int}= 20)

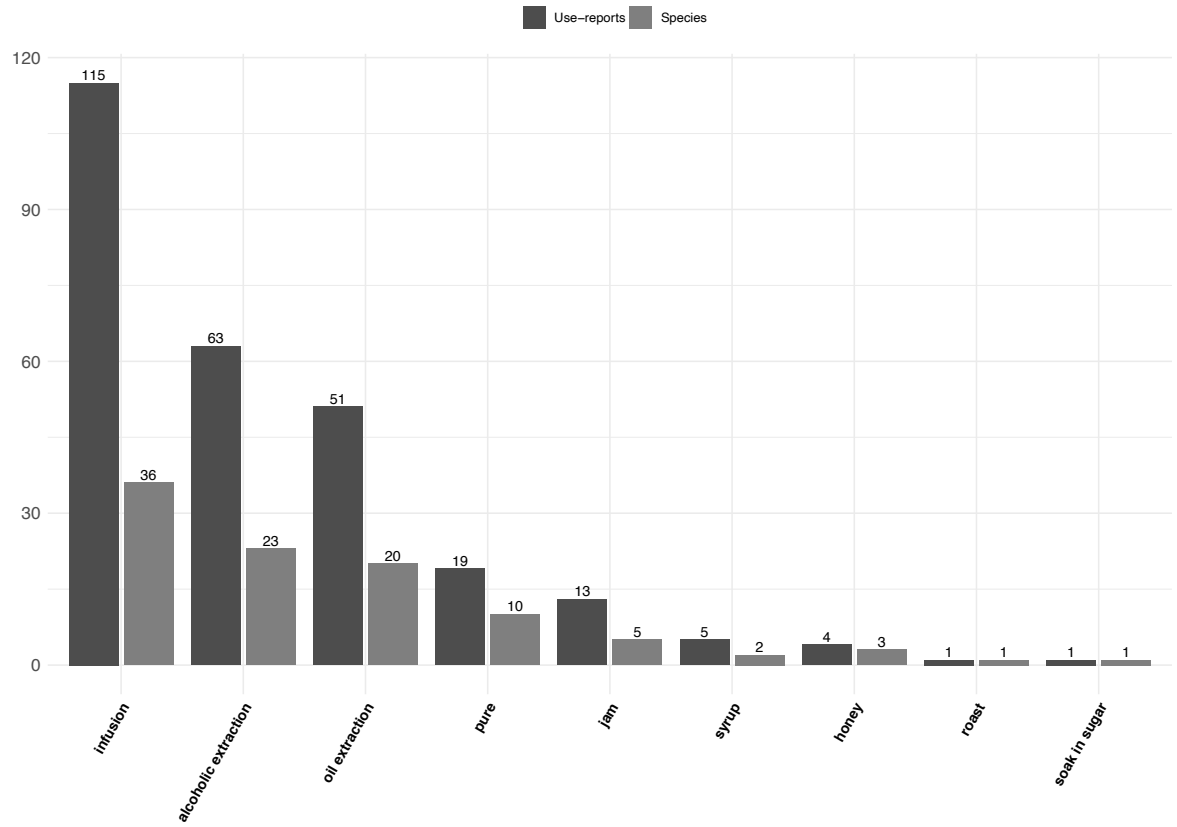

Figure 4: Medicinal categories of use-reports (n_{UR}=272, $n_{species}$=64; n_{Int}= 20)

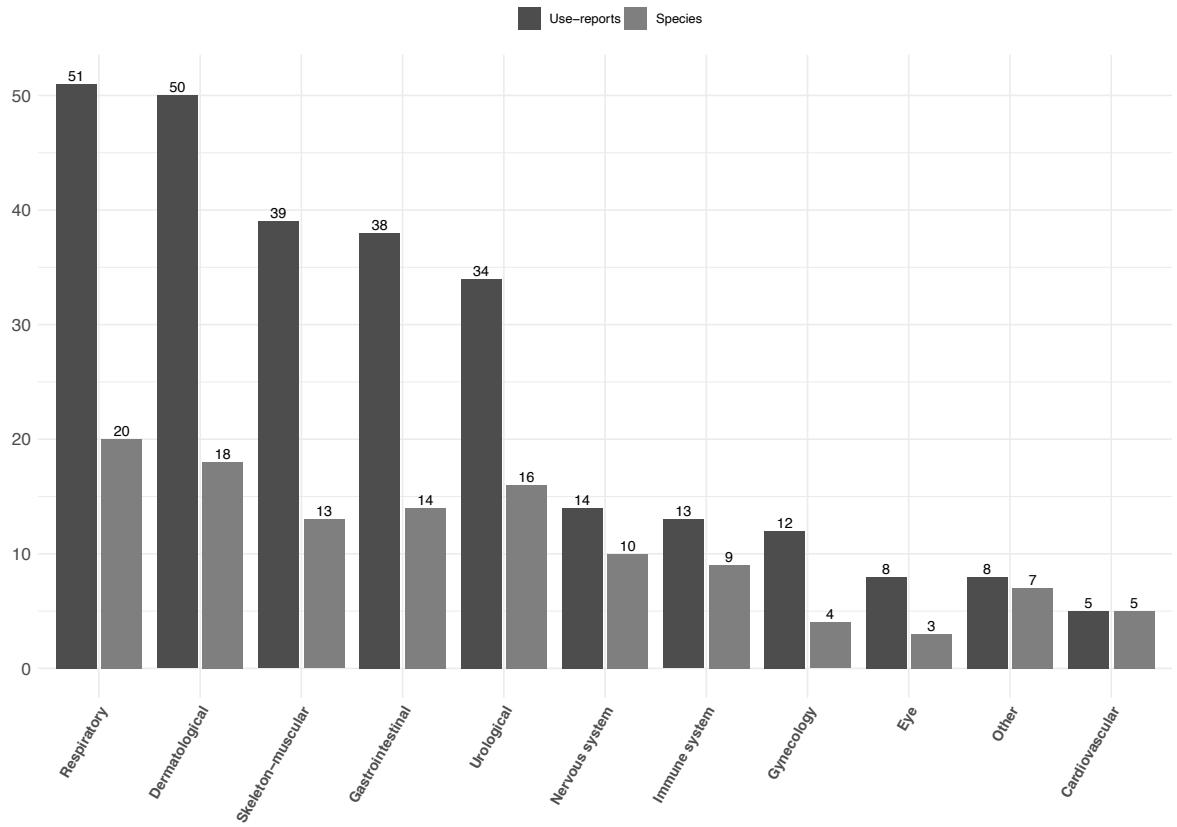

Table 2: Medicinal categories of effects and symptoms of use-reports

Medicinal Categories	
Cardiovascular	High blood pressure, cholesterol level, cardiotonic, heart pressure, vein complains, varices
Dermatologic diseases	Wounds, inflamed wounds, incised wounds, slashes, psoriasis, neurodermitis, dry skin, skin irritation, blemished skin, babies bottom, skin recovery, skin protection against UV and cold, callus, eczemas, scars, blistering, skin rashes, face ointment
Eye	Eyes, inflamed eyes, festering eyes, strengthening of eyes, intraocular pressure
Gastrointestinal and liver diseases	Flatulence, digestion, gastric trouble, appetizing, stomach cramps, diarrhea, intestine, liver
Gynecology	Females herb, female complaint, abdominal pain
Immune system	Fever, diaphoretic, vitamins, prevention in Winter, support immune system, reinforcement, anti-inflammatory, Inflammation, antibiotic
Nervous system	Sleep aid, vertigo, calmative, stimulant, Alzheimer disease, stress reduction, anti-aging, stress, nervousness, nerves, sleep disorders, depression
Urological	Diuretic, kidney, bladder, inflamed bladder, detoxification, spring tea, blood-purifying, purification
Respiratory	Cold, sore throat, cough, lung
Other	Panacea, diabetes, prostate, lymphedema, lymphatic flow disturbance, hair loss, breast pain (after radiotherapy), nosebleed

Table 3: Use-Reports of the interviewees from Saastal

Family								***TI**
Scientific Name[1]	*English Name* [2]	*Vernacular Name*	*Habitat*[3]	*Collection Place (Time)*	*Parts Used*	*Application*	*Use*	**UR*
Adoxaceae								
Sambuccus nigra L.	Black Elderberry		Scrub, Forest Border, Forest (W)					**1**
					fructus	systemic	Cold: **Tincture** mixed with red wine	1
Sambucus racemosa L.	Red Elderberry		Scrub, Forest Border, Forest (W)	Furgstal SA; Almageller Alp SA; near the settlement (August)				**4**
					fructus	systemic	Cold, vitamins, prevention in winter: **Jam**, put jam in tisane/1 spoon per day	3
					flos	systemic	Cold, fever, diaphoretic: **Infusion**. Fever, diaphoretic: Mixture with Tiliae flos	2
Amaryllidaceae								
Allium cepa L.	Globe Onion	*Zwieble*	Cultivated (K)	Garden				**1**
					bulbus	systemic	Cold: **Soaked in sugar** (rock candy), drink in sips	1
Allium sativum L.	Cultivated Garlic	*Chnobli*	Cultivated (K)	Market				**1**
					bulbus	systemic	High blood pressure, cholesterol level: **Tincture** (pome fruit schnapps), 2-3x daily 15-30 drops	1
Allium schoenoprasum L.	Wild Chives		Cultivated, Moor (S)	Garden				**1**
					folium		**Cullinary**: Spice	1
Apiaceae								
Aegopodium podagraria L.	Bishop's Goutweed	*Girsch*	Shrub Meadow, Forest (W)	Eienalp SA				**1**

Family								***TI**
Scientific Name[1]	*English Name* [2]	*Vernacular Name*	*Habitat*[3]	*Collection Place (Time)*	*Parts Used*	*Application*	*Use*	**UR*
					folium	topical	Gout, arthritis, rheumatism: **Oil**	1
Carum carvi L.	Caraway	*Chemmi*	Rich Pasture, Alpine Meadow, Shrub Meadow (F)	on the alp during haymaking				**1**
					fructus	systemic	Flatulence: **Infusion**	1
Peucedanum ostruthium (L.) WDJ Koch	Masterwort	*Aschtränzu, Schtränzu*	Tall Herbaceous Vegetation, Brookside, Alpine Meadow (B)	Mattmark SA; near the settlement (spring, autumn)				**5**
					folium	topical	Wounds, inflamed-, incised-: **Compress** (fresh leaves)	3
					folium	topical	Wounds, joints: **Oil extraction** (cooking up with milking grease)	2
					rhizoma	systemic	Sore throat, digestion: **Tincture** (vodka)	1
					rhizoma	systemic	Sore throat, digestion: **Infusion**	1
					rhizoma	systemic	Sore throat, digestion: **Dry** rhizome pieces	1
					herba		**Ornamental**: Bouquet	1
					herba		**Fodder**: Additional fodder at evening for cows with *Rumex alpinus*	1
Asteraceae								
Achillea erba-rotta ssp. *moschata* (Wulfen) Vacc.	Musk Millfoil	*Iva-Chrüt*	Lime-deficient Rock Debris, Moraine, (B)	Heimischgarte SB, Hoferälpi SB; Eienalp SA; Triftalp SG; Mattmark SA; Furgstalde SA (early				**5**

Family								***TI**
Scientific Name[1]	*English Name* [2]	*Vernacular Name*	*Habitat*[3]	*Collection Place (Time)*	*Parts Used*	*Application*	*Use*	**UR*
					herba	systemic	Gastric trouble, digestion, appetizing, detoxification: **Infusion** (dry herba in shadow). Detoxification: After chemotherapie , mixture with *Urtica dioica, Calendula officinalis*	4
					herba	systemic	Digestion, females herb: **Liqueur** (tincture, water, sugar)	1
					herba		**Cullinary**: Liqueur (tincture, water, sugar)	1
Achillea millefolium agg.	Yarrow		Meadows (F)	Heimischgarte SB, Hoferälpi SB; near the settlement				**9**
					folium	systemic	Gastric trouble, digestion, appetizing, prevention in winter, females herb, panacea: **Infusion** (dry herba in shadow)	7
					flos	systemic	High blood pressure, spring tea: **Infusion** with *Tussilago farfara, Equisetum arvense*	1
					folium	systemic	Digestion, sleep aid: **Tincture** (vodka)	2
					folium	topical	Joint pain, wounds: **Oil extraction** (coconut oil/milking grease)	2

Family								***TI**
Scientific Name[1]	*English Name* [2]	*Vernacular Name*	*Habitat*[3]	*Collection Place (Time)*	*Parts Used*	*Application*	*Use*	**UR*
Antennaria carpatica (Wahlenb.) Bluff & Fingerh.	Carpathian Pussytoes	*Chatzepfötli*	Stony Mountain Pastures (B)	Eienalp SA; Triftalp SG (July)				**1**
					flos	systemic	Cough, blood-puryfing, anti-inflammatory: **Infusion**	1
Arnica montana L.	Mountain Arnica		Alpine Pastures (B)	Heimischgarte SB; Hoferälpi SB; Furggstalde SA; Mattmark SB; Distelalp SA; Furggtälli SA; Kreuzboden SG; Almageller Alp SA (July)				**17**
					flos	topical	Joint pain, swollen joints, limb pain, sport injury, sprain, fractures, slashes, bruises: **Tincture** (schnapps/fruit schnapps/pome fruit schnapps/vodka, handful flos). Do not take in!	16
					flos	topical	Bruises, sport injury, joint pain, varices, muscle pain, rheumatism: **Oil extraction** (lard/olive oil/milking grease)	5
Artemisia absinthium L.	Absinthium	*Wärmüeta*	Waysides, Dry Grassland (U)	Heimischgarte SB, Hoferälpi SB; near the settlement				**6**
					folium	systemic	Digestion, gastric trouble, female complaint, appetizing: **Infusion**, 3 sips per day/for 8 days	4
					folium	systemic	Digestion: **Tincture** (schnapps/vodka), 1-2 drops	2
					folium	systemic	Digestion: **Pure** (eating fresh leaves)	1

Family								***TI**
Scientific Name[1]	*English Name* [2]	*Vernacular Name*	*Habitat*[3]	*Collection Place (Time)*	*Parts Used*	*Application*	*Use*	**UR*
					folium	systemic	Weakness, anorexic (veterinary medicine): **Infusion**. Calves	1
					folium	topical	Inflamed wounds (veterinary medicine): **Compress**. Cows	1
***Artemisia umbelliformis* Lam.	Alpine Wormwood	*Genepi*	Stony Mountain Pastures (B)	Distelalp SA; Mattmark SA (July)				**5**
					herba	systemic	Prevention in winter, cold, gastric trouble, digestion, stomach cramps: **Tincture** (apple schnapps/pome fruit schnapps/schnapps, sometimes processed into liqueur)	4
					herba	systemic	Digestion: **Infusion**	2
Bellis perennis L.	Lawndaisy		Rich Pasture, Waysides (F)	Vispertal				**1**
					flos	topical	Psoriasis: **Oil extraction** (olive oil)	1
Calendula officinalis L.	Pot Marigold	*Ringelblüemu*	Cultivated (K)	Garden				**11**
					flos	topical	Wounds, dry skin, skin irritation, blemished skin, babies bottom, varices, psoriasis, neurodermitis, joint pain, limb pain, panacea: **Oil extraction** (milking grease/lard/olive oil/vaseline)	11
					flos	systemic	Vertigo: **tincture** (pome fruit schnapps)	1
					flos	systemic	Detoxification: **Infusion** with *Achillea erba-rotta* ssp. *moschata*, *Urtica dioica*. After Chemotherapy	1

Family								***TI**
Scientific Name[1]	*English Name* [2]	*Vernacular Name*	*Habitat*[3]	*Collection Place (Time)*	*Parts Used*	*Application*	*Use*	**UR*
Echinacea spp.	Coneflower	*Echinacea*	Cultivated (K)	Garden				**2**
					herba	systemic	Support immune system, cold: **Tincture** (vodka)	1
					flos	systemic	Support immune system: **Infusion**	1
Leontopodium alpinum Cass.	Edelweiss	*Edelwiis*	Cultivated, Stony Mountain Pastures (B)	Garden				**2**
					herba	systemic	Diarrhea: **Infusion**	1
					herba	topical	Skin protection against UV and cold, skin recovery: **Oil**	1
Matricaria chamomilla L.	Chamomile		Cultivated, Ruderal Areas, Fields (U)	Garden				**4**
					flos	systemic	Fever, digestion, stomachache, sleep aid: **Infusion**	4
					flos	topical	Inflamation:**Infusion**, bath, compress, burble	2
Taraxacum officinale agg.	Common Dandelion	*Schwiimäie*	Rich Pastures (F)	Heimischgarte SB, Hoferälpi SB; Eienalp SA; Triftalp SG; near the settlement (in spring)				**6**
					stipes	systemic	Diuretic, kidney, digestion: **Pure** (eat fresh stem), several times per day for certain weeks	2
					folium	systemic	Purification: **Pure** (fresh leaves as salad)	1
					flos	systemic	Cold: **Honey**	4
					flos	systemic	Cold: **Syrup**	2
					flos		**Cullinary**: Jam, honey	3
					folium		**Cullinary**: salad	2

Family								***TI**
Scientific Name[1]	*English Name* [2]	*Vernacular Name*	*Habitat*[3]	*Collection Place (Time)*	*Parts Used*	*Application*	*Use*	**UR*
Tussilago farfara L.	Coltsfoot	*Sandpflanze*	Waysides, Ruderal Areas (P)	(in spring)				**3**
					flos	systemic	Cough, spring tea: **Infusion**. Spring tea with *Achillea millefolium, Equisetum arvense*	3
Berberidaceae								
Berberis vulgaris L.	European Barberry		Scrubs, Stony Areas (W)	Near the settlement				**1**
					fructus	systemic	Kidney: **Jam**, 1 spoon per day	1
Betulaceae								
Betula pendula Roth	Common birch		Pioneer Areas, Forest (W)	Eienalp SA; Triftalp SG (in spring)				**2**
					folium	systemic	Diuretic, blood-purifying: **Infusion** (taking the young	2
Corylus avellana L.	Cobnut	*Nussbaum*	Scrubs, Forest (W)					**1**
				near the settlement	cortex	systemic	Diabetes: **Infusion**	1
Boraginaceae								2
Symphytum officinale L.	Comfrey	*Beinwell*	Cultivated, Wet Meadows, Banks (S)	Garden				
					radix	topical	Wounds, bruises, callus: **Ointment**	2
Brassicaceae								
Brassica oleracea var. *sabellica* L.	Kale	*gekräuster Chabus*	Cultivated (K)	Garden (in autumn)				**1**
					folium	systemic	Cold: **Oil extraction,** one spoon per day	1
					folium	topical	Cold, cough: **Oil extraction** (only the green leaves, lard)	1

Family								***TI**
Scientific Name[1]	*English Name* [2]	*Vernacular Name*	*Habitat*[3]	*Collection Place (Time)*	*Parts Used*	*Application*	*Use*	**UR*
Brassica oleracea var. capitata L.	White Cabbage	*Wiis-Chabus*	Cultivated (K)	Garden				**1**
					folium	topical	Joints: **Compress** (fresh leaves)	1
Capsella bursa-pastoris (L.) Medik.	Shepherd's Purse		Ruderal Area (U)	Near the settlement				**1**
					folium	systemic	Nosebleed: **Infusion**	1
Caprifoliaceae								
***Valeriana celtica* L.	Alpine Valerian	*Baldrian*	Stony Mountain Pastures (B)	Rufibodmen SA				**1**
					flos	systemic	Calmative: **Infusion**	1
Crassulaceae								
Rhodiola rosea L.	King's Crown		Stony Mountain Pastures (B)	Mattmark SA				**1**
					rhizoma	systemic	Stimulant, Alzheimer disease, stress reduction, anti-aging: **Tincture**	1
Cupressaceae								
Juniperus communis L.	Juniper	*Holderbeer, Chrüzerli*	Scrubs, Open Forest (W)	Almageller Alp SA; Furgställi SA; Heimischgarte SB; Hoferälpi SB (in autumn)				**6**
					fructus	topical	Joint pain, limb pain, stiffness, gout, chondroic hands, arthrosis, fractions: **Tincture** (williams) every day	4
					fructus	topical	Breast pain: **Jam.** After Radiotherapy of breast cancer)	1

Family								*TI
Scientific Name[1]	*English Name* [2]	*Vernacular Name*	*Habitat*[3]	*Collection Place (Time)*	*Parts Used*	*Application*	*Use*	*UR
					fructus	topical	Swollen fingers: **Compress** (cooked and smashed fruits)	1
					fructus	topical	Joint pain, inflammatory, arthritis: **Oil extraction**	1
					fructus		**Cullinary**: Spice for sauerkraut. Eat berries of tincture	3
Dryopteridaceae								
Dryopteris filix-mas (L.) Schott	Male Fern		Tall Herbaceous Vegetation, Forests, Meadows (W)	Near the settlement				**1**
					folium	topical	Rheumatism, knee pain: **Tincture, oil extraction, compress** (fresh leaves)	1
Equisetaceae								
Equisetum arvense L.	Field Horsetail	*Chatzeschwanz*	Ruderal Areas, Waysides (U)	Furgstalden SA; Rufibodmen SA; near the settlement				**3**
					herba	systemic	Diuretic, spring tea, analgesic: **Infusion**. Spring tea with *Achillea millefolium, Tussilago farfara*	2
					herba	topical	Joint pain, inflamed joints, open wounds: **Infusion** (take a bath or compress with infussion)	2
Ericaceae								
Rhododendron ferrugineum L.	Alpine Rose		Meadows, Forest (B)	Near the settlement				**2**
					flos	systemic	Cardiotonic: **Infusion**. Cold: **Jam** with *Abies alba*	2

Family								***TI**
Scientific Name[1]	*English Name* [2]	*Vernacular Name*	*Habitat*[3]	*Collection Place (Time)*	*Parts Used*	*Application*	*Use*	**UR*
Vaccinium myrtillus L.	Whortleberry	*Heipere*	Meadows, Forest (W)	Heimischgarte SB, Hoferälpi SB; Eienalp SA; Triftalp SG; Rufibodme SA				**5**
					fructus	systemic	Diarrhea: **Pure** (eat dry berries)	3
					fructus		**Cullinary**: Jam, cooked (poor	2
Vaccinium vitis-idaea L.	Lingonberry	*Griffle*	Meadows, Forest (W)	Heimischgarte SB; Almageller Alp SA; Furgställi SA; Rufibodme SA; near the settlement (in autumn/september)				**5**
					fructus	systemic	Diuretic, kidney, inflamed bladder, bladder: **Jam**	5
					fructus	systemic	Diuretic: **Infusion** (dry berries)	1
					fructus		**Cullinary**: Jam	1
Fabaceae								
Anthyllis vulneraria agg.	Kidneyvetch		Meadows (T)	Eienalp SA				**1**
					herba	topical	Wounds: **Oil extraction** (olive oil)	1
Gentianaceae								
Gentiana purpurea L.	Purple Gentian		Tall Herbaceous Vegetation, Forests, Meadows (B)					**1**
					rhizoma	systemic	Digestion: **Tincture** (schnapps)	1
Geraniaceae								
Geranium robertianum L.	Herb Robert		Ruderal Area, Forests (U)					**1**
					folium	topical	Eczemas: **Oil extraction**	1

Family								*TI
Scientific Name[1]	*English Name* [2]	*Vernacular Name*	*Habitat*[3]	*Collection Place (Time)*	*Parts Used*	*Application*	*Use*	*UR
Hypericaceae								
Hypericum perforatum L.	St John's Wort	*Johannischrüt*	Cultivated, Dry Meadows, Forest Border, Open Forest (T)	Kapellenweg SF; garden; purchased (June, July)				**7**
					flos	topical	Joint pain, back pain, arthrosis, disc prolaps, massage-oil, psoriasis, neurodermitis, wounds, scars: **Oil extraction** (olive oil/sheep's wool)	5
					flos	topical	Wounds, scars: **Tincture** (schnapps)	2
					flos	systemic	Stress, nervousness, sleep disorders, depression: **Tincture** (schnapps/pome fruit schnapps), one spoon per day	2
					flos	systemic	Nerves, calmative: **Infusion**	2
Lamiaceae								
Hyssopus officinalis L.	Hyssop	*Isob*	Dry Meadows (T)					**1**
					herba	systemic	Lung: **Infusion**	1
Monarda didyma L.	Scarlet Beebalm	*Melisse*	Cultivated (K)	Garden				**1**
					flos		**Cullinary**: Infusion	1
Mentha x pipera L.	Peppermint		Cultivated (K)	Garden				**1**
					folium	systemic	Intestine: **Infusion**	1
Rosmarinus officinalis L.	Rosemary		Cultivated (K)	Garden				**1**
					folium	topical	Stress, nerves, anticonvulsive, massage-oil: **Oil extraction** (olive oil)	1
					folium	systemic	Vertigo: **Tincture** (pome fruit schnapps)	1

Family								***TI**
Scientific Name[1]	*English Name* [2]	*Vernacular Name*	*Habitat*[3]	*Collection Place (Time)*	*Parts Used*	*Application*	*Use*	**UR*
Salvia pratensis L.	Introduced Sage		Dry Meadows (T)	Eienalp SA; Triftalp SG (July)				**2**
					folium	systemic	Blood-purifying, cough, burble: **Infusion**	2
Thymus spp.	Thyme	*Fäldchelle*	Dry Meadows, Stony Alpine Pastures (T, B)	Heimischgarte SB; Hoferälpi SB; Triftalp SG; Furggalp SA; Eienalp SA; Furggstalden SA; Mattmark SA;near the settlement (July or end of summer)				**14**
					herba	systemic	Cold, flu, cough, lung, catarrh, antibiotic, anti-inflammatory, cardiotonic, blood pressure: **Infusion** (dark rock candy/honey). Drv in shadow	13
					herba	systemic	Cold, flu, cough: **Syrup**	1
					herba	systemic	Cough, antibiotic: **Tincture** (vodka)	1
					herba	topical	Cold: **Oil extraction**. Apply on nose, chest, upper back	1
					herba		**Cullinary**: Spice	1
Lycopodiaceae								
Lycopodium annotinum L.	Stiff Clubmoss		Forest, Scrubs (W)					**1**
					herba	systemic	Liver: **Infusion**	1

Family								***TI**
Scientific Name[1]	*English Name* [2]	*Vernacular Name*	*Habitat*[3]	*Collection Place (Time)*	*Parts Used*	*Application*	*Use*	**UR*
Onagraceae								
Epilobium spp.	Willowherb		Open Forests (P)					**1**
					herba	systemic	Diuretic, prostate: **Infusion**	1
Orobanchaceae								
Euphrasia spp.	Eyebright	*Ägsterli*	Alpine Pastures (S, B)	Eienalp SA; Triftalp SG; near the settlement				**5**
					herba	topical	Eyes, inflamed eyes, festering eyes: **Infusion**	4
					herba	topical	Inflamed eyes: **Compress** (Fresh herbs)	1
Parmeliaceae								
***Cetraria islandica* (L.) Ach.	Iceland moss	*Mooseggä*		Heimischgarte SB, Hoferälpi SB; Furgtal SA; Mattmark SA; Eienalp SA; Triftalp SG; near the settlement				**6**
					lichen	systemic	Flu, cold, cough: **Infusion** (milk, honey). Contains penicilin	6
Pinaceae								
Larix decidua L.	European larch		Forest (W)	Eienalp SA; near the settlement				**2**
					summitates	systemic	Cold: **Honey**	1
					resina	topical	Rheumatism, lumbago, sciatic nerve, cough, blistering, eczema, skin rashes: **Oil extraction** (olive oil). Can be used as an additional ingredient in ointments	1
					summitates		**Cullinary**: Honey	1

Family								***TI**
Scientific Name[1]	*English Name* [2]	*Vernacular Name*	*Habitat*[3]	*Collection Place (Time)*	*Parts Used*	*Application*	*Use*	**UR*
Picea abies L.	Norway Spruce		Forest (W)	Eienalp SA; Triftalp SG; Heimischgarte SB, Hoferälpi SB; near the settlement				**6**
					summitates	systemic	Cold, cough, reinforcement, prevention in winter: **Syrup**	4
					summitates	topical	Festering wounds, rheumatism, joint pain, panacea: **Oil extraction**.	2
					strobulus	systemic	Cold, cough: **Syrup**	1
					summitates		**Cullinary:** Jam	1
Plantaginaceae								
Plantago lanceolata L.	English Plantain		Dry Meadows, Waysides (F)	Eienalp SA; Triftalp SG; near the settlement				**2**
					folium	systemic	Cough: **Infusion**	1
					folium	topical	Wounds: **Compress** (fresh leaves)	1
Plantago media L.	Hoary Plantain	*Wägiblätter, Wägiläsu*	Meadows, Waysides (T)	Heimischgarte SB, Hoferälpi SB; near the settlement				**3**
					folium	topical	Wounds: **Compress** (washed leaves with boiling water/smashed leaves)	2
					folium	systemic	Weakness, anorexic (veterinary medicine): **Infusion**. For calves	1

Family								***TI**
Scientific Name[1]	*English Name* [2]	*Vernacular Name*	*Habitat*[3]	*Collection Place (Time)*	*Parts Used*	*Application*	*Use*	**UR*
Polygonaceae								
Rheum rhabarbarum L.	Garden Rhubarb		Cultivated (K)	Garden				**1**
					stipes		**Cullinary:** Liqueur	1
Rumex alpinus L.	Munk's Rhubarb	*Blaggo*	Alpine Pastures (B)	Near the settlement				**3**
					folium		**Cullinary**: Cooked with sugar. Poor dishes in the past	1
					folium		**Fodder**: Additional fodder in the evening for cows with *Peucedanum ostruthium*	1
Primulaceae								
Primula spp.	*Primrose*		Open Forest, Dry Meadows (W, T)	Eienalp SA; Triftalp SG; near the settlement (in spring)				**4**
					flos	systemic	Cough, detoxification, sleep aid, calmative: **Infusion**. Dry in shadow	4
Rosaceae								
Alchemilla alpina L.	Alpine Lady's Mantle	*Silbermänteli*	Alpine Pastures (B)	Heimischgarte SB, Hoferälpi SB; Triftalp SG; Furgalp SA; Eienalp SA; Mattmark SA				**5**
					folium	systemic	Menstruation pain, femail complaint, abdominal pain, diuretic: **Infusion**	5

Family								***TI**
Scientific Name[1]	*English Name* [2]	*Vernacular Name*	*Habitat*[3]	*Collection Place (Time)*	*Parts Used*	*Application*	*Use*	**UR*
Alchemilla vulgaris agg.	Lady's Mantle	*Fröwamänteli, Fromantel*	Dry Meadows, Alpine Pastures	Heimischgarte SB, Hoferälpi SB; Triftalp SG; Furgalp SA; Eienalp SA; Mattmark SA				**5**
					folium	systemic	Menstruation pain, femail complaint, abdominal pain, diuretic: **Infusion**	5
Cratageus spp.	Whitethorn		Scrub, Forest Border (W)	Vispertal (September)				**1**
					fructus	systemic	Cardiotonic, heart pressure, vertigo: **Tincture** (pomes fruit schnapps). 2-3x daily 10-15 drops	1
Cydonia oblonga Mill.	Guince		Agriculture (K)	Purchased on market				**2**
					semen	topical	Strengthening of the eye, inflamed eyes: **Tincture** (Kirsch schnapps/schnapps). Slime seed	2
					fructus		**Cullinary**: Jam or compote	1
Rosa canina L.	Dog Rose	*Hagebutte*	Scrub, Forest Border (W)	Near the settlement				**1**
					fructus	systemic	Cold: **Infusion**	1
Sorbus aucuparia L.	European Rowan	*Vogelbeeri*	Forest (W)	Eienalp SA; near the settlement (September)				**2**
					fructus	systemic	Intraocular pressure, lymphedena, lymphatic flow disturbance, anti-inflammatory: **Tincture** (pome fruit schnapps), 3x daily 20 drops	2
					fructus		**Cullinary**: Jam with *Malus domestica* Borkh.	1

Family								***TI**
Scientific Name[1]	*English Name* [2]	*Vernacular Name*	*Habitat*[3]	*Collection Place (Time)*	*Parts Used*	*Application*	*Use*	**UR*
Santalaceae								
Viscum album L.	European misteltoe		Forest (W)					**1**
					folium	systemic	Diabetes: **Infusion**	1
Sapindaceae								
Aesculus hippocastanum L.	Horse Chestnut		Agriculture (K)	Vispertal				**1**
					semen	systemic	Vein complains, heavy legs: **Tincture** (pome fruit schnapps), 3x daily 10 drops	1
					semen	topical	Varices, heavy legs: **Oil extraction** (Olive oil), apply every evening	1
Scrophulariaceae								
Verbascum spp.	Mullein		Cultivated (K)	Garden				**1**
					flos	systemic	Sore throat, cough: **Tincture** (vodka), take in with a sugar cube. Slime plant	1
Tropaeolaceae								
Tropaeolum majus L.	Garden Nasturtium	*Kapuzinerli*	Cultivated (K)	Garden				**1**
					flos	systemic	Antibiotic: **Pure** (fresh flowers), 3x daily	1

Family								***TI**
Scientific Name[1]	*English Name* [2]	*Vernacular Name*	*Habitat*[3]	*Collection Place (Time)*	*Parts Used*	*Application*	*Use*	**UR*
Urticaceae								
Urtica dioica L.	Common Nettle		Ruderal Areas, Forest, Bushes (U)	Eienalp SA; Triftalp SG; near the settlement; garden (in spring/June)				**9**
					folium	systemic	Diuretic, bladder, kidney, blood-purifying, gastric trouble, purge, spring tea: **Infusion**, 14 day cure. Collection of young shoots. Detoxification after chemotherapy mixture with *Achillea erba-rotta* ssp. m*oschata, Calendula officinalis*	8
					folium	systemic	Bladder, purge: **Tincture**	1
					folium	topical	Sleep aid: **Infusion** (foot bath)	1
					folium	topical	Face oitnment: **Oil extraction**	1
					radix	topical	Hair loss: **Infusion**	1

1: Flora Helvetica

2: Encycopedia of Life. URL: https://eol.org/

3: Flora Helvetica: Red list of habitat, ecological group as letter in brackets
F: Rich Pasture Plant, K: Crop,P: Pioneer Plant, S: Swamp Plant, T: Dry Plant U: Ruderal Plant, W: Forest Plant

* TI: Total Interviewees per species
UR: number of interviewees per Use-Report

** *Artemisia umbelliformis:* Herbar specimen and picture available. due to similar appearance and same place of occurrence
Other possible species: *A. genipi, A. borealis, A. glacialis*
Valeriana celtica: Only widespread species in the valley, interviewee described species as small plant with dark red flowers
Cetraria islandica: Lichen

Appendix D: Citation-Reports

Table 1: References of history and recent ethnobotanical Studies.

ID	Name used for *Peucedanum ostruthium*	References
Monastic medicine 8th - 12th Century		
Macer Floridus (1065)	Ostrutium, Meisterwurz	Höhepunkte der Klostermedizin: Der Macer floridus und das Herbarium des Vitus Auslasser. (Mayer, 2001)
Bingen (1150-1160)	Astrencia (Astrantia Ostruthium), Strenze	Die Physica der heiligen Hildegard (Berendes, 1897)
Renaissance 16th - 18th Century		
Paracelsus (1536)	Ostrutio	Die Heilkraft der Pflanzen (Flamm and Kröber, 1935)
		Chrut und Unchrut (Künzle & Opplinger, 2018)
Fuchs (1543)	Meisterwurz, Laserpitium germanicum	New Kreuterbuch (Leonhart Fuchs, 1543)
Bock (1546)	Meisterwurz	Kreuterbuch (Hieronymus Bock, 1546)
Wolff (1690)	Radicem Ostrutii, Imperatoriae, Magistrantiae	Scrutinium amuletorum medicum (p. 99) - Jacobi Wolff, 1690 (Hoffmann-Krayer, 1935; Marzell, 1922)
Zedler (1744)	Imperatoria	Grosses vollständiges Universal-Lexicon aller Wissenschafften und Künste (Zedler, 1744)
Modern and contemporary era 19th and 20th Century		
Geiger (1840)	Imperatoria Ostruthium L.	Pharmaceutische Botanik (Geiger, 1840)
Rochholz (1857)	Meisterwurz	Alemannisches Kinderlied und Kinderspiel aus der Schweiz (Rochholz, 1857)
Herzog (1871)	Astränzen, Astrantia	Schweizersagen: Für für jung und alt dargestellt (Herzog, 1871)
Wartmann (1874)	Strenza, Hoorstrenza, Ostrenza	Beiträge zur St. Gallischen Volksbotanik (Wartmann 1874)
Tschumpert (1892)		Versuch eines bündnerischen Idiotikons (Tschumpert, 1892)
Weinhold (1894)	Imperatoria Ostruthium L.	Zeitschrift des Vereins für Volkskunde (Weinhold, 1894)
Luck (1902)	Astrenzenwurzeln	Rätische Alpensagen: Gestalten und Bilder aus der Sagenwelt Graubündens (Luck, 1990)
John (1905)	Meisterwurzel	Sitte, Brauch und Volksglaube im deutschen Westböhmen (John, 1905)

von Andrian (1905)	Meisterwurzeln, Imperatoria Ostruthium	Die Altausser - ein Beitrag zur Volkskunde des Salzkammergutes (von Andrian, 1905)
Stoll (1909)	Strenzenwurzeln	Zur Kenntnis des Zauberglaubens, der Volksmagie und Volksmedizin in der Schweiz (Stoll, 1909)
Künzle (1911)		Chrut und Unchrut (Künzle & Opplinger, 2018)
Marzell (1922)	Meisterwurz, Peucedanum Ostruthium	Unsere Heilpflanzen: ihre Geschichte und ihre Stellung in der Volkskunde – Ethnobotanische Streifzüge (Marzell, 1922)
Zimmermann (1927)	Meisterkraut, Meisterwurz, Imperatoria ostrutium	Badische Volksheilkunde (Zimmermann, 1927)
Hoffmann-Kayer (1935)	Meisterkraut, Meisterwurz, Imperatoria ostrutium	Handwörterbuch des deutschen Aberglaubens (Hoffmann-Kayer, 1935)
Vonarburg (1988)	Meisterwurz, Imperatoria ostruthium L.	Natürlich gesund mit Heilpflanzen (Vonarburg 1988)
Recent ethnobotanic Studies		
Salzburg (1983)		Ethnobotanik oder die Vernetzung von Menschen und Pflanze, Fieldwork in 1983 (Pohl-Sennhauser, 2008)
Osttirol (2006)		Lokales Erfahrungswissen über Pflanzenarten aus Wildsammlung mit Verwendung in der Fütterung und als Hausmittel in der Volksheilkunde bei landwirtschaftlichen Nutztieren in Osttirol (Vogl-Lukasser et al. 2006)
Val d'Anniviers (2008)	agró, l'	Plantes et Savoirs des Alpes: L'example du val d'Anniviers (Brüschweiler, 2008)
Tessin (2009)	Aschtraanzu, Ggunellanuchrüt (Bosco Gurin)	Recherche ethnobotanique dans la région du Canton du Tessin (Poretti 2009)
Valle Variata (2009)	imperatoria (it)	Alpine ethnobotany in Italy: traditional knowledge of gastronomic and medicinal plants among the Occitans of the upper Varaita valley, Piedmont (Pieroni 2009)
Walsertal (2010-2012)		„Meisterwurz und Aderlass“ Anwendung und Wandel des ethnoveterinärmedizinischen Wissens im Großen Walsertal/Vorarlberg unter Hervorhebung der pflanzlichen Hausmittel und des religiösen Brauchtums (Grabowski 2010)
		Gathering “tea” – from necessity to connectedness with nature. Local knowledge about wild plant gathering in the Biosphere Reserve Grosses Walsertal (Austria) (Grasser et al. 2012)
Graubünden (2013)		Jenzerwurz und Chäslichrut: Pflanzliche Hausmittel für Rinder, Schafe, Ziegen, Schweine und Pferd (Klarer et al. 2013)
Prättigau (2013)	Astränzä	Ethnobotanik im Prättigau: Medizinalpflanzen - Nutzung und Wissen (Wegmann, 2013)
central/lower Valais (2014)		Forgotten Edible Alpine Plants in the Canton of Valais (Abbet 2014)

Swiss (2016)	Herbalist	Swiss medicinal flora: a result of knowledge transmission over the last two millennia (Dal Cero 2016)
Saas-Tal (2019)	Astränzu, Schtränzu	Knowledge from locals of Saas-Tal, recorded for this thesis

Table 2: Categories of medicinal, apotropaic and veterinary application

Medicinal categories		
CAR: Cardiovascular and lymph system		
blood cotting	internal wounds	oedema
circulation	lymphedema	
internal bleeding		
DER: Dermatological		
abscess	drying out wounds	infected wounds
abcess pain	excemas	inflamed wounds
anal warts	festering wounds	pemphigus
boils	itch	wounds
cut	incised wounds	wound healing
disinfectant		
DET: Detoxification		
animal bites	disinfectant	infection
animal stitches	external poisoning	internal poisoning
bite wound	food intoxification	sepsis (internal, external)
FEV: Fever and immune system		
anti-inflammatory	hay fever	strengthening immune system
diaphoretic	immunostimmulant	swollen glands
fever	prevention in winter	
GAS: Gastrointestinal and liver system		
abdominal pain	digestion	sickness
appetizing	flatulence	spleen sclerosis
bloating	icterus	stomach
chronic gastritis	heartburn	stomachache
colic	liver	stomachic
diarrhea	pyrosis	weak digestion
GYN: Gynecology		
abortion	inflammation of uterur	milkflow support
dead birth	labor pain	pregnant fatigue
female disorders	menstrual stimulating	

NER: Nervous system		
calmative	general strengthening	meningitis
general activation	headache	nervous spasm
TEE: Teeth		
mouth	Toothache	
RES: Respiratory		
asthma	loung	spitting of blood
breathlessness	pneumonia	sore throat
cold	sinusitis	sternutatory
cough	sniffles	throat
influenza		
SKM: Skeleto-muscular		
arthritic knees	gout nodes	joints
fracture pain	hip pain	sciatic
gout	injuries	
URO: Urological		
diuretic	urinary tract infection	urolith
inflammation of the bladder		
OTH: Other		
abdominal tumor	lepra	tuberculosis
allergies	male impotence	ulcer
diabetes	plague	uterus tumor
ear infection	splenic tumor	warm up the body

Apotropaic applications		
BLE: Blessing		
blessing cows	christmas	disinfection on 3 kings day
HEA: Healing		
anti-inflammatory	coughing	teething calves
backache	epilepsy	tuberculosis
catarrh	eye disease	wound healing
PRO: Protection		
apotropaic	keep away diseases	prevention against suffering
carry in pocket	keep away harm	protect wounds from festering
defense against suffering	keep away lightnings	protection against disease
gives special forces	plague	protection against plague

WIT: Witchcraft		
bewitched cows	magic powder	witch defense

Veterinary medicine		
DER-V: Dermatological		
bruises	open wounds	wound healing
open claws	wounds	
GAS-V: Gastrointestinal		
Abdominal pain	chronic diarrhea	gastrointestinal disease
digestion	flatulence	stomachache
INF-V: Infections		
claw disease	navel infection	udder inflammation
festering claw wounds	teat infection	viral infection
inflamed wounds		
OTH-V: Other		
afterbirth	limb complains	strengthen immune system
bloody mouth mucosa	pulled muscels	swollen knees

OTH-A: Other applications		
bouquet	fodder	protect cheese from mice
brush object	ingredient in cheese	odor
disinfection of rooms		

Plant Part Used App- lication	Preparation and Indication	Reference[1]	Mixture
Folium			
systemic application			
	Liver, stomach, internal poisoning: **Raw, juice**	Bock (1546)	
	Pneumonia, spitting of blood (from lung), sickness: **Infusion**	Val d'Anniviers (2008)	
topic application			
	Bite wound (from a dog or a natter): **Pulp**	Fuchs (1543)	
	Festering wounds: **Raw, pulp,** leaves are laid on the wound	Marzell (1922)	
	Arthritic knees, disinfectant, wound healing, drying out wounds, festering wounds: **Compress** (fresh leaves mashed with a rolling pin or flask, dry leaves laid in milk or white wine over night). Arthritic knees: Put in compress with a bit of salt	Val d'Anniviers (2008)	
	Abscess, abscess pain: **Compress** (leaves coated with larch resin or simply cut into small pieces)	Val d'Anniviers (2008)	*Larix decidua* L.
	Disinfectant, wound healing, drying out wounds, festering wounds: **Infusion** (wash out the wounds)	Val d'Anniviers (2008)	
	Pain after fracture, allergies, itch: **Bath** (with fresh or dry leaves, cooked in water)	Val d'Anniviers (2008)	
	Allergies, itch: **Raw** (with fresh or dry leaves), rub on the skin	Val d'Anniviers (2008)	
	Toothache: **Chewing**, mixed with tobacco (region Blenio)	Tessin (2009)	*Nicotiana tabacum* L.
	Wounds, inflamed wounds, incised wounds: **Compress** (with fresh leaves)	Saas-Tal (2019)	
	Wounds, joints: **Ointment** (cooking up with milking grease)	Saas-Tal (2019)	
veterinary application			
	Claw disease (cattle): **Compress** (fresh or dry leaves), with *Thymus* spp., dry the moistness and disinfect the claw	Val d'Anniviers (2008)	
	Wound healing, inflamed wounds: **Infusion** (fresh or dry leaves), wash out the wounds	Val d'Anniviers (2008)	
	Wounds (cattle): **Infusion** (with 4-5 leaves), wash out the wounds	Graubünden (2013)	

Plant Part Used App- lication	Preparation and Indication	Reference[1]	Mixture
Flos			
other application			
	Protect the **cheese** from mice: Before leaving the cheese to overwinter, rub it with the leaves to keep the mice away	Val d'Anniviers (2008)	
Herba			
systemic application			
	Internal wounds, calmative, dead birth: **Infusion** (with wine and water)	Fuchs (1543)	
flos, semen and rhizoma	Flatulence, bloating, colic, cold, immunostimulant: **Infusion**	central/lower Valais (2014)	
topic application			
flos and rhizoma	Infected wounds, gout nodes: **Ointment** (mix powder with olive oil)	Künzle (1911)	
flos and/or rhizoma	Wounds: **Bath** (infusion)	Walsertal (2010-2012)	
volatile application			
	Plaque (toxic air): **Fumigation** (of the room)	Fuchs (1543)	
	Anal warts: **Fumigation** (over the spot)	Fuchs (1543)	
flos and rhizoma	Labor pain, pregnant fatique : **Fumigation** (hot coal on the ground with rhizome and hot coal in pot with leaves. With schnapps and other herbs e.g. *Thymus* spp.), sit on the pot	Val d'Anniviers (2008)	*Thymus* spp., etc.

Plant Part Used App-lication	Preparation and Indication	Reference[1]	Mixture
Herba			
apotropaic application			
	Bouquet with seven herbs blessed on Assumption day ("Frauenbüschel"): Fumigation (bouquet and incense) and blessing of all rooms in the house and sheds to **keep away harm and diseases**	Osttirol (2006)	*Boswellia* spp.
	Bouquet (from Assumption day) used in the twelve nights after christmas ("Raunächte"): Fumigation of the house and sheds to **keep away harm, disease** and especially **lightnings**, further the fumigation dispels evil spirits	Osttirol (2006)	
	Bouquet on Assumption day (with many other healing herbs): Bless the bouquet, drink tea with a part of bouquet (**gives special forces**) and put the other part in the hey for **livestocks to bless** them	Walsertal (2010-2012)	
veterinary application			
	Part of **litter** in shed	Tessin (2009)	
	Open wounds, festering claw wounds (cattles). Swollen knees, limb complaints, open claws, claw disease, udder inflammation, bruises (cattles, cows): **Bath, compress** (infusion)	Walsertal (2010-2012)	
flos and/or rhizoma	Claw disease: **Bath** (infusion), **pulp**	Walsertal (2010-2012)	
	Wounds (cattle): Infusion, wash out the wounds	Graubünden (2013)	
	Fodder: Additional fodder at evening for cows with *Rumex alpinus*	Saas-Tal (2019)	*Rumex alpinus* L.
other application			
	Ingredient of green goat **cheese** in Glarus	Geiger (1840)	
	Brush objects with the Infusion (desinfectant, keeps mice away)	Val d'Anniviers (2008)	
	Bouquet	Saas-Tal (2019)	

Plant Part Used App- lication	Preparation and Indication	Reference[1]	Mixture
Rhizoma			
systemic application			
	Liver, Icterus, spleen sclerosis, urolith, diuretic, menstrual stimulating, breathlessness: **Pulp** (with wine)	Macer Floridus (1065)	
	Sniffles: **Juice** (mixed with honey), nasal application	Macer Floridus (1065)	
	Icterus: **Juice** (mixed with female milk), nasal application	Macer Floridus (1065)	
	Sternutatory (as effective as *Veratrum album* L.): **Powder**, nasal application	Macer Floridus (1065)	
	Abortion, menstrual stimulating: **Suppository** (woollen sup.), vaginal application	Macer Floridus (1065)	
	Weak digestion: **Bread** (eat 1-3 pieces every morning)	Bingen (1150-1160)	*Aristolochia* spp., *Pimpinella* spp., *Zingiber officinale* Roscoe., "Citocaciensaft"
	Fever: **Pulp** (take in with wine)	Bingen (1150-1160)	
	Diabetes, splenic tumor, tumor in abdominal cavity or uterus, urolith, hay fever, internal poisoning: **Infusion** (with whine)	Paracelsus (1536)	
	Animal bites and stitches (poisonous), nervous spasm, lung: **Juice**	Fuchs (1543)	
	Icterus, oedema, milkflow support, blood cotting: **Juice** (mixed with dried figs)	Fuchs (1543)	*Ficus carica* L.
	Stomachic, appetizing, diuretic, menstrual stimulating: **Juice** (mixed with raw egg)	Fuchs (1543)	
	Diaphoretic, male impotence: **Infusion** (with wine)	Fuchs (1543)	
	Sniffles: **Powder**, nasal application	Bock (1546)	
	Liver, stomach, internal poisoning: **Raw, juice**	Bock (1546)	
	Milkflow support, blood cotting: **Powder**	Bock (1546)	
	Cough, diuretic, urolith, female disorders, dead birth, hip pain, sciatic, diaphoretic, oedema, male impotence, calmative, nervous spasm: **Infusion** (cooked with red wine), **distilled**	Bock (1546)	

Plant Part Used App- lication	Preparation and Indication	Reference[1]	Mixture
Rhizoma			
systemic application			
	Fever, plague: **Infusion** (cooked with white wine)	Bock (1546)	*Angelica* spp., *Levisticum* spp., *Ruta* spp., *Rosmarinus officinalis* L., *Origanum majorana* L., *Ocimum basilicum* L., *Laurus nobilis* L., *Myristica fragans* Houtt., *Cinnamomum* spp., etc.
	Flatulence, colic, pyrosis: **Distilled**, *Peucedanum ostruthium* was a part of Spiritum carminativus Sylvii ("Blähungsgeist")	Zedler (1744)	
	Stomachache: **Raw** (in pieces)	Wartmann (1874)	
	Sniffles: **Powder**, nasal application	Künzle (1911)	
	Fever: **Powder** (with red wine), daily one tea spoon	Künzle (1911)	
	Internal bleeding, internal poisoning, diarrhea: **Infusion**	Künzle (1911)	
	Abdominal pain	Marzell (1922)	
	Chronic gastritis, asthma, sniffles, hay fever, circulation, lymphedema, inflamation of uterus, digestion, infection, strengthening of the immune system: **Infusion, tincture, tincture** (with wine)	Vonarburg (1988)	
	Stomachache, cold, toothache: **Dry or raw pieces** (chewing)	Walsertal (2010-2012)	
	Circulation: **Distilled** (schnapps)	Walsertal (2010-2012)	
	Toothache, stomachache: **Dry pieces** (chewing)	Prättigau (2013)	
	Stomachache, general strengthening, activation: **Infusion, tincture**	Prättigau (2013)	
	Digestion, food intoxification: **Tincture**	Swiss Herbalist (2016)	
	Sore throat, digestion: **Tincture, Infusion, dry pieces**	Saas-Tal (2019)	

Plant Part Used App-lication	Preparation and Indication	Reference[1]	Mixture
Rhizoma			
topic application			
	Lepra: **Ointment** (juice, strong wine, pulp with flour)	Macer Floridus (1065)	
	Pemphigus ("Blatterblase"): **Ointment** (juice, barley powder)	Macer Floridus (1065)	*Hordeum vulgare* L.
	External poisoning	Paracelsus (1536)	
	Animal bites and stitches (poisonous): **Juice**	Fuchs (1543)	
	Excemas: **Juice** (mixed with vinegar)	Fuchs (1543)	
	Hip pain: **Juice** (mixed with cooked honey)	Fuchs (1543)	
	Gout: **Compress** (infusion with water and vinegar)	Fuchs (1543)	
	Toothache: **Infusion** (cooked with red wein)	Bock (1546)	
	Wounds, infections, blood cotting, festering wounds, animal bites (poisonous): **Raw, juice, distilled**	Bock (1546)	
	Gout: **Compress** (cooked with water and vinegar)	Bock (1546)	
	Toothache: **Raw** (a piece), "zieht den kalten Fluss"	Wartmann (1874)	
	Swollen glands, ulcer, boils, festering wounds, sepsis (internal, external): **Compress** (pulp of powder and water)	Vonarburg (1988)	
	Tuberculosis, pneumonia, cough: **Compress** (with lard, schnapps and wool), put compress on chest and back	Val d'Anniviers (2008)	
	Wounds, anti-inflammatory: **Ointment**	Walsertal (2010-2012)	
	Wound infection, injuries, toothache: **Bath**	Swiss Herbalist (2016)	
volatile application			
	Mouth, throat: **Inhalation** (fume)	Bock (1546)	
	Toothache: **Smoke**	Wartmann (1874)	
	Headache, toothache: **Smoke**, take 3 pipes (magic number)	Stoll (1909)	
	Sniffles: **Inhalation**	Künzle (1911)	

Plant Part Used App-lication	Preparation and Indication	Reference[1]	Mixture
Rhizoma			
volatile application			
	Ear infection: **Fumigation**	Salzburg (1983)	
	Disinfection of the room, prevention in winter, influenza, meningitis, sinusitis, ear infection, disinfectant, wound healing, drying out wounds, festering wounds, abscess: **Fumigation** (smoking over the spot of sickness)	Val d'Anniviers (2008)	
	Urinary tract infection, inflammation of the bladder: **Fumigation** (coal and rhizome in bucket), sit on the bucket	Val d'Anniviers (2008)	
	Disinfection after sickness or deaths: **Fumigation** of rooms	Walsertal (2010-2012)	
apotropaic application			
	Coughing, catarrhs**:** Rhizomes are dug up at waxing moon, **tied on the back** and then thrown into the river	Wolff (1690)	
	Epilepsy: Rhizomes are **tied to the thumbs and toes**	Wolff (1690)	
	5th January: **Blessing** of *P. ostruthium* and other plants on january 5 after the church. "*In der Kirche, nach der Litanei, werden Enzian- Meister- (Imperatoria Ostruthium), Bibernel- (Pimpinella saxifraga) und Neunhäutelwurzeln (Allium Victorialis), Salz, Wasser, Kreide, Hanf, Wacholderbeeren und Weihrauch* ***geweiht****.",* in Altausee (AT)	von Andrian (1905)	*Gentiana lutea* L., *Pimpinella saxifraga* L., *Allium victorialis* L., *Juniperus* spp., *Boswellia* spp.
	Weisat in Altausee (AT): Blessing of a cow that had given birth to a live calf. "*Hat eine Kuh ein lebendes Kalb geboren, schält man sofort demselben die Klauen aus und lässt die Schalen von der Mutter fressen. Sie bekommt hierauf ein an ihrem rechten Horn aufgeschlagenes Ei, ein eigrosses Stück Rindsschmalz, ein Stück Zucker, einen Schnitt Brot mit Meisterwurzen und Weihwasser (das Weisat)."*	von Andrian (1905)	

Plant Part Used App- lication	Preparation and Indication	Reference[1]	Mixture
Rhizoma			
apotropaic application			
	Protection against the plague with a slogan ("Pestspruch"), contains *P. ostruthium* and *Pimpinella* spp. *"Vor vielen hundert Jahren wüthete einmal die Pest in Grindelwald, so dass unzählige Menschen starben. Kein Mittel wollte dagegen helfen. Allgemeine Trostlosigkeit. Da ruft von einem Felsen herab vernehmlich ein Bergmännlein:* "Bruchit Asträntzen und Pimpinäll, So stärben die Kranken nid so schnäll!" *Astrantia und Bibernell wurden angewendet, und dem Tod ward Einhalt gethan.",* Grindelwald (CH)	Herzog (1871)	*Pimpinella* spp.
	Eye diseases: **Necklace** (with red string and odd number of rhizome pieces), Evil substances are pulled by the necklace, in St. Gallen (CH)	Wartmann (1874)	
	Wound healing, anti-infammatory: **Carry in pocket**	Wartmann (1874)	
	Witch defense: Rhizomes are dug up on St. John's Eve and placed on the upper crossbeam of the stable door; then the witches cannot enter the stable and damage the cattle, in Graubünden (CH)	Tschumpert (1892)	
	A woman was accused of witchcraft in Graubünden (CH) in 1654 because she used a **magic powder** (made from rhizomes of *P. ostruthium* and 8 dried crickets) to bring diseases to livestock and to destroy the crop.	Luck (1902)	
	For bewitched cow that gives no more milk. Chopped garlic and masterwort sprinkled on salted bread and give it to the cow to **feed**. *"Es ist sehr gut vor Beraubung der Milch."*	John (1905)	*Allium sativum* L.
	Prevent the wound from festering: **Carry in pocket**	Marzell (1922)	
	Helps consumptives (tuberculosis): *"Nach einem alten Arzneibuch soll man die Meisterwurz am Karfreitag oder an einem Freitag im Neumond graben, sieben Stücklein davon nehmen und ebensoviel von einer Totentruhe, worin eine Kindbetterin gelegen, und das dem Schwindsüchtigen anhängen."*	Hoffmann-Kayer (1935)	

Plant Part Used App-lication	Preparation and Indication	Reference[1]	Mixture
Rhizoma			
apotropaic application			
	Christmas: **Fumigating** the living quarters before the christmas meal. "*In den Hoachenzeitentagen - so hiessen die Weihnachten - wird das heilige Mahl bereitet, die Richten (Gerichte) in die Stube gestellt, mit Weichenbruun besprengt und mit Meisterwurz (imperatoria ostrathium) eingeraucht; ebenso werden alle Gezimmer und Kammern geräuchtert.* ", in Giesstal (AT)	Weinhold (1894)	
	Teething calves: **Necklace** or amulet with masterwort to make teething easier for calves, in Frickingen (DE)	Zimmermann (1927)	
	Keep away disease ("Rindergrippe"): **Fumigation** of the cattle shed once a year (in combination with incense)	Osttirol (2006)	*Boswellia* spp.
	Protection against diseases: **Carry in Pocket** (region Bosco Gurin)	Tessin (2009)	
	Disinfection of the sheep shed on holy three kings day: **Fumigation** (mixed with other herbs)	Walsertal (2010-2012)	
	Protection against disease: **Carry in pocket**	Walsertal (2010-2012)	
	Backache: **Carry on the back** in a bag:	Walsertal (2010-2012)	
	Defense against suffering: **Fumigation**	Prättigau (2013)	
	Prevention against suffering: **Carry in pocket**	Prättigau (2013)	
	Apotropaic: **Fumigation**	Swiss Herbalist (2016)	
veterinary application			
	Stomachache: **Raw** (in pieces)	Wartmann (1874)	
	Abdominal pain (application in alpine regions)	Marzell (1922)	
	Wounds, claw disease (cattle), festering abscesses and hoof diseases (horse): **Infusion** (wash out)	Osttirol (2006)	
	Gastrointestinal diseases (cattle): **Infusion** (give with a bottle)	Osttirol (2006)	

Plant Part Used App- lication	Preparation and Indication	Reference[1]	Mixture
Rhizoma			
	Flatulence (calves), difficulty with the afterbirth (cows): **Tincture** (mixed with water)	Osttirol (2006)	
veterinary application			
	Navel infection (the smoke dries and disinfects), wound healing, inflamed wounds, fractures: **Fumigation** (smoking over the spot)	Val d'Anniviers (2008)	
	Inflammation of teats (sheeps): **Compress** (infusion)	Val d'Anniviers (2008)	
	Digestion (cattle and sheep): **Infusion, pulp** (with fresh rhizomes, mixed with salt)	Valle Variata (2009)	
	Pulled muscels (cattles): **Tincture**, rub	Walsertal (2010-2012)	
	Navel infection of calves (smoking over the spot), viral infections in cattle shed ("Stallgrippe"): **Fumigation**	Walsertal (2010-2012)	
	Chronic diarrhea, gastroitestinal disease, bloody mucous membranes in the mouth (cows): **Powder** (with lard), feed	Walsertal (2010-2012)	
	Gastroitrstinal disease, strengthen the immune system and the defences (cattle): **Infusion** (cold, water or schnapps)	Walsertal (2010-2012)	
	Sick foot (cows): **Ointment**	Walsertal (2010-2012)	
	Wounds of cattle: **Infusion**, wash out the wounds	Graubünden (2013)	
	Wound healing (cattle): **Compress**	Prättigau (2013)	
other application			
	Spread a good odor (especially in winter), keeps mice away: **Fumigation** (of the room)	Val d'Anniviers (2008)	

Plant Part Used App- lication	Preparation and Indication	Reference[1]	Mixture
Semen			
systemic application			
	Liver, stomach, internal poisoning: **Raw, juice**	Bock (1546)	
Stipes			
apotropaic application			
	Eye disease ("Schwäraugen"): **Necklace** (hang the stems around the neck of children)	Rochholz (1857)	

1 *Reference in Appendix D table 1*

Kreuterbuch – Hieronymus Bock (1546)

Von Meisterwurz. Cap. cxliiii (p. 341)

Die Meisterwurtz hatt mich schier verderbt /
also ubel brandt mich der zähe gä1 safft auff der zungen.
Der grün Pfeffer ist nicht so scharpff /
als die grün Meisterwurtz /
die zielt [zieht] man auch inn den Gärten /
inn sonderheit würt sie zum Rindtvihe gepflantzet /
dem gibt man sie gepuluert mit Saltz

Ihr lieben Meister sagen mir/wa gehört ewer Ostericium/oder Astrencium/ wie ihrs nennen/ doch hien? Under welches capitel Diosco. oder Galeni wollt ihrs setzen oder gelten lassen? oder vermeinet ihr auch das sie den alten wie Angelica/nit bekandt sey gewesen?
Glaubt von der Beschreibung her könnte Smyrnion passen von den Griechen. Fragt sich aber wieso sie nicht vom Geruch der Meisterwurz reden.

Von den Namen

Imperatoria hat ihren namen ab effectu, ob raras & insignes virtutes, quibus prae multisalijs simplicibus pollet. Herrschet und regieret gleichsam "uber vil leibspresten"/ sonderlich aber uber die Pestilens und andre gifft. Deßwegen sie auch Magistrantia und Meisterwurz genent würdt/weil sie dieselbe gleichsam meistert und zwinget/ und ist solcher nam auch andern gewächsen gegebt wordt/ das sie victoriales unn vincetoxica geheissen worden.

Von der Krafft und Würckung

Das ganz gewächß ist hitziger scharpffer natur und art/uber alle Wurtz und Pfeffer/die Wurtzel und Samen seind am strengsten/ mögen doch zimmlich in Leib und ausserhalb genützet werden. Dieweil die Wurtzel sehr scharff/ auch etwas bitter/ und einen zimlichen geruch von sich gibt/ so achtet sie Matthiolius für warm (tertio gradu completo), oder im anfang deß vierten: für trucken aber (gardu secundo). Andre halten sie für warm und trucken im dritten grad/ und wie Tabernaemontanus meinet/ fast im vierten. Zertheilt/verzehret/eröffnet/zihet herauß/ treibt die Weibliche Blum/ den harn und Schweiß.
Man braucht fürnemlich die Wurtzel/ würd sehr geprisen für die Pestilenz/ und das gifft gifftger Thier: Item, für das grimmen und Leibwehe/ Magenwehe/verstopffung der Leber/ Milzes/ und

deß Kröses/ für das Keichen/Stein/ Läme/ Krampff/ Schlaffsucht/ Podagram/etc. Dann sie wärmet/ wie gesagt/ trucknet/ zertheilt/ verzehrt/ eröffnet/ säubert/ und reiniget/ dempffet die bläst und Winde.
Etliche machen ein extractum und öhl davon.

Innerlich

Erstlich ist Wurzel/ Samen/ Kraut/ Safft/ oder das gebrandt Wasser/ alles gut und nutz für alle kalte pressen/ der faulen Feber/ deß kalten Magens/ und für alle Gifft/ zimmlich und nach gelegenheit der Person und Krankheit/ wenig oder vil eingenommen und Eusserlich auffgelegt.
Dienet/ wol in Wein gesotten/ zu der kalten Lungen/ Keichen/ und feuchten Husten/ Abendts und Morgens getruncken.
Treibt auß also genützet/ nicht allein den Harn und Lenden Stein/ sonder auch der Frawen Kranckheit/ todte Frucht und andere Geburt/ miltert den kalten Schmerzen der Hüffkranckheit/ Ischias/ bewegt den Schweiß/ treibet die Wassersucht/ hilfft dem erstorbenen Mann wider auff den Gaul/ unnd ist kein lugen. Gemelte tugent hat auch das gebrandt Wasser/ ist aber anmütiger zubrauchen/ weder Samen oder Wurzel.
Meisterwurz oder Kraut in Wein gesotten und getruncken/ ist gut wider den Schlag/Tropffen/ Fallendesucht/ Krampff/ und alle kalte gebresten der Neruen.
Ein halben Löffel voll der gepulverten Meisterwurtz in weissem Wein warm getruncken/ ein Stund für des viertägigen Febers ankunfft/ solches etlich mal gethan/ bringet das Feber von tag zu tag in abgang.
Für die Pest ein guter tranck. Nim gepulverte Meisterwurtz i halb quintlin/Theriae. Androm. s quintlin gebrent Meisterwurtzel wasser u. so. h/Essig i löffel voll.

Äusserlich

Meisterwurz übertrifft Angelicam und Liebstöckel mit der hitz und außtreibenden Krafft/ sein sonst einander gleich/ Wunden und gifftige Schäden zuheilen/ Eusserlich auffgelegt/ den Safft in die Wunden gelassen/ oder mit dem gebrandten wasser gereiniget.
Alle Geschwulst und Knollen mögen mit diser Wurtzel/ oder ihrem Safft (darüber legt) zertheilt und nider getruckt werden/ und zur heilung kommen.
Der Safft etzt und verzert faul Fleisch/ zertheilet gerunnen Blut.
Mit Essig und Wasser gesotten/ ubergeschlagen/ lindert das Podagram.
Die Wurtzel mit Meisterwurtz gekewet/ zeucht gewaltig den Rotz und Schleim vom Kopff

Meisterwurtz Pulver eingenommen zertheilt die gerunnen und knollecht Milch in Brüsten und gerunnen Geblüt.
Ein Experiment wider die Hauptslüß. Strewe das Pulver von der Meisterwurtz auff glüende kolen/ und zihe den rauch zu dich mit Mundt und Nasen
Die Wurzel in Wein gesotten/ und in den Mundt gehalten/ stillet das kalte Zanwehe. Dann sie zihet die flüß auß.

New Kreuterbuch – Leonhart Fuchs (1543)

Von Meisterwurz Cap. CCXCIII

Namen
Meisterwurtz ist on zweifel ein geschlecht des gewechß so vonn den Griechen Silphion/ und von den Römern Laser/ und Laserpitium genent ist worden. Daher kompts das zu unsern zeiten würdt Osteritium geheyssen/von ettlichen aber Ostritium/ von andern Asteritium/ welche namen alle/ wie auch der name Meisterwurtz/ auß dem alten wörtlin Laserpitium entsprungen seind. Und ist sölch kraut/ meins erachtens/ vor zeiten Laserwurtz genent worden/ unnd volgends darauß geflossen der name Meisterwurtz/ wie wir sölches im Lateinischen Kreuterbuch weitleuffiger haben angezeygt.

Gestalt
Die natur und complexion
Die Meisterwurtz ist hitziger und scherpffer dann der Pfeffer/ darumb sie warm und trucken fein muß biß in den dritten grad. Die wurtzel aber und der samen übertreffen die bletter und den stengel.

Krafft und würckung
Die wurtzel/der samen/kraut unnd safft der Meisterwurtz seind treffenlich nütz und gut wider allelerey **gifft**.
Sollen in sonderheyt zu der zeit der **Pestilentz** wider den vergifften bösen lufft gebraucht werden. Sie zerteylen und verzeren die groben/ zähen/ kalten flüß im leib.
Seind gut zu dem **Husten** der von kellte kompt.
Sie verzehren auch die groben feuchtigkeyt so sich umb die **brust** gesamlet hat.

In sonderheyt aber der safft ingenommen/ oder von außwendig angestrichen ist gut wider **allerley stich und bissz der gifftigen thier**.

Mit **essig** vermengt unnd angestrichen/ heylet er die **flecht**.

Er ist gut denen so die **geelsucht** haben/ oder **wassersüchtig** seind/ mit dürren feigen ingenommen.

So er an dem essen gebraucht würdt/überkompt der ganz lei daruon ein gute farb.

Er zerteylt die **knollechte milch**/ unnd das **zusamen gerunnen blut**/wann man ihn eusserlich anstreicht.

In eim weychen oder lind gesottnen ey ingenommen/ sterckt er den **magen**/ macht **lust zu essen**/ treibt den **harn**/ und bringt den **frawen ire zei**t.

Die grünen bletter zerstossen/ unn in die **wunden** so von einem wütenden **hund**/ oder natern gebissen seind/gethon/heylet dieselbigen.

Das kraut in **wein** unn **wasser gesotten**/ heylet die **innerlichen wunden**. Reynigt auch diser gestalt genützt die muter/ und **treibt auß die todte frucht**.

So es dürr würt/ein **rauch** damit zum offtermal gemacht/ vertreibt es allerley **wartzen** so am hindern gewachsen seind.

Der safft mit gekochtem **hönig** vermischt und angestrichen/ ist gut zu dem **hüfftwee**.

In wein ingenommen ist er gut zu bewegung des **schweyß**/ hilfft dem erstorben kalten **mann** wider auff.

Ein halber scrupel daruon ingenommen/ ist gut zu dem **krampff**/ und dergleichen kalten gebresten der **neruen**.

Er ist gut zu der kalten **lungen**/ dem keichen/ unnd andern dergleichen gebreften der brust. Mit essig und wasser gemischt und überschlagen/lingert das **Podagra**

Statement of Authorship

I declare that no other sources and aids other than those indicated were used in the writing of this thesis with the title:

Botanical and ethnobotanical studies in *Peucedanum ostruthium* (Apiaceae) from the upper Saastal: Variability of morphology and coumarin components, and use as a medicinal plant

All passages quoted from publications or paraphrased from the sources are indicated as such, i.e. cited and/or attributed. This thesis was not submitted in any form for another degree or diploma at any university or other institution of tertiary education.

Zürich, 31.07.2020
Camille Amedea Brioschi