

***Helleborus* diversity in Slovenia**

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Keywords: habitats, hybrids, colour variation, Pannonian region

Abstract

Slovenia lies at the crossroads of different geographical influences. Its northwestern and central northern regions extend into the Alps, in the southwest it reaches into the sub-Mediterranean, while its northeastern and eastern parts belong to the sub-Pannonian region, and its southwestern and central southern parts to the Dinaric world. The genus *Helleborus* (L.) is naturally distributed in Central and Southern Europe as far as Western Asia, where it is represented by 15 different species. A third of them, five species, grow in Slovenia. Considering the small size of the Slovenian territory, they reveal an extraordinary diversity. They may begin to bloom already in late autumn, continue over winter and last well into spring. Wherever several hellebore species grow side by side, interesting hybrids appear which further increases the diversity of the hellebores in Slovenia. The Christmas rose (*H. niger* L.) grows both in lowlands and highlands. In exposed positions the first flowers opening in early winter are suffused with pink. The reddish hue becomes more intense after the flower has been pollinated. This species is found only on dolomite substrates. The other species growing in Slovenia are not restricted to alkaline substrates. They include the species notable for their exclusively green flowers: *H. odorus* Waldst. & Kit., *H. dumetorum* Waldst. & Kit., *H. multifidus* Vis. subsp. *istriacus* (Schiffner) Merxm. & Podl. and purple-flowered *H. atrorubens* Waldst. & Kit. In numerous local populations making part of the green-flowered group extremely diverse, specimens appear in a wide range of shades, shapes and sizes of flowers. With the exception of the Christmas rose, all of the above-mentioned species cross-breed with one another. Where *H. atrorubens* Waldst. & Kit. and *H. odorus* Waldst. & Kit. grow in close proximity, the diversity in the colour range, shape and size of flowers is all the more outstanding.

Background

The name *Helleborus* has been in use for more than 2200 years and the plant was known primarily for medical reasons even before Theophrastus (372-287 BC). The ancient Greeks distinguished between two species: *Elleborus melas* and *Elleborus leucas*. In his 'Natural History', *Naturalis Historia*, Pliny the Elder (23-79 AD) describes hellebores and their uses. Hellebores are also described by Dioscorides (40-90 AD) in his work *De Materia Medica* (c. 77 AD). In 1565 Mathioli drew a clearly recognizable representation of the Christmas rose (*H. niger*) and green hellebore (*H. viridis*) as mentioned by John Gerard in 1567 [1]. According to Schiffner 1890, the name

hellebore is often referred to in different works by Roman authors both in the BC and AD period [2].

Hellebores were considered to be interesting garden plants as early as the middle of the 19th century. Studies were carried out in the Botanic Garden of the Berlin-Schöneberg University in the 1850s. Two forms of *H. orientalis* appear in its Seed Index (*Index seminum*) [3].

In Slovenia, the most important botanist was Mathioli who often visited this part of the world and occasionally treated Idrija miners. Hellebores are subsequently mentioned in the famous *Flora Carniolica* by Scopoli [4, 5]. In the second edition of the work Scopoli [5] already refers to two species denominated as *H. niger* and *H. viridis*.

Hellebores are also mentioned in the first list of plants that Hladnik compiled for the Botanic Garden in 1812 [6]. This list of the plants represented in the Botanic Garden includes two hellebore species: *Helleborus niger* and *H. viridis*. In his *Flora Wochinensis* from 1826 (AS 882) he describes two species: *H. foetidus* and *H. niger*. However in *Botanische Notizen*, he already refers to nine species which he may have had planted in the Ljubljana Botanic Garden (AS 882): *Helleborus niger*, *H. viridis*, *H. hyemalis Eranthis*, *H. atrorubens*, *H. dumetorum*, *H. laxus*, *H. altifolius*, *H. graveolens* and *H. multifidus*.

In *Flora Austriaca*, Host [7] lists a total of 13 hellebore species with reference to the former common state, the Habsburg Monarchy, which also included the territory of present-day Slovenia. The following species are stated for Carniola (present-day Slovenia): *H. hiemalis in monte Nanas* - the species is now in the second independent genus *Eranthis* - *Eranthis hiemalis*, but its presence on Mt Nanos can no longer be confirmed; *H. niger*; *H. intermedius* and *H. viridis*. Host makes an indirect reference to *H. atrorubens* because not all of the area in question made up part of Carniola.

In his *Uebersicht der Flora Krains (A Survey of Carniolan Flora)* [8] Fleischmann refers to a number of species: *H. graveolens* Host, *H. bocconi* Ten., *H. viridis* L., *H. dumetorum* Kit., *H. laxus* Host, *H. odoratus* Kit., *H. purpurascens* W., *H. atrorubens* W. Kit., *H. niger* L., *H. altifolius* Heyne.

In his work *Naše škodljive Rastline (Our Pestilential Plants)*, [9] Cilenšek cites and describes three species: *Helleborus niger*, *H. viridis*, *H. foetidus*. In Paulin's remarkable collection *Flora exsiccata Carniolica*, Paulin refers to seven species [10]: *Helleborus niger* L., *H. macranthus* (Freyn) Fritsch, *H. altifolius* Kerner, *H. odoratus* W. & Kit., *H. dumetorum* W. & Kit., *H. odoratus* W. & K. var. *istriacus* Schiffn., *Helleborus dumetorum* W. & K., *H. atrorubens* W. & K., *Helleborus x carniolicus* Paulin (*H. atrorubens* x *H. odoratus*).

Glovacki's identification key [11] lists seven species: *H. niger* L., *H. macranthus* Freyn., *H. atrorubens* W.K., *H. multifidus* Vis., *H. dumetorum* W. K. Plotni, *H. viridis* L., and *H. odoratus* W.K. In the first and second editions of her *Ključ za določanje Cvetnic in Praprotnic (Key to Determining Flowering Plants and Ferns)* [12, 13] Piskernik cites six species: *H. atrorubens*, *H. niger*, *H. macranthus*, *H. multifidus*, *H. odoratus* and *H. dumetorum*. Mayer's list [14] includes only five species: *H. niger* L. subsp. *niger*, *H. niger* subsp. *macranthus* (Freyn) Schiffner, *H. odoratus* Waldst. et Kit., *H. multifidus* Vis., *H. dumetorum* Waldst. et Kit. and *H. atrorubens* Waldst. et Kit. The same species are cited also in the first edition of *Mala Flora Slovenije (The Small Flora of Slovenia)* [15]. The subsequent editions of *The Small Flora of Slovenia* cite just the five above

mentioned species among which *H. niger* is represented by only one subspecies [16-18].

Materials and Methods

The research material has been collected over the last 15 years, but more intensively in the last decade. The plants showing deviation from the descriptions of individual species were brought to the University Botanic Gardens Ljubljana where they were cultivated.

A number of species were monitored in, and collected from different parts of Slovenia. It often happens that the time when a plant is transferred to garden conditions marks the height of its season, meaning that with regard to observing the plant and comparing it with other specimens that particular year is lost. So it is necessary to wait till the following year to see what the plant looks like in garden conditions. Further difficulties are associated with single years and the breeding of all the special features in culture, as each of them requires special conditions for optimal growth. The growth of these plants in flower beds or surrogate habitats in the Botanic Garden does not usually pose problems. However, if the plants are to be closely monitored, a pot experiment has to be carried out by assigning a number to every pot and monitoring the appearance of the plants in the subsequent years. This requires an enormous amount of work, as each pot needs individual care. So it often happens that single plants require several years to reach full growth, for only a plant in its optimal phase is fit to ensure proper comparison.

The work in natural habitats started with a detailed survey of the areas where local populations were numerically massive. Some of the most deviating specimens were collected at once, whereas the others, only after the major part of single local population areas had been examined. Each specimen was photographed first in its habitat, then dug out and photographed once again to expose its special characteristics with more contrast. Specimens were put in separate bags and labelled with the designation of their habitat. On return to the Botanical Garden, each specimen was described and planted into a 14 x 4cm pot filled with a mixture of compost and leaf mold. All pots were provided with information labels. The pots were placed on a foil that had been spread over flower beds to prevent weed growth. The plants were watered when necessary. Seeds were collected from all plants that had seeded and were subsequently sown.

Results and Discussion

Christmas rose (Helleborus niger), which grows in different parts of Slovenia, is a widely variable species, although it is ecologically bound to alkaline grounds. It grows from the lowlands to highlands. It is absent only from the warmer coastal areas – the Submediterranean and Subpannonian phytogeographic regions of Slovenia. The colour of the Christmas rose flowers ranges from white to pale pink, then later turns yellow to orange yellow, or even completely red. The most radical colour change occurs after the flowers have matured. Specimens can be found with mature flowers whose colouration ranges from yellow-olive green, rose-coloured to perfectly red. In between one finds orange yellow specimens and every possible shade of white to

green yellow, pink to pink red. Our research has shown that the period of flower maturation coincides with the widest range of colours. The first flowers *pushing into the open* are rather pink-flushed, particularly from the outside. When the weather becomes warmer, the subsequent flowers of the same plant turn completely white. Pink tones appear also in populations occupying colder areas sufficiently exposed to the sun. There, the flowers have a very lovely pink hue, which is usually concentrated along the veins originating from the base of the sepal towards the top. As the sepal margin is whiter, the flower looks as if it has a white outline. After pollination, the Christmas rose flowers show richest colouration in open areas: meadows, thin thermophilous forests and highland meadows. Mostly higher lying areas and sun-exposed positions with a considerable slope inclination are involved. The plants seen in forests are more uniform. McLewin [19] reports that flower colour is very rich in extensive meadows in the mountains of the Triglav area. Let us add that such and similar habitats can be found in many parts of Slovenia where the Christmas rose is very common. Ravnik [20] states that at the end of the blooming period, the sepals of the plants growing in the shade turn green, while the sepals of sun-exposed plants assume different colours. During the course of our field work, this statement proved to be correct in the majority of Slovenian locations. The stem leaves are also pink-coloured in some specimens.

In local, numerically large, natural populations of plants growing in Slovenia there are always at least some plants that reveal stable distinguishing characteristics. Similarly as with other species, the probability that, once a sufficient number of specimens of a variety are available, at least one of them will prove stable is essentially higher [21]. Mathew [1] reported an exceptionally large morphological diversity in garden grown Christmas roses sown by gardeners. Flower shape differs; some are more cup-shaped, others more tray-shaped. In some, the sepals overlap like the blades of a windmill, in others they are almost free, while in others sepals can be spherically rounded or pointed. Flowers with more sharply pointed sepals give the impression of a windmill, while those with rounded sepals create an imaginary circle in which the empty interspaces between sepals are barely noticeable. Analyzing the Christmas rose in Slovenia in an attempt to establish differences between the subspecies *H. niger* subsp. *niger* and *H. niger* subsp. *macranthus*, Ravnik [20] states that the sepals can overlap by half of their length or more, or else they can be completely free, which according to him is characteristic of the subspecies *H. niger* subsp. *macranthus*. He attributes all of the mentioned differences in Slovenia exclusively to the subspecies *H. niger* subsp. *niger*. Furthermore, he states that the sepals reveal variations in breadth and shape. McLewin [19] also observed sepal variation. According to Slopek-Sondi and co-authors [22], sepal size increases in mature flowers. Experimenting on removed carpels, they proved that cytokinins, and similarly gibberellins, stimulate the green colouration of the sepals, while paclobutrazol inhibits it, which indicates that the maturity of flowers and the coloration of sepals are hormonally related.

Diversity is not limited only to the sepals but is also obvious in the nectaries. Ravnik [20] states that the nectariferous leaves are tubular and bilabiate, have shorter or longer pedicels and vary in size and shape. He adds that the nectariferous leaves of the plants of the lowland and montane zones are mostly greenish or greenish yellow, rarely yellow, whereas the nectaries of the plants of the subalpine zone are mostly

yellow. All of these findings have also been confirmed in the course of our research. A similar situation as with *H. niger* can be observed also with the spring snowflake (*Leucojum vernum* L.) in which the tips of the perigone leaves are mostly yellow in the highlands but mostly green in the lowlands [21].

In addition to its diverse flowers, the Christmas rose also has highly diverse green leaves. A single leaf has five to seven or even eight, nine, or more, strongly toothed leaflets. Analyzing the leaves on the basis of herbarium material, they can comprise of 5 to 6, or 7 to 11 leaflets which show great variation in shape. As evidenced by our field observations, a wide range of leaves can be found in a single, densely populated habitat. Some specimens have large leaves with more numerous leaflets, others have smaller, rounded leaves with fewer leaflets. Leaflets can be rather coarsely saw-toothed or finely toothed, or even entire. The diversity of the green leaves of Christmas rose is also stated by Eler [23].

The Christmas rose is considered to be a highly diverse species, which is pointed out by practically all the authors who have studied it. Let us mention just a few of them: Schiffner [2], Ravnikar [20], Mathew [1], Pape [24], McLewin [19, 25], Sušek *et al.* [26], Colston Burrell & Knott Tyler [3]. Mathew [1] stresses, however, that in spite of the great diversity of *H. niger* most of the variations do not show a sufficient number of distinguishing features to be of any taxonomic significance. They are nonetheless important in the horticultural sense, since these variants can also have names of their own.

The fragrant hellebore (*Helleborus odorus*). In Slovenia the fragrant hellebore (*H. odorus*) is likewise considered to be a very diverse species. As a result it is sometimes hard to tell apart from its relative *H. dumetorum*, even though the respective flowers vary in size, with *H. odorus* having larger flowers and in the winter hardiness of leaves which is said to be a fine distinguishing characteristic for *H. odorus*. In practice, however, things prove less certain. In Slovenia, the leaves of *H. odorus* are rarely winter-hardy. The plant exudes a mild fragrance noticeable if one is near it during the initial phase of flower unfolding and at the right hour of the day. A more reliable distinguishing feature seems to be the distribution area of the species in Slovenia. *H. dumetorum* has a more eastern distribution, which supports the assumption that the central and western parts of Slovenia are more predominantly occupied by *H. odorus* and the easternmost part by *H. dumetorum*. According to McLewin [27], *H. odorus* is widespread and creates mixed colonies, which is why it exerts such a powerful influence on the other hellebore species, *H. atrorubens*, *H. multifidus* subsp. *istriacus* and *H. dumetorum* on the way to *H. odorus*.

The fragrant hellebore (*H. odorus*) reveals higher levels of diversity in its early phase of growth. It begins to bloom early, usually while the first common snowdrops (*Galanthus nivalis* L.) are breaking ground. This early-phase diversity is largely *environment*-related. First of all, in winter leaf litter covers the ground of deciduous forests in fairly thick layers. As snow weighs down on it and compresses it, the plants need more time to emerge. The first plants range from pale yellow to green yellow. With warmer temperatures and longer days, the plants become greener. But some of them nonetheless preserve their yellow colouring for a very long time. At the fructification stage, the majority of the plants turn completely green. Although most of these differences result from various influences from the environment, in such a large number of hellebores single varieties are found that manage to hold on to

these properties. Mrs Ballard, also known as the 'Hellebore Queen', reports on this for Slovenia. In the nineteen-seventies, Mrs Ballard found an intensely yellow variety in the environs of Bohinj. She used this specimen as a basis for further crossbreeding and selection through which she obtained a perfectly yellow variety [28-30].

The diversity of its colour range is complemented by that of its flower shapes and their uni- and multiflorous character. The specimens are mostly one- or two-flowered, but one also finds well-branched plants with several flowers. Luxuriant specimens with bunch-like growth usually bloom later. Occasionally it occurs that the first plants are more or less isolated specimens with fewer but larger flowers.

Ravnik [31, 32] explains that the yellowness of the flowers arises in a similar way as the yellow colour of Christmas rose nectaries. The yellow colour of the fragrant hellebore flowers results from the plant's long wait under the snow cover or thick layers of leaf litter, which prevent the formation of chlorophyll but not of yellow pigments. At a later stage the majority of these flowers turn green. In Slovenia, yellow colouration is frequent for fruit capsules and the pattern on the inside of the inner perianth segments of the species *G. nivalis*, where yellow coloured specimens are found in places where snow persists for a longer period of time and the ground is full of molehills, or covered in thick layers of leaf litter [33]. The similar reasons stated for fragrant hellebore are therefore perfectly logical, but all of them are not environment-related. Mathew [1] states that with a species as diverse as *H. odorus* varieties are not difficult to find.

H. dumetorum is most widespread in the northeastern part of Slovenia. Schmieman & Weistrich [30] report having seen very large, variable populations of *H. dumetorum* subsp. *dumetorum* together with *H. dumetorum* subsp. *atrorubens* beside the Sava river, but what they actually saw must have been the species *H. odorus* and *H. atrorubens*. According to the relevant data the area they mention is populated only by *H. odorus* [23].

It is no less diverse than the other species but as it is confined to less extreme circumstances and a smaller distribution area, the conditionality in its diversity is reduced, although *H. dumetorum* is in fact as highly diverse as the other species. The specimens that can be found here are yellow green and yet different. In general, the flowers are at first light green to faintly yellow green, but during the blooming phase, when the stamens fully develop, they turn entirely green, blending with the colour of their leaves. Their yellow colouration often reminds us of the green yellow flowers of *Gagea lutea*. The stripes in the central part of the floral leaf, running from leaf apex to leaf base, are yellow but can be green along the margins. In some areas the flowers are nodding and quite small. The colour of the leaves changes as they age. The first leaves can be purple green, but when fully developed they turn green. The leaves develop gradually and when the plant blooms, new, more divided leaves emerge which, too, are entirely purple green. The first leaves are markedly basal while later leaves are larger and more divided.

H. dumetorum is the species with the smallest flowers among the acaulescent hellebores. Larger-sized bracts exceed the flowers that are 2.5 to 3.5 cm in diameter. During the blooming stage, the basal leaves are hardly present at all [1, 19]. According to Mathew [1], *H. dumetorum* is the least frequently bred of all hellebores. He believes it is less diverse than the other species. In Slovenia it is also less widespread, but its diversity easily matches that of *H. odorus*.

Helleborus atrorubens seems less diverse, and yet it reveals an interesting colour range. The colour varies from light-coloured specimens to purple brown and dark, black brown, scarlet specimens. On the outside, they often display traces of a faint green colour, while yellow green hues are discernible in the rounded part of the sepals. The diversity of *H. atrorubens* in Slovenia has been researched by McLewin *et al.* [34, 35]. In *Flora Europaea*, *H. atrorubens* is considered merely a subspecies of *H. dumetorum* [24, 36]. Similarly, some other authors treat *H. atrorubens* as a variety of *H. dumetorum*. Regardless of this, among the hellebore species growing in Slovenia, *H. atrorubens* is, apart from the already-mentioned *H. niger*, the one that is most easily distinguishable from the other species. It is usually much more difficult to distinguish between the other three green representatives.

In addition to its colour diversity, the species is notable also for the diversity of its flowers in terms of growth and size. In forests the plants are smaller, with smaller flowers that are few in number, i.e. just one to two. A totally different sight meets the eye in open areas, where *H. atrorubens* can be a luxuriantly developed plant with numerous flowers that can also be larger. Such a form is particularly frequent in the Lower Carniolan vineyards which used to be woodlands that have been depleted over the centuries. The plant has survived there in spite of the fact that the area is today listed as a cultural landscape. In secondary locations of this type, one often finds local populations with a more luxuriant growth than that found in the original woodland habitats. This indicates that *H. atrorubens* is not only a plant of shady forests but also of open sunny areas.

H. multifidus* subsp. *istriacus: Some authors consider it to be a transitional form between *H. odoratus* and the real species *H. multifidus*. This applies to northern Italy and Slovenia [1, 37]. Furthermore, the flowers which appear in February or March are reported to be fewer than 5 cm in diameter, cup-like or stellar, yellow or pale green [37]. In Slovenia, *H. multifidus* subsp. *istriacus* is the earliest-blooming representative of the green group. Relying on the observations made during our field research, we can confirm that the first plants are strikingly yellow green, even though in the areas which are home to *H. multifidus* subsp. *istriacus* snow does not occur regularly. If snow falls at all, it covers the ground for a very short time. Additionally, there is not much leaf litter, since *H. multifidus* subsp. *istriacus* is the only one of the Slovenian species that is found in karst and Istrian commons, mountain meadows and overgrown areas where there is hardly any leaf litter at all. *H. multifidus* subsp. *istriacus* begins turning greener only after the flowers have matured. Our own research allows us to conclude that the colouration of this species ranges from yellow green to almost completely yellow. Cold is one of the factors that could, in the early phase, affect the yellow green colouration, however, other species growing in the area, e.g. common snowdrop (*G. nivalis*), reveal no more frequent occurrence of yellow colouration in the inner perianth segments - a phenomenon more often observed in the interior of Slovenia [33].

According to our findings, confirmed also by other authors [23], *H. multifidus* subsp. *istriacus* has widely diverse leaves. During the summer, a typical *H. multifidus* develops a truly bristled character, it is extremely prickly. The most deeply clefted and narrowest leaves occur in *H. m.* subsp. *hercegovinus* [38]. All possible transitions can be found within the same habitat, from plants with very broad saw-toothed leaf lobes to plants with very narrow bifurcated lobes. In terms of the diameter they

cover, the leaves can be either very large or small. Smaller leaves usually have larger, less divided lobes. The only rule that applies to almost all leaves is that there is one central lobe which is entire and attached to the petiole, while the remaining lobes already begin to divide.

Hybrids - Hybrids between hellebores are present in large numbers, but that does not mean they exist between all species [39-41]. Between 1853 and 1880 [3], German cultivators bred hybrids, particularly dark-coloured ones, at the Berlin Botanic Garden. Similar projects were underway in England and Ireland at the same time.

Despite the fact that in Slovenia Christmas rose grows in numerically extremely rich populations, touching upon or coming into contact with other species of hellebores particularly *H. odorus*, no hybrids seem to occur. This observation is confirmed by the literary sources according to which *H. niger* and *H. odorus* do not crossbreed [1, 27]. In the course of our on-going research and longtime field work in the areas where the two mentioned species often grow side by side we have, apart from two exceptions, registered no hybrids. The two specimens found in the autumn of 2011 will need to be further monitored and tested because they show possible characteristics of both *H. niger* and *H. odorus*.

In some Slovenian habitats where three hellebore species, *H. niger*, *H. odorus* and *H. atrorubens*, appear side by side, hybrids occur just between the latter two. This clearly supports the fact observed not only by the mentioned author, but also by others, with respect to naturally growing plants and thousands of plants growing in gardens [27]. As for the other species from the mentioned group which, according to the literature crossbreed, their hybrids are actually often found in nature. The question is primarily of hybrids between *H. odorus* and *H. atrorubens* which are the easiest to recognize. Concerning the rest of the green hellebore species which crossbreed with each other, i.e. *H. odorus* x *H. dumetorum* and *H. odorus* x *H. multifidus* subsp. *istriacus*, their hybrids do exist but it is extremely difficult to establish their ancestry, as the species themselves pass into one another, so the probability of noticing their hybrids in nature is very small. In terms of their colour and leaf shape, the most striking hybrids occur between *H. odorus* and *H. atrorubens* because the two species come into contact with each other more frequently. These hybrids reveal all of the colour transitions, from dark purple to green. The hybrids differ from the basic green species *H. odorus* in that they show at least some shades that are neither yellow nor green, but tend towards purple tones. As for flower-size, the flowers are mostly larger than those characteristic of the species *H. atrorubens*. But as is usual with hybrids, all transitional forms appear from one species to another. Traces of purple are sometimes detectable only along the margins of the flowers, which look exactly the same as in *H. odorus*. The leaves themselves are less important because they initially differ only in colour, namely, the leaves of *H. atrorubens* are at first dark purple, whereas those of *H. odorus* are always bright to yellow green.

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