Iwona Szot

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Wydawnictwo Uniwersytetu Przyrodniczego w Lublinie

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Rewievers of the polish version
dr hab. inż. Anna Bieniek
dr hab. inż. Tomasz Tarko, prof. UR w Krakowie

Translation into English
Green Małgorzata Kornijów

Editorial development
Magdalena Marcewicz

DTP
Jack Pałyszka

Cover design
Anna Szwajgier

Picture used on the cover
Małgorzata Szot

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Wydawnictwo Uniwersytetu Przyrodniczego w Lublinie
ul. Akademicka 15, 20-950 Lublin
https://up.lublin.pl/nauka/wydawnictwo/
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Introduction

Fruit constitutes an indispensable element of human diet. It can be consumed with any meal, supplying our organism with necessary carbohydrates, vitamins, fibre, macro-, and microelements. It supports the de-acidification and detoxification of the body, therefore preventing many diseases. Basic pome and stone fruits available in Poland include apples, pears, plums, sweet and sour cherries, peaches and apricots, as well as berries: strawberries, raspberries, highbush blueberries, currents, gooseberries. Consumers appreciate the befits of varied meals, and are eager to reach for tropical or less known fruits. Hence, Kamchatka honeysuckles, shadbushes, seaberry, and cornelian cherry have begun to appear in the Polish market.

Cornelian cherry is still not a popular fruit, although many people have heard about it as perfect material for home-made liquors. Its natural range of occurrence does not cover Poland, although it grows well and bears fruit in our conditions, reaching old age. It is a perfect tree for large commercial plantations due to annual yields that are increasingly abundant with age, and high immunity to diseases (lack of accumulated pathogens). Moreover, it responds well to training and pruning. In the case of long-term intensive cultivation, the available cultivars bear fruit from mid-July to October, resulting in the supply of fresh fruit over a period of more than three months. The fruit is a drupe featuring various sizes, shapes, and skin colours. It can be consumed fresh, or processed at different stages of ripeness, beginning from the phase when the fruit is already large, but the skin is still not blush, green. Such fruits are suitable for pickling. The resulting product closely resembles green olives. Ripe but still not falling fruit is perfect for candying, and can serve as an addition to muesli, energy bars, etc. Like cherries, it is perfect for juices and compotes, whereas the production of the latter does not require pitting the fruit, because the seeds contain no hydrocyanic acid. Cornelian cherry stands out with a high content of pectin, and under short heat processing it obtains the desired consistency of jam or conserve. Due to their vivid flavour, the products go well with both desserts and savoury dishes. Cornelian cherry fruit contains high amounts of vitamin C and anthocyanins that prevent antioxidant stress. Components distinguishing cornelian cherry among other fruit are iridoids that show a broad spectrum of healthy properties. The unusual chemical composition of the fruit makes it a fantastic ingredient of functional diet. Next to nutrition, it offers protection from diseases.

This publication offers a collection of knowledge and own experiences aiming at familiarising a possibly large group of readers with this incredible plant, and facilitating its cultivation in both amateur and commercial plantations.

The monograph has been prepared with a contribution of many people for whom cornelian cherry is a fascinating and valuable plant deserving interest, research, and popularisation.

I would particularly like to thank Mr. Roland Choina. Many years of co-operation with him allowed me for investigating issues regarding the biology, morphology, and ways of optimisation of reproduction and cultivation of cornelian cherry. Moreover, I would like to thank Prof. Svetlana Klymenko, Prof. Alicja Kucharska, and Director Narcyz Piórecki for providing me with valuable information on Ukrainian and Polish cultivars and health benefits of the fruit of this incredible plant.

1. Systematics and origin

Cornelian cherry, also known as European cornel (*Cornus mas* L.), is a fruit bearing plant belonging to angiosperms. It belongs to genus Cornus (*Cornus*) and Cornaceae family (*Cornaceae*) that mainly includes ornamental plants. The family belongs to order Cornales (*Cornales*). The genus covers approximately 60 species (trees, shrubs, and herbaceous plants) that predominantly occur in the temperate climate on the Northern Hemisphere. Approximately 30 species grow in South-East Asia, and 20 in North America [Kucharska 2012]. It is worth investigating detailed systematics of cornelian cherry, because in the case of fruit species propagated from rootstock grafting, possibly closely related species are sought for.

Cornelian cherry has a characteristic flower structure. The flowers are tetramerous, hermaphroditic, with an inferior ovary. The fruit is a drupe with

Phot. 1. Fruit of *C. kousa* can remain on the tree throughout winter

one, often two seed stone. The leaves have no stems, produce a petiole, and are simple leaves with smooth edges, with a characteristic pattern of veins running parallel from the base to the tip. In terms of diversity of the inflorescence, the designation of the following subgenera is proposed:

1. *Kraniopsis*: Examples include species *Cornus sericea* – red osier dogwood, *Cornus alba* L.– white or Siberian dogwood, *Cornus amomum* – silky dogwood, *Cornus sanguinea* L. – common dogwood. The plants feature white flowers, with no bracts, collected into corymbs. The fruits are white, blue, navy blue and black [Kucharska et al. 2009].

Cornus sericea (*C. stolonifera*) – red osier or red osier dogwood, originates from North America: Canada, Florida, west Texas, Dakota. It is a small shrub reaching 2–3 m in height. It flowers at the turn of May and June in the form of small white flowers collected in corymbs. The fruit ripens in autumn, and is white in colour. *Cornus alba* and *C. sericea* are very closely related, as suggested not only by the morphological, but also genetic similarity [Xiang et al. 2006]. The paper by Woźnicka et al. [2014] evidenced that distinguishing both species based on stone morphology is difficult, because the differences are subtle. Zieliński et al. [2014] presented a concept for the name *Cornus alba* to have a broader meaning and cover two subspecies susp. *alba* and susp. *stolonifera*. In Poland, *Cornus sericea* is recognised as an invasive species at a regional scale, particularly in Lower Silesia, Ziemia Lubuska, and Wielkopolska. The shoots take root easily. It also rapidly spreads through seeds, transported by birds and water. In an open space, it can form a compact cover and limit the development of native species [Tokarska-Guzik et al. 2012].

Phot. 2. *C. sessilis* in leafless state – leaf buds develop first

Cornus amomum – silky dogwood. It originates from the eastern states of the USA. It is a small shrub up to 3 m in height. It has large leaves, up 10 cm in length, elliptical, dark green on top, and delicately hairy underneath. In autumn, they feature various decorative shades of red. At the turn of May and June white flowers appear, collected into apical corymbs. The fruits are round, navy blue, and ripen in autumn. It is an ornamental shrub, also due to shoots featuring intensive red colour in winter. The species is resistant to frost.

Cornus sanguinea L. – common dogwood is a European species. In Poland it occurs in natural state. It forms shrubs with a height of up to 3–4 m. In winter, its shoots have red colour. The fruit is black and poisonous [Popescu et al. 2016].

2. *Benthamia*: An example is *Cornus kousa* – kousa dogwood. The plants have flowers with large bracts white or yellow in colour. They are collected in heads, and the pistils and fruits are connate (Phot. 1).

3. *Benthamidia*: An example is *Cornus florida* L. – flowering dogwood. The plants have inflorescences with large bracts, flowers in heads, fruits and pistils of individual flowers not connate [Xiang et al. 2006].

4. *Cornus*: Exemplified by six species belonging to the so-called group of "cornelian cherries": *Cornus officinalis, C. chinensis, C. sessilis, C. mas*, and *C. volkensii, C. eydeana* [Mrozowska and Wysakowska 2016]. In the case of these species, the flowers are small, collected in dense round or umbrella -shaped inflorescences. At the base, the inflorescences are surrounded by bracts, like in ornamental dogwoods (*C. florida, C. kausa*), but they are somewhat more modest.

Phot. 3. Flowers of *C. officinalis* developing in early spring, and fruit still remaining on the plant from the previous season

Phot. 4. Seedlings of cornelian cherry growing among stones in Anica Kuk (Paklenica, Chroatia)

Phot. 5. Fruiting cornelian cherry shrub in mountain conditions

Cornus chinensis – Chinese dogwood, originates from west and central China, north India, and north Birma. It is a tree reaching a height of 4–12 m. It produces leaves with a vivid vein pattern and oval-elliptic shape, with a length of 10 cm and width of 5.5 cm, comparable to leaves of plantain lily. Flower buds develop in pairs, but are separated by the apical leaf bud. Inflorescences larger than in *C. mas* and *C. officinalis*. The bark is brown, and shoots are purple-brown.

Cornus sessilis – blackfruit cornel, originates from Sierra Nevada in California and the Cascade Mountains (American Cordillera). The tree grows up to a height of 5 m, produces leaves with deep veins, oval, adopting red colour in autumn. Young shoots intensively green (Phot. 2), later the bark is brown -red. The inflorescence – loose cluster, small yellow-green flowers. The fruit is a round drupe, initially white, and gradually becoming shiny black, eagerly consumed by birds [Xiang et al. 2003].

Cornus officinalis – Japanese cornelian cherry (Japanese cornel) is a shrub or tree originating from south Korea and the Chinese province of Chekiang, as well as Japan, where it reaches a height of up to 9 m. A characteristic feature of *C. officinalis* is developing a single trunk, or several trunks close to one another. The bark on older specimens is flaky, revealing whiter layers,

Phot. 6. Comparison of leaves of *C. officinalis* (left) and *C. mas* (right)

as a result appearing to be spotted. The leaves are large, elliptical, red in autumn. The leaves have from 6 to 7 pairs of veins, and underneath, along the main vein, small brown hairs grow. The flowers are very abundant and yellow (Phot. 3). They appear in early spring (March-April), several days before *Cornus mas*. The flower stems and flower bases are delicate and covered with straw colour hairs. The fruit is a red drupe. It does not fall from the plant. It was introduced for cultivation in Europe in 1870 [Czerwińska and Melzig 2018].

Cornus mas L. – cornelian cherry (cornel) is a species commonplace in Eurasia. Its range of occurrence extends from central and south Europe to the Caucasus and central Asia. It prefers sunny sites, and dry, rocky mountain slopes. The range of its occurrence reaches up to 1400 m a.s.l., and even up to 1511 m a.s.l. [Hassanpour et al. 2012]. It also tolerates strongly shaded sites (Phot. 4 and 5) – it occurs in forests with hornbeam (*Carpinus*) and Hungarian oak (*Quercus frainetto*). Larger clusters of these plants are encountered in the basin of the Aegean, Mediterranean, Black Sea, and in north-west Anatolia in Turkey [Šilić 2005].

Unlike *C. officinalis*, *C. mas* usually grows as a large shrub producing multiple trunks at the base (rarely only several). The bark of mature specimens does not peel, and has a form of densely packed scales. The leaves usually have 4–5 pairs of veins, and underneath, along the veins, hardly discernible white hairs occur (Phot. 6). The flower stem and base are densely covered with short, slightly curled white hairs [Czerwińska and Melzig 2018].

2. History of cultivation globally and in Poland

According to some researchers, naturally occurring cornel constitutes remains of the Pleistocene forest that together with other vegetation survived the unfavourable conditions of the cold Quaternary [Udra 1984, Klepov 1990]. Cornelian cherry has been known since prehistoric times, as suggested by Greek archaeological excavations from the Neolithic period. The benefits of the plant were appreciated by Hippocrates who recommended extract from the leaves for upset stomach. In his work "Metamorphoses", Ovid provided a recipe for cornelian cherry confit. Pliny described flowering cornelian cherries as *the first gust of westerly wind…* . Pits from cornelian cherry fruits were found during excavations in Biskupin. Excavations from the Middle Ages revealed objects made of cornelian cherry wood, pointing to its exceptional durability. Cornelian cherry in Latin is *Cornus mas*, and both parts of the name refer to hardness, robustness. "Cornus" means horn, and "mas" – strong [Jaćimović and Božović 2014]. Romans added the species description "mas", in Latin meaning "male", because young plants were often observed to produce only male flowers, hence not forming fruits. The popular name is "cornelian cherry", or in short "cornel". It refers to the fruit with a shape resembling sweet or sour cherries, and colour resembling a precious stone from the quartz family, namely carnelian. Cornel wood was used to make weapons, among others arrows and javelin shafts, dishes, and in wheelwrighting and clock making it was used for producing gears.

Yellow dye was extracted from the bark, and oil from the seeds. In medieval monasterial writings, cornelian cherry was frequently mentioned as a valuable fruit with healthy properties (astringent, antidiarrheal). In the work by M. Cervantes "Don Quixote", cornelian cherries and acorns were food of the noble knight Don Quixote and his loyal squire Sancho Pansa. A description of the shrub occurred in the herbarium of John Gerard "Herbarium or general history of plants" from 1597, where he compared cornelian cherry to common dogwood, ascribing the former with male noble features, and the latter with female peasant ones. In the 17th century, processed fruit of cornelian cherry was served at the English royal court. The aesthetic values of cornelian cherry and the originality of the fruit were appreciated by the Royal Horticulture Association that gived it the Award of Garden Merit in 1924 [Gasik et al. 2008].

In Poland, cornelian cherry was usually planted at mansions and monasteries, and treated as a symbol of exquisiteness and luxury. In the inter-war period, cornelian cherry liquor was one of the most popular liquors among the nobility. In the post-war period, due to the developing communism and attempts to destroy anything "noble", along with mansions, many of the plants growing around them were damaged. The popularity of the fruit of cornelian cherry as an ingredient of liquors, jams, and juices considerably decreased.

In Ukraine, cornelian cherry is encountered in the natural state in Crimea and in the narrow belt at the western border of the Ivano-Frankivsk oblast extending along the Dniester River. The northern boundary of natural occurrence of cornelian cherry is designated by the line running through Czernihów and Głuchów. The range of natural occurrence of cornelian cherry almost reaches Polish borders. The specimens rarely occurring in the country are therefore rather an effect of adaptation. Antoniewska et al. [2018], describing cornelian cherries growing in Łukowe in the Bieszczady Mountains, discussed whether it is their natural place of occurrence or their purposeful planting. Approximately 30 specimens of different ages grow there, from very old to new growth. Older cornelian cherries often take the form of multiple trunk shrubs, with a diameter at the base exceeding 150 cm. A first sight, the steep sunny slope of the Kalniczka valley appears to be their natural site of occurrence, similar to many more in Slovakia and Ukraine. In Ukraine, cornelian cherry grows nearest in Podole, on the left bank of the Dniester River, and on Zakarpattia. In Slovakia, natural areas of occurrence include the vicinity of the city of Žilina, along the Orava River, to the southern boundaries of the East Beskids. In Łukowe, however, it may be a purposeful manor planting. In former times, cornelian cherry was highly popular, particularly on the Polish -Ukrainian borderland. A scarp unsuitable for any other planting was probably used for cultivation of plants producing the desirable cornelian cherry fruit.

3. Production volume

Cornelian cherry is known in many European countries, but commercial plantations are scarce. At an amateur scale, it is planed in Italy, France, Poland, Czechia, Slovakia, and Spain. High numbers of seedlings from spontaneous pollination occur in Iran, Azerbaijan, and Turkey [Damirov 1983]. Natural land yields from 0.5–1 t/ha, and yields from commercial plantations can exceed 10–15 t/ha [Kazimierski et al. 2018]. In Turkey, the annual harvest of approximately 14,800 tonnes of fruit of cornelian cherry is processed into jams and marmalades, pestil, paste, sherbet, or dried fodder [Kökosmanli and Keles 2000].

Another country with abundant occurrence of cornelian cherry is Georgia, where it is called "shindi". It occurs there even up to a height of 1350 m a.s.l., and at a height of 600–1000 m it develops vast spontaneous plantations [Ketskhoveli 1957]. The total surface area of such forests is 100,000-130,000 ha. One tree yields 2.0–4.0 kg of fruit, therefore the estimated yield from the entire surface area reaches 17,000–20,000 tonnes of fruit, although in reality 700–800 tonnes of the fruit is harvested annually. Cornelian cherry fruit has been sun-dried in east Georgia for centuries. It results in "kerki" – fruit with a pit, or "churcha" – fruit without a pit [Nizharadze and Buchukuri 1979]. The product is a valuable addition to beverages, compotes, sauces, and teas. Cornelian cherry plantations are slowly expanding in Georgia. Their current surface area totals more than 135 ha, corresponding to 0.3% of the surface area of orchards. The number of cornelian cherry trees in orchards is 60,204, and additional 146,534 grow in scattered single plantings [Maghradze et al. 2009].

In the case of cornelian cherry, it is possible to maintain numerous semi-natural sites, so-called Halbkultur [Schramayr 2009], as applied by Austrians in the Drindl valley (drindl=cornelian cherry) with a length of 35 km, surrounded by the high Alps. Such areas are suitable for the establishment of large commercial plantations. Old (250-year-old) specimens of cornelian cherry occur in the valley. They have been recognised as part of the so-called cultural landscape. For the purpose of protection of such landscape, local communities are encouraged to plant cornelian cherry on slopes. The importance of biodiversity is emphasised, as well as the beauty of diverse landscape. All this is concentrated in the Pielachtaler Dirdl region, where you can familiarise yourself with, taste, and purchase various cornelian cherry products. A brand is therefore created that makes the region stand out. Almost 60,000 trees currently grow there on slopes, meadows, pastures, and as solitaires in rural gardens. It is a relatively new trend (since 2005), although the production of fruit in 2017 amounted to 60 tonnes, yielding a profit of 700,000 €. It is estimated that in 2025 it will reach a level of 1,700,000-2,000,000 €. Next to the benefits of fruit production, cornelian cherries contribute to the strengthening of slopes and water retention. The decorative pompon-like inflorescences appearing very early in the season are the first sign of spring used as a tourist attraction. Cornelian cherry growing in such conditions needs to be very resistant to variable, sometimes severe conditions occurring in the mountains. Therefore, it is currently propagated through seedlings as the most natural way preparing the plant for the conditions in which the seed sprouts. The tasks faced by the local producers of cornelian cherry fruit include ensuring a sufficient amount of fruit and selection of regional cultivars based on the flavour of the fruit, its suitability for processing, and resistance to drought. The cornelian cherry brand is continuously strengthened.

To sum up, the market of cornelian cherry globally and in Poland is difficult to describe due to selective data from scientific articles or those provided in presentations in related conferences. The information suggests that cultivation develops in countries where cornelian cherry occurs at natural sites, namely in Turkey and Iran, ut the fruit quality from such a source is unsatisfactory (inconsistent shape, taste, sugar content and acidity, often bitter). Moreover, attempts to cultivate cornelian cherry at a larger scale are undertaken in Georgia, Moldavia, Bulgaria, Serbia, Bosnia and Hercegovina, Montenegro, Slovenia, Slovakia, Ukraine, Poland, Germany, Austria, France, as well as the USA and Australia. They are usually small pilot plantings, occupying approximately 1 ha, with harvested fruit provided to local markets.

4. Morphological description of the plant

The appearance of the plant changes depending on the season. It is related to phenological phases (phenophases) occurring cyclically each year as a result of changing meteorological conditions. The seasonal rhythm of phenological changes can be used for the designation of optimal terms for maintenance treatments such as pruning, fertilisation, irrigation, plant protection, etc.

Among phases determining the yield size and quality, the most important ones include those involving the development of flower buds, flowering, and setting fruit.

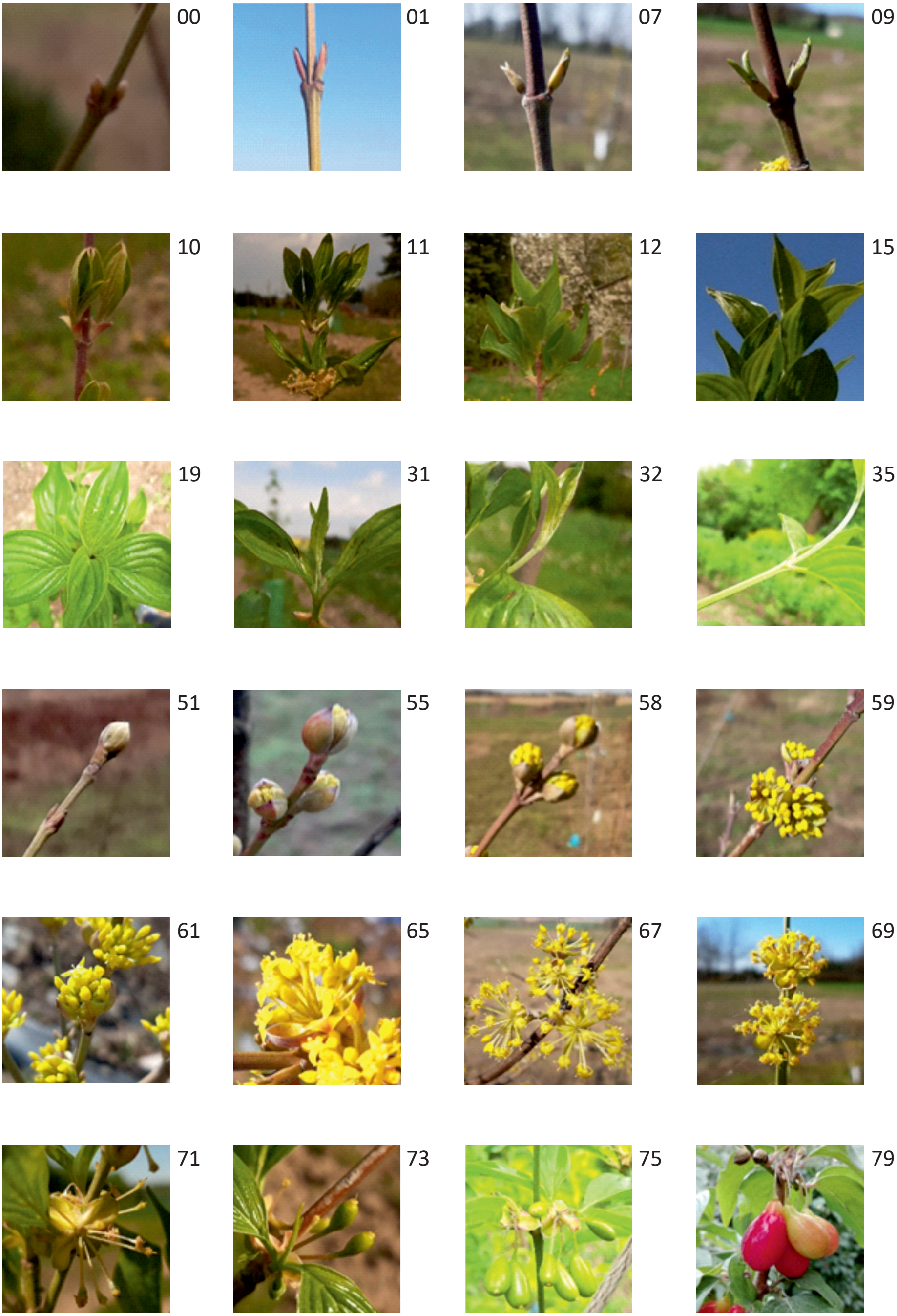
In the case of commonly cultivated fruit plants such as apple trees, pears, plums, or sweet cherries, terminology has been established that describes certain characteristic stages of bud development, e.g. for apple tree buds: pink bud, balloon stage [Chapman and Catlin 1976].

Phenological phases can also be presented at the BBCH scale. Its name comes from German: Biologische Bundesanstalt, Bundessortenamt und Chemishe Industrie [Meier 1997]. The scale uses a decimal code system, and designates 10 basic phases (0–9) and secondary phases (0–9). Based on the scale and own observations conducted in 2019, a description of phenological stages of cornelian cherry was proposed. In the case of cornelian cherry, the first visible phenophase is the development of flower buds (Table 1). A specific feature of cornelian cherry is the fact that phases covering bursting of flower buds and flowering (50–59 and 60–69 BBCH) occur before the phases of development of leaf buds and leaves (01–09 and 10–19 BBCH) (Table 1, Phot. 7).

The appearance of the plant also depends on its age. A characteristic feature of cornelian cherry is its longevity and slow growth. It can reach its final size even after 100 years, and some known specimens at an age of several hundred years (200–300 years) are still in perfect condition. The juvenile period is long in the case of propagation from seeds – the plants begin to flower and bear fruit after 8 years the earliest. At natural sites, cornelian cherries usually occur

Table 1. Phenological phases of cornelian cherry based on the example of the Roch genotype in 2019. Terms of particular stages adjusted to BBCH codes [Source: own observation]

Code BBCH	Phase of growth and development	Start date
00	State of dormancy, leafless period: leaf and flower buds closed and covered with dark brown scales. Flower buds are round and considerably larger than leaf buds	< 07.02
51	Start of bud swelling (flower buds), visible light brown scales with light edges forming a shape of a cross	07.02
52	End of bud swelling, scales separated, visible change in colour to light green	19.02
53	Bud opens and yellow flower buds are visible, brown scales open	21.02
55	Half-open bud, individual flowers visible with closed calyces	03.03
56	Flower petals become elongated, sepals closed, individual flowers separate	06.03
59	Sepals open, all separate individual flowers visible, petals still closed	13.03
60	First flowers open	16.03
61	Start of flowering phase, approximately 10% of flowers open	19.03
62	Approximately 20% of flowers open	21.03
65	Full bloom, 50% of flowers fully open	25.03
67	Decline of flowers	29.04
69	End of flowering, unpollinated flowers fall	09.05
01	Start of swelling of vegetative buds – buds burst, separating in their top part	27.03
07	Bud opens, revealing green tips of the first leaves	03.04
09	Length of the first leaves equal to the length of scales surrounding the leaf bud	08.04
10	Bud scales wide open, first leaves appear	12.04
11	First leaf developed; axis of shoot development visible	17.04
12–15	Leaves increase in size, still not reaching proper sizes	19.04
19	First leaves completely developed	13.05
31	Start of shoot growth, visible shoot development axes	04.05
32	Shoots reach approximately 20% of typical length	10.05
33	Shoots reach approximately 30% of typical size	20.05
34	Shoots reach approximately 90% of typical length	31.05
71	Setting fruit, start of ovary growth	29.04
73	Ovary growth; falling of unpollinated primordia	11.05
75	Fruit reaches approximately half of typical size	05.06
76	Fruit reaches approximately 60% of typical size	15.06
77	Fruit reaches 70% of typical size	20.06
78	Fruit reaches approximately 80% of typical size	24.06
79	Fruit reaches approximately 90% of typical size	28.06
81	Start of ripening phase, colouring of the fruit	04.07
85	Advanced colour of the fruit, 50% of fruit has vivid red colour	07.07
87	70% of ripe fruit is red in colour. Ripe fruits begin to fall	15.07
89	Ripe fruits for consumption have a typical taste and firmness, are matte, and fall	30.07
39	Secondary shoot growth	20.08
91	End of shoot growth, leaves still vividly green	20.10
92	Start of aging, leaves start to change colour	05.11
93	Leaves start to fall	08.11
95	50% of leaves have changed colour or fallen	20.11
97	70% of leaves have fallen	28.11
99	All leaves have fallen. Period of winter dormancy	05.12



Phot. 7. Selected phenological phases of cornelian cherry according to the BBCH scale

Phot. 8. Several decades old cornelian cherry with multiple trunks growing in Bolestraszyce

Phot. 9. Developing flower buds and still dormant leaf buds

in the form of multiple trunk shrubs reaching a height of up to 3–7 m (Phot. 8). Trained, they develop a trunk and crown. First, they develop high crowns, and at later age they become round or flattened. In Poland in Pobiedno near Sanok (in Subcarpathia), a large specimen with six trunks grows, with a diameter of the trunks at the base reaching 308 cm, the diameter of the crown 12 m, and height 7 m [Piórecki 2007].

Phot. 10. Bursting of flower buds of cornelian cherry

The plant develops a dense crown. The bark is greyish and dark brown in colour. Cornelian cherry wood is very heavy, hard, with no evident age rings, very resistant, flexible, hardly cleavable. The colour of the heartwood is red-brown, and sapwood red-white. The wood is suitable for wood turning, particularly useful in production of craftwork tools [Otwarta Encyklopedia Leśna 2013].

The root system is dense and often develops offshoots. The main root mass persists at a depth of 70–80 cm. The leaf buds have an elongated shape (Phot. 9), slightly stick out from the shoot, and have a small diameter.

Flower buds are larger than leaf buds, round, with short stems (Phot. 10), resistant to frost, and strongly swollen in winter.

Phot. 11. Development of individual flowers in an inflorescence of cornelian cherry

Phot. 12. Flower bracts after falling of all flowers due to unfavourable climate conditions

Phot. 13 and 14. In early spring, not only bees are active in pollinating cornelian cherry

The flowers are collected in round umbels (2 cm) 10–20 flowers in each, small (approximately 5 mm in diameter) and yellow, offering a beautiful sight in early spring. An average of 15–25 flowers develop from an individual bud (Phot. 11). Each flower is composed of a four-part calyx, 4 crown petals, 4 stamens and one pistil. The scales covering each bud after opening constitute bracts of the inflorescences [Bieniek et al. 2001].

In the case of disruption of pollination and insemination, all flowers fall, and only four-scale bracts remain (Phot. 12).

The flowers are self-incompatible which means they require another specimen for flower pollination (they cannot be pollinated with their own pollen). The resistance of generative parts to spring frost is high. Moreover, they do not bloom evenly – half of the total number of flowers appears first, and other after approximately a week. This prevents damage of all flowers by strong frost. When temperature is too low, scales around the inflorescences cover the flowers again [Brindza et al. 2009]. The flowers have a large nectary, and constitute a valuable resource for various insects in early spring (Phot. 13 and 14).

The flowers produce a strong smell. Pollen is transported by insects, and cornelian cherry flowers are eagerly frequented by bees if a beehive is located nearby. During flowering, temperature is often low, and at 10°C the foraging honeybee does not leave the hive. On sunny and windless days at 12°C, bees begin foraging (Phot. 15 and 16), although the peak of their activity is recorded at 14–16°C. In the case of cornelian cherry it is important that the hives are near a plantation, because unfavourable temperature conditions limit the distance of flight of worker bees to 30–50 m from the hive. Bumblebees are good pollinators, visiting flowers even at lower temperatures, cloudy weather, and even in light rainfall. The bumblebee nest, however, needs to be located near a plantation, because the range of flight of the insect is 1 km, and approximately half the foraging bumblebees do not fly further than 100–200 m. Wild Apidae are good pollinators, e.g. red mason bee, but they are most likely to be active at a higher temperature of 15°C, in sunny weather, and relatively close to the nest (100–200 m). The bumblebee and red mason bee show low flower loyalty, because during search for food they do not exchange information with one another like bees do through their "dancing". Therefore, they penetrate

Phot. 15. First spring flowers attract bees

Phot. 16. Flowers of cornelian cherry are a good source of nectar and pollen for bees

the area around the nest in all directions, and are often attracted by plants competitive to the cultivated crop [Alkassab et al. 2020].

The quantity and quality of yield from fruit trees largely depend on the degree of flower pollination. A low degree of pollination, and then setting fruit depends among others on particular properties of the pollen such as the number of pollen grains, rate of germination, and morphological uniformity [Stösser 1984]. Pirlak and Güleryüz [2005] determined the quantity and quality of pollen for several types of cornelian cherry. Based on the analysis of the pollen viability index, they determined that among the studied types, viable pollen constituted from 53.3 to 66.9%, semi-viable pollen from 2.1 to 20.4%, and non-viable from 13.5 to 27.6%. Like in the case of other stone fruits, cornelian cherry pollen in *in vitro* conditions germinated best on 15–20% sucrose solution [Werner and Chang 1981, Parfitt and Ganeshan 1989, Eti 1991], and considerably weaker on boric acid. The average number of anthers in a flower was 3.925–3.975. The number of pollen grains per flower did not differ between the analysed types, and varied from 7082 to 13,500 per flower. Particular anthers, however, developed a highly variable number of pollen grains ranging from 1782 to 3418 per anther. Pollen grains showed a high degree of morphological uniformity (from 92.4 to 96%). Dokuzoguz [1964] evidenced a close dependency between the degree and rate of germination of pollen grains and morphological uniformity of pollen. High morphological uniformity of cornelian cherry pollen grains suggests their high ability to inseminate ovules. According to Klymenko [2013], optimal yields of cornelian cherry fruit are obtained when 4–5 flowers are set per inflorescence (Phot. 17).

Cornelian cherry is characterised by opposite, reticulated leaves on shoots (Phot. 18). The leaves are shiny, with smooth unbroken edges, dark green – in autumn they turn yellow and red. The shape of the leaves is oval, obovate-elliptic, pointed. The laves feature very characteristic arched veins (3–5 pairs), and underneath at the connection of the veins, wooly white hairs (Phot. 19).

Cornelian cherry fruit is associated with cherries or plums. It is also juicy with a pit, with a bitter and sour, sometimes sweet and sour flavour, and specific aroma. It develops very slowly, and the first small primordia can be observed at the end of April, together with the development of leaves. The shape of the fruit depends on the cultivar. It can be round, oval, longilinear, pear-shaped, bottle-shaped, elongated. The length of the fruit varies from 1 to 4 cm, and the diameter is approximately 2 cm. The colour of the fruit can range from white, yellow, pink, red, through cherry red, to almost black. The skin of the fruit is flexible and shiny. The weight of the fruit varies from 1.2 g to 6 g, and even up to 10 g (Ukrainian cultivars) [Klymenko 2017]. The term of ripening of the fruit depends on the cultivar. It usually ranges from August (although there are cultivars ripe in mid-July) to October. The fruit ripens unevenly (Phot. 20), and fully ripe fruit spontaneously falls. Harvest can be

Phot. 17. Optimal number of set flowers of cornelian cherry

Phot. 18. Leaves of cornelian cherry with opposite arrangement

Phot. 19. Leaf blade of cornelian cherry – matte bottom side with evident white hairs

Phot. 20. Flower buds and ripening fruit of cornelian cherry

extended over 20 to 50 days [Szot et al. 2018]. The period of ripening depends on the genetic properties of the plants, but also on the climate conditions occurring during the vegetative season. The flesh is bitter and sour due to a high amount of acids and tannins in comparison to the amount of sugar. The flesh structure is lumpy and juicy.

The pit is relatively large, elongated, closely adjacent to the flesh. Cornelian cherry pits are very hard. The seeds can account for 9–30% of the weight of the fruit.

Flower buds of cornelian cherry are set a year earlier, and they are already well visible at the moment of fruit ripening. The flower buds are much larger than the leaf buds, round, and covered with brown scales (Phot. 20).

5. Chemical composition of the fruit and its health benefits

Human living conditions have been rapidly changing due to the development of technologies that affect all aspects of human existence. Unfortunately, higher living standard does not entail healthier diet. The diversity of the diet has been particularly negatively affected.

An intensification of chronic non-communicable (so-called civilisational) diseases has been recently observed. One of the causes of the development of such diseases is so-called oxidation stress that occurs in the case of disturbance in the balance between the amount of free radicals and the antagonising disinfectant substances. Free radicals (primarily reactive forms of oxygen and nitrogen) are produced in each organism through natural metabolic transformations, and fulfil e.g. protective functions against microorganisms in the cell, preventing infection. After eliminating the threat, the organism activates protective processes that neutralise the activity of free radicals. In a situation of oxidation stress, however, the organism is weakened and susceptible to diseases. The organism develops a system of endogenic antioxidants such as superoxide dismutase, catalase, glutathione, and many others. When the said protective mechanisms fail, the organism can be aided by supplying exogenic antioxidants, namely bioactive substances of plat origin such as ascorbic acid, tocopherols, carotenoids, vitamin A, and a rich group of compounds called polyphenols [Kitajewska et al. 2014]. The best source of vitamins and polyphenols are fruits, vegetables, and herbs, because they contain such substances in forms most readily available for our organism. Cornelian cherry is a relatively little known fruit, and that fact alone makes it perfect for diversifying human diet. Moreover, due to the chemical composition of the fruit, it offers health benefits both in the fresh and processed form.

An ancient Crimean legend has it that once upon a time, a daughter of the Great Khan was very ill. With a promise of a generous reward, her father summoned a famous Byzantine physician. Upon entering the room with the patient, the foreign guest looked at the wide open windows overlooking swaying branches of cornelian cherry in golden bloom, and announced he would be returning home. Surprised Khan asked why the important guest would not examine the patient. The doctor answered: “Where there is cornelian cherry, you need no doctor. If that plant did not help the patient, Allah himself will not save her”. The daughter recovered owing to the exceptional properties of cornelian cherry… What determines the health benefits of the plant?

The fruit of cornelian cherry contains what the human organism needs, namely carbohydrates, proteins, and fats, without high calorific value. 100 g of fresh mass of the fruit contains 21.7 g of carbohydrates, 0.4 g of protein, and 0.1-0.3 g of fat, supplying 46 kcal. The chemical composition of the fruit is very rich, but like with all fruits, it depends on many factors, particularly genetic, climate, and agrotechnical conditions [Da Roch et al. 2016].

The assessment of the fruit in terms of its nutritional value should involve the determination of the basic composition that shapes its quality, i.e. content of dry mass, extract, acidity, and pectins. The basic property characterising the quality of the fruit is the extract content. According to Sochor et al. [2014], popular cultivars of cornelian cherry such as Devin, Elegantmyj, Fruchtal, Jaltsky, Joliko, Sokolnicky, and Wydubieckij have 15.46% of extract content. Jaćimović and Božović [2014], assessing the chemical composition of approximately a dozen genotypes from Montenegro, recorded extract content from 12.23% to 20.10%. Kucharska et al. [2011] estimated that the extract content of Polish cultivars of cornelian cherry varied from 13.8% (Juliusz) to 19.85% (Szafer). In Slovenian research of Vidrih et al. [2012], extract content oscillated between 10.70 and 19.30%.

According to the study by Tarko et al. [2010], the fruit of cornelian cherry is very similar to cherries in terms of content of reducing sugars and the fructose to glucose ratio. They contain approximately 9% of simple sugars, whereas the proportions of fructose to glucose are 2:3. In the study by Kucharska et al. [2011], the content of reducing sugars varied from 9.1% (Podolski) to 14.7% (Szafer). According to Petkova and Ognyanov [2018], the content of reducing sugars in fresh fruit was 14.56%, glucose 12.26%, and fructose 1.90%. It is assumed that fruit for consumption in fresh state should contain at least 10 times more sugars than acids [Lesińska 1986]. In lemons, the ratio of the content of sugars to acids is approximately 1:1 [Pijanowski et al. 1973]. In quince, it oscillates around 2:1, suggesting unsuitability of the fruit for direct consumption [Tarko et al. 2010]. In the case of most cultivars of cornelian cherry, the ratio of sugars to acids is approximately 3:1 which determines its primary use in processing. Sweet cultivars of cornelian cherry with low acidity exist, however. In favourable climatic conditions, they reach values of the ratio of 3.0-9.3, and therefore are suitable for consumption as dessert [Guleryuz et al. 1998, Pirlak et al. 2003, Tural and Koca 2008]. Kucharska et al. [2011], assessing cultivars from Bolestraszyce, determined their ratio values from 4.6 (Podolski) to 9.3 (Dublany).

Sochor et al. [2014] recorded 17.94% of dry mass for cornelian cherry, and Petkova and Ognyanov [2018] as much as 30.74%. The causes for such high differences in the content of dry mass may result from different cultivation conditions, not only their genetic properties.

The content of pectins in the fruit determines its suitability for processing. Fruits with high content of pectins are useful in the production of jams and purees, because they provide for appropriate consistency, and in the case of cloudy juices – stabilise cloudiness. Cornelian cherry stands out among stone fruits in terms of pectin content. In the study by Kucharska et al. [2011], from 1.13 to 1.86% of the compounds were recorded.

Fruits of cornelian cherry also contain fat fractions, both in the flesh and the stone. According to Kucharska [2012], the percent content of fats differs between the flesh and stone. The content of the fat fraction in the flesh varied from 0.32 to 0.72%, and in stones from 1.7 to 3.6%. The fruit contains primarily unsaturated fatty acids dominated by linoleic acid 73% [Kucharska 2012] or 68% [Vidrih et al. 2012]. The remaining acids include oleic acid 16.07% [Kucharska 2012]; 19.65% [Vidrih et al. 2012], stearic acid 4.6% [Kucharska 2012]; 2.3% [Vidrih et al. 2012], palmitic acid 4.12% [Kucharska 2012], 7.74% [Vidrih et al. 201], linolenic acid 1.67% [Kucharska 2012]; 1.53% [Vidrih et al. 2012]. Vidrih et al. [2012] also determined 0.45% of the arachidonic acid fraction in the stones of cornelian cherry. The stone also contains mineral salts Ca (409.32 $mg \cdot kg^{-1}$), K (306.42 $mg \cdot kg^{-1}$), P (234.14 $mg \cdot kg^{-1}$), Mg (45.66 $mg \cdot kg^{-1}$), Na (16.81 $mg \cdot kg^{-1}$), and Cu (0.48 $mg \cdot kg^{-1}$) [Vidrih et al. 2012]. The fruit of cornelian cherry also contains mineral salts such as K (3639.77 $mg \cdot kg^{-1}$), Ca (594.12 $mg \cdot kg^{-1}$), P (362.2–371.27 $mg \cdot kg^{-1}$), Mg (269.96 $mg \cdot kg^{-1}$), Na (74.55 $mg \cdot kg^{-1}$), Fe (44.79 $mg \cdot kg^{-1}$), Mn (26.60 $mg \cdot kg^{-1}$), Zn, (3.05 $mg \cdot kg^{-1}$), and Cu (1.32 $mg \cdot kg^{-1}$) [Dokoupil and Řezníček 2012, Sochor et al. 2012].

The fruit of cornelian cherry contains at least 15 amino acids: aspartic acid, glutamic acid, serine, histidine, glycine, threonine, arginine, alanine, tyrosine, valine, phenylalanine, isoleucine, lysine, and proline [Brindza et al. 2009].

Since the discovery of vitamins, they have been known to have a strongly beneficial effect on the human organism, particularly vitamin C. Unfortunately, in the course of evolution, people have lost the ability to synthesise this valuable vitamin, and need to supply it with food every day. Of course a method of supplying synthetic vitamin C has already been invented, and it is identical to the natural vitamin in its structure. It turns out, however, that the human organism absorbs vitamin C from food much better than that in the form of artificial supplements. Natural vitamin is bonded with biocomponents that permit its easier absorption and longer maintenance of its optimal level in the organism. The content of vitamin C in the fruit of cornelian cherry varies from 34.29 to 75,05 mg·100 g^{-1} [Kucharska et al. 2011]. According to Vidrih et al. [2012], the concentration of vitamin C in the fruit of cornelian cherry is at a level of 29.29–71.22 mg·100 g^{-1}.

An increased interest in healthy foods has led to intensive research on substances of plant origin. From among approximately 400,000 plant species, around 40,000 show medicinal properties. Out of this number, 1–1.5% of them are investigated in detail in terms of health benefits. Polyphenols enjoy particularly high popularity as phytotherapy substances. More than 8000 of polyphenols have been isolated. They primarily occur in plants, and accumulate in all parts of the plant organism: sprouts, roots, stems, leaves, flowers, and fruits. They are nonnutritive substances, and fulfil a protective function in the plant, e.g. against harmful UV radiation or pathogenic microorganisms. Due to their variable structure resulting from the number, type, and location of substituents in the particle, polyphenols show varied properties, e.g. anti-inflammatory, antioxidant, anti-allergenic, anti-carcinogenic, anti-atherogenic. They are characterised by the presence of a benzoic ring with a high number of hydroxyl groups. They usually bond with sugars, organic acids, and esters, and few are aglycones.

Many studies have determined total amount of polyphenols in the fruit of cornelian cherry as 158–600 mg GAE·100 g^{-1} [Tarko et al. 2010, Kucharska et al. 2011, Petkova and Ognyanov 2018, Martinović and Cavoski 2020].

Anthocyanins belong to polyphenols and constitute a large group of dyes. They are nonnutritive substances soluble in water. Anthocyanins content depends on many factors, among others the cultivar, climate and habitat conditions, and degree of ripeness of the fruit. In the study by Martinović and Cavoski [2020], the recorded total anthocyanins content was at a level of 11.85–195.43 (mg·100 g^{-1}), whereas in the study by Kucharska et al. [2011] 27.52–160.51 (mg·100 g^{-1}). In research by Sengul et al. [2014], individual genotypes significantly differed in total content of anthocyanins, ranging from 262 mg·100 ml^{-1} to 342 mg·100 ml^{-1}.

Anthocyanins occur not only in the fruit of cornelian cherry, but also in other species from genus *Cornus*. Vareed et al. 2006 evidenced that the primary anthocyanin contained in the fruit of *Cornus alternifolia, C. controversa, C. kousa*, and *C. florida* is 3-*O*-cyanidin glucoside. The fruit of cornelian cherry has been found to contain anthocyanins belonging to cyanidins, pelargonidins, and delphinidin. Cyanidins totalled from 0.17–166 mg·100 g^{-1} [Moldovan et al. 2016, Ochmian et al. 2019]. Among cyanidins, the fruit of cornelian cherry contains 21.44–130.93 mg·100 g^{-1} of cyanidin thiogalactoside [Ochmian et al. 2019, Martinović and Cavoski 2020] and 3.12-130.93 mg 100 g^{-1}

of cynanidin tribenoside [Ochmian et al. 2019, Martinović and Cavoski 2020]. Among delphinidins, 0.69–162 mg·100 g^{-1} of delphinidin thiogalactoside was determined [Moldovan et al. 2016, Ochmian et al. 2019]. Among pelargonidins, 177.43 mg·100 g^{-1} of pelargonidin thiogalactoside was recorded, 19.78 mg·100 g^{-1} of pelargonidin tribenoside, and 0.43 mg·100 g^{-1} of pelargonidin tripentoside [Ochmian et al. 2019].

In the assessment of the chemical composition of several genotypes of cornelian cherry in Turkey by means of HPCL, Sengul et al. [2014] evidenced that the dominant anthocyanin was cyanidin 3-*O*-rutinoside chloride, followed by delphinidin chloride and peonidin 3-*O*-glucoside chloride.

Gunduz et al. [2013] determined a strong dependency of the content of anthocyanins on the degree of ripeness of the fruit. The fruit of cornelian cherry was found to contain dephinidin-3-*O*-glucoside, delphinidin-3-*O*-galactoside, cyanidin-3-*O*-galactoside, and pelargonidin-3-*O*-galactoside. It was observed that an increase in the degree of ripeness is accompanied by a decrease in the content of polyphenols, and a decrease in their antioxidant capacity. Although fully ripe fruit with dark red colour is the most eagerly consumed, fruit that is still yellow or delicately dyed red contain the highest amount of active antioxidants due to the high content of phenols and tannins. The content of anthocyanins increases with the degree of ripeness of the fruit of cornelian cherry from the stage of light yellow to dark red fruit. The changes result from the decomposition of chlorophyll and synthesis of anthocyanins in ripe fruit [Gunduz et al. 2013].

Among flavonols of cornelian cherry, derivatives of kaempferol were identified such as kaempferol trigalactoside to the amount of 1.61–2.35 mg·100 g^{-1} [Ochmian et al. 2019, Kucharska 2012] and kaempferol triglucoside 0.10 mg·100 g^{-1} [Ochmian et al. 2019]. The group of quercetins in cornelian cherry comprises 0.51 of quercetin trigalactoside [Ochmian et al. 2019], 2.49–29.66 mg·100 g^{-1} of quercetin triglucuronide [Kucharska 2012, Ochmian et al. 2019, Martinović and Cavoski 2020], 0.64 mg·100 g^{-1} of quercetin trirhamnoside, 0.29 mg·100 g^{-1} of quercetin trirutinoside, and 0.37 mg·100 g^{-1} of quercetin trixyloside [Ochmian et al. 2019].

Phenolic acids in the fruit of cornelian cherry occur to the amount of 158 mg·100 g^{-1} [Martinović and Cavoski 2020]. Chlorogenic acid was frequently recorded at a level from 11.27 to 32.76 mg·100 g^{-1} [Moldovan et al. 2016, De Biaggi et al. 2018, Ochmian et al. 2019]. According to Nurzyńska-Wierdak [2016], one of particularly interesting active compounds in cornelian cherry is ellagic acid a considerable source of which had been sought for in strawberries 0.7–4.3 and raspberries 3.7–4.7 mg EA mg·100 g^{-1}). In the fruit of cornelian cherry, its content varied from 0.63 to 187.91 mg·100 g^{-1} [Moldovan et al. 2016, De Biaggi et al. 2018, Ochmian et al. 2019]. Ochmian et al. [2019] also found gallic acid in the fruit of cornelian cherry to the amount of 21.25

mg·100 g^{-1}, as well as its derivatives such as glucose gallate 1.0 mg· 100 g^{-1}, glucose digallate 16.87 mg·100 g^{-1}, glucose trigallate 1.72 mg·100 g^{-1}, glucose tetragallate 2.92 mg·100 g^{-1}, and glucose pentagallate 7.80 mg·100 g^{-1}.

The fruit of cornelian cherry has high biological value due to its antioxidant properties resulting from the content of many polyphenols and vitamin C [Rop et al. 2010]. The antioxidant properties of the fruit have been recognised in the prevention of dangerous chronic noncommunicable diseases such as cancer, diabetes, hypertension, and others. The conducted research assessed the anticarcinogenic potential in the case of use of relevant *in vitro* cellular models imitating a specified type of cancer. It was determined that for the anthocyanins from cornelian cherry the value reahes approximately 50% for colon, breast, lung, stomach, and central nervous system cancer [Vareed et al. 2006].

Scientists have developed methods permitting the determination of antioxidative activity of plant extracts. They are based on chemical reactions between an antioxidant and model free radicals (ABTS, DPPH) or metal ions (FRAP). Of course, the methods are not the actual antioxidative activity in a living organism, because they do not consider metabolism and transport of antioxidants in human cells [Koss-Mikołajczyk et al. 2017]. According to research by Kucharska et al. [2011], among Polish cultivars, the highest amount of vitamin C, polyphenols, and therefore the highest antioxidative activity was found for the fruit of cornelian cherry of Szafer cultivar.

David et al. [2019] evidenced that anthocyanins contained in the fruit of cornelian cherry can persist in the human organism over a longer period of time. Through an *in vitro* simulation of the digestion process, the study assessed the stability of anthocyanins from cornelian cherry during their passing through the upper digestive tract. Fruit extract from cornelian cherry was rich in anthocyanins such as: cyanidin 3-*O*-galactoside, pelargonidin 3-*O*-glucoside, and pelargonidin 3-*O*-rutinoside. It was evidenced that stomach digestion had no considerable effect on the amount of anthocyanins, and only intestinal digestion caused a significant decrease in their content and antioxidative activity. These findings suggest that the fruit of cornelian cherry is an important source of anthocyanins in human diet. They can have a positive effect on health at the stomach level, whereas their degradation products and metabolites can serve as antioxidants in the small intestine.

Yigit [2018] investigated the effect of water and alcohol extract from the fruit of cornelian cherry in terms of their antioxidant and antimicrobial properties. The antimicrobial activity of the aforementioned extracts was analysed by means of the disc diffusion method on 93 clinical isolates of human pathogenic strains belonging to 5 bacteria (*Entorobacter aerogenes, Escherichia coli, Proteus mirabilis, Pseudomonas aeroginosa, Staphylococcus aureus*) and 5 species of yeast (*Candida albicans, Candida glabrata, Candida krusei, Candida parapisilosis, Candida tropicalis*). According to the author, the fruit extract can be applied in treatment of diarrhoea and gastrointestinal conditions due to high activity of the fruit against some human pathogens (*E. coli*). Moreover, high antioxidative activity can support ethnopharmacological applications such as the improvement of the functioning of the immune system.

Another very important group of compounds contained in the fruit of cornelian cherry are iridoids. Due to the intensification of the occurrence of inflammatory diseases, emphasis is currently put on the development of herbal medicines that could replace non-steroidal anti-inflammatory drugs and glucocorticosteroids. Researchers focus on medicinal plants that show anti-inflammatory properties. It turns out that each of such plants contains iridoids. Iridoids primarily occur in the leaves and young shoots, and rarely in the fruit. They are found in Japanese cornelian cherry (*Cornus officinalis*), but its fruit is bitter. In the fruit of *C. officinalis*, the content of all identified iridoids was 188–332 mg·100 g^{-1} [Czerwińska and Melzig 2018]. In *C. mas* in the study by Kucharska [2012] it averaged 221.1 mg·100 g^{-1}, and according to Martinović and Cavoski [2020] it varied from 129.07 to 341.20 mg·100 g^{-1}. The fruit of cornelian cherry was found to contain iridoids, primarily loganic acid (88-96% of total content of iridoids), as well as loganin, sweroside, and cornuside [Deng et al. 2013]. Martinović and Cavoski [2020] recorded 118.18–303.37 mg·100 g^{-1} of loganic acid. Loganic acid shows strong anti-inflammatory properties [Wei et al. 2013]. Loganin and sweroside show strong antibacterial, antifungal, and antispasmodic properties [Dinda et al. 2007]. Moreover, loganin has been determined to have neuroprotective properties [Shi et al. 2012].

Nawirska-Olszańska et al. [2010 a] investigated the content of fibre in the fruit of cornelian cherry. Fibre has been long considered an indigestible ballast substance. Since the mid-1960's, however, interest in fibre has considerably increased, because its components were discovered to bond a number of substances harmful to the organism, including cholesterol. Therefore, it can be helpful in prevention and treatment of obesity, diabetes, atherosclerosis, heart diseases, as well as colon and colorectal cancer. Hemicelluloses and pectins, as well as to a lower degree celluloses and lignins, also have the ability to bond metals. In the cited experiment, the analysed cultivars contained different amounts of fibre and its fractions. The level of particular fractions considerably depended on the cultivar and vegetative season. The highest value of the neutral and acidic fraction of fibre was recorded in the fruit of the Florianka cultivar, (16.1 g·100 g^{-1} d.m. and 12.2 g·100 g^{-1} d.m., respectively), and the lowest – in the fruit of the Bolestraszycki cultivar (10.7 g·100 g^{-1} d.m. and 7.6 g· 100 g^{-1} d.m., respectively). The highest amount of lignins (8.5 g·100 g^{-1} d.m.) was determined in the Florianka cultivar, and the lowest (3.3 g·100 g^{-1} d.m.) in the Bolestraszycki cultivar. In the fruit of cornelian cherry, the range of concentrations of hemicellulose and cellulose was 2.3–4.5 g·100 g^{-1} d.m. and 3.1–6.7 g·100 g^{-1} d.m., respectively. In the study by Tarko et al. [2010], fibre content in cornelian cherry was 1.53%.

According to Sozański et al. [2014], the mechanism of activity of compounds contained in cornelian cherry can prevent dyslipidaemia and atherosclerosis. In the thoracic and thoracoabdominal aorta of rabbits fed fodder with an addition of lyophilised fruit of cornelian cherry, a lower level of atherosclerotic lesions was determined in comparison to the group of rabbits fed fodder with a 1% addition of cholesterol. Moreover, cornelian cherry was determined to potentially show anti-inflammatory properties, which in the context of the current theory of development of atherosclerosis plays a crucial role. The inflammatory process can lead to the development of atherosclerotic plaque and clots. According to Iranian research [Rafieian-Kopaei et al. 2011], powdered lyophilised or dried fruit shows anti-atherosclerotic properties due to the content of loganic acid and anthocyanins. One of the indicators is the presence of prothrombotic factors and fibrinogen. Research on rats recorded a decrease in the level of fibrinogen and malondialdehyde due to diet enriched with the fruit of cornelian cherry.

In medicine, a lot of attention is paid to substances the consumption of which limits the accumulation of fat tissue, therefore reducing the risk of cardiovascular diseases and diabetes. Such substances are e.g. anthocyanins such as pelargonidin 3-*O*-ramnoside and cyanidin 3-*O*-glucoside [Faienza et al. 2020]. Jayaprakasam et al. [2006] investigated the effect of purified anthocyanins such as cyanidin 3-*O*-galactoside, pelargonidin 3-*O*-galactoside, and delphinidin 3-*O*-galactoside, as well as ursolic acid isolated from the fruit of cornelian cherry on the reduction of obesity and glucose intolerance. Mice were initially fed high-fat diet for 4 weeks. Then the diet was changed to high-fat diet with anthocyanins (1 g/kg of high-fat diet) and ursolic acid (500 mg/kg of high-fat diet) for an additional eight weeks. The high-fat diet induced glucose intolerance, prevented by anthocyanins and ursolic acid. Mice treated with anthocyanins showed a 24% decrease in body weight increase. These mice also exhibited reduced accumulation of lipids in the liver, including a decrease in the concentration of triacylglycerol in the liver. Gholamrezayi et al. [2019] confirmed that extract from the fruit of cornelian cherry counteracts dyslipidaemia, because it causes a decrease in total cholesterol, TG, LDL cholesterol, and to a certain degree also HDL. The authors explain it with high content of anthocyanins that affect receptors activated by peroxisome proliferators (PRAR). PRAR show antiproliferation properties.

Glaucoma, covering a number of diseases leading to systematically progressing damage of the optic nerve and retina ganglionic cells, is manifested in a decrease in field of vision. It is the second disease after cataract that is the cause of blindness. It is estimated that by 2040, glaucoma morbidity will have increased by 75%. Glaucoma is a chronically progressing disease, therefore it requires safe methods of its prevention and support of treatment. The only proven factor causing glaucoma is increased intraocular pressure (IOP) that can permanently impair vision in the affected eye. Because only a limited number of chemical compounds exists that can reduce IOP and blood flow in eye vessels, new substances are continuously searched for. [Szumny et al. 2015] investigated the chemical composition of the dried fraction of cornelian cherry fruit, rich in iridoids and polyphenols. The main components included loganic acid (50%) and polargonidin-3-galactoside (7%). Among other components, the fraction contained iridoid cornuside and anthocyanins, cyanidin 3-*O*-galactoside, cyanidin 3-*O*-robinobioside, and pelargonidin 3-*O*-robinobioside. An animal model (on New Zealand rabbits) was used to investigate the effect of loganic acid and the polyphenol fraction isolated from cornelian cherry fruit. A strong hypotension effect of IOP was determined for 0.7% solution of loganic acid that can be compared with the broadly ophthalmologically applied timolol. During the first 3 hours of application, an approximately 25% decrease in IOP was observed.

To sum up, results by many researchers regarding the fruit of cornelian cherry point to a broad range of activity of the components of plant preparations based on this resource. They illustrate the mechanism of activity of both whole fruits and isolated biologically active substances. Sozański et al. [2014, 2018, 2019] evidenced that some mechanisms of activity of preparations from cornelian cherry fruit are the same as the mechanisms of activity of medicinal products, and therefore constitute a bridge between folklore medicine and modern pharmacotherapy. The importance of this area of research is emphasised by the Nobel Prize awarded to Professor Youyou Tu from the Academy of Traditional Chinese Medicine in 2015. They developed drug Artemisin that reduced mortality of malaria patients. Folklore medicine is based on natural resources and the experimental method using experience with results handed down from generation to generation. Modern achievements of molecular techniques and experimental pharmacology allow for an explanation of its effect on the human organism based on detailed investigation of the composition of the plant material.

6. Cultivation of cultivars

Fruit from natural sites is small, sour, with relatively low juiciness and a large stone, particularly in the case of a long-lasting draught. Moreover, yields from such sites are usually small: 3–5 kg of fruit per shrub. They rarely reach 10–15 kg per shrub in optimal humidity and temperature conditions. In the case of cornelian cherry, selection for cultivation is performed in accordance with the following criteria: size of the fruit, its colour and shape, share of the stone in the entire mass of the fruit, term of ripening and harvest, uniformity of ripening of the fruit, yield quantity and quality, frost resistance, growth strength, and self-pollination [Hassanpour and Ali Shiri 2014].

The origin of the crop cultivars of cornelian cherry is not completely known, because its large fruit forms occur both in Crimea and Anatolia (Turkey). In former times no one dealt with selection and purposeful cultivation, and even when interesting genotypes were designated, they disappeared over centuries. Successive accumulation of genetic resources and cultivation was developed in Ukraine by Prof. Svetlana Klymenko (Phot. 21).

Phot. 21. Prof. Svetlana Klymenko talks with fascination about cornelian cherry

She began intensive cultivation works in 1960 in the National Botanical Graden of N.N. Griszka in Kiev. She obtained valuable cultivars standing out in terms of size and flavour of the fruit, resistant to frost, and ripening over a relatively short period of time (Phot. 22). She based her works on material collected over many years in the botanical garden, as well as that sought for in nature and among cultivations throughout the country, as well as from Bulgaria, Slovakia, England, Austria, and Georgia. Out of approximately 350 forms distinguished by biological and production diversity, she selected and propagated more than 100 [Klymenko 2013].

Phot. 22. Ukrainian cultivar of cornelian cherry 'Ekzotycznyj', with exceptionally large fruit

The cultivation works primarily involved the selection of incidental seedlings and combining promising types of cornelian cherry, but several cultivars such as Ekzoticznyj, Swietijaczok, and Prezent resulted from spontaneous somatic mutation. In Ukraine, works have also commenced on obtaining new cultivars through interspecies combinations. The result of such works is cultivar 'Etiuda' (Phot. 23) that was developed through supplying a mixture of pollen of cultivars (Lukjanowskij oraz Jeljena) of cornelian cherry (*C. mas*) onto the flowers of *C. officinalis* No 1. The resulting cultivar differs from cultivars of cornelian cherry in terms of morphological and biochemical properties. A feature inherited after *C. officinalis* is weaker falling of fruit. In the National Ukrainian Register of Cultivars, the first cultivars of cornelian cherry appeared in 1987. There are currently 14 such entries [Klymenko 2007].

Next to Ukraine, also other countries such as Austria, Bulgaria, Slovakia, former Yugoslavia, Germany, and Turkey have begun intensive selection and cultivation of new cultivars (Table 2). In Bulgaria, owing to the works by researchers and the production plant Sortovi Semena i Posadchen Material, the first cultivars were registered in 1985. They were Kazanlytsky, with

Table 2. Origin of particular cultivars of cornelian cherry

Place of cultivation	Name of cultivar	Literature
Austria	Jolico, Fruchtal, Reichtragende Selection, Schönbrunner Gourmet Dirndl, Shan	Dokoupil and Řezníček [2012]
Azerbaijan	Ag-Zogal, Armudi-Zogal	Klymenko [2007]
Bulgaria	Flava, Kazanlytsky, Pancharevsky, Posadchen Material, Shumensky, Sortovi Semena	Klymenko [2007]
Czechia	Olomoucky, Sokolnicky, Ruzynsky	Bijelic et al. [2011]
Georgia	17 autochthonic forms, including: Adreula, Aromatnyj, Botliseburi Cchneturi, Łagodechskij Rannyj, Okroszinda	Maghradze et al. [2009]
Germany	Macrocarpa, Cormas	Klymenko [2007]
Poland	Bolestraszycki, Dublany, Florianka, Juliusz, Kotula, Kresowiak, Paczoski, Podolski, Raciborski, Słowianin, Szafer, Swietłana	Piórecki [2017]
Russia	Mosvir 1, Mosvir 2	Klymenko [2007]
Serbia and Montenegro	Approximately 16 genotypes designated in Novi Sad, including Aprani, Backa	Bijelić et al. [2012]
Slovakia	Devin, Titus, Ovidius, Santana	Brindza et al. [2007]
Turkey	7 genotypes	Turnal and Koca [2008], Yalcinkaya [2009], Yilmaz et al. [2009]
Ukraine	14 cultivars entered into the National Register of Cultivars of Ukraine: Elegantnyj, Ekzoticznyj, Etiuda (*C. officinalis* x *C. mas*), Grienadier, Jeljena, Jewgenija, Korałłowyj Marka, Łukjanowskij, Nikołka, Radost, Siemen, Swietljaczok, Wawiłowiec, Władimirskij, Wydubieckij. Other valuable cultivars: Aliesza, Bukowinskij, Jantarnyj, Jubilejnyj Klymenko, Korałłowyj, Kostia, Mrija Szajdarowoj, Nespodiwanyj, Narcyz, Nieżnyj, Oryginalnyj, Perweniec, Priorskij, Samofertylnyj Słastena, Sokolinoje, Starokijewskij, Sulija, Ugolek, Wyszgorodskij	Klymenko [2004]

Phot. 23. Flowers of cultivar 'Etiuda' appear earlier than on other cultivars of cornelian cherry

pear-shaped fruit, and Pancharevsky, with cylindrical fruit. In 1989 in Slovakia, based on works of the Slovakian Institute of Horticulture, two cultivars were registered, namely Devin and Titus. In 1991 in Austria, Ph.D. Helmut Pirc developed cultivar Jolico that was registered in the United States and quickly became popular in Austria, Germany, and Switzerland [Klymenko 2004].

In countries where cornelian cherry occurs in high abundance in forests, i.e. in Turkey, Iran, and Moldova, search for valuable cultivars also commenced, but in terms of an increase in the size and improvement in the flavour of the fruit. Natural resources are sufficient for processing, but the sour and sometimes bitted fruit is not suitable for the dessert fruit market.

In Georgia, genetic material covers only autochthonic types and one cultivar. The mass of fruit of Georgian cornelian cherries is 1–5.6 g. Three botanical cultivars are identified there:

1. *Cornus mas* var. *typica* Sanadze with red cylindrical fruit;
2. *Cornus mas* var. *pyriformis* Sanadze with red pear-shaped fruit;
3. *Cornus mas flava* with yellow fruit [Maghradze et al. 2009].

In Poland, the first collections of cornelian cherry were established by Jerzy Piórecki in the Arboretum in Bolestraszyce near Przemyśl at the turn of the 1970's and 1980's. He collected the most valuable ecotypes found in south-east Poland, e.g. in Bolestraszyce, Prałkowce, Florianka, Wyszatyce. They became output material for obtaining the first Polish cultivars of cornelian cherry such as: 'Bolestraszycki', 'Dublany', 'Florianka', 'Julisz', 'Kotula', 'Kresowiak', 'Paczoski', 'Podolski', 'Raciborski', 'Słowianin', 'Swietłana', and 'Szafer' (Table 3). Owing to the long-lasting work of Prof. Alicja Kucharska from the University of Life Sciences in Wrocław and employees of the Arboretum in

Table 3. Division of Polish cultivars by term of fruit ripening [Piórecki 2007]

Term of ripening	Cultivars
Early cultivars (harvest in mid-August)	Dublany, Juliusz
Medium-early cultivars (harvest – turn of August and September)	Raciborski, Szafer
Cultivars with average term of ripening (harvest in September)	Bolestraszycki, Kresowiak, Paczoski, Słowianin
Cultivars with late term of ripening (harvest – turn of September and October)	Florianka, Podolski

Table 4. Division of Polish cultivars by fruit shape [Kucharska et al. 2011]

Round	Oval	Oval-elongated	Pear	Pear-elongated	Bottle-pear
Juliusz	Florianka Podolski	Raciborski	Bolestraszycki Kresoviak Szafer	Dublany Paczoski	Słowianin

Bolestraszyce, and particularly head of the Arboretum Narcyz Piórecki, the said cultivars were assessed in terms of their biological properties of trees, as well as the quality of fruit and its usefulness.

The selection of a cultivar for a commercial plantation should depend on the planned application of the fruit. A very important useful trait of fruit is its mass. According to Polish researchers [Bieniek et al. 2001, Gąstoł and Skrzyński 2007], the mass of a single fruit varies from 1.20 to 3.78 g. Kucharska et al. [2011], assessing 10 Polish cultivars, determined that fruit with a mass below 3 g was typical of the following cultivars: 'Raciborski' (2.65 g), 'Juliusz' (2.71 g), 'Słowianin' (2.85 g), and 'Paczoski' (2.92 g). Fruit weight in a range from 3 to 4 g was characteristic of cultivars: 'Kresowiak' 3.01 g, 'Bolestraszycki' 3.26 g, 'Dublany' 3.31, 'Florianka' 3.42 g, 'Szafer' 3.34 g, and 'Podolski' 3.47 g.

Fruit suitable for direct consumption as dessert should have the highest weight possible. Ukrainian cultivars are worth attention here. The highest weight (above 7 g) concerns the following ones: 'Władimirskij', 'Ekzoticznyj', 'Swietljaczok' with pear-shaped fruit, or those standing out with skin colour, i.e. yellow fruit: 'Bukowinskij', 'Flava', 'Galitskij', 'Jantarnyj', 'Neżnyj', 'Pervenets', and 'Present' (yellow with red dots). Cultivars for direct consumption should also contain the highest content of sugars and show low acidity [Kucharska et al. 2011, Kucharska 2012].

Cultivars suitable for processing are those with red fruit characterised with the smallest share of the stone in the fruit mass (average 9–10%): 'Jelena', 'Grienadier', 'Nikołka', 'Oryginalnyj', 'Swietljaczok', 'Priorskij', 'Nespodiwanyj', 'Ekzoticznyj', and 'Wyszogorodzkij' among Ukrainian cultivars. Among Polish cultivars, the smallest share of the stone in the entire mass of fruit was determined for cultivars 'Podolski', 'Florianka', and 'Dublany' (10–13%). Jaćimović and Božović [2014], analysing approximately a dozen genotypes in Montenegro, determined that the smallest values of the said property reached 10.1%, and the highest 20.22%.

Cultivars with a large stone can be used to produce oil, rich in unsaturated fatty acids, dominated by linolic acid (70–75%) and oleic acid (15–16.7%). The valuable oil from stones of cornelian cherry can be applied as a diet supplement. Some Polish cultivars show a large share of the stone in the entire mass of the fruit, e.g. 'Kotula', 'Kresowiak', 'Bolestraszycki', 'Paczoski', and 'Kresowiak' (15–16.5%). Mean yield of stones per ha varied from 7500 to 24000, with weight ranging between 20 and 25 tonnes [Klymenko 2004]. In ripe fruit of cornelian cherry, the stone is usually closely adjacent to the flesh, although in some Ukrainian cultivars it is easily separated: 'Nikołka', 'Oryginalnyj', 'Ekzoticznyj'. The fruit of Polish cultivar 'Dublany' is characterised by relatively easy separation of the stone from the flesh.

Klymenko [2007] points out that the production of cornelian cherry in Polish conditions will be mainly suitable for cultivars with a relatively short vegetation period (Table 3). Cultivars developed in Poland and Ukraine are therefore recommended. Slovakian cultivars should be avoided (small fruit), as well as part of Austrian (with a long vegetation period) and Bulgarian cultivars (from mild climate). Particularly in the conditions of north-east Poland, cultivars that ripen until October, e.g. Polish 'Florianka' and 'Podolski' will not be suitable. In the conditions of that region, Bieniek et al. [2017] assessed 45 biotypes in terms of their usefulness for cultivation, and recognised it as a promising species. Days with spring frost in April and May, however, had a significant effect on yielding of the plants. Four biotypes obtained from seeds of the fruit of Ukrainian cultivars were the most stable in terms of yielding and fruit quality.

Among cultivars of Polish origin, based on the designation of the shape index, i.e. ratio of length to width, Kucharska et al. [2011] designated fruit with the following shapes: round (shape index 1.10), oval (1.23–1.26), oval-elongated (1.41), pear (1.52), pear-elongated (1.64–1.82), and bottle-pear (1.84). The fruit of Polish cultivars is usually pear-shaped (Table 4). The largest fruit with an average weight of 3.25–3.46 g is represented by cultivars

‘Podolski’, ‘Florianka’, ‘Szafer’, ‘Dublany’, and ‘Bolestraszycki’, and the smallest ‘Juliusz’ and ‘Raciborski’ (2.65 and 2.71 g).

‘Bolestraszycki’ – seedling found in Florianka. Medium-early cultivar, ripening at the end of August. Large fruit (3.3 g, 2.5 cm in length), pear-shaped (Table 4), dark cherry colour (Phot. 24). Share of the stone 14%. General-use cultivar, content of sugars 16%, acids 2.8%. Shrub with rising branches.

‘Dublany’ – seedling found in Florianka. Early cultivar, with fruit ripening in August. Large fruit (3.3 g, 2.5 cm in length), pear-shaped, dark red. Share of stone 12%. General-use cultivar, content of sugars 14%, acids 2.4%.

‘Florianka’ – seedling found in Florianka. Late cultivar, ripening in the second half of September. Large fruit (3.4 g, 2 cm in length) with oval shape, red (Phot. 25). Share of stone 11%. Fruit for processing, content of sugars 10%, acids 2.8%. Broad strongly growing shrub.

‘Juliusz’ – seedling found in Prałkowice. Early cultivar, ripening in mid-August. Small fruit (2.8 g, 1.8 cm in length) with round shape, red-pink. Share of stone 13%. Cultivar for processing and pickling, content of sugars 11%, acids 3%. Strongly growing, broad shrub.

‘Kresowiak’ – seedling found in an old manor park. Medium-early cultivar, ripening in the first half of September. Small fruit (2.8 g, 2.2 cm in length), pear-shaped, cherry in colour (Phot. 26). Share of stone 15%. Fruit for processing, content of sugars 15%, acids 3%. Broad shrub.

‘Kotula’ – seedling found in an old manor park by Władysław Kotula. Medium-early cultivar, ripening in the second half of September. Large fruit (2.7 g, 2.3 cm in length), pear-shaped, dark red. Share of stone 16.5%. Fruit for processing, content of sugars 12%, acids 2.2%. Broad shrub.

‘Paczoski’ – seedling found in an old manor park by Józef Paczoski. Medium-early cultivar, ripening in the second half of September. Large fruit, elongated (3 g, 2.6 cm in length), bottle-shaped, red (Phot. 27). Share of stone 14%. General-use cultivar, content of sugars 13%, acids 2.7. Broad shrub.

‘Podolski’ – seedling found in a manor park in Bolestraszyce. Late cultivar, ripening at the turn of September and October. Large fruit (3.1 g, 2 cm in length), oval shape, red-cherry colour (Phot. 28). Share of stone 12%. Industrial cultivar, content of sugars 10%, acids 2.8. Broad shrub.

‘Raciborski’ – seedling found in an old manor park by Marian Raciborski. Medium-early cultivar, ripening in the first half of September. Large elongated fruit (3 g, 2.3 cm in length), oval shape, dark cherry colour (Phot. 29). Share of stone 12%. General-use cultivar, content of sugars 14%, acids 3%. Broad shrub.

‘Swietłana’ – seedling found in Ukraine. Medium-early cultivar, ripening in mid-September. Large fruit (3.5 g, 2.4 cm in length), pear-shaped, dark-cherry colour. Share of stone 14%. General-use cultivar, content of sugars 14%, acids 2.5%. Broad shrub, fast falling fruit.

Table 5. Division of Ukrainian cultivars of cornelian cherry by term of fruit ripening [Klymenko 2004]

Term of ripening	Cultivar
Early cultivars (harvest in mid-August)	Aliesza, Eliegantnyj, Jeljena, Nieżnyj, Nikołka
Medium-early cultivars (harvest at the turn of August and September)	Bukowinskij żółty, Galickij żółty, Grienadier, Korałłowyj, Radost, Słastiena, Ugolek, Wyszgorodskij
Cultivars with average term of ripening (harvest in September)	Ekzoticznyj, Jantarnyj, Jewgenija, Korałłowyj Marka, Łukjanowskij, Mrija Szajdarowoj, Nespodiwanyj, Oryginalnyj, Perweniec, Priorskij, Samofertylnyj, Swietliaczok, Starokiewskij, Wawiłowiec, Władimirskij, Wydubieckij
Cultivars with a late term of ripening (harvest at the turn of September and October)	Kostia, Kozierog, Siemen, Sokolinoje, Sulija

Fot. 24. 'Bolestraszycki'

Fot. 25. 'Florianka'

Fot. 26. 'Kresowiak'

Fot. 27. 'Paczoski'

Fot. 28. 'Podolski'

Fot. 29. 'Raciborski'

Fot. 30. 'Słowianin'

Fot. 31. 'Szafer'

Table 6. Characteristics of particular Ukrainian cultivars of cornelian cherry [Klymenko 2013]

Cultivar	Average weight of fruit (g)	Share of weight of stone in total weight of fruit (%)	Average yield kg/plant	Ripening date	Days	Dry mass	Sugars	Vit. C	Acids
Aliesza	3.5–5.7	10–11	12–15 (10 years old)	VII/VIII	15	19.8	12	117–145	1.4–1.5
Bukowinskij żółty	3.5–4.5	10.8	40–50 (15 years old)	8 VIII–20 VIII	12	20.1	12.5	120-135	1.5-1.6
Ekzoticznyj	6.8–8.5	9.9–10/0	40–50 (15 years old)	15 VIII–5 IX	20	22.7	10.4	154.0	1.5
Elegantnyj	4.5–5.0	10.8	20–80 (15 years old)	5 VIII–15 IX (not falling)	20	21.8	9.1	110.3	1.84–1.9
Grienadier	5–7	8–9	30–40 (12 years old)	2-11 August	9	21.7	8.9	126	1.7
Jantarnyj	3.2–4.0	10.5–12.0	50–60 (20 years old)	18 VIII–20 IX	30	20.3	9.6	121.0	1.7
Jeljena	5.0–6.0	3.6–9.0		From 10 to 12 VIII		32.3	7.7	137.4	1.6–1.7
Jewgenija	6–7.5	8.5–10	50–70 (20 years old)	15 VIII–15 IX	30	21.2	9.7	177	1.8
Korałłowyj	3.4–4.4	11.4–12.1	35–40 (15 years old)	10 VIII–1 IX	20	19.7	9.1	117	1.5
Korałłowyj Marka	5.8–6.8	10.1	35–40 (10 years old)	5–20 VIII	15	22.8	12.7	129.5	1.2
Kostia	5.6–8.0	11.7	45–50 (17 years old)	5–25 IX	20				
Łukjanowskij	6–7.5	9.8–10.2	35–40 (15 years old)	15 VIII–1 IX	15	22.4	9.4	127.8	1.7–1.9
Mrija Szajdarowoj	6.3–8.0	8.5–9.0	30–40 (15 years old)	nd	nd	22.7	11.3	137.6	1.7
Nespodiwanyj	5.5–6.5	9.6–10	40–45 (15 years old)	15 VIII–5 IX	20	21.7	13.7	157.3	2.5
Nieżnyj	4.5–5.5	9.5–10.5	35–40 (12 years old)	8–20 VIII	12				
Nikołka	5.5-6.5	8.5–9.3	35–45 (15 years old)	25 VII/p. 10 VIII	15	21.7	8.6	119	1.3
Oryginalnyj	4.4–4.8	8.9–9.1	15–20 (10 years old)	15 VIII–20 IX	35	20.8	9.3–11.7	140.5–167.0	1.7
Perweniec	4.7–6.6	8.2–9.3	25–30 (15 years old)	15 VIII–15 IX	30	23.2	6.2	100	2.07
Priorskij	4.7–6	9.0–9.5	40 (15 years old)	31 VIII/15 IX	15				
Radost	5.2–6.6	10.6	25–30 (15 years old)	27 VII–10 VIII	15	24	7.1	106	1.4
Samofertylnyj	3.5–4.5	12	30–40 (15 years old)	From 15 VIII	nd	20.7	12.4	150.4	1.4–1.6
Siemen	6–7.2	11–11.2	23–35 (15 years old)	25 VIII–20 IX	25	21.7	10.8	193.1	1.6
Starokiewskij	5.6–7.8	9.8–10.8	35–40 (15 years old)	15 VIII–10 IX	25	19.9	7.8	148.0	2.24
Swietljaczok	6,.5–10.0	8.9–9.3	40–45 (15 years old)	15 VIII–5 IX	20	22.7	9.7	150.0	1.6
Wawiłoweic	6–7.5	10.1–10.7	25–30 (10 years old)	15–31 August	16	22.7	7	101	1.4
Władimirskij	7.5–9.5	10.9–11.1	30–35 (15 years old)	15 VIII – 15 IX	30	20.3	8.5	142–150	1.4–1.8
Wydubieckij	6.5–7.5	9.8–10.5	35–45 (15 years old)	15 VIII–10 IX	25	20.1	7.5	157.3	1.6
Wyszgorodskij	4.5–5.3	9–10.6	50–60 (15 years old)	1–15 VIII	15	22.9	7.2	121	1.56

Table 7. Time and method of development of particular Ukrainian cultivars of cornelian cherry [Klymenko 2013]

Cultivar	Cultivation method	Year of first fruiting	Fruit colour
Aliesza	Found seedling	1996	yellow
Bukowinskij Żełtyj	Found seedling	2000	yellow
Ekzoticznyj	Mutation of cultivar 'Swietljaczok'	1985	dark red
Elegantnyj	Combination of selected genotypes	1980	dark red
Grienadier	Seedling from spontaneous pollination of cultivar 'Wydubieckij'	1990	dark red
Jantarnyj	Seedling from spontaneous pollination	1982	yellow
Jeljena	Seedling from spontaneous pollination of cultivar Siemen	1975	dark red
Jewgenija	Combination of selected genotypes	1989	dark red
Korałłowyj	Seedling from spontaneous pollination		red
Korałłowyj Marka	Combination of 'Jantarnyj' x 'Jelena', 'Wydubieckij', 'Władimirskij'	1990	bright red
Kostia	Combination of genotypes	1990	red
Łukjanowskij	Seedling from spontaneous pollination	1975	dark red
Mrija Szajdarowoj	Seedling from spontaneous pollination of cultivar 'Priorskij'	1998	dark red
Nespodiwanyj	Seedling from spontaneous pollination of cultivar 'Starokiewskij'	1999	red
Nieżnyj	Found seedling		yellow
Nikołka	Seedling from spontaneous pollination	1976	dark red
Oryginalnyj	Seedling from spontaneous pollination of cultivar 'Jewgenija'	1996	dark red
Perweniec	Seedling from spontaneous pollination	1972	dark red
Priorskij	Found seedling	1997	red
Radost	Combniation of selected genotypes	1976	dark red
Samofertylnyj	Cultivar received from England	1995	red
Siemen	Vegetative propagation of a genotype from Crimea	1984	dark red
Starokiewskij	Combination of selected genotypes	1975	dark red
Swietljaczok	Mutation of cultivar 'Łukjanowskij'	1981	dark red
Wawiłoweic	Seedling from spontaneous pollination of cultivar Łukanowskij	1988	red
Władimirskij	Combination of selected genotypes	1975	dark red
Wydubieckij	Combination of selected genotypes	1976	dark red
Wyszgorodskij	Seedling from spontaneous pollination of selected genotype	1973	dark red

‘Słowianin’ – seedling found in Ukraine. Medium-early cultivar, ripening in early September. Large fruit (3 g, 2.8 cm in length), bottle-pear shaped, red (Phot. 30). Share of stone 13%. Dessert and processing cultivar, content of sugars 14%, acids 2.7%. Broad shrub.

‘Szafer’ – seedling found in Florianka. Medium-early cultivar, ripening at the end of August. Large fruit (3 g, 2.5 cm in length), pear-shaped, dark cherry in colour (Phot. 31). Share of stone 14%. Universal cultivar, content of sugars 16%, acids 2.4%. Shrub with straight branches [Piórecki 2017, Szot et al. 2018].

The division of Ukrainian cultivars by term of ripening is difficult to refer to Polish ones, because they differ in the average ripening period duration (Table 5, 6 and 7). Ukrainian cultivars have a shorter time of fruit ripening: 5–21 days [Klymenko 2004] in comparison to Polish ones: 18–67 days [Kucharska et al. 2011, Szot et al. 2018].

7. Methods of propagation of cornelian cherry

Cultivation of popular fruit trees such as apples, pears, plums, or sweet cherries at the commercial scale is based on the use of saplings obtained by the method of tree improvement through bud grafting or grafting on rootstock. Rootstock controls the strength of growth of the plant allowing for cultivation of tress in a smaller space than in the case of cultivation on own roots, and particularly accelerates the onset of the fruiting stage. One of the main challenges when establishing a cornelian cherry plantation is the production of high quality planting stock. Cornelian cherry is still a little known fruit species, and methods of obtaining high quality planting stock have not been properly developed yet. There are attempts to propagate the species by means of seeds and vegetatively, but each of the methods carries difficulties [Pirlak 2000, Korszun and Kolasiński 2001, Korszun and Kolasiński 2002, Jagła and Król 2011].

7.1. Generative propagation

Propagation through seeds is the basic method of expansion of many trees. In the case of orchard plants, however, it is rarely applied, because the obtained offspring does not replicate the features of the parent. Moreover, the juvenile period is considerably longer than in the case of plants propagated vegetatively. In the case of cornelian cherry, it lasts from 8 to 20 years. Propagation of cornelian cherry through seeds, however , is used to obtain seedlings that constitute very good rootstock for budding or grafting cultivated varieties on it. Obtaining rootstock of cornelian cherry requires technological refining, because seed germination usually occurs after two winter seasons. Seeds of many species of trees and shrubs do not germinate right after their extraction from the fruit, even in optimal conditions. It depends on so-called “tendency to dormancy”. Cornelian cherry tends to remain dormant for a period from 15 to 17 months. Temperature is the most important factor determining the survival of the seed dormancy period for plants from a temperate climate region. Most species require a frosty period before germination or for the purpose of accelerating germination in spring. They require storage at low temperatures (2–6°C) for a period from several weeks to a dozen months, depending on the species. It is the so-called stratification period [Klymenko 2004].

Cornelian cherry has thick seed shells. Research by Kollman and Pflugshaupt [2005] on germinations of seeds of stone species shows, however, that a hard endocarp does not mechanically restrict the process. At the moment of breaking the period of dormancy of the seed due to stratification, it gains the ability to slow down the cracking of the stone (Phot. 32 and 33). In the

Phot. 32. Germinating seedlings of cornelian cherry after two years of stratification

Phot. 33. Particular stages of development of seedlings

case of species from genus *Prunus*, warm-cool stratification is effective. For the purpose of obtaining good germination of cornelian cherry, warm-cool stratification of seeds is recommended with a long warm phase (18 weeks) at cyclically variable temperature (24+24 h) of 15–25°C, and a cool phase of approximately 24 weeks at a temperature of 3°C. Another method of breaking the dormancy of cornelian cherry seeds is their rinsing with a stream of running water, permitting seed germination after 11–12 months. Rogulski [1936] proposes acceleration of the stratification of seeds by burying them with slaked lime (at a dose of 1 kg of lime per 10 kg of seeds), or storage of seeds freshly extracted from fruit in hot water over a period of 24 h.

The best time for harvesting seeds is the period when ripe fruit begins to fall. After fruit harvest, separation and cleaning the seeds is performed, followed by their drying. Fruit of cornelian cherry is juicy, and the flesh is strongly accreted to the stone. To facilitate separation of the seeds, the fruit is placed in a barrel and poured over with a small amount of water. It becomes softer over a period of 2–3 weeks. Then, the mashed fruit is rinsed on a sieve while carefully rubbing to avoid damage to the seeds. Rinsed seeds should be dried on sieves, and then placed in containers and provided optimal storage conditions until their sowing, e.g. mixing them with peat, bark, moss, or sand.

Phot. 34. Sowing of whole fruits of cornelian cherry immediately after harvest

Phot. 35. Effective method of marking the place of sowing of cornelian cherry

After the end of the dormancy period of the seeds, they are sown in appropriate conditions permitting germination and growing into seedlings. Seeds of cornelian cherry after the first cool period can also be sown to the soil in autumn for the second coolling period, so that they germinate and develop into seedlings in spring.

Between 2017 and 2019, observations on the germination of cornelian cherry seeds were conducted at the University of Life Sciences in Lublin (UP), with seeds sown directly into the ground immediately after harvesting (Phot. 34). This type of technology eliminates the necessity of cleaning and proper storage of seeds during stratification. In the first year, maintenance only involves weeding (the application of herbicides is allowed). Therefore, while sowing the fruit, it is worth marking the location of rows, e.g. with sand (Phot. 35). During the following season, germination of cornelian cherries can be expected already in early spring, when only manual weeding is applied.

According to Marković et al. [2014], after fruit harvest, seeds should be immediately separated from the flesh, because the fruit contains substances inhibiting sprouting. In their experiment, seed germination was observed in the second season, suggesting that the flesh of the fruit which decomposed within the first dormancy season had no negative effect on the analysed process. After germinating, the growth of cornelian cherry is slow. It produces a root system with numerous lateral roots. Adult cornelian cherries are relatively resistant to diseases, but seedlings can die off due to stronger contamination by fungal pathogens.

Establishing and running a commercial plantation requires the possibility to predict the terms of basic treatments such as fertilisation, protection, and fruit harvest. Cornelian cherries propagated generatively differ in the strength of growth, size, and fruit colour, as well as the term and duration of fruit ripening. The assessment of the term of ripening of approximately a dozen ecotypes of cornelian cherry in the conditions of the Lublin Region [Szot et al. 2019] showed among others differences in the term of beginning of fruit ripening as well as the duration of their entire harvest period of at least several days. Cornelian cherry is a plant ripening unevenly, and harvest in some vegetative seasons can extend over even up to 50 days. The quality of cornelian cherries propagated generatively is also variable in terms of size, shape, share of the stone in the entire mass of the fruit, shade of red and yellow colour, and content of particular chemical components, including vitamin C, loganic acid, and polyphenols. Therefore, rootstock material for a cornelian cherry plantation must be obtained through vegetative propagation [Dokupil and Řezníček 2012, Bijelić et al. 2016].

7.2. Vegetative propagation

In vegetative propagation, no fusion of germ cells occurs, and the offspring develops from special vegetative parts of plants such as sections of stems, roots, and leaves. In horticulture practice, propagation of woody plants is usually done by means of cuttings obtained from stems, more seldom from roots, and by means of grafting and bud grafting. Among stem cuttings, herbaceous, semi woody, and woody seedlings are distinguished. This type of propagation is relatively fast and cheap, provided the plants root well. Unfortunately, cornelian cherry is an example of a plant developing very weak roots. It was evidenced by Jagła and Król [2011] who compared rooting of several little known fruit species such as cranberry, actinidia, cornelian cherry, and elderberry with the application of cuttings. The cuttings were collected in two terms, i.e. in mid-June and at the turn of July and August as three-node apical stem sections. Rooting employed Polish rooting stimulator Himal (growth substances) and Dutch Rhizopon (5-(3-indolilo) butyric acid IBA) in tunnel conditions in plugtrays, in a substrate of peat + sand. Among the analysed species, cornelian cherry proved to be the most difficult to root for both terms of collecting cuttings, showing a degree of rooting from 0% in control to 33% after Rhizopon treatment. The application of rooting stimulators for cuttings collected in mid-June proved more effective than at the turn of July and August.

Herbaceous cuttings, due to the presence of chlorophyll in their skin cells, are photosynthetic shoot cuttings. In this type of cuttings, roots develop in a secondary way through regeneration. In the place of separating the cutting from the parent plant, a cork layer develops, protecting the damaged plant against microorganisms. Under the cork layer, a meristematic layer develops that with time forms a so-called callus. The development of roots and callus is subject to polarity, i.e. they are located at the morphological bottom end of the cutting. Herbaceous cuttings collected from stems immediately before reaching maximum growth but right before its end, i.e. collected from stems intensively growing for a long time, root best. The appropriate period for this type of propagation is considered to be time from mid-June to mid-August. When rooting herbaceous cuttings, leaves should not be completely removed, but delicately shortened, not more than to half their length. Smaller leaves are left without cutting. Shortening leaves reduces transpiration of the plant which until the moment of development of roots cannot uptake a sufficient amount of water from the substrate. Herbaceous cuttings should be separated directly before planting. In the case of pruning cuttings of fruit trees, it is recommended to perform the bottom pruning approximately 0.5 cm below the leaf base to facilitate the development of a callus. Particular species differ in the ability to root, and therefore groups of plants that are easy, medium, and difficult to root can be distinguished. Cornelian cherry belongs to the latter group, where it is necessary to support rooting by means of phytohormones (auxins – indole butyric acid IBA).

Cornelian cherry can be propagated through cuttings, with the application of herbaceous cuttings, although they are very difficult to root. Herbaceous cuttings are delicate, and it is necessary to apply fogging. It is an effective method, but plants in the first year of production grow very slowly. The ability to root largely depends on the genetic features, and it can be improved with the application of auxins (K-IBA) at a concentration of 3000 mg/l, particularly in the form of liquid root stimulator. In research by Marković et al. [2014] in Slovenian conditions it was also evidenced that 1% IBA in the form of powder is suitable for satisfactory rooting of single-node herbaceous cuttings taken from this year's top shoots (degree of rooting 96.7%, at an average number of roots of approximately 12.9), of course with the application of fogging.

Korszun and Kolasiński [2001, 2002] evidenced that cornelian cherry can be effectively propagated through semi woody cuttings collected as two-node subapical stem sections with a length of 10–12 cm in the second half of June with the application of rooting stimulator Rhizopon AA (containing IBA) 1% or 2%. Cuttings without growth stimulator developed no adventitious roots. The highest percent of rooting (100%) was obtained in the case of placing cuttings in a mixture of peat and perlite with pH in H_2O of 5.0, at a Rhizopon AA concentration of 1%, without cutting the cuttings along the shoot 2 cm from the base. The most abundant roots with the greatest length were observed in the case of application of Rhizopon AA 2%, in a mixture of peat and perlite (1:1). Substrate made of perlite and sand (1:1) was considerably less effective in rooting semi woody cuttings of cornelian cherry. In the case of this method, it was necessary to apply periodical fogging.

Iranian researchers Hassanpour and Ali Shiri [2014] attempted to propagate several genotypes of cornelian cherry by woody cuttings treated with various concentrations of IBA (auxin – indole butyric acid), and then placed them in two types of substrate: sand and a mixture of sand and perlite (1:1). They determined a significant correlation of the degree of rooting of the cuttings with genetic features. Moreover, sand alone was a more beneficial substrate, as well as the application of IBA at a concentration of 2000 ppm. The highest effectiveness of thinning, however, only reached 47.4%.

In Turkish research [Pirlak 2000], three genotypes of cornelian cherry were propagated by woody cuttings collected from one year old shoots in two terms (28 January and 28 February). The base of the cuttings was treated with IBA solution at three concentrations (2000, 4000, and 6000 ppm) for 5–10 seconds. Then the cuttings were placed in substrate made of perlite, and after 4 months the degree of rooting and quality of roots were compared. The number and quality of developed roots significantly depended on genetic features (differences between genotypes), term of collection of cuttings, and IBA concentration. The earlier term (January) proved considerably more beneficial for the effectiveness of rooting and root quality. An increase in IBA concentration was accompanied by an increase in the degree of rooting. The best IBA concentration for obtaining the highest quality cuttings was 6000 ppm. The highest effectiveness of rooting in this experiment reached 53.3%.

Cornelian cherry can also be propagated *in vitro*. It is a species reproducing relatively easily, but in tissue cultures, like in the case of cuttings, it roots very weakly. A method of fast obtaining cornelian cherry seedlings due to breaking the dormancy of seeds in *in vitro* conditions could find application in nursery production. Research conducted to date shows that *in vitro* conditions permit breaking the dormancy and germination of seeds of many plant species. Moreover, the *in vitro* method is more effective in obtaining a uniform population in comparison to heterovegetative propagation. Ďurkovič [2008] discussed the possibility of propagation of cornelian cherry of cultivar Macrocarpa by means of the *in vitro* method. He evidenced that the process of microreproduction is determined by the selection of the medium, its pH, mineral composition, choice and mutual proportion and concentrations of growth and development regulators. According to the author, axillary buds were collected from 27 year old trees in April, and placed in two types of agar mediums: basal with pH 5.6–5.7 and modified with pH 6.8–7.0 (with a higher concentration of $Ca(NO_3)_2$, lower of $CaCl_2$, enriched with calcium gluconate, glutamine, and ascorbic acid). The buds placed in the basal medium with pH 5.5–5.7 supplemented with 6-benzylaminopurine (BAP) and 1-naphthalenaecetic acid (NAA) showed incidental proliferation for a period of one year. The growth then discontinued, necrosis of the apex occurred, and the shoot cultures died. Placing the buds in modified medium with pH 6.8–7.0 contributed to energetic growth of shoot cultures without a decrease in the proliferation coefficient and a decrease in longevity. The application of 6-benzylaminopurine with 1-naphthalenaecetic acid proved better than the application of thidiazuron (TDZ) that caused te development of short bushy shoots. In the case of rooting shoots *in vitro*, 1-naphthalenaecetic acid contributed to considerably better rooting (up to 73.3%) in comparison to indole-3-butyric acid (IBA). Two-year-old plants propagated *in vitro* acclimatised in nursery conditions showed no morphological variability. The first flowering occurred after 2 years from planting in the field.

Jagła and Król [2011] collecting explants in the form of axillary buds in standard initial medium after Murashige and Skooga (MS), and then proliferation medium with modified content of nitrogen compounds and growth substances, determined that cornelian cherry proliferated very well, and rooted very weakly. Microcuttings of cornelian cherry showed only 6% degree of rooting in medium containing 1 mg/l IBA in which they remained for 7 days, and then transferred to MS medium without growth regulators. In such conditions, other analysed species such as actinidia, cranberry, and blue-berried honeysuckle reached a rooting percent of 93, 60, and 46%, respectively.

At the amateur scale, cornelian cherry can be propagated by layering and root suckers. Propagation by layering involves rooting shoots without separating them from the parent plant. It is a relatively simple and natural form of plant propagation that can be used by beginners and inexperienced enthusiasts of plant cultivation, both at home and in the garden. Layering involves covering a shoot that is still a part of the parent plant with soil. With time, the shoot takes root and then it can be separated, resulting in a new plant. Among the techniques of this method, simple layering stands out, which is excellent for propagating many trees and shrubs, both evergreen and deciduous. It involves bending the shoot of the parent plant to the ground. The parent plant should be young, and preferably pruned in the previous season which allows for the production of strong and flexible shoots. The treatment is best performed in spring or autumn. The soil around the mother plant (where the shoots are growing) is lightly loosened and enriched with well-rotted compost or manure. If the soil is very compact (heavy, loamy), it needs to be somewhat loosened by adding sand. Then, a healthy, young, flexible shoot is selected and bent to the ground at a height of around 25 cm from the apex. In the place where the shoot touches the ground, leaves and side shoots are removed. The underneath of the shoot in the place of contact with the ground is slightly incised with a knife (at a slant from underneath) to accelerate rooting. The place can also be dipped in a rooting stimulator. Then the shoot is tied to a stake or pressed down with a stone so that it is immobilised touching the ground. The place of contact of the shoot with the substrate is buried under a thin layer of soil and watered. After approximately a year, it is checked whether the shoot took root. If roots appeared, the rooted shoot can be cut off from the parent plant and planted at the designated site.

Modern horticulture is based on the application of planting stock constituting trees propagated by bud grafting or grafting. It is heterovegetative propagation involving combining two plants, usually mutually closely related, for the purpose of creating a new organism. The separated part of the plant, usually a short section of the shoot, is called a scion, and the part of the plant that forms the root system onto which the scion is grafted is called the rootstock. The method where a scion composed of an internode or several internodes and one to several buds is transferred to the rootstock is called grafting. On the other hand, if only a bud is transferred along with a small piece of internode (known as a shield), it’s called bud grafting.

Phot. 36. Dug up one-year-old rootstocks of cornelian cherry

Phot. 37. Scions of particular Ukrainian cultivars of cornelian cherry

There are two methods of bud grafting: “dormant eye” and “live eye.” With the “dormant eye” bud grafting, the noble bud grows in the next growing season, while with “live eye” bud grafting, it grows in the current year when the bud grafting is performed. Before proceeding with bud grafting, it’s necessary to plant rootstocks (Phot. 36) which are typically seedlings of the Cornelian cherry. When they reach a diameter of approximately 12 mm, you can start the improvement process.

The timing of bud grafting depends on the growth of rootstocks and activity of the cambium tissue. In practice it is recognised by easy separation of bark from wood, suggesting “the presence of cambium”. The second condition of initiating bud grafting is having shoots with well-developed leaf buds (Phot. 37). Bud grafting with badly developed nodes provides weak results due to their weak acceptance. In the case of too early bud grafting, many accepted nodes in the same year develop shoots that do not lignify by winter and are prone to frost damage. The optimal timing for bud grafting of particular species of fruit trees in Poland is generally between 5 and 25 August.

As a result of conductivity of solutions of mineral salts and assimilates, as well as the interaction of metabolites, the scion and rootstock influence each other, modifying their growth (abundance of flowering and quality of fruit) and ecological requirements (resistance to frost).

Cornelian cherry can be propagated by bud grafting, done during summer with dormant buds on cornelian cherry seedlings, and also by grafting in winter onto cornelian cherry rootstocks "accelerated" in a greenhouse (using the "side-veneer" or "whip-and-tongue" methods). The grafting site should not be too high, practically in the area of the second internode (Phot. 38). Besides faithfully replicating the characteristics of the mother

Phot. 38. Place of performing bud grafting with a noble node of cornelian cherry

Phot. 39. "Improved" cornelian cherry growing in spring from a grafted node

Phot. 40. In spring of the year following bud grafting, vertical growth of the graft should be ensured

Phot. 41. Correctly formed graft of cornelian cherry

plant, this guarantees a much faster entry into the fruiting period. Approximately 50% of the grafts flower and bear fruit in the second year after grafting, and almost 100% in the third year. Bijelić et al. [2016] demonstrated significantly higher success rates for bud grafting performed under Serbian conditions in August (69.38%) compared to winter grafting performed in April (25.33%). In the year following bud grafting, the "noble part" sprouts from the grafted bud (Phot. 39). A crucial maintenance procedure in the nursery is to tie the newly grown shoot so that it grows vertically upwards (Phot. 40). This ensures the successful union of the rootstock with the noble plant (Phot. 41).

Establishment of commercial plantation of cornelian cherry is only possible with the application of cultivars, i.e. plants propagated vegetatively. Cultivars differ in the effectiveness of bud grafting and growth strength. Bijelić et al. [2016], comparing the effectiveness of dormant node bud grafting in August and the strength of growth of grafts from particular cultivars and ecotypes, determined that the best effectiveness of this type of propagation was characteristic of cultivar Aprani (83.62%) and Backa (76.42%). The highest growth was recorded in cultivar R1 (906.82 mm), greatest diameter in Aprani (13.61 mm), and highest number of the longest roots in Aprani (19.67 roots; 142.38 mm).

In an experiment conducted in 2017 in the Lublin Region, growth of grafts of cornelian cherry was analysed in the first season after bud grafting [Szot et al. 2020]. The comparison of several cultivars: Bolestraszycki, Dublany, Paczoski, Szafer, and genotypes: Gruszkowy, Okazały, Roch, Za bankiem $S_{1,}$ and Za bankiem S_2 showed that cultivar Dublany was characterised by the strongest growth in all terms of measurements (52.5; 96.5; 133, and 145.7 cm): the greatest diameter of the main shoot (16.84 mm) and the highest number of branches (11.6/plant) among the analysed ecotypes and

Phot. 42. Grafts of cornelian cherry in pots

Phot. 43. Grafts of cornelian cherry dug out with the entire "root ball"

cultivars. The weakest growth was typical of ecotypes 'Za bankiem S_1 and S_2' (101.3 and 111.9 cm) in comparison to the remaining grafts. They were, however, characterised by dense shoot foliage (17.7 and 16.45/plant). The results of the above studies indicate that cornelian cherry can be vegetatively propagated by T-budding onto an understock consisting of cornelian cherry seedlings. The technology for obtaining this material is divided into the period of obtaining a strong understock (4–5 years) and bud grafting and the growth of young seedlings in the nursery (1.5 years). Work in the first period needs further refinement to obtain an understock with a minimum diameter of 12 mm as quickly as possible.

According to Ochmian et al. [2019], a compatible rootstock for cornelian cherry is *C. amomum*, i.e. silky dogwood. In their experiment, *C. amomum* had a strongly dwarfing effect on the growth of cornelian cherry. The researchers compared the effect of rootstock and clonal trees on the physico-chemical properties and content of bioactive substances in the fruit of four cultivars of cornelian cherry: Jolico, Schőnbrunner, Shumen, and Yellow. They determined that despite strong weakening of the growth of trees due to the rootstock (the trunk diameter on own roots 81 mm, and on rootstock 46 mm), the quality of fruit did not decrease. The analysed cultivars differed in the colour of the fruit, and due to rootstock the red colour of the fruit was darker. The fruit of cultivar Yellow, with the lightest yellow skin, was characterised by the lowest content of bioactive substances, contained no anthocyanins, but proved the richest in selenium. The most valuable fruit among the analysed cultivars was that of Jolico due to the largest size and darkest skin colour. The fruit showed the highest content of anthocyanins, particularly pelargonidin 3-*O*-galactside. Moreover, it showed the strongest antidiabetic and antioxidative properties.

Next to the applied rootstock, the quality of planting stock is largely determined by the development of the root system. In the case of plants cultivated in too small pots, the root system will always be shallower (Phot. 42) than where roots grow freely, and before expedition it is dug out in their entirety, together with the soil (Phot. 43).

Among all the methods discussed above, bud grafting appears to be the most promising in terms of effectiveness and acceleration of the start of the fruiting period. According to Klymenko [2004], propagation by bud grafting is the most effective (90–98% accepted nodes), although avoiding excessive costs of this type of material requires improvement of all the technological stages, and particularly annual production of uniform rootstock. The effectiveness of rooting cuttings is 85–90%, "in-hand" grafting is 75–78%, while field grafting is only 50–60%. For a commercial plantation, one- or two-year -old scions measuring 120–160 cm in height with 3–5 well-developed lateral branches should be selected. The root system is highly branched, and there is no well-developed taproot, with a length not exceeding 12–15 cm. The length of strongly branched lateral roots is approximately 20–25 cm, and their width is 15–25 cm.

8. Establishment of a commercial plantation

The establishment of a plantation of cornelian cherry should start with the selection of a place for its long-term functioning. It is a little known species, which results in a low number of large commercial plantations. Therefore, there is no particular need for isolation from old sick trees like in the case of apple, pear, plum tree, and the remaining popular orchard species. The selection of the place for a plantation is adjusted to the requirements of the plant, whereas it is worth remembering that the better conditions for good growth are created, the healthier and more resistant to diseases, pests, and unfavourable weather conditions it will become.

8.1. Choice of location

In its natural state, cornelian cherry occurs in a warmer climate, although often in mountain areas, susceptible to the effect of strong winds and long exposure to solar radiation. Cornelian cherry is a plant resistant to frost. According to Klymenko [2013], in very cold winters when temperature fell to -35°C, no serious damage to the plants was recorded. The shoots of cornelian cherry in experimental conditions showed symptoms of damage only at -37°C. Suitably selected land for a cornelian cherry orchard will allow for obtaining regular yields of high quality fruit with simultaneous limiting of the application of plant protection products. Although the tree is resistant to frost in winter, for commercial cultivation, it is important to choose locations with no frost pockets and waterlogged soils. Cornelian cherries are among the first fruit trees flowering in a given growing season. They already flower in February, making the flowers strongly exposed to spring frost. Good locations for an orchard are small hills that prevent the accumulation of the morning and evening fog. Cornelian cherry requires no specific soil conditions. It does well on dry soils poor in nutrients, with variable pH (5.3–7.4). Cultivation on acidic soils, however, carries the threat of release of toxic exchangeable ions of aluminium and manganese. Moreover, such soils are characterised by low activity of microorganisms responsible for mineralisation, resulting in potential nutrient deficits. According to Klymenko [2013], optimal soil pH on a cornelian cherry plantation should be 7.5–8.0. At too low pH, quick-acting garden lime should be applied, and in already existing orchards – dolomite that will additionally enrich the substrate in magnesium. Fertiliser doses should be adjusted to the current pH and organic category of the soil (Table 8)

Tabela 8. Maksymalne dawki nawozów wapniowych CaO (kg/ha) stosowane jednorazowo w sadzie [Sadowski i in. 1990]

Soil reaction	Agronomic category of soil		
	Light	Medium	Heavy
< 4.5	1500	2000	2500
4.5–5.5	750	1500	2000
5.6–6.0	500	750	1500

For suitable growth and obtaining high yield, cornelian cherry needs fertile soils: loess, sandy-loamy, and rich in calcium. Cornelian cherry responds well to abundant fertilisation, as suggested by the fact that transferred from natural sites to fertile substrate, it positively responds in size and juiciness of the fruit. Therefore, before the establishment of a plantation, it is worth applying well-composted manure, such as horse or sheep manure [Klymenko 2017].

Before planting the plants, it is recommended to cultivate phytosanitary plants (mustard, buckwheat, maize, oat, rye) for at least a year before the establishment of an orchard. It is best to cultivate the said sanitary plants in mixtures, e.g. rye with clover, because it prevents the development of soil microorganisms. For the eradication of pathogenic fungi, nematodes, and other soil pests, it is worth applying biostimulation. In the case of cultivation of brassicas (radish) or oilseeds (mustard and rape) as a pre-crop, natural volatile compounds are released that limit the population of pathogens in the soil [Usha et al. 2015].

When establishing an orchard, the spacing between plants is important. The spacing between rows is adjusted to the width of machinery used for cultivation: 4–4.5 m. The distance between plants in a row must be sufficient so that plants developing a crown do not shade one another with time. That would strongly negatively affect setting flower buds and yielding. Cornelian cherry is a long-lived plant that grows very slowly, but with time it reaches a height of 8–9 m, with a slightly dispersed and high-rising crown. A cornelian cherry orchard is a long-lasting investment; the plant still yields well at the age of 100 years, reaching yields of up to 100 kg/tree. With the assumption of systematic pruning and mechanisation of harvest, the trees can be planted every 2.5–3 m. Therefore, the average number of trees per hectare recommended for commercial orchards is 740–1000 [Klymenko 2004].

The timing of planting depends on the availability of high quality planting stock. The plants can be planted in spring, best at the end of March and in early April, or in autumn, but not later than by mid-October (2–3 weeks before the expected frost). During planting, pits with a width of 80–100 cm and a depth of 70–80 cm are prepared and filled with composted soil. Seedlings are planted in such a way that the grafting point is above the ground. After planting, the plants should be watered, and mulch should be applied as soon as possible (Hassanpour and Ali Shiri 2014).

Cornelian cherry is a pollinator-dependent plant. Therefore, planning its cultivation should involve planting at least two cultivars, or applying wild types as pollinators. Only one pollinator-independent cultivar has been developed so far. It is cultivar Samofertylnyj the shrub of which grows up to 1.5–1.8 m in height, and yields 30–40 kg of fruit per shrub in the 15th year after planting. Although it is a self-pollinating cultivar, the presence of pollen from another cultivar considerably improves the quantity and quality of the yield. There are also cultivars that can mutually pollinate weaker due to their close affinity, e.g. Łukjanowskij – Swietljaczok (mutation of cultivar Łukjanowski) – Ekzoticzeskij (mutation of cultivar Swietljaczok) [Klymenko 2013].

8.2. Maintenance treatment

High yielding of high quality fruit of cornelian cherry requires a great amount of water, but the tree does not tolerate waterlogged sites. It is relatively resistant to draught due to its adaptation to difficult conditions. With the passing of years, it develops a strongly branched and well penetrating root system, and the leaf blades have hairs underneath. Cornelian cherry bears juicy fruit, and lack of water results in its worse quality. Cornelian cherry requires approximately 750 mm of precipitation annually, and the greatest demand for water occurs in summer. Young plants are recommended to be irrigated using a drip system, subsurface mini-sprinklers, or overhead sprinkling (this system can also be used to protect flowers from early spring frosts). Considering the water needs of cornelian cherry and average precipitation total for Poland, it is estimated that maximum demand for water in the case of sprinkling irrigation is 3–5 mm, and drip systems 2–4 mm/day [Gąstoł and Skrzyński 2007]. The tree prefers sunny sites, although it also does well in semi-shaded locations, i.e. in the vicinity of taller trees. A limited amount of solar radiation, however, causes weaker setting of flower buds within the crown, and bearing bitter and less juicy fruit. Next to sunny slopes, natural places of occurrence of cornelian cherry also include forest understory. Young plants grow better when slightly shaded due to the sensitivity of shallow roots to overheating. Therefore, in cultivation of cornelian cherry, it is recommended to apply mulches consisting of mowed grass, straw, bark, composted wood shavings from coniferous plants, or non-woven fabric [Klymenko 2004]. They secure the shallow root system of young plants from drying, and additionally limit competition by weeds. In the case of application of organic mulches rich in cellulose (bark, wood shavings, straw), additional fertilisation with nitrogen should be conducted, supplying 15–20 kg N in pure component/ha. Of course the dose refers to the mulched surface. The mulch should have a thickness of 10 cm, therefore it should be systematically supplemented. Organic mulches prevent soil trampling, normalise temperature and substrate moisture, and as they decompose they supply nutrients to the plants. Synthetic mulches: black polyethylene film, black polypropylene and polyacrylic nonwoven fabric have a durability of up to 3 years. After that period, they need to be removed and processed or incinerated in incineration plants [Larco et al. 2013].

Phot. 44. Several decades-year-old cornelian cherries with a crown maintained in the shape of a cup

Phot. 45. Several-year-old cornelian cherries grown in the form of a conical crown

Cornelian cherry evidently responds to fertilisation with a greater mass of fruit and more abundant growth. It is best fertilised organically, although fertilisation with artificial fertilisers is equally effective and has no negative side effects. Long-term experiments regarding the effect of fertilisation of cornelian cherry on its growth and yielding are still missing. Initial experiments of researchers from Kraków, however, suggest that the plant adjusts to variable availability of macroelements such as P, K, and Mg, without showing evident symptoms of their deficit. A strong correlation has been found between P and K content in soil and the amount of the elements in the leaves. Deliberate fertilisation can be based on initial indicator contents in the leaves of cornelian cherry. They are as follows for macroelements (% of dry mass): 1.5–2.4 N, 2.0–3.0 Ca, 1.0–1.5 K, 0.3–0.55 Mg, 0.2–0.35 P, and 0.3–0.4 S,

Phot. 46. The crown of cornelian cherry before annual winter pruning

Phot. 47. Tree of cornelian cherry after winter pruning

and for microelements (mg·kg^{-1} of dry mass): 20–40 B, 3.0–5.0 Cu, 60–100 Fe, 20–60 Mn, 0.3–0.5 Mo, and 20–30 Zn [Domagała-Świątkiewicz et al. 2013]. Further detailed research is necessary, because the content of macro- and microelements in plant tissues largely depends on conditions occurring in a given growing season.

Cornelian cherries can be grown in the form of shrubs or trees, although the selection of the form should depend on the planned method of fruit harvest. If the fruit is collected after falling onto ground cover, the plants can be grown in the form of shrubs.

When planning mechanical harvest, the crown should be formed on a short trunk (50–70 cm) with a wide cup-shaped or conical crown. This will permit the use of shaking devices in harvesting fruit. The plant tolerates pruning well. For the first 2–4 years, no pruning is conducted, or only damaged branches are removed. In the following years, excess of one-year shoots is removed to loosen the crown (Phot. 46 and 47). Pruning is best performed in February/March, before the sap starts flowing, otherwise the plants "bleed" [Klymenko 2004].

8.3. Costs of establishment of a cornelian cherry plantation

Planning a commercial plantation involves the consideration of its costs. In the case of cornelian cherry they are strongly variable due to various prices of planting stock. Seedlings serving as planting stock, which in the case of cornelian cherry is very risky due to the lack of uniformity of genetic features and late start of fruiting, cost 10–15 PLN per seedling. Cornelian cherry propagated by cuttings is more expensive (20–40 PLN), but it offers the possibility of choice of cultivars with specific features, and the plants begin fruiting after 4–5 years. Plants propagated by bud grafting are the most expensive due to their time-consuming process of nursery technology (40-70 PLN), but it is the most suitable material for such long-lasting cultivation. The grafts are correctly formed and begin fruiting practically in the year following the planting. Moreover, vegetative propagation allows for the selection of a specific cultivar. The costs that need to be incurred for the establishment of a cornelian cherry plantation also depend on the applied density. If suitable machines are available (for soil maintenance, harvest, protection), the distance between rows can be reduced to 4 m, and the plants can be planted every 2.5 m in a row. In that case, planting over an area of 1 ha requires 1000 trees. Therefore, high quality planting stock such as grafts will cost from 40 to 70 thousand PLN. The remaining costs, with the choice of suitable location, are analogical to those in the case of the establishment of other orchards. It should be remembered, however, that cornelian cherry, particularly at a young age, is susceptible to drying of the still underdeveloped root system. It therefore requires mulching with nonwoven fabric or organic mulch. Moreover, it is worth implementing irrigation. Mulching and irrigation cost approximately 6–8 thousand PLN [Golis et al. 2019]. Another element to be added is the cost of fencing the plantation. If 60–70% of the cost of establishment of a cornelian cherry plantation are costs incurred for the purchase of planting stock, the young orchard should also be fenced as soon as possible. Of course the costs of fencing depend on the price of stakes, fencing net, and potentially a gate, amounting to approximately 2.5–3 thousand PLN/ha. The estimated cost of establishing a cornelian cherry plantation with the application of high quality planting stock is 48.5–81 thousand PLN per hectare. It is comforting that the duration of the investment process is reduced to minimum in this case, because budded cornelian cherries begin fruiting from the second year after planting, and offer higher yields in the following years.

Considering the current lack of monocultures of cornelian cherry in Poland, it is a plant that can be recommended for ecological plantations. It will permit obtaining fruit and products not containing chemicals that can be sold for higher prices [Bijelić et al. 2015].

8.4. Fruit harvest

The fruit of cornelian cherry ripens unevenly, and when it is fully coloured and soft, it spontaneously falls. The long-lasting period of fruit ripening is caused by an extended flowering period. Moreover, it is determined by a number of other factors such as: genetic features, climate, microclimate, soil conditions, heigh above sea level, land exposition, and insolation. Cornelian cherry usually matures from the end of July to October, best with mean daily temperature of 18–23°C [Klymenko 2013]. Most fruit of cornelian cherry, of both Polish and Ukrainian cultivars, is harvested in September, therefore in Polish conditions this term is considered typical of the species. The period of maturing and fruit harvest depends on the conditions occurring in a given growing season. Relatively low temperature and precipitation prolong the harvest period, whereas draught can reduce it. Harvest usually lasts from 20 to 30 days, but in some cases reaches even 52 days [Szot et al. 2018]. Cornelian cherry from Montenegro [Jaćimović and Božović, 2014] cultivated at a level of 540–1125 m a.s.l., matured on average over 22 days, and Bijelić et al. [2008] specify a period of 27 days. In Montenegro, cornelian cherries matured from 28 August to 13 October, and in Serbia [Bošnjaković et al. 2012] from 17 August to 20 September, or according to Bijelić et al. [2008] from 27 July to 29 September. Based on an experiment conducted in the Lublin Region [Szot et al. 2019], it was evidenced that climate conditions in a given growing season can prolong the average period of ripening even to 26 days. In such conditions, average temperatures of both the analysed growing periods (2014 and 2015) were higher by approximately 3ºC than the multiannual average. Season 2014 was characterised by excessive rainfall, particularly in May. This may have decreased the yield, and therefore reduced the time of fruit ripening. It turns out that a serious draught in June, July, and particularly in August 2015 did not contribute to the reduction of the period of fruit ripening. It is at variance with the observation by Inglese et al. [1999] who investigated olive trees and determined that draught considerably weakened the growth of fruit, intensified its falling before harvest, and reduced the ripening period. Perhaps the plants of cornelian cherry are adapted to draught and strong insolation, as evidenced by the ability to overgrow mountain slopes.

Ripe fruit falls, and therefore right before the expected beginning of their ripening a net or nonwoven fabric should be spread under the trees (Phot. 48). It prevents getting the fruit dirty. This type of harvest is work-intensive and possible to conduct only at a small scale.

In intensive orchards with dense planting and a dozen-years-old plants, it is necessary to facilitate harvest. Fruit harvest accounts for 50-80% of the costs of fruit production, therefore it should be facilitated as much as possible. No attempts of mechanical harvest of cornelian cherry fruit have been made so far, but it can be referred to other trees with a similar structure and producing stone fruit, e.g. olive trees. Depending on their purpose, olives are harvested at their green stage, or when they are ripe. In the case of cornelian cherry, mechanical harvest should be easier, because their common

Phot. 48. Spreading nonwoven fabric in the period of cornelian cherry fruit ripening allows for its fast harvest while keeping the fruit clean

use involves fully ripe fruit that falls easily. Formerly, olive harvest was facilitated by lining nets under trees and strongly shaking the branches. Currently, in large intensive orchards it is not possible, and mechanical harvest is common. Amirante et al. [2012] assessed different methods of harvesting olives in terms of their efficiency. They compared manual harvest involving preliminary shaking of fruits by means of light aluminium masts followed by manual raking. Another method involved the application of a portable shaking device composed of an engine that drove a crank mechanism, followed by an arm shaking the branch. This harvest method involved the participation of three people. Another method employed two pneumatic combs placed on stakes with length regulation and an air compressor mounted in a three-point linkage. The harvest involved the participation of four people. Among the mechanical harvesting methods, a machine was evaluated which was constructed with a shaking element attached to the tree trunk. It consisted of a gripping arm driven by two hydraulic motors, generating a sinusoidal, multi-directional oscillation. In one of the variants of such harvest, the shaking element was equipped with a container storing the shaken fruit in the form of an inverted umbrella. Another variant assumed collecting falling fruit onto nets with a length of 7 m and width of 3 m, held by 6 workers. The authors of the study evidenced that in intensive olive orchards, each of the mechanical methods employing an inverted umbrella or nets was more efficient in comparison to manual harvest with the application of a shaking device. The most efficient in terms of labour proved to be an inverted umbrella, although it requires verifying for the length of branches growing out of the trunk not exceeding 80–90 cm.

The yield depends on many factors, among others the propagation method, age, genetic features, and conditions occurring in a given growing season. Bud grafted plants bear fruit already in the second year after planting, whereas those obtained from cuttings – in the 4–5th year after planting, and from seedlings – only in the 8th year from planting. Cornelian cherries show no hormonal regulation of fruiting and bear fruit annually. One plant depending on its age yields 10–20 kg (5–10 years), 30–40 kg (15–20 years), or 80–100 kg (25–30 years) [Klymenko 2004]. Century-old specimens are known that yield approximately 200 kg of fruit. Based on research on 16–17-year-old seedlings of cornelian cherry in 2015, Szot et al. [2019] determined that the yield was approximately 7 kg higher than in 2014 due to the age and weather conditions. Dokoupil and Řezníček [2012] investigating yielding of various cornelian cherry cultivars over a period of 4 years from the moment of their permanent planting determined that the genetic factor significantly determined the volume and efficiency of yielding. Most of the analysed cultivars, however, responded with an evident decrease in yielding in the second year after planting, and a substantial increase in yields only occurred in the fifth year (approximately 8 kg/plant). They evidenced that a large volume of a plant (m^3) did not entail high yield efficiency, because cultivars Jaltsky and Lukjanovsky, characterised by the greatest volume, i.e. the strongest vegetative growth (4.87 and 4.17 m^3), also showed the smallest yielding efficiency among 7 analysed cultivars: 1.03 and 1.14 ($kg \cdot m^{-3}$), respectively. Cultivars with the smallest volume: Jolico and Fruchtal (1.86 and 1.96 m^3) yielded the most effectively, reaching 3.07 and 3.73 $kg \cdot m^{-3}$, respectively. In the following years of research, the volume of the plants successively increased, but yielding was evidently higher only in the fifth year after planting. This suggests that cornelian cherry requires a long time of adaptation to the habitat and climate conditions for yields to become increasingly abundant.

8.5. Threats involved in running a plantation

Cornelian cherry is a tree resistant to diseases and pests that can live up to more than 200 years. With lack of monocultures and provision of optimal cultivation conditions, it will show high resistance to unfavourable conditions, including infection with diseases and infestation with pests. The occurrence of harmful pathogens on the plants can be currently prevented by providing them with optimal growth conditions. Therefore, the selection of location is of high importance, as well as the choice of high quality planting stock, fertilisation, and pruning. Young cornelian cherries are the most susceptible to diseases. The appearance of fungal diseases on them (Table 9) is highly dangerous. It can even lead to their death (youg seedlings, young grafts).

Bobev et al. [2009] were the first to report symptoms of a fungal disease caused by *Phytophthora citricola* in Bulgarian nurseries. Dark brown necrotic spots usually appeared on the edges of leaves, and rapidly covered more than half of their surface. Necrosis of leaves and shoots expanded towards older woody tissues, and cuttings died within several weeks. In laboratory conditions, they also found that the artificial application of mycelium on the leaves, stems, and mature fruits of cornelian cherry of cultivar Kazanlashki caused tissue necrosis after just 4 days, followed by the spread of necrotic spots up to a diameter of 20–25 mm within the next two days. Due to the high polyphagy of *P. citricola* which causes seedling rot in beech, ash, fir, birch, larch, alder, and spruce [Orlikowski et al. 2004], and because of the significant harm caused by phytophthora, it should be assumed that this may be a serious problem for nursery growers and cultivators of cornelian cherry.

Another dangerous polyphagous threat in nurseries can also be the bacteria from genus *Pseudomonas*. There are already initial reports [Kałużna 2019] of the occurrence of a disease caused by this bacterium in Polish nurseries, manifesting as bacterial leaf spot on cornelian cherry plants (Phot. 49 and 50). The author observed that the bacterium belongs to genus *Pseudomonas* and is closely related to *Pseudomonas avellane*, a common pathogen of hazelnut. Meanwhile, on the common dogwood (*Cornus sanguinea*), she isolated *Pseudomonas syringae* pv. *syringae*. *Pseudomonas syringae* causes bacterial cancer in fruit trees, and affects more than 180 plant species, often distantly related in systematic terms.

Phot. 49 and 50. Symptoms of *Pseudomonas* on leaves of 3-year-old grafts of cornelian cherry

Symptoms of diseases such as anthracnose are sometimes observed on cornelian cherry, caused by fungi such as *Discula destructive*, *Elsinoe corni*, *Colletotrichum acutatum*, septoriosis caused by *Septoria cornicola* and *Septoria corni-mas* [Ershad 2009], as well as powdery mildew caused by *Phyllactinia corni*, *Phyllactinia guttata*, and *Erysiphe spp.* [Redlin 1991, Pirnia et al. 2006]. Bobev et al. [2009] in Turkey and Arzanlou and Torbati [2013] in Iran recorded the appearance of anthracnose symptoms on the leaves and fruits of cornelian cherry caused by the fungus *Colletotrichum acutatum*.

On artificially infected fruits, the first disease symptoms appeared after 7 days as concave, watery spots. *C. acutatum* is easily distinguishable among other species of genus *Colletotrichum* based on the morphological structure of conidia that are characteristically pointed. The appressoria are dark brown, egg-shaped, or irregularly lobed, without finger-like branches. Bacigálová and Brindza [2005], for the first time in Slovakia, documented symptoms of powdery mildew on the leaves of cornelian cherry (Cornus mas) caused by *Phyllactinia corni*. They were completely different from the symptoms of another powdery mildew *Microsphaera tortilis*. *M. tortilis* lacks bulbous appendages, and its asci contain 3–6 ascospores, while those isolated from *C. mas* had bulbous appendages with two ascospores in each ascus. It was found that both the anamorphic and ascus-forming stages were similar to *Phyllactinia corni* on *Cornus officinalis* [Shin 2000].

Another fungal pathogen of cornelian cherry may be brown rot *Monilia fructigena*, the most common cause of brown rot in apple and pear trees in Europe. It can also affect plums, peaches, cherries, Japanese pears, apricots, and cherries. Among less well-known fruit species, it occurs on quince, barberry, blueberry, Japanese persimmon, and cornelian cherry [Stępniewska–Jarosz 2017]. While *M. fructigena* and *M. laxa* occur in Europe, *M. fructicola* is found in North and South America, Japan, and Australia. In the United States, in 2010 and 2013, the presence of brown rot caused by *Monilinia fructicola* on the fruit of the Elegans cultivar of cornelian cherry was recorded for the first time, while the fruit of cultivar Sunrise under field conditions proved to be resistant. Beckerman and Creswell [2014] confirmed that the fruit of cornelian cherry was precisely affected by *Monilinia fructicola*, not *M. laxa*, *M. fructigena*, or *Lambertella corni-mas*, due to their characteristic morphological structure. On potato dextrose agar (PDA) medium at a temperature of 25°C, after 5 days, grey concentric rings with smooth colony margins appeared. Hyaline single-celled conidia in the form of branched chains and elongated ellipsoids measured 10–15 μm in size [Côté et al. 2004]. Also based on molecular methods and the analysis of the ITS rDNA region sequence, species *M. fructicola* obtained from the GenBank showed 100% similarity to isolates from Italy, China, and Spain [Lane 2002]. Although *M. fructicola* was not originally present in Europe, its presence was already documented in France, Spain, and the Czech Republic in 2001. Further spreading of the pathogen in Europe could lead to increased diseases in peaches, apricots, nectarines, and occasionally on cornelian cherry (Phot. 51) [Leeuwen and Kesteren 1998].

Another dangerous fungal disease is grey mould (*Botrytis cinerea*) that affects many plants and occurs on their dead tissues, often forming a white, powdery coating in severe cases. It damages various plant organs such as flowers, leaves, buds, stems, seedlings, and fruits. Özer and Bayraktar [2014] first recorded symptoms in Turkey at the turn of May and June, appearing as

Phot. 51. Symptoms of moniliasis on the fruit of cornelian cherry

small expanding brown spots on the flowers which were then covered with a layer of grey-brown mycelium and conidia. Subsequently, brown necrotic changes and mycelium growth spread to the leaves, causing them to wrinkle and deform. Heavily affected stems dried up and died.

In West Europe (England, the Netherlands), there is an increasing occurrence of leaf damage on cornelian cherry caused by moths from family *Heliozelidae*: *Antispila treitschkiella* – larvae emerge twice a season, with the first generation in June-July and the second in September or November, and *Antispila petryi* – a single generation, occasionally on cornelian cherry. The larvae feed on the leaves, causing what is known as "leaf mining". Caterpillars of both species have a different number and size of warts on the dorsal surface of the eighth abdominal segment. This is a very distinct difference. The small black dots on the dorsal surface of the caterpillar vary depending on the species [Nieukerken et al. 2018]. The first reports of the expansion of the range of *A. treitschkiella* to planted *C. mas* plants were published by Dziurzyński [1948, 1952] who reported it as his new species *A. stachjanella* from the Krakow Region in Poland. It occurred in high abundance in parks between 1944 and 1946, with a decline in 1947 after a severe winter. Polish records of this pest are not far to the north of the native distribution of *C. mas* in southern Slovakia [Da Ronch et al. 2016]. From 1947 to the 1990's, no literature regarding the expansion of this species was found, even though *C. mas* was planted in many urban areas.

Another pest observed on cornelian cherry is *Eupoecilia ambiquella* [Schmieder-Wenzel and Schruft 1990]. This moth, which in southern Europe (Bulgaria) poses a threat to grapevine cultivation, can damage up to 50–70% of flowers in the first generation. Larvae from the second generation create webs on immature fruits, which can lead to secondary infection by grey mould (*Botrytis cinerea*). In Slovenia, since 1990, feeding by *Metcalfa pruinosa* on cornelian cherry has been recorded. The insect originates from North

Table 9. Diseases caused by specific fungal and bacterial pathogens, the plant parts they attack, and the optimal temperatures for their development [own elaboration based on: Redlin 1991, Leeuwen and Kesteren 1998, Bobev et al. 2009, Ershod 2009, Beckerman and Creswell 2014, Özer and Bayraktar 2014, Stępniewska-Jarosz 2017, Kałużna 2019].

Pathogen	Disease	Affected plant part	Optimal temperature (°C)
Fungi			
Phytophtora citricola	Rot	Seedlings	25
Discula destructive, *Elsinoe corni*, *Colletotrichum acutatum*	Anthracnose	leaves, fruit	20–25
Septoria cornicola and *Septoria corni-mas*	Septoria	Leaves	21–24
Phyllactinia corni, Phyllactinia guttata, Erysiphe ssp.	Powdery mildew	Leaves	18–25
Monilia fructigena	Brown rot	Leaves, fruit	15–25
Monilia fruticola	Brown rot	Leaves, fruit	15–25
Botrytis cinerea	Grey mould	Flowers, leaves, stems, fruit	18–25
Bacteria *Pseudomonas avellane*	Bacterial cancer	Leaves of seedlings and maiden trees	18–32

America but is now commonly found in Europe and demonstrates harmful effects on grapevine cultivation in the southern part of the continent [Pencheva and Yovkova 2016].

In Poland, the occurrence of the plum fruit moth has been observed on cornelian cherry. Its presence is best noticed in the leafless stage, when the female scales on the stems are clearly visible. They are so dangerous that during the season, the larvae feed on plant juices, causing the leaves to turn yellow and fall off. This reduces the plant's photosynthetic surface, and they become malnourished, resulting in reduced yields. The occurrence of leaf rollers has also been noted on cornelian cherry, especially the rose leaf roller whose caterpillars feed in nests located at the top of the branches, chewing holes in the leaves. Omnivorous aphids can also appear on cornelian cherry, particularly aphids of genus *Anoecia*, such as the larch-grass aphid. Aphids form colonies and feed on young, juicy leaves. They also produce a lot of honeydew on which sooty molds often develop as a black coating. In June, they transform into winged forms and fly to a second host, namely grass, and then return to cornelian cherry in September to lay winter eggs [Sekrecka 2018]. There have been no large plantings of cornelian cherry so far. Therefore, typical monophagous pests have not accumulated. However, it can be attacked by polyphagous pathogens that are commonly found in our orchards, such as leaf rollers (Phot. 52 and 53) and aphids (Phot. 54).

Phot. 52. Leaf roller climbing on its web onto a leaf of cornelian cherry

Phot. 53. Leaf roller cocoon on a leaf of cornelian cherry

Phot. 54. Young shoot of cornelian cherry of cultivar Radist attacked by amphids

Phot. 55–58. Symptoms of presence of a pest the larvae of which attack seeds

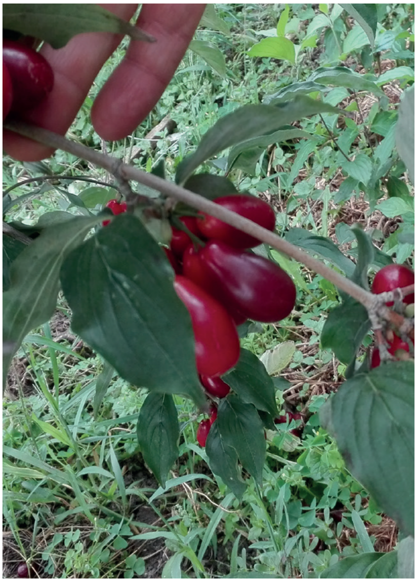
Phot. 59. Orange lichen on a woody stem of cornelian cherry

Phot. 60. Frost and snowfall in full bloom of cornelian cherry (23 March 2020)

Phot. 61. Flowers of cornelian cherry damaged by frost (6 April 2020)

Phot. 62. Very poor setting of fruit of cornelian cherry

Phot. 63. Russeting on the fruit of cornelian cherry as a result of low temperatures



Phot. 64 and 65. Longitudinal fruit cracking in the fruit of cornelian cherry (Ukraine, 2017)

In July, signs of pest feeding were observed in the fruit of cornelian cherry (Phot. 55–58). The larvae consume the entire interior of the seed, and then exit the fruit [own observation].

Young trees are also vulnerable to attacks by animals such as deer and hares. It is important to protect the trunk, especially from bark consumption. On the branches of "venerable" specimens, fungi from genus *Xanthoria*, such as the common orange lichen (*Xanthoria parietina*), may appear. Its foliose, closely interconnected, golden-yellow thalli have a diameter of approximately 10 cm (Phot. 59). This species is very common in Poland and, due to its symbiosis with algae, it is classified as a lichen. Its presence on cornelian cherry branches does not harm the plant [Piórecki and Rydzak 1970].

It is worth emphasising that not only biotic factors pose a threat to the cultivation of cornelian cherry. The spring season of 2020 revealed that the temperature conditions in February, March, and April resulted in early and very prolonged flowering of the 3-year-old cornelian cherry (almost 2 months). During that'; time, the temperature dropped below 0°C several times (Phot. 60). However, it was only the frost during full bloom that caused significant damage to the flowers. This turned out to be a good test to assess the resistance of the flowers of different varieties to sub-zero temperatures (Phot. 61). All observed cultivars set fruit poorly, with just one fruit in every fifth inflorescence (Phot. 62). However, cultivars such as Wydubieckij, Władimirskij, Kostia, Flava, after abundant flowering, did not produce a single fruit [own observation].

Frosts and cold temperatures during flowering and the development of young fruit buds can lead to russeting of the skin. Russeting is associated with the abnormal formation of cork on the typically smooth skin surface. It is commonly observed in stone fruit trees such as plums, cherries, and nectarines. Russeting can manifest as streaks or bands in different parts of the fruit (Phot. 63), and in severe cases, it can cover the entire fruit with a dense network. Sometimes, such damage is accompanied by deformation and a reduction in the size of natural fruit [Curry 2009].

Another issue, especially in the cultivation of large-fruited cultivars of cornelian cherry, can be fruit cracking (Phot. 64 and 65). It is caused by an osmotic process in which water accumulates on the fruits after rainfall and penetrates into their interior. Fruit cracking intensifies in the late stage of fruit ripening when they contain a high amount of sugars. Sudden rainfall, especially after a prolonged period of drought, is particularly unfavorable in this regard [Khadivi-Khub 2015].

9. Cornelian cherry in amateur plantations

Due to the uniqueness of its taste, the health benefits of its fruit, and the versatility of its use, cornelian cherry is also a valuable plant for amateur gardeners. It is still a relatively unknown plant, and it is worth having it in your garden to stand out among your neighbours and enjoy the diverse qualities of cornelian cherry every year. In early spring, it catches the eye with a delicate veil of flowers. During its flowering period, cornelian cherry delights with its unique yellow colour against the overall greyness of other trees and shrubs, and this display lasts for a relatively long period. In the case of early, cool springs (as was the case in the 2020 season), this can even last for up to 2 months. Moreover, it serves as a valuable food source for bees. A little later, cornelian cherry captures attention with the fresh greenery of its leaves, and in the case of ornamental varieties, their bi-colouration, such as cultivar Pstrolistnyj that features white and green leaves (Phot. 66).

Phot. 66. Cornelian cherry of cultivar Pstrolistnyj – to achieve the proper yellow-white-green coloration, it requires a sunny location

The fruit ripening period occurs in summer, and by choosing the right cultivars, you can enjoy fresh cornelian cherry fruit for three months, from mid-July to mid-October.

When selecting a location, just as with commercial plantations, the climatic and soil requirements of cornelian cherry should be considered. This means a sunny location, protection from the wind in the plant's early years, and the possibility of providing some shade during excessively sunny periods. Mature cornelian cherry is exceptionally resilient to adverse conditions such as frost, drought, and high solar radiation.

Ideally, the soil pH should be close to neutral, with a high organic matter content. Therefore, on less fertile soils, it is advisable to dig a relatively large hole when planting, and enrich it with compost while also applying manure, but ensuring it is not in direct proximity to the roots of the planted plants.

For amateur cultivation, it is better to choose cultivars that are not commonly found in mainstream plantings, such as those with yellow or black fruit colours (Prezent or Ugolek) or unique fruit shapes such as Sulija. Sulija stands out among other cornelian cherry cultivars due to the round shape of its fruit featuring distinctive ring-like bulges before transitioning into the stem. The author of the cultivar, Prof. Svetlana Klymenko, named the cultivar after the Ukrainian term for a moonshine bottle, "sulija," because its shape resembles one. When planting on your property, it is beneficial to plant at least two different cultivars, because cornelian cherry plants require cross-pollination with genetically diverse pollen for fruit production.

Having a choice of many cultivars, it is a good idea to plant several cornelian cherry plants that differ in terms of fruit ripening time, fruit colour, and fruit size. For those who appreciate fresh fruit, Ukrainian varieties are worth considering. They are known for their large fruit size and delicious taste (high sugar content to acidity ratio). It is widely known that diversity in fruit colours and shapes enhances the attractiveness of the fruit, making it more appealing for fresh consumption. Examples of cultivars with very large fruits include Ukrainian ones (average weight above 6 g): Ekzoticznyj, Jewgenija, Łukjanowskij, Mrija Szajdarowoj, Siemen, Swietljaczok, Wawiłowiec, Władimirskij, Wydubieckij, and Polish cultivars (average weight above 3 g): Bolestraszycki, Dublany, Florianka, Paczoski, Podolski, Raciborski, Swetlana, Słowianin, Szafer.

All the fruits are suitable for processing because even if they are not red, you can make original yellow jams or compotes from them (Table 10). However, it has been proven that processed products from dark-coloured fruits are richer in health-beneficial anthocyanins. Therefore, for juices, liqueurs, chut-

Table 10. Cultivars recommended for amateur orchards due to the dark red and yellow colour of the fruit, easy separation of the flesh from the stone, and the earliest and latest term of ripening [own elaboration based on: Kucharska et al. 2011, Klymenko 2013]

Vividly red fruit	Yellow fruit	Fruit with flesh easily separated from the stone	Cultivars ripening the earliest	Cultivars ripening the latest
Szafer Raciborski Swietłana Bolestraszycki Dublany Kresowiak Kotula, Podolski Ugolek	Aliesza Bukowinkij Galicyjskij Jantarnyj Nieżnyj, Flava	Ekzoticznyj Nikołka Oryginalnyj Dublany	Dublany Juliusz Aliesza Elegantnyj Jeljena Nieżnyj Nikołka	Florianka Podolski Kostia Kozierog Siemen Sokolinoje Sulija

neys, pestils, and other products made in large quantities, it is better to choose fruits with the darkest colour possible.

Cornelian cherry can be used to create low and tall hedges, because it tolerates intensive pruning exceptionally well. An example of a beautiful low hedge can be seen planted along the avenue leading to the palace complex in Lednice, Czech Republic (Phot. 69). A dense and compact hedge can be achieved by planting the plants in two rows spaced approximately 0.4–0.5 meters apart and planting the plants in each row every 0.4–0.5 meters in a "cross" pattern relative to the rows (Phot. 67). Despite heavy pruning, the plants continue to bloom vigorously every year and then produce fruit (Phot. 68).

Phot. 67. Cornelian cherries planted in “cross” arrangement in two rows develop a dense hedge

Phot. 68. Strongly pruned cornelian cherry hedge produces flower buds and sets fruit

Phot. 69. Cornelian cherry hedge in Lednica (Czech Republic)

Cornelian cherries can also be used to create tall hedges, for example to separate your property from your neighbour's. In this case, besides having a solid wall that is yellow in spring (Phot. 70) and green shortly thereafter

Phot. 70. Cornelian cherry hedge in the flowering period

Phot. 71. Cornelian cherry hedge after the development of leaves

Phot. 72. Shrubs of cornelian cherry of cultivars Pstrolistnyj and Ekzotycznyj trained into a fan-shaped form

(Phot. 71), you will also have a fruit bearing wall that stands out in summer with its ripening yellow, pink, red, crimson, and black fruits.

In addition to using cornelian cherry as a hedge, it can be trained to grow on trellises in a fan-shaped form (Phot. 72).

In an amateur garden, if cornelian cherry is primarily intended for fruit production, it should be planted away from benches, paths, and sidewalks, because the fruit that ripens over an extended period and falls to the ground can obstruct the use of these areas. A good place to plant cornelian cherry is on a slope, because in this case, the ripe falling fruit will collect at the base of the slope on the spread-out nonwoven fabric. Ripe cornelian cherry fruit immediately falls to the ground (Phot. 73). It is therefore necessary to spread ground cover, netting, or mats. Ground cover should also be spread out on flat terrain so that it covers the area within the tree's canopy (Phot. 74). Harvesting should be done every 2 days, and it is significantly easier when the fruits are clean and easily accessible [Mika 2016].

Phot. 73. Fruit of cornelian cherry fall to the ground when it becomes collectively ripe

Phot. 74. Method of securing the fruit of cornelian cherry against dirt by means of ground cover

9.1. Maintenance treatments in an amateur orchard

Due to its high tolerance for adverse weather conditions (low temperatures, drought), cornelian cherry requires no special attention. However, it is worth providing the best possible conditions for its growth and development to enhance its resistance to diseases and pests. Therefore, the primary practice is to ensure that there is no competition from weeds, especially for young trees. Weeding around the base of the trees with a hoe should be done very carefully, because cornelian cherry roots close to the soil surface (Phot. 75).

In the case of unfenced areas, another significant practice is protecting the plants from animals such as hares and deer. For the winter season, it is advisable to protect valuable specimens with paper or ground cover. Until mid-June, it is essential to shield the trees from bucks that readily rub against the shoots

Phot. 75. Roots of cornelian cherry developed right under the soil surface

Phot. 76. Method of protecting trunks of cornelian cherry from deer

of the tree trunks, potentially damaging the young crown. A good method is to hang a piece of mesh around the tree trunk to discourage animals from rubbing against it (Phot. 76).

In the case of larger plantings, cornelian cherry is not a very popular plant, so it should not be frequently plagued by diseases and pests. By providing the conditions for proper growth, you enable the plant to maintain its vitality. Even in unfavorable environmental conditions, it will continue to grow and develop, producing delicious fruit. Cornelian cherry has a high regeneration capacity, and even if it briefly shows signs of infestation, it can produce healthy leaves in the next period under favorable weather conditions. Cornelian cherry is readily visited by various insect species (Phot. 77–79), which helps maintain ecological balance and limits pest infestations.

Phot. 77. Green lacewing on cornelian cherry

Phot. 78. Spider on cornelian cherry

Phot. 79. Insect from the beetle family on cornelian cherry

Phot. 80. Intensive rain and wind during the period of flowering of cornelian cherry

Phot. 81. Squirrel under an old cornelian cherry (Bolestraszyce)

Due to its high adaptability to environmental and climatic conditions (Phot. 80), cornelian cherry can be successfully cultivated in Poland. Its slow growth and longevity make it an attractive addition to the garden for many years and a source of valuable fruits. It is well-suited for organic cultivation and is an ideal plant for enhancing landscape and cultivation biodiversity (Phot. 81).

10. Possible uses of the fruit

The versatility of cornelian cherry fruit lies in the wide range of its uses in food processing. It can be used at various stages of ripeness. Immature fruit, before the skin begins to turn red, can be pickled or preserved. Such a product resembles Mediterranean olives and can serve as an excellent snack, a salad ingredient, or an addition to meat dishes.

Recipe for pickled cornelian cherry

To prepare the brine, take 1 part salt and 9 parts water. Then, add allspice, thyme, bay leaves, grape leaves, and oak leaves. Pour the brine into a large jar or barrel. Wash the largest but still immature (completely green) cornelian cherry fruit thoroughly and drown it in the brine. Allow the cornelian cherry to ferment for 3 months. After this period, transfer the pickled fruit to smaller jars and cover them with olive oil. You can also add some herbs such as marjoram, thyme, oregano, or finely chopped chili pepper for seasoning.

Fruits that are already covered with an intense, bright red blush but are still firm and juicy are suitable for making compotes and candying. At this stage of ripeness, it is easiest to separate the firm flesh from the stone. Later, when the flesh becomes very soft, attempting to separate it from the stone is impossible without damaging its structure, and only the skin separates from the stone. Some cultivars are characterised by easier separation of the flesh from the stone, for example Grienadier, Jewgenija, Kostia, Nikołka, and Oryginalnyj [Klymenko 2013]. Compotes made from cornelian cherry can be prepared without the need to pit the fruit (Phot. 82), which is necessary for cherries and plums if you want to store the preserves for an extended period. Cornelian cherry seeds contain no hydrocyanic acid that can be released over time when stored in compotes [Kucharska 2012].

However, the fullest potential for utilisation is with fruits in full ripeness. *The Economic and Technical Herbarium* by Józef Gerard Wyżycki from 1845 (which was probably Czesław Miłosz's favourite book in his youth) reads as follows: *From the pressed juice, a drink called "dereniak" is made in Podolia,*

Phot. 82. Compotes from cultivars of cornelian cherry producing yellow and red fruit

similar to wine; it is a tasty and healthy beverage, and when added to young Hungarian wine, it is said to give it the flavour of matured, old wine... [Piórecki 2007].

There is still a prevailing belief that cornelian cherry fruit is primarily used to make liqueurs (Phot. 83), and connoisseurs claim that it is the best for this type of alcoholic beverage. It is often referred to by enthusiasts as the "queen of liqueurs." In Poland, "Traditional Cornelian Cherry Liqueur" with 40% alcohol content is produced by the Polmos Vodka Factory in Łańcut, and "Wawel Liqueur" with 30% alcohol content is produced by Poltrep S.c. Fruit and herbal liqueurs remain popular due to their attractive taste, aroma, and colour. Cornelian cherry liqueurs should be prepared with vodka due to their high pectin content. Pure ethanol precipitates pectins, resulting in a jelly-like consistency. Cornelian cherry liqueur is a product that matures over time, as alcohol extracts the active compounds from the fruit only after 3 months. Over time, the liqueur acquires a caramel flavour, but not an almond flavour characteristic of liqueurs made from other stone fruits such as cherries and apricots [Kucharska et al. 2007].

Phot. 83. Cornelian cherry liqueur

Liqueurs also contain many valuable compounds derived directly from plant materials, including polyphenols, which are known for their high antioxidant activity. Liqueur enthusiasts make them

Phot. 84. Fruit of cornelian cherry from liqueur

to achieve interesting flavours, or for their medicinal properties. Cornelian cherry, among many wild fruits, has been used for centuries to make liqueurs, especially in southeastern Poland and Ukraine. Kucharska et al. [2007] assessed the production efficiency and quality of honeysuckle liqueurs depending on various methods of preparation. They observed that it is more beneficial for a higher polyphenol content in liqueurs to add sugar not immediately at the beginning when pouring alcohol over the fruit, but rather in later stages of liqueur production. To obtain a liqueur rich in polyphenols, it is recommended to puncture the fruit containing stones, and pour alcohol with a concentration higher than 40% (ideally 60–70%). This may be due to the additional extraction of active compounds from the stones. It's worth emphasising that cornelian cherry stones contain no cyanogenic compounds like the stones of species from genus Prunus (cherries, plums), so there's no need to remove them quickly from the liqueurs to avoid the formation of hydrogen cyanide. Fruit used for making liqueurs (Phot. 84) makes an excellent addition to cakes or pastries, and can be used in sauces for game dishes.

After 6 months of storage, the polyphenol content in the examined liqueurs ranged from 1819 to 2457 mg/L. Rodtjer et al. [2006] found similar polyphenol content in cherry liqueur (1080–1525 $mg \cdot L^{-1}$), while green unripe walnut liqueur contained 2001–3522 $mg \cdot L^{-1}$ polyphenols [Alamprese et al. 2005]. The colour of liqueurs changes with the storage period. Kucharska et al. [2007] observed that as liqueurs matured, their color became less red (lower parameter a*) and more yellow (higher parameter b*). The authors proposed naming cornelian cherry liqueurs "cornelle" by analogy with the name of the French plum liqueur "*prunelle*."

Phot. 85. Like apples and pears, the fruit of cornelian cherry
is suitable for direct consumption as dessert

Fully ripe cornelian cherry fruit is best for direct consumption (Phot. 85), but it can also be used to make a wide variety of preserves, starting with jams, jellies, syrups, and ending with the still not very popular "skórka" (a traditional Polish preserve). The only difficulty is separating the seeds from the pulp. This can be done after gentle heating of the berries with a small amount of water and then straining them through a sieve.
An original product made from cornelian cherry is jam (Phot. 86) or preserves which due to their characteristic aroma and subtle bitterness are suitable not only for desserts but also for savory dishes, e.g. as an addition to meat, especially game, cheeses, and more. Cornelian cherry is excellent for making jams because of its high pectin content and high acidity that determine the appropriate consistency of the product.

Recipe for cornelian cherry jam

Prepare 1 kg of ripe cornelian cherry fruit and 40–50 dag (400–500 grams) of sugar. Wash the honeysuckle berries thoroughly. Place them in a saucepan and add about 1/3 of a glass of water. Heat the mixture until the berries start to break down. Mash the berries through a sieve to remove the seeds. Combine the resulting puree with sugar. Cook the mixture until it reaches the desired consistency, usually for about 15–20 minutes. While it is still hot, transfer the jam to sterilised jars and seal them tightly. Once the jars have cooled, label them, and you can use the jam as a topping for bread, cookies, and cakes [Kawecki et al. 2007].

Recipe for cornelian cherry confit

Thoroughly wash very ripe cornelian cherry fruit, i.e. that fallen from the tree. Place the washed berries in a pot and add a small amount of water. Heat the mixture until the berries become soft, and then strain them through a sieve to separate the pulp from the seeds. Combine the strained cornelian cherry with

Phot. 86. Jams from cornelian cherry cultivars producing yellow and red fruit

sugar (0.70 kg) and the additional kilogram of cornelian cherry pulp. Cook the mixture for about 30 minutes while stirring continuously. While it is still hot, transfer the jam to sterilised small jars. Seal the jars and pasteurise them for approximately 15 minutes.

Nawirska-Olszańska et al. [2010b] investigated the possibility of using cornelian cherry, quince, and strawberries for making pumpkin jams. It was found that the added fruits significantly enriched the pumpkin jam with polyphenols and increased its vitamin C content. Moreover, cornelian cherry fruit positively influenced the jam's more pronounced red colour.

A highly valuable food product, produced on a large scale, is fruit juice. Juices provide an excellent dietary supplement with essential minerals, vitamins, and water. Although the pulp of fully ripe fruit has a "mealy" structure, it is suitable for juice production. In their study on the influence of temperature on the polyphenol content in extracts from cornelian cherry fruit, Moldovan et al. [2016] found that temperatures up to 22°C did not cause a rapid decrease in the content of these compounds. Therefore, cornelian cherry fruit extract can be successfully stored for up to 2 months at room temperature without concerns about a significant reduction in the total polyphenol content.

Gąstoł et al. [2013] compared cornelian cherry fruit juices with juices from popular fruits such as apples, pears, and plums in terms of their content of biologically active compounds. They found that among the species they examined, the fruit of cornelian cherry had the highest content of organic acids and polyphenols, making it a valuable source of substances with antioxidant properties.

The juice industry is developing in two directions: the production of clear and cloudy juices. Cornea et al. [2016] demonstrated that the fruit of cornelian cherry is suitable for the production of high-quality juice. The fruit yield for producing cloudy juice was 77%, and for clear juice it was 62%. Therefore, to obtain 1000 litres of clear juice, you would need 1613 kg of cornelian cherry fruit. After processing, the nutrient content was only slightly lower than in fresh fruits, with an increase in acidity. The ratio of sugars to acids, which determines the taste harmony, was 0.60, giving the cornelian cherry juice a sweet-tart flavour. Due to its specific composition of tannins and other components, cornelian cherry juice has a unique and very pleasant taste. Notably, the calcium/phosphorus ratio is close to optimal, with cornelian fruit having a ratio of 2.07/2.9. The optimal calcium-to-phosphorus ratio is 1/1, while in pork it is 1/97. In cases where the diet is poorly balanced in these nutrients, limited calcium absorption occurs, resulting in decreased calcium levels in the blood, and calcium is leached from the bones, leading to osteoporosis.

In the case of products obtained using thermal processing, there is a risk of a drastic reduction in their health properties. However, Moldovan et al. [2017] demonstrated that after 10 days of storing cornelian cherry fruit extract at 75°C, there was no significant decrease in its antioxidant activity compared to the extract stored under refrigeration conditions. Different results were obtained by Gasik et al. [2008] who investigated the impact of maceration and storage conditions on the antioxidant activity and the content of selected components in cornelian cherry juice. They found that extending the thermal treatment time from 15 minutes to 2 hours led to a reduction in the total polyphenol content by approximately 4%, anthocyanins and vitamin C by approximately 12%, and antioxidant properties by about 10%. Storage also caused a decrease in the content of bioactive components and antioxidant activity, with the storage temperature having a significant impact. In the case of fresh juices, after four months of storage at 7°C and 20°C, losses in total polyphenols were approximately 15% and 20%, losses in anthocyanins were approximately 50% and 90%, and losses in vitamin C were approximately 30% and 40%, respectively. They emphasised that the storage temperature did not have a highly differentiated effect on reducing their antioxidant activity. The antioxidant capacity of cornelian cherry juices stored at 7°C decreased by about 35%, while those stored at 20°C decreased by about 37%.

Research conducted in Wrocław [Salejda et al. 2018] examined the suitability of cornelian cherry juice to improve the sensory and health properties of meat burgers. Even the lowest dose of cornelian cherry juice effectively reduced lipid oxidation and allowed for the maintenance of the desired sensory properties of the products. It was suggested that using cornelian cherry juice is a beneficial approach for extending the shelf life of meat products while simultaneously offering new products enriched with bioactive health components.

Recipe for cornelian cherry juice Caucasian style

Wash ripe cornelian cherry fruits, place them in a saucepan with a small amount of water, and bring them to a boil until they start to fall apart. Then, strain the mass through a cheesecloth to extract the juice. Mix two parts of cornelian cherry juice with one part of water and sweeten to taste. Cook for 5 minutes and pour into sterilised bottles, sealing them immediately. Pasteurise for 10–15 minutes [Kawecki et al. 2007].

The growing popularity of vegetarianism, increasing lactose intolerance, and the high cholesterol content in dairy products have recently increased the demand for non-dairy probiotic products. Nematollahi et al. [2016] studied the viability of probiotic bacteria and some chemical and sensory properties of cornelian cherry juice during refrigerated storage. They found that the low pH of the juice (2.6) reduced the viability of all bacteria strains, even the most resistant ones, to only 7 days. It was only when the pH was raised to 3.5 that the viability of bacteria, especially the strain *L. casei* T4, was extended to 28 days, even resulting in an increase in the bacterial population compared to the initial one. Therefore, the mentioned strain was considered as a robust gold-resistant strain, used in food matrices to work under very challenging conditions, such as in the production of beverages like fruit juices and beer. Sometimes, probiotics can lead to an unpleasant aftertaste in products fortified with them, which often discourages consumers from consuming them [Lucknow et al. 2006]. In this study, no unpleasant aftertaste was noted in corneliam cherry juice containing probiotic strains compared to the control sample (without probiotics). Barat and Ozcan [2018] found that cornelian cherry juice increased the total count of beneficial bacteria: *Streptococcus thermophilus*, *Lactobacillus delbrueckii subsp. bulgaricus*, *Lactobacillus acidophilus*, and *Bifidobacterium lactis* in yogurt, and improved their overall survival. Cornelian cherry yogurt had the highest content of vitamin C and phenolic compounds compared to yogurts with black mulberries or red grapes.

In Turkey, Celik et al. [2006] investigated the suitability of cornelian cherry fruit to prepare a paste that could be added to dairy yogurt. They made the paste in a similar manner to making jams or preserves. Ripe cornelian cherry fruits were heated to 60°C with a small amount of water, and then they were strained to separate the seeds. They used various proportions of cornelian cherry paste and sugar. They found that the addition of the paste influenced an increase in whey separation and a decrease in viscosity. During 21 days of storage, the acidity of the product significantly increased, leading to a decrease in pH. The most acceptable product for consumers was the one where 10 kg of cornelian cherry paste and 10 kg of sugar were used for 100 litres of yogurt.

Following the example of Serbia, Turkey, or China, it is possible to popularize the production of a very healthy snack called pestil. This is due to the relatively low temperatures used during thermal processing (50–60°C) that do not result in the same losses as cooking or frying. Depending on the country, in the production of pestil, in addition to fruit juice or pulp such as mulberries, grapes, apples, wild rose, etc., starch and sugar are used [Maskan 2001]. The traditional Turkish product known as Gümüşhane pestil also includes honey, wheat flour, milk, and nuts, making it softer and lighter in colour than fruit pestil [Yildiz 2013]. Because of its high pectin content and acidity, cornelian cherry fruit is excellent for making pestil, but it requires sweetening or combining with sweet fruits like apples or quince.

Recipe for cornelian cherry pestil

Wash fresh fruit, place it in a pot, add a small amount of water, and heat it briefly to soften. Then strain it through a sieve to separate the seeds from the pulp. Add sugar (about 30 decagrams per 1 kilogram of fruit), mix it carefully, spread it out in an even layer (about 1.5–2 mm) on baking paper, and put it in

Phot. 87. Dried cornelian cherry pestil

Phot. 88. Cornelian cherry pestil sprinkled with coarse sugar

Phot. 89. Pestil stars

Phot. 90. Pestil circles

the oven to dry for approximately 3–4 hours at a temperature of 50–60°C. After removing it from the oven, sprinkle with granulated sugar. The dried layer can be cut into slices with a pizza cutter and rolled up into rolls, or you can use cookie cutters to create various shapes (Phot. 87–90).

This type of pestil can be stored in a box for an extended period. It can be especially reached for after prolonged exertion, to quickly and healthily replenish energy, minerals, and vitamins.

Dark, rich in flavour, sweet-tart cornelian cherry juice is suitable for making fruit jellies (Phot. 91) enjoyed by children. It is worth replacing artificially coloured store-bought jellies and making your own treats with various shapes by thickening them with gelatin or agar.

Phot. 91. Jellies made of cornelian cherry juice

The trend for fitness products like muesli and energy bars has led to a high demand for dried fruits (Phot. 92) and candied fruits (Phot. 94). Raisins, popular for a long time, are increasingly being replaced by candied cranberries, cherries, plums, and currants. Candied cornelian cherry fruits have an exquisite taste, surpassing candied cranberries, because they are more tart. They can also be an excellent addition to traditional cakes and cookies.

Recipe for candied cornelian cherry

To prepare a syrup, use equal parts of sugar and water. For candying, it is best to use fruits that are not fully ripe but already red. Wash them, remove the stone (Phot. 93), and then immerse them in the heated syrup for about 3-5 minutes. Let them cool down and then bring them to a boil again. Afterward, remove them from the heat and let them cool down. Drain the cold cornelian cherry fruits on a sieve and then spread them on a baking sheet lined with parchment paper, making sure they don't overlap. Dry them in an oven at around

50–60°C for about an hour. Once they have cooled, transfer them to small jars, where they can be stored throughout the winter and gradually used to enhance dishes. Boil the remaining syrup from candying, pour it into sterilised bottles, and seal them tightly. This syrup is an excellent addition to crepes, pancakes, and ice cream.

Fruit puree can find application in the production of tarhana powder used in Turkey to make the famous spicy soup [Işik et al. 2014]. Tarhana powder is a mixture of yogurt, yeast, flour, grated vegetables such as tomatoes, peppers, and onions. The mixture is left in a warm place for several

Phot. 92. Dried cornelian cherry fruit available in stores

Phot. 93. Pulp of cornelian cherry separated from the stones

Phot. 94. Candied cranberry (to the left) and cornelian cherry fruit (to the right)

days for fermentation, and then it is dried in thin layers and ground into a dry powder. Işik et al. [2014] compared the taste, rheological properties, and chemical composition of traditional tarhana soup, where the vegetable additives were tomatoes or peppers, with tarhana enriched with cornelian cherry puree. They found that after just one day of fermentation, the tarhana dough with cornelian cherries had a pH of 3.6, while the traditional one had a pH of 4.2. They attributed this difference to the chemical composition of cornelian cherries that contain significant amounts of organic acids. The rheological properties that determine the viscosity and density of both soups, as well as their chemical composition and consumer evaluations, were similar. The authors concluded that cornelian cherry fruit should be used on a larger, commercial scale for the production of tarhana powder that is the basis of the famous Anatolian soup.

It has been observed that processing fruits increases the content of valuable ellagic acid and iridoids. This may be associated with the easier extraction of these compounds due to the disruption of cell structures caused by heat treatment. The content of ellagic acid increases through the hydrolysis of ellagitannins and glycosidic compounds, and the concentration of iridoids increases through their detachment from other structures [Kucharska 2012].

Fruit vinegar is a valuable product obtained through a two-stage fermentation process. Many studies have demonstrated the health benefits of fruit vinegars due to their strong antioxidant properties which play a protective role against the adverse effects of gut flora. Additionally, they have shown potential in managing diabetes, lowering blood lipid levels, and preventing high blood pressure. Fruit vinegars are often used in the production of medical preparations that are less burdensome on the body [Chen et al. 2015, Chou et al. 2015]. Kawa-Rygielska et al. [2018] demonstrated the potential health properties of various cultivars of cornelian cherry (Jantarnyj, Koralovyj, and Podolski) for the production of fruit vinegar. The highest concentration of bioactive compounds was found in vinegars made from cultivars with pink or red fruit (Koralovyj and Podolski). Cornelian cherry juice allows for the production of vinegar rich in iridoids. Furthermore, the study confirmed that the fermentation method significantly influences the final concentration of active substances in the finished product. Using fruit yeast *S. bayanus* – Safspirit for alcoholic fermentation significantly increased the content of bioactive compounds in the final products. Cornelian cherry vinegar, as a natural food product, can be a good source of antioxidants in the human diet.

Lately, especially during the summer, there has been a trend in drinking non-alcoholic beer. Adamenko et al. [2020] demonstrated that cornelian cherry is an excellent choice for producing such beverages. They compared traditional non-alcoholic beers with sour non-alcoholic beers brewed with the addition of juice from a red-fruit cultivar of cornelian cherry. The final products had low alcohol content (0.41% v/v for traditional beer and 0.43% v/v for sour beer) and low calorie content (ranging from 116–148 kcal per 500 ml of beer). The addition of cornelian cherry significantly increased the sour beers' antioxidant potential, as well as the polyphenol content, compared to traditional beer. Furthermore, they were rich in anthocyanins and iridoids, not to mention the new flavour experiences they provided.

Fresh fruits are, of course, the most beneficial for our health when consumed as a dessert. Cornelian cherries are relatively perishable, and they can be stored for approximately one week under refrigeration conditions. The health properties of the fruits are maintained during storage, as confirmed by Romanian research by Hosu et al. [2016]. Ripe cornelian cherries were stored for 4 days at 22°C, and their total antioxidant capacity was evaluated. For fresh fruit, depending on the method used (ABTS test, FRAP, HPTLC method), the total antioxidant capacity ranged from 36.13, 33.51, and 12.91 µmol Trolox per gram of fresh weight, respectively. After storage, the values were 34.15, 31.56, and 12.90 µmol Trolox per gram of fresh weight. Food producers are constantly seeking optimal ways to extend the shelf life of fruits without compromising their quality attributes, including both their chemical composition and physical parameters. In addition to the common refrigerated storage conditions for berries (such as blackberries and blueberries) which involve temperatures of 0–5°C and humidity levels of 80–95%, modified atmosphere packaging (MAP) has been introduced. MAP involves replacing the air with a modified atmosphere rich in carbon dioxide (CO_2), nitrogen (N_2), and oxygen (O_2). The elevated CO_2 levels, easily soluble in water and fats, inhibit the growth of microorganisms such as bacteria and moulds. Oxygen is used to control the respiration of fruit and to prevent colour changes. The type of packaging film used is crucial, as it determines the appropriate permeability to CO_2, O_2, and water vapour, as well as resistance to damage. In an Iranian study by Mohebbi et al. [2015], cornelian cherry fruit of cultivar Youzbashchay was stored in two types of films (low-density polyethylene and polypropylene) under three different atmospheric conditions: 5% O_2 + 20% CO_2 + 75% N_2, 60% O_2 + 20% CO_2 + 20% N_2, and ambient air (21% O_2 + 1% CO_2 + 85% N_2) at a temperature of 1°C and a relative humidity of 90-95% for 35 days. Unpackaged cornelian cherries served as the control. The results showed that at each measurement interval (every 7 days), regardless of the atmospheric composition, the MAP technologies allowed the fruit to maintain its mass and visual quality characteristics, while the control group experienced a 30% decrease in fruit mass and significant adverse changes in appearance. The most favourable storage method was found to be the use of polypropylene and an atmosphere composition of 60% O_2 + 20% CO_2 + 20% N_2, as well as low-density polyethylene with ambient air (21% O_2 + 1%

CO_2 + 85% N_2). These storage conditions resulted in the smallest decrease in extract content, acidity, ascorbic acid content, and anthocyanin content, along with the least increase in pH.

The fast pace of modern life, often accompanied by stress, sedentary lifestyles, and poorly balanced diets, has increased the demand for vitamins and minerals. Cornelian cherry fruit can find practical applications in the production of dietary supplements and nutraceuticals with health-promoting and preventive effects. These products are easy to use, typically available in the form of capsules, pills, or extracts. There are already methods for isolating valuable bioactive substances from cornelian cherry fruit and concentrating them. Researchers at the Food Science Department of the Wrocław University of Life Sciences have developed and patented a method for obtaining loganic acid from cornelian cherry fruit. Loganic acid exhibits therapeutic activity, particularly in the treatment of autoimmune disorders and inflammatory conditions. The creators of the patent emphasise the simplicity and effectiveness of obtaining loganic acid from cornelian cherry fruit. In addition to this valuable compound, it's possible to simultaneously obtain pelargonidin and cyanidin rutinoside, as well as pelargonidin and cyanidin galactosides. This way, approximately 5 g of dry lyophilised product containing approximately 1.5 g of loganic acid can be obtained from 1 kilogram of cornelian cherry fruit [Kucharska et al. 2001]. Sozański et al. [2015] have developed a preparation for reducing triglyceride levels and a dietary supplement based on this preparation, derived from cornelian cherry of cultivar Raciborski. They have also formulated a composition for preventing and treating cardiovascular diseases.

Due to its high content of bioactive compounds with among others antibacterial, anti-inflammatory, and astringent properties, cornelian cherry fruit finds significant applications in the cosmetics industry. Natural products in cosmetics have seen substantial growth recently, as consumers have shown increased interest in products containing plant-based ingredients. Herbal companies are also paying more attention to this growing sector of the industry. Nizioł-Łukaszewska et al. [2017] have highlighted the importance of iridoids, secondary metabolites in the form of cyclopentanoid monoterpenes, as valuable compounds found in cornelian cherry fruit. Iridoids can have a simple or complex chemical structure, including glycosidic, esteric, or dimeric forms. Based on their chemical structure, iridoids can be divided into four main groups: iridoid glycosides, non-glycosidic (aglycone) iridoids, secoiridoids, and bisiridoids. Cornelian cherry fruit mainly contains compounds such as oleanolic acid, ursolic acid, loganic acid, sweroside, and cornuside. Iridoids exhibit strong antibacterial, anti-inflammatory, sedative, antifungal, and anticancer activities. They also react with amines, resulting in a colourful product, making them suitable for use as colouring agents in the cosmetics industry. Additionally, iridoids are used in hair dyes.

Research by Newzioł-Łukaszewska et al. [2018] suggests that cornelian cherry fruit can have cosmetic applications. They investigated the potential use of iridoids from cornelian cherry fruit to reduce the irritating effects of surfactants used in cosmetics production. Iridoids from cornelian cherries can enhance the antioxidant and nourishing properties for the skin. Both water and water-alcohol extracts from cornelian cherry fruit can help reduce skin pigment disorders, such as unsightly dark spots, associated with melanin synthesis, including its excessive accumulation. The enzyme tyrosinase controls the rate of melanin formation, and many substances used to lighten the skin work by modifying its activity. Iridoids inhibit the enzyme's activity by blocking its active centre and preventing it from binding with the reaction substrate. Plant extracts from cornelian cherry fruit exhibit strong antioxidant, toning, antibacterial, and anti-inflammatory properties for the skin. In the extraction process, a mixture of water, glycerol, and plant oil was used, resulting in the extraction of biologically active substances that are soluble in both water and oils. The physicochemical and biochemical assessment of the obtained extracts suggests that they are innovative and multifunctional raw materials, suitable for use in products such as nourishing body balms.

Summary

Due to its many advantages, cornelian cherry deserves more attention from growers and gardeners. Expanding the cultivation of this remarkable plant can contribute to increased biodiversity and the creation of biological richness. The fruit is characterised by the presence of valuable bioactive substances such as anthocyanins, vitamins, and iridoids. The diversity of uses for this fruit allows for the enrichment and improvement of modern food. Products made from cornelian cherries, such as juices, syrups, jams, liqueurs, pestils, and candied fruits, are innovative and, as a result, sought after by consumers.

Cornelian cherry is not a demanding plant in terms of its growing conditions, making it suitable for cultivation throughout Poland. With high-quality nursery material, such as improved tree saplings, you can expect annual yields from the second year after planting. They are long-lived plants that increase their productivity with each passing year. It is worth considering the choice of cultivar, because they differ in the appearance of their fruits, as well as in the timing and duration of their ripening. Cornelian cherry requires cross-pollination, so it is advisable to plant at least two different cultivars. Different cultivars ripen from mid-July to late October, allowing for fresh fruit availability for more than three months. Depending on the fruit's quality characteristics, you can select dessert cultivars with large, sweet-tart fruits weighing more than 7 g that ripen over an extended period. For processing, choose cultivars with dark-coloured skin, small seeds, and a shorter ripening period.

Cornelian cherry is currently free from troublesome diseases and pests, which means it does not require the application of chemical agents. It is a plant that is readily inhabited by beneficial organisms, contributing to biodiversity.

Cornelian cherry tolerates pruning well, making it possible to shape trees consisting of trunks and crowns in an orchard without the need for intensive procedures. Such tree management prepares them for mechanical harvesting using various types of shakers. Home gardeners can cultivate cornelian cher-

ry as multi-stemmed shrubs or as part of a hedge. It is a plant that provides nectar for bees very early in the growing season, starting in March and April. In addition to producing valuable fruit, cornelian cherry is also an ornamental plant. During the flowering period, it attracts attention with its yellow pompom-like flowers that appear before the leaves unfold. When the fruit ripens, it captivates with its vibrant colours, changing from green to yellow, then reddening, and finally turning pink, crimson, or black, depending on the cultivar. The varied shapes of the fruit that can be round, oval, oval-elongated, pear-shaped, or bottle-pear-shaped, add to its unique charm.

When promoting a species from another region of the world, it is essential to consider its method of spreading. In the case of the cornelian cherry, there is no risk of it becoming an invasive species. It produces no underground runners, and its seeds require a two-year stratification period before they start to germinate. Therefore, it is a very suitable plant for controlled increases in biodiversity in our crops and landscapes

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List of contents

Iwona Szot, an associate professor, works at the Institute of Horticulture Production of the University of Life Sciences in Lublin. Specializes in improving the production technology of less popular fruit species such as cornelian cherry, haskap berry and goji berry. In her research, she also determines the possibility of using the growth bioregulators in .the cultivationof basic fruit species such: apple, pear, plum and cherry trees. She is interested in the health-promoting properties of fruits and their use in the production of food and cosmetics.

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