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History, Cultivation, and Adaptation of Papaver Species Globally

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ABSTRACT

Türkiye has 27% of the World's *Papaver* species in its flora, and 15 of them are endemic. Poppy (*Papaver somniferum* L.) is the most cultivated and economically significant species of the Papaver genus. There is a need to study and exploit other *Papaver* species as well. Poppy is an important strategic plant with a history dating back to 5000 BCE and records of its being valued in the lives of different civilizations, art archives, food (seed), and medicine (opium gum). Although opium gum and seed have been produced for centuries in today's Türkiye, its cultivation was banned between 1971-74. Years of opium gum experience were destroyed, and after 1974, alkaloid production began to be obtained by processing the dry capsule (unscratched). Today, it is counted as one of the two traditional legal poppy-producing countries in the world. It has the largest legal poppy cultivation area, capsule processing, and alkaloid production factory in the world. The seeds and alkaloids are obtained from the same plant. Türkiye has one of the largest morphine stocks in the world and is capable of meeting 25% of global morphine demand. However, it is insufficient in the production of different alkaloids (noscapine, thebaine, codeine). Seed production is, on average, 20,000 tons, and the capacity has the potential to increase to 40,000 tons with appropriate agricultural techniques.

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Origin

Species of the *Papaver* genus are generally distributed in the temperate and subtropical regions of the northern hemisphere. The *Papaver* genus has 137 species in the World, with 37 species and 52 taxa belonging to the *Papaver* genus in the Turkish flora. It accounts for 27% of the number of *Papaver* species found in the world, and 15 of them are endemic (Table 1a,b). The most economically important species among them is *P. somniferum.* The high number of species and endemism in its flora supports the idea of Türkiye contributing largely to making this area a part of the gene center along with other neighboring countries. *Papaver* species are spread throughout the country and are generally found in high, sloping, and rocky areas of Eastern and South Eastern Anatolia (Davis, 1965; Ekim & Güner, 2000; https://bizimbitkiler.org.tr/; https://www.worldfloraonline.org/). The poppy plant (*Papaver somniferum* L.), also known by Turkish and Persian synonyms of haşhaş, haşgeç, haşikeş, haşeş, khashkhash, and gelincik in Türkiye, is a very old medicinal plant that is evaluated by the producers in different parts of the world and different forms. The first historical documents record that it was used by the Sumerians in the south of Mesopotamia 5000 BCE years ago and that there is information about opium in their literature. Likewise, it is stated that it was cultured in Europe for 4000 years BCE years (Jesus et al., 2023; Oguz & Yener Ogur, 2023). The papaver plant species are reported from ancient Greece (Presently Türkiye) for hypnotic qualities, where they were used in religious portrayed for Nyx (Night), Thanatos (Death), and Hypnos (Sleep). It has been mentioned by Hippocrates for more than 350 years BCE (Duke, 1973). Seeds and charred capsules were found in lake settlements of Sweden, dating back to the Neolithic age. It was stated that it was grown by the Hittites in 2000 BCE because it was known for its sedative effect and that the plant is used today as 'haşşika', which is close to its meaning in Turkish. In Assyrian reliefs dating back to 700-900 BCE, the king was depicted holding a bunch of poppy capsules. It was determined that people use opium gum in medicine under the name "izzu" (Başer & Arslan, 2014). It is stated that there are words meaningful to poppy and opium in their inscriptions. Pliny (61-113 ADC) mentions the healing properties of opium poppy in Egyptian records. In Homer's Iliad, it is mentioned that poppy was grown in Asia Minor before historical times, the Greeks referred to opium as "mekononion", and Pedanius Dioscorides (40-90 ADC), a physician, pharmacist, and botanist who lived in the Ancient City of Anavarza (Ceyhan/Adana/Türkiye), wrote in his famous work In "Materia Medica" he explained all the stages of the activity in Anatolia, from poppy cultivation to opium production.

Table 1a. Species Found in the Flora of Türkiye*

Species	L F	G F	FL M	Habitat	Altitude (m)	EN	Element	Distribution in Türkiye	General Distribution
Papaver acrochaetum BORNM.	BI	HE	8--9	Rocky slope	1--1	NE	Iran-Turan	East Anatolia	Northwest Iran, North Iraq
Papaver arachnoideum KADEREIT	AN	HE	4--6	Open vegetation on volcanic rocks, sedimentary shale or ice	1--1	EE	East Mediterranean	North and East Türkiye	Türkiye
Papaver arenarium M.Bieb.	AN	HE	4--7	Oak thicket area, hill slope	500-2300	NE	Unknown	East Anatolia	South Russia, Cascade, North Iran
Papaver argemone L. subsp. *argemone* L.	AN	HE	4--6	Fields, roadside, cultivated area	0-2000	NE	Unknown	Türkiye	Europe, North Africa, Southwest Asia
Papaver argemone L. subsp. *davisii* KADEREIT	AN	HE	4--5	Bare sandy area, calcareous volcanic soil	0-500	VE	East Mediterranean	West Türkiye	Türkiye
Papaver argemone L. subsp. *nigrotinctum* (FEDDE) KADEREIT	AN	HE	3--5	Dune and calcareous rock areas	0--0	NE	East Mediterranean	West Anatolia	Greek, Aegean Islands
Papaver armeniacum (L.) DC.	BI	HE	7--8	Limestone, rubble, eroded slope	2600-3400	NE	Iran-Turan	East Anatolia	Caucasus, Northwest Iran
Papaver bracteatum Lindl.	PE	HE	5--9	Rocky slopes	1000-1400	NE	Iran-Turan	South and East Anatolia	Türkiye
Papaver clavatum BOISS. ET HAUSSKN. EX BOISS.	AN	HE	5--5	Hillside, rubble, fields	600-1250	LE	Iran-Turan	South and East Anatolia	Türkiye
Papaver curviscapum NABELEK	BI	HE	6--6	Rock crevices	1500-1500	NE	Iran-Turan	East Anatolia	North Iraq
Papaver cylindiricum CULLEN	BI	HE	7--8	Steps	1640-2000	NE	Iran-Turan	East Anatolia	North Iraq
Papaver dubium L. subsp. *dubium*	AN	HE	4--6	Meadows, field	1-1000	NE	Unknown	South, Central and East Anatolia	Europe, Asia
Papaver dubium L. subsp. *laevigatum* (M. BIEB) KADEREIT	AN	HE	4--4	Stony areas	50-2100	NE	Iran-Turan	West, Central And East Anatolia	Armenia
Papaver dubium L. subsp. *lecoqii* (LAMOTTE) SYME var. *albiflorum* BESSER	AN	HE	4--5	Unknown	4--5	NE	Unknown	Northeast Türkiye	Central and Southeast Europe
Papaver dubium L. subsp. *lecoqii* (LAMOTTE) SYME var. *lecoqii*	AN	HE	4--5	Unknown	1--1	NE	Unknown	West Türkiye	Europe, Northwest Africa
Papaver fugax POIRET var. *fugax* POIRET	BI	HE	4--6	Arid slopes, rubble	1700-3100	NE	Unknown	East Anatolia	Caucasus, North and West Iran, North Iraq
Papaver fugax POIRET var. *platydiscus* CULLEN	BI	HE	5--6	Rubble	2600-2600	E	Iran-Turan	East Anatolia	Türkiye
Papaver glaucum BOISS. ET HAUSSKN.	AN	HE	5--6	Limestone	1-1700	NE	Iran-Turan	East and South Anatolia	Syria Deserts, North Iraq, West Iran
Papaver gracile BOISS.	AN	HE	4--4	Rocky and maquis	0-1300	NE	East Mediterranean	South and West Anatolia	Cyprus
Papaver guerlekense STAPF	AN	HE	4--4	Rocky limestone slope	0-50	EE	East Mediterranean	Southwest Anatolia	Türkiye
Papaver hybridum L.	AN	HE	4--5	Fields	0-1000	NE	Unknown	East, South and West Anatolia	Europe, Southwest Asia
Papaver lacerum Popov	AN	HE	4--5	Fields, rocky areas, sope	1150-2400	NE	Iran-Turan	Türkiye	Türkiye
Papaver lateritium K. KOCH subsp. *lateritium*	PE	HE	7--8	Shores, meadow, rubble	1200-3000	VE	Blacksea	Northeast Anatolia	Türkiye
Papaver lateritium K. KOCH subsp. *monanthum* (TRAUTV.) KADEREIT	PE	HE	6--7	Stony places in the alpine zone	2500-2800	NE	Unknown	Northeast Türkiye	Georgia
Papaver libanoticum (Schott & Kotschy ex Boiss.) Kadereit	PE	HE	5--6	Stony areas	1300-1650	NE	Iran-Turan	Northeast Anatolia	Georgia
Papaver libanoticum subsp. *polychaetum* (Schott & Kotschy ex Boiss.) Kadereit	PE	HE	5--6	Slope areas	1800-1950	NE	East Mediterranean	East Mediterranean	Türkiye, Syria
Papaver macrostomum BOISS. ET HUET EX BOISS.	AN	HE	6--6	Fields	1300-1600	NE	Iran-Turan	East and Central Anatolia	South Russia, Caucasus, West and South Iran, Syria
Papaver minus (BOIV.) MEIKLE	AN	HE	3--5	Sandy area, gravelly soil, calcareous soil, volcanic soil	0-800	NE	East Mediterranean	East Anatolia	Armenia, North Iraq, Iran, West Syria
Papaver orientale L.	PE	HE	6--8	Meadows	2100-2400	NE	Hirkan-Blacksea	Northeast and East Anatolia	Caucasus, Northwest Iran
Papaver persicum LINDL. subsp. *fulvum* KIT TAN ET SORGER	PE	HE	6--7	Igneous slopes	900-2790	LE	Iran-Turan	East and South Anatolia	Türkiye, North Iraq, Northwest Iran

Table 1b. Species Found in the Flora of Türkiye*

Species	L	G	FL	Habitat	Altitude (m)	EN	Element	Distribution in Türkiye	General Distribution
Papaver persicum LINDL. subsp. *persicum* LINDL.	BI	HE	6--8	Rubble, rocky slope	1100-2800	NE	Unknown	East and South Anatolia	North Iraq, Iran
Papaver pilosum SIBTH. ET SM. subsp. *glabrisepalum* KADEREIT	PE	HE	8--9	Between the rocks	1700-2100	E	East Mediterranean (Mountains)	South Türkiye	Türkiye
Papaver pilosum SIBTH. ET SM. subsp. *pilosum*	PE	HE	6--9	Rocky alpine slope	1100-2200	VE	Unknown	West of 34 degrees E	Türkiye
Papaver pilosum SIBTH. ET SM. subsp. *sparsipilosum* (BOISS.) KADEREIT	PE	HE	5--7	Stony areas	1400-1800	E	East Mediterranean	South Türkiye	Türkiye
Papaver pilosum SIBTH. ET SM. subsp. *spicatum*	PE	HE	6--6	Limestone creek, rocky area	600-1400	E	East Mediterranean	West and South Anatolia	Türkiye
Papaver pilosum SIBTH. ET SM. subsp. *strictum* (BOISS. ET BALANSA) WENDT EX KADEREIT	PE	HE	7--7	Rocky areas	1400-1600	E	Unknown	West Anatoila	Türkiye
Papaver postii Fedde	PE	HE	7--7	Stony areas	0-800	NE	East Mediterranean	North and South Anatolia	Latakia, Cyprus
Papaver purpureomarginatum KADEREIT	AN	HE	4--5	Vegetation along roadsides or on calcareous substrates, often in humid habitats	1--1	NE	East Mediterranean	Southwest Anatolia	Greece, Crete island
Papaver ramosissimum Fedde	AN	HE	4--5	Fields, Roadside	1000-1650	NE	East Anatolia	Southwest Anatolia	Türkiye, North Syria
Papaver rhoeas L.	AN	HE	3--8	Fields	600-1250	NE	Unknown	Türkiye	Temperate Europe and Asia, Northwest Africa
Papaver rhopalothece Stapf	AN	HE	4--7	Rocky, Slope	800-2350	NE	West Mediterranean	Southwest Anatolia	Türkiye, Cyprus
Papaver setiferum Goldblatt	PE	HE	6--7	Meadows	1300-1550	NE	Iran-Turan	East Anatolia	Tükiye, North Iraq, Iranian
Papaver shepardi Post ex Dinsm.	BI	HE	5--7	Slope, Limestone	850-1700	NE	Iran-Turan	East Anatolia	Türkiye, North Syria
Papaver somniferum L. var. *pullatum* M. A. VESELOVSKAYA	AN	HE	4--6	Unknown	1--1	CE	Unknown	Northwest and Western Anatolia	Türkiye
Papaver somniferum L. var. *somniferum* L.	AN	HE	4--6	Cultivated species	1--1	NE	West Mediterranean	West, East, and South Anatolia	Europe and Asia
Papaver stylatum BOISS. ET BAL.	AN	HE	3--6	Fields, Hill slope, Dune	0-1200	NE	East Mediterranean	South Anatoila	Lebanon
Papaver syriacum BOISS. ET BLANCHE	AN	HE	4--7	Fields	0-1600	NE	Unknown	South Anatolia	West Syria
Papaver triniifolium BOISS.	BI	HE	6--7	Fields edge, Rubble	1000-1900	LE	Iran-Turan	East and South Anatolia	Türkiye
Papaver virchowii ASCHERS. ET SINT.	AN	HE	4--5	Fields	1--1	CN	Unknown	West Anatolia	Eagean İslands
Papaver yildirimlii Ertekin	AN	HE	6--7	Rocky slope	1150-1200	E	Iran-Turan	East Anatolia	West Asia, Asia-Temperate

L: Living; G: Growth; FL: Flowering; F: Form, M: Months; EN: Endemism; AN: Annual; BI: Biennial; PE: Perennial; HE: Herbaceous; NE: Non-Endemic; EE: EN-Endemic; VE: VU-Endemic, LE: LC-Endemic; E: Endemic;CE: CR-Endemic; N: CD-Non-Endemic; *(Davis, 1965; https://bizimbitkiler.org.tr; https:// tubives/index.php)

Great Medical scholar Avicenna (ADC 980–1037) mentions information about the effects and use of opium in his travelogue, Belon (ADC 1516-1519). He emphasized that the opium trade was carried out between Anatolia, Iran, India, and Europe and that Turkish opium was used as a commercial material by Venetian sailors. Turkish deep-rooted opium poppy and French wheat contributed significantly to trade, respectively (Bernath, 1999). All these records clearly reveal that there was a deep-rooted poppy cultivation culture in Anatolia (Figure 1). This situation can be explained by the presence of charred poppy seeds in recent excavations in the ancient city of Isparta Pisidia Antiocheia (Taşlıgil & Şahin, 2018). Today, it is known that poppy cultivation has been done in this region for years.

Adaptation

The first records of the remains of the *Papaver setigerum* species were found in the excavations of the Körtic Tepe (Excavation start date: 2020, Bismil/Diyarbakır/Türkiye, west of Göbekli approximately 150 km away) and are attributed to 10400-9250 BCE (Özkaya et al., 2015; Jesus et al., 2023). This excavation site describes the first data on the *Papaver* genus and coincides with the northern tip of Mesopotamia, the gene center of many plants and the starting point of agriculture. The archeological records further describe the gradual movement of *P. setigerum* to the west to almost the entire European continent between 5000-6000 BCE and the South Asian sub-continent in approximately the same period (Ekim & Güner, 2000; Bernath & Nemeth, 2010; Başer & Arslan, 2014).

Figure 1. Some Examples from the History of Türkiye. (a) Antalya Perge Ancient City. (Original), (b) Scratched capsule. (Original)

This confirms that the plant species has strong adaptability against both cold and temperate climates of Europe and the hot climates of South Asia. During these excavations, it was determined that besides *P. setigerum*, some other species from the genus *Papaver* were also used and cultivated there. The cytogenetic studies indicate that there is a large diversity between the cultivated *P. somniferum* (with diploid) and *P. setigerum* (with a tetraploid number of chromosomes) (Hong et al., 2022). Another claim accepts diploid *P. setigerum* species as well. Recent studies, accept *P. setigerum* as the wild ancestor of *P. somniferum* or as a subspecies of *P. somniferum*. This situation creates multiple subspecies claims due to *P. somniferum*'s wide geographical distribution (high adaptability) and differences in morphological features (branching, seed-flower color, fruit shape). Moreover, since the cultivated species are selected according to the breeding purpose, genetic and morphological differences between cultivated species and wild species increase over time (Başer & Arslan, 2015; Guo et al., 2018; Jesus et al., 2023).

Cultivation in Türkiye and some Selected Countries

Although Afghanistan is currently the largest producer of poppy, it is believed that it is the oldest cultivated plant species since the earliest Neolithic ages because it is defined poorly in archaeological records (Hong et al., 2022). Poppy cultivation continued in different civilizations in the Anatolian geography. After the collapse of the Ottoman Empire, the cultivation of the plant has been carried out uninterruptedly within the borders of Türkiye. Since it is a narcotic plant class, all control responsibility was transferred to the Turkish Grain Board (TMO) in 1938. The number of provinces in which production is carried out fluctuates over the years under the supervision of TMO. Poppy cultivation (opium and seed production), which continued uninterruptedly until 1971, was banned when the United States suppressed its policy of using opium as dangerous to human health and as a political argument (Okumuş, 2018). However, it was later determined by the public that there was no situation related to Türkiye and that illegal production was coming from other Asian countries. Its cultivation and production were being carried out until recently in the so-called "Golden Triangle" countries of Afghanistan, Pakistan, and Iran, and the "Golden Crescent" countries of Myanmar, Laos, and Thailand. Repressive policies were lifted in 1974 when it was understood that Türkiye was not the source of illegal opium (Taşlıgil & Şahin, 2018). Before it was banned, it produced 10% of the world's opium gum and was a source of income for approximately 400 thousand farmers. In addition, it caused damage to genetic resources leading to the unavailability of loss of high opium and morphine-yielding cultivars to the producers during the 1970-74 period. After the restructuring, the Afyonkarahisar Factory was established in 1981 with the start of extraction of alkaloids from unscratched dry capsules (https://www.tmo.gov.tr/). The opium harvest was done in May and June, depending on the climatic conditions of the opium-producing provinces before 1971. The capsules were scratched when they reached the hardness of a tennis ball. The capsules were one time scratched horizontally in Türkiye, whereas, in other countries like Afghanistan, India, and Pakistan, it is scratched multiple times downwards (vertically) from the stigmatic plate. The number of scratches varies depending on the number of capsules, the largeness of the capsule, and ripening times. The scratching is generally made by using a sharp knife to wrap parallelly around the bottom of the capsule. The scratching is done in the morning time before sunrise. Usually, the scratching is done on the same day, and the gum is collected in the evening. Sometimes, the capsules are scratched in the evening, and the gum is collected the

next morning. However, this is not preferred as the gum accumulation on the capsules could be washed away the next morning dew. Opium gums are carefully collected on plant leaves and then brought together in appropriate containers. An experienced worker could collect 500 g of opium gum per day with a harvest of about 2-5 kg gum per hectare. Knowing that the use of opium in daily life in Turkish culture is not as widespread as in China or Europe, there is no restriction on its sale. However, its open use in traditional social life is not tolerated. It was used, on a restricted scale, to calm crying babies in places where poppy cultivation was intensive and by adults for pleasure purposes (Taşlıgil & Şahin, 2018). Adults generally used raw opium tablets smaller than chickpeas or lentils in size and carried them in small cloth pouches. In Türkiye, the poppy is under control from planting to harvest for security reasons as it is also a plant widely used as a narcotic. The cultivation of the plant was carried out on a 70-thousand-hectare cultivation area, a limit and quota allowed by the United Nations (UN) Organization (since 1970). It is mostly cultivated in 13 provinces (Afyonkarahisar, Amasya, Burdur, Çorum, Denizli, Isparta, Kütahya, Tokat, Uşak, Balıkesir, Eskişehir, Konya and Manisa provinces) lying in between 37-40° latitudes and 28-33° longitudes in two pockets as shown in Figure 2 (https://www.tmo.gov.tr/). There are 11 registered poppy varieties in Türkiye, all of which are winter cultivated, and most of them have high morphine content. Of these, 8 are rich in morphine, 2 in noscapine, and 1 in thebaine (https://www.tarimorman.gov.tr/). The sowing of varieties is planned according to alkaloid production and stock status. The cultivation of the varieties is carried out in small agricultural areas (7 da on average) in winter (October) and summer (March), but since winter planting is more productive due to ecological reasons, winter planting is preferred. Türkiye is the only country in the world where winter cultivation is in vogue. Farmers do 40% of sowing on flat and irrigated lands.

Figure 2. Türkiye Poppy Cultivation Areas Map (2022).

Whereas the rest of the sowing is done on slopy lands with no irrigation facilities and no alternative crops. Poppy is resistant to cold (3-5 d) with snow cover (<-20 °C). Longer periods of cold induce 33-100% damage to plants, depending on the conditions. Therefore, the crop must be sown before the start of expected snowfall and allow the plants to pass through the rosette stage before the vegetative stage. It can be reduced by irrigation, sowing before rain, and sowing seeds in moist soil or by priming for uniform germination. Otherwise, harsh winters could cause catastrophic nonreturnable damages to plants with drastic fluctuations in both alkaloid production (Figure 3). Since poppies produce very small seeds, which are difficult to sow, therefore they are mixed with sand before sowing on well-hoed soil free of stones and large pieces of soil without considering edaphic factors. Seed sowing is done with a seeder in large areas and manually by scattering in small areas at a depth of 2-3 cm with a rate of 2-5kg/ha. 50 kg/ha and 5 kg/ha P fertilizer is applied at the time of sowing. During the sowing process, the row distance is adjusted to 30-40 cm. Considering the possibility of damage due to winter cold, it is planted less densely by reducing the number of plants in a specified area. The plants are thinned in March, and the row spacing is adjusted to 10-20 cm. At the same time, 50 kg/ha N fertilizer is applied as the top fertilizer, and hoeing is done to combat weeds. If the weed density is high and the workers cannot be found, weed killer (Laudis OD 66-Bayer) is applied. Aphids can be seen in April-May; when necessary, drugs containing the active ingredients Acetamiprid, Chlorpyrifos ethyl, and Cypermethrin are also used. If the spring months are dry, irrigation is done by sprinkling or drip irrigation where possible.

To compensate for this, damaged fields can be (re-sowing) in early spring (March). In places where irrigation is not possible, the yield varies significantly from year to year but can be around 1000 kg hectare^{-1} (dry capsule+seeds) on average. However, in places where advanced agricultural facilities are applied, this figure reaches or even exceeds 3000 kg hectare^{-1}.

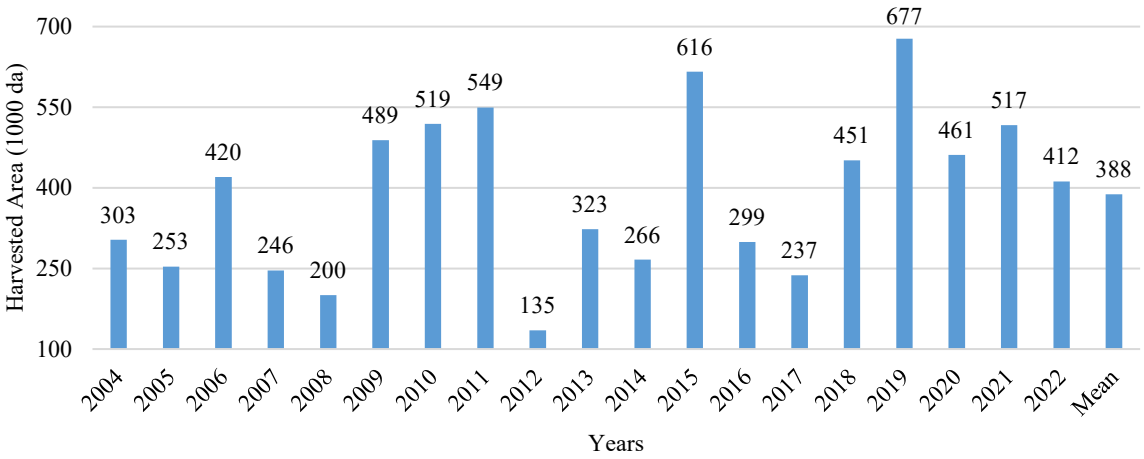

Figure 3. Türkiye Poppy Harvest Areas (1000 da) (https://www.tuik.gov.tr/).

Harvesting is mostly done manually in June-July, followed by manual or machine threshing, depending on the economic condition of the farmer. The capsule must be delivered to the TMO within the specified period during the production year. Seeds separated from the capsule (mostly white and blue) are sold under free market conditions. Türkiye produces the highest amount of seeds in the world and exports an average of 20 thousand tons seeds annually (https://www.fao.org/statistics/en). According to the seed color preference of the recipient countries, Blue seeds are exported to European countries, and white seeds are exported to India. Poppy has the largest cultivation area among medicinal and aromatic plants in Türkiye. It is also counted among the top 20 plants in Turkish field crops. A fluctuation in morphine and seed-based yield of 25.65-114.30 tons and 5.21-26.13 thousand tons per annum exports ended up with earnings of US$ 11.75-56.46 million from morphine and US$ 8.43-59.09 million during 2011-19 period in the same order (https://www.tuik.gov.tr/).

Legal poppy cultivation, production, control, and trade in the world is carried out under the supervision of the United Nations (UN) within the framework of the 1961 Single Convention on Narcotic Drugs. Its cultivation is mostly done for alkaloid raw materials and seeds. Alkaloids are obtained from dry capsules, green plants, and opium gum. Turkiye stands in first place in legal alkaloid (morphine) production in the list of morphine-producing countries (Türkiye, India, Australia, France, Spain, and Hungary) during 2000-2019. Similarly, Türkiye was placed at the top position from the largest to smallest (average of 2001-17) in the list of poppy seed-producing countries of Türkiye, Czech Republic, France, Hungary, Germany, and Australia (https://www.fao.org/statistics/en). Among these countries, Türkiye and India are important traditional legal producers. Türkiye has a share of more than 50% of the cultivation area for seed and opioid raw material for medicinal and scientific purposes production purposes in the World and is referred to as rule No. 80/20 (https://www.tmo.gov.tr/; https://www.fao.org/statistics/en; https://www.incb.org/incb/en/; https://www.unodc.org/). Alkaloid processing in Türkiye is done by the State-authorized TMO Factory in the Bolvadin district of Afyonkarahisar province. It has the largest mechanized capacity to process alkaloids (morphine and its derivatives) and processes about 25 thousand tons of capsules per year (Özgen et al., 2017).

Alkaloids

Excluding seeds, alkaloids occur in varying ratios from all parts of the plant, and the highest amount is found in the capsules with more than 80 different alkaloids. The most important one is morphine, followed by noscapine, thebaine, codeine, and oripavine. They are extensively evaluated in the medicinal and pharmaceutical industry (Bajpai et al., 2000; Diaz-Bárcena & Giraldo, 2023). Alkaloids are obtained differently depending on the climate and edaphic factors.

Extraction methods vary from country to country. Extraction from dried poppy capsules is preferred in Türkiye, Australia, Hungary, and Spain; the extraction from the green plant is dominant in practice in France. India is the only country where capsule scratching after collection of opium gum is in vogue (https://www.tmo.gov.tr/). The alkaloids in the poppy capsule can be obtained by chemical methods, but this process is time-consuming and not economical. Alkaloids such as noscapine and codeine, required in the pharmacognosy and pharmaceutical industry, can be obtained by derivatizing morphine (Desgagné-Penix & Facchini, 2012). Türkiye exports 95% of the morphine, it produces from capsules. Today, Türkiye's morphine production is sufficient to meet 25% of the world's needs. According to International Narcotics Control Board (INCB) reports, the world morphine stock reached 645 tons (as reported at the end of 2019), which has shown an increase of 564 tons compared to the previous years. Türkiye ranks first with 207 tons and has more than twofold as much stock compared to its closest rival, France (https://www.incb.org/incb/en). INCB reports show that Türkiye has always had an important place in morphine production, but the production of other alkaloids is not as successful when compared with morphine. The solution to this situation can be solved by improving the capsule processing and extraction system of the factory in Afyonkarahisar. To achieve competitive production in the world alkaloid market, it must adopt the latest production technologies to meet local and global demands.

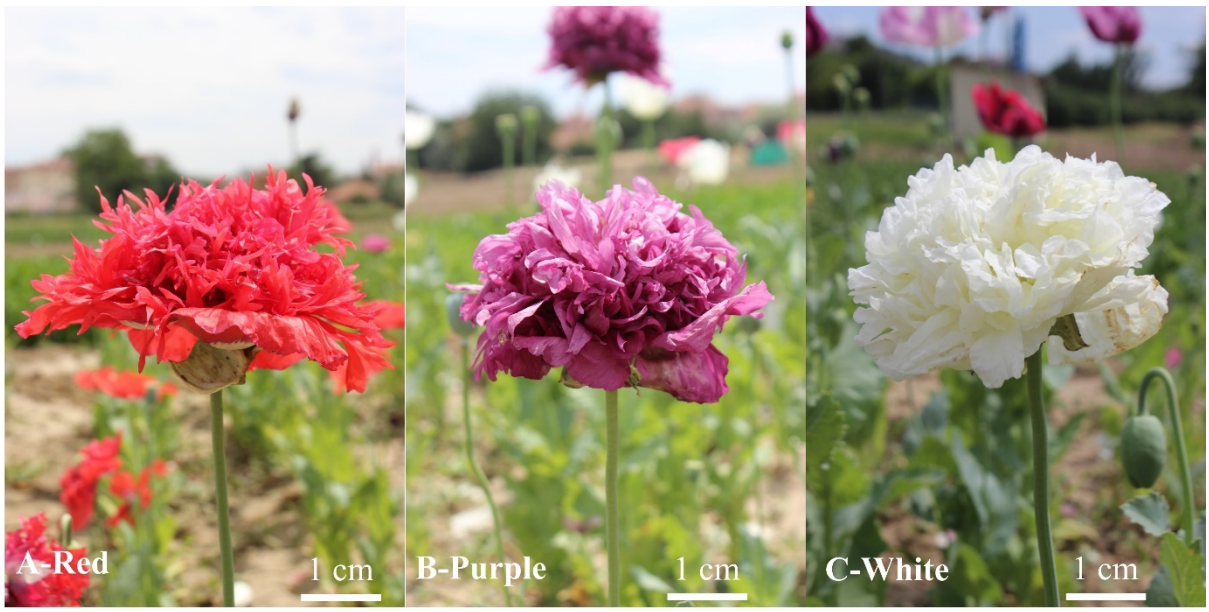

Figure 4. Turkish Ornamental Poppy (red, purple, white). (Original)

The most abundant alkaloid in the capsules of Turkish poppy populations is morphine, followed by noscapine. As a result of the studies carried out in recent years, winter varieties with high morphine, noscapine, and thebaine contents (over 1.5%) have been developed to compete with other countries. However, a codeine-type variety is being bred and is in the pipeline expected to be released shortly. On the other hand, the morphine yield obtained from the capsule has still not reached in noscapine and thebaine varieties (Gümüşçü et al., 2008). Like France, if, besides dry capsules, other parts of the plant are also used for extraction by Türkiye, it can come to a better competitive position in the global alkaloid trade.

Eating Habits and Pharmaceutical Uses

Poppy seeds contain 44-50% fixed oil, 22.3-24.4% protein, 4.8-5.8% crude fiber, 4.3-5.2% moisture, and 5.6-6.0% ash with pale or golden, yellow which is rich in beneficial oleic and linoleic acid. It has intensive use in the provinces where it is cultivated (Arslan et al., 2000; Kahraman-Yanardağ et al., 2024). It is preferred in ready-made bakery and confectionary-based products. In addition, fresh green leaves (rosette stage) of the plant are consumed as salad or vegetables in Turkish ethnobotanical culture because of the low amount of hemicellulose and fiber contents. The leaves contain very low amounts of alkaloids (Yıldırım et al., 2020). Care should be taken when consuming leaves from new cultivars because of increased alkaloid ratios in them by 3-4 folds, which may pose a risk to human health.

Ornamental Uses

The poppy is a very hard and drought-tolerant plant and could be grown under license for ornamental purposes in two different ways. The first way is growing them in hobby gardens, rock gardens, national parks, or places where ornamental cultivation is allowed, and the other way is growing them for decorative purposes and using them as dried cut flowers in dry capsules as ornamental plants. Unlike other plants, the poppy has different mosaic petal colors and states. These can be in white, red, and purple colors (Figure 4). The petals are large and showy, reminiscent of the tulip plant. There are spots of different sizes at the base of these leaves, or their tips may be segmented at different depths. Due to a recessive mutation that is very common in ornamental poppies, anthers turn into petals and have a "layered" structure. It is preferred for winter sowing because the petals are large and showy, the flowers are numerous, and the flowering period is longer (Başer & Arslan, 2014; Özgen et al., 2019).

Secondly, at the time of maturity, the stalked capsules are cut from the flower stalk and evaluated for their different capsule shapes (oval, conical, barrel, round), either in natural color or dyed form, and used in arrangements for ornamental purposes, singly or in combination with other plants, to visual beauty. In genotypes originating from Türkiye, the capsule is generally round in shape in winter sowing, while elongated capsules can be seen in summer sowing. Winter sowing, as mentioned above, is recommended because the capsule has a long stem and is larger and more showy than summer ones. Petals with varied colors are classified to obtain natural dyes for use in ethnocultural activities to dye fiber or threads for use in fabrics. It grows as a short-day plant with a determinate flower structure under temperate conditions in Türkiye. Apart from poppy (*P. somniferum*), *P. glaucum*, *P. bracteatum*, *P. orientale*, *P. pseudo-orientale,* and *P. rupifragum* within the *Papaver* genus are also grown for ornamental purposes (Carolan et al., 2002).

Care should be taken when *papaver* species are used for ornamental purposes (Özgen et al., 2019). The local varieties show morphine and total alkaloids between 0.300-0.809% and 0.648-1.743% in the same sequence. Meanwhile, *P. glaucum* indicates an average morphine of 0.041% and papaverine of 0.625%. Paradoxically, morphine is reduced to 0.0137% and thebaine to 2.135% in *P. bracteatum*. *P. orientale* has morphine and thebane concentration of 0.160% and 0.397%, respectively. Furthermore, 0.175% morphine was noted as *P. pseudo-orientale* by Özgen and Arslan (2017). Research on

breeding ornamental poppy varieties, which could be a source of large foreign exchange, is neglected. Therefore, the breeders in the universities and research centers should be encouraged to breed low-alkaloid and morphine cultivars.

Conservation of Papaver Genetic Resources

Poppy cultivation was prohibited in Türkiye according to the 30 June 1971. The cultivation ban was lifted by the decree no. 7/8522 dated 01.07.1974, as a result of intense pressure from farmers on the government. During this period restricted or no breeding activities were carried out by the researchers in the local research institutes or universities. These researchers have collected a rich amount of local germplasm. Some of the material is collected by individual researchers and is in their possession. The other material is in the possession of big organizations like the Turkish Grain Board and Genebanks of Ankara and Izmir. Furthermore, these are kept and maintained by Dr. Yasin Özgen of the Department of Field Crops at Ankara University. These populations are germinated after every 5-10 years to refresh and conserve the cultivars. The research is being carried out on these populations to compare them and breed varieties for increased alkaloids like morphine to obtain improved seeds and ornamental varieties using crossing, selection, and hybridization (Abhishek & Choudhary, 2010; Singh et al., 2011; Özgen & Arslan, 2017). The seeds of perennial populations of *P. bracteatum*, *P. orientate,* and *P. pseudo-orientale* were also collected to carry out molecular studies by Parmaksız (2004). Agronomic studies are being continued on annual *P. glaucum*, *P. dibium,* and *P. rohaes species*. Similarly, the researchers are also working on breeding varieties for high seed yield, oil ratio, high alkaloid, ornamental purpose, etc., in cooperation with TMO. Global genebanks at the Leibniz Institute of Plant Genetics and Crop Plant Research (IPK) Germany and the Institute of Protection of Biodiversity and Biological Safety at the Slovak University of Agriculture are not mentioned. All of them are underexploited because detailed genetic diversity studies are yet to be carried out (Hong et al., 2022).

Conclusion

Türkiye is the legal and traditional poppy-producing country with the largest cultivation area by the UN agency permits. However, more than 50% of the area recommended for poppy is rainfed without any irrigation facilities. The culture is done on marginal and very small lands unsuitable for mechanized agriculture, without any irrigation facility. Sometimes, capsule and morphine stocks rise to high levels, making the process difficult to manage. Therefore, renovation of the factory is desired. The production infrastructure for the extraction of noscapine, thebaine, and codeine, excluding morphine, is not at the desired level. Apart from dry capsules, alkaloids should also be extracted from both the above and underground parts of the dried and green parts of the cultivated and other species. Varieties with high codeine contents should be bred from the existing populations through *in vitro* and *ex-vitro* selection, hybridization, and related techniques. At the same time, a high seed yield, an oil percentage, and ornamental varieties with a low alkaloid percentage should be the focus of breeding. Seeds of existing lines of *Papaver* species in the gene banks and individual collections should be characterized at the morphological, chemical, and molecular levels to have up-to-date information by assigning a bar code to them for conservation and protecting them systematically (as Turkish germplasm). The pharmacy faculties and pharmacognosy departments should be activated (in Türkiye) to support the development of methodologies for domestic drug production.

Declarations

Author Contribution Statement

Y.Ö.: Data collection, investigation, formal analysis, and writing the original draft

D.B.: Data collection and investigation

Conflict of Interest

The authors declare the existence of no conflict of interest whatsoever.

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