

Asafoetida (*Ferula asafoetida*): A high-value crop suitable for the cold desert of Himachal Pradesh, India

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Abstract

Asafoetida (*Ferula asafoetida*) also known as heeng, Devil's drug, ferula, food of Gods, incense of Devil, stinking gum is an important spice crop belonging to family Apiaceae. It is native to Iran and Afghanistan. Its dried latex (gum oleoresin) is generally used for flavouring curries, sauces, and pickles. Therapeutically, it stimulates the intestinal and respiratory tracts as well as the nervous system. It is beneficial in asthma, whooping cough, and chronic bronchitis. Its essential oil is also used in medicines, food and cosmetic industries. Besides, it is also used as an alternative for pesticides in organic farming. The major constituents of asafoetida are the resin (40–64%), gum (25%) and essential oil (10–17%). The butyl propenyl disulphide is responsible for the aroma of asafoetida. The asaresinotannol is the major constituent present in the resin. It can be grown on unproductive cold deserts of dry temperate areas of Himalayas. It is mainly propagated by seeds. The seeds are sown either in winters or spring. It becomes ready for harvesting after 5 years of planting and yields around 900g per plant. The oleo gum resin and essential oil derived from this plant are sold at premium prices in the international market. The small and marginal farmers of Kinnaur, Lahaul-Spiti and Chamba can benefit from this new emerging crop.

Keywords: Asafoetida, Apiaceae, *Ferula asafoetida*, Hing, Oleo gum resin

INTRODUCTION

Ferula asafoetida belongs to the family Apiaceae. It is known by various names like Asafoetida, Devil's drug, Ferula, Food of Gods, Incense of Devil, stinking gum, etc (Shah and Zare, 2014). In India, it is commonly known as *Hing* or *Hingu*. In different countries, it is known by other names as given in Table 1. It grows in cold arid regions of Afghanistan, Kazakhstan, Uzbekistan and Iran. The Gulmarg region of Kashmir in India also has small tracts of cultivation (Anonymous, 2020a).

It is oleo gum resin obtained from the stem and root of the plant. It is unpalatable in its purest form because of its pungent odour and stinking flavour. So, it is blended with flour and edible gum for consumption. The acrid taste and displeasing pungent odour is due to the presence of sulphur compounds. It contains about 40-64% resin, 25% endogenous gum, 10-17% volatile oil and 1.5-10% ash (Takeoka, 2001). The sulphur compounds present in its resin had various biological activ-

ities and therefore had great medicinal value. Ancient manuscripts consider it as a tempting spice with trusted medicinal properties. It is considered to be an anthelmintic, antiseptic, antispasmodic digestive, analgesic, carminative, diuretic, expectorant, laxative, and a sedative in its properties (Yaqoob and Nawchoo, 2016). In folklore and mythology, it is used to banish all negative energy, evil spirits and demons. In modern medicine, it is used to treat stomach cancer, asthma, bronchitis, dry cough, intestinal parasites, seizure, corns and calluses. It is also used to stop menstruation pain. It acts as a natural antidote for insect bites and stings (Mahendra and Bist, 2012). It is also used as a flavouring agent in Indian curries, dal, sambhar and pickles. It is used in developing green pesticides due to its antimicrobial and insecticidal properties (Salehi *et al.*, 2019).

India consumes nearly 40% of the world's total production of asafoetida. The basic raw material is imported mainly from Iran and Afghanistan and processed into powder and tablet form for domestic and

export markets. In 2015-16, India imported 1199 MT of asafoetida valued Rs 527.42 crores and after processing the raw material, exported around 885 MT valued Rs 46.27 crores (Hamid, 2019). The demand for quality asafoetida in the domestic, as well as in international markets, is high. The UK, Yemen, Belgium, Kenya, Malaysia, Oman, Switzerland, United Arab Emirates are the major importing countries. The price of quality asafoetida in the domestic market varies anywhere between Rs.10,000 to 15,000/- per kg (Anonymous, 2020a). The demand for this spice is rising at a steady rate because people in India have become health conscious.

While the product is finding increasing usage in India, asafoetida cannot be grown in most parts of India as the climate does not suit the plant. Since the cold deserts of Himachal Pradesh have the same climatic conditions that are found in Iran, Turkey and Afghanistan, therefore with refinement in cultural practices of asafoetida it can be made to grow in these regions. Its cultivation will uplift farmer's livelihood conditions in Kinnaur, Lahaul-Spiti and Bharmour of Chamba districts, as it is a high demand and profitable crop. Since the crop is newly introduced in our country, therefore cultivation under technical guidance would change the economy of hill states like Jammu & Kashmir, Uttarakhand and Himachal Pradesh. One kg of pure asafoetida can fetch approximately Rs 35,000 to Rs 40,000 (₹ 469- ₹ 536) in the international market. Hence, one hectare plantation is likely to increase farmer's income by seven times (Arya, 2020). Also the production of asafoetida in the country would reduce the dependence on other countries, thus saving valuable foreign exchange. In this review, efforts have been made to collect information on botanical description, origin and distribution, uses, chemical composition and cultivation practices of this valuable spice. Its harvesting and processing have also been reviewed.

Botanical description: The Latin name ferula means "carrier" or "vehicle". The Asa is a latinized form of Farsi asa "resin", and Latin foetidus means "smelling, fetid". Ferula is a monoecious, herbaceous and perennial plant. It belongs to the family Apiaceae or Umbelliferae. It grows to height of 2.5 to 3 meters with a circular mass of leaves having a diameter of 30-40cm. Flowering stems are 10cm thick which are hollow inside with a number of schizogenous ducts in the cortex containing the resinous gum. It has large, compound, bipinnate, pubescent radical leaves with sheathing petioles. The inflorescence is also densely pubescent. Flowers are pale greenish-yellow in colour borne in large compound umbels. It has about 10–20 flowers in main umbels and 5–6 in the partial umbels (Peter, 2004; Mahendra and Bist, 2012).

There are two kinds of plants, male and female. The female plant produces inflorescences whereas the male plant does not. Only the female plant produces the oleo gum or asafoetida (Pruthi, 2001). Fruits are

Table 1. Common names of *Ferula asafoetida* in different countries.

Name of country	Common Name
Afghanistan	Kama I anguza
Bangladesh	Hing
China	A-wei
England	Asafetida
Germany	Asafotida/Asant/Stinkasant/ Teufelsdreck
India	Hengu/Hing/Ingu/Inguva/Kayam
Iran	Zaz
Netherland	Sagapeen
Pakistan	Anjadana/Kama I anguza
Russia	Asafetida
Srilanka	Perunkayan
United states of America	Stinking Gum/Asafetida/Devil's dung

Source: Ross (2005)

oval, flat, thin, reddish-brown and have a milky juice. The fruits are 0.8 cm long and 0.6 cm broad, with tender hairs. The white exudate of the fruit is fragrant, pure and crystalline. The brownish to reddish exudate smells foul. The flowers and fruits generally appear in March–April. The shrub of Asafoetida needs 4 to 5 years for producing seed and after that plant dies. Carrot shaped roots are thick, massive, and pulpy which are covered with bristly fibres, with one or more forks. After about five years, the fusiform taproots attain a diameter of 12 to 15 cm at the crown which gives the indication that plant is ready for extraction of asafoetida (George, 2012). Roots yield a resin similar to that of the stems. All parts of the plant have a distinctive putrid smell (Ross, 2005; Peter, 2004; Shah and Zare, 2014). Tapping is usually done before flowering (March–April), when the plant sprouts from the taproot. After a month, the green foliage turns yellow. At this stage, the stem is cut near the crown. The milky juice exudes from the cut surface, which coagulates on exposure to air. After a few days, the exudate gum resin is scraped off (George, 2012; Giri *et al.*, 2008).

Origin and distribution: The genus *Ferula* consists of about 130 species worldwide with the majority of thirty species found in Iran, of which fifteen are endemics (Mozaffarian, 1996; Mozaffarian, 1983). From India, only four species have been reported (Santapau and Henri, 1973). The species which yield 'Heeng' are *F. assa-foetida* Linn, *F. narthex* Boiss and *F. alliacea* Boiss. *F. assa-foetida* was native to Iran, Turkey and Afghanistan while *F. narthex* Boiss found wild in Afghanistan, Baltistan, Astore, Kashmir and Western Tibet. While *F. alliacea* Boiss originated from Iran and Afghanistan. From the Western Himalaya only one species, *i.e.*, *F. jaeschkeana* Vatke. was reported by Rau (1975). The details of different species of asafoet-

ida which originated in India and western Himalayas are given in Table 3.

According to Pandey (2008) there are two species which serve as source of asafoetida *i.e.* *F. narthex* or Hing Kabuli Sufaid (Milky white asafoetida) and *F. foetida* or Hing Lal (Red asafoetida). The plants of both species look almost identical. *F. narthex*, grows abundantly in Western Tibet and Afghanistan. In India, it was found in Kashmir and some parts of Punjab. Sultana *et al.* (2015) reported that *F. asafoetida* was grown chiefly in Afghanistan and Iran, and from these areas, it was exported to the entire world. According to Nadjafi *et al.* (2006), *F. assa-foetida* was widely spread in the steppes of Iran, Afghanistan, USSR, and West Pakistan and further from Zagros and Elburz mountains to Persian Gulf. While *F. narthex* was mainly found in Afghanistan, Russia (former USSR), West Pakistan, Baltistan,, Gilgit, Astore and also in Western Tibet. Dutt (1928) reported that *F. alliacea* Boiss grows in Eastern Persia, Khorasan and Kirman (Iran). It was mostly reddish in colour and popularly known as 'Multani Hing' which was used for cooking purposes.

Chemical composition: The food composition data showed that 100g of asafoetida contains 68% carbohydrates, 16% moisture, 4% protein, 1% fat, 7% min-

erals and 4% fibre. It also contains minerals and vitamins like calcium, phosphorus, iron, carotene, riboflavin and niacin (Gopalan *et al.*, 1996; Takeoka, 2001). It is mainly rich in calcium (1.0 -1.5%) and iron (54-62mg/100g) (Pardeep *et al.*, 1993).

It chiefly contains resin (40-65%), gum (20-25%), and volatile oil (4-20%) (Iranshahy and Iranshahi, 2011; Handa and Kapoor, 1987). According to Pandey *et al.* (2008), it contains 50% resin, 25% gum and 10 % volatile oil. The resin fraction contains ferulic acid and its esters, coumarins, sesquiterpene coumarins and other terpenoids. Assaresinotannol is the chief sesquiterpene present in either free form or in a combined form with ferulic acid or galbanic acid (Wallis, 2004). The chemical constituents present in *F. asafoetida*, along with their pharmacological activities, are given in Table 2.

The gum includes glucose, galactose, 1-arabinose, rhamnose, glucuronic acid, polysaccharides and glycoproteins and the volatile fraction (Saeidy *et al.*, 2018). The volatile fraction contain three sulphur compounds *viz.*, 1-methylpropyl-1-propenyl disulphide, 1-(methylthio)-propyl-1-propenyl disulphide, and 1-methyl-propyl 3-(methylthio)-2-propenyl disulphide. Same compounds had also been isolated from the

Table 2. Chemical constituents responsible for pharmacological activity *Ferula asafoetida*.

Pharmacological activity	Chemical constituents
Anticancer	α -pinene; α -terpineol; diallyldisulfide; ferulic-acid; isopimepinellin;luteolin; umbelliferone; vanillin
Anti-inflammatory	α -pinene; azulene; β -pinene;ferulic-acid; isopimepinellin; luteolin;umbelliferone;
Antileukemic	Luteolin
Antimutagenic	Diallyl-sulfide; ferulic acid; luteolin; umbeliferone; vanillin
Antineoplastic	Ferulic-acid
Antitumor	Diallyl- disulfide; diallyl - sulfide; ferulic-acid; luteolin; vanillin
Antiviral	α -pinene; diallyl- disulfide; ferulic acid; luteolin; vanillin
Antibacterial	α -pinene; α -terpineol; azulene;diallyl - disulfide;diallyl - sulfide ferulic-acid; luteolin;umbelliferone
Antispasmodic	Azulene; ferulic-acid; luteolin; umbeliferone; valeric-acid
Antiseptic	α -terpineol; azulene; β -pinene; diallyl - sulfide; umbeliferone
Antiulcer	Azulene
Hepatoprotective	Ferulic-acid; luteolin
Anti-HIV	Diallyl- disulfide; luteolin
Antiinotropaminic	Ferulic-acid;
Antioxidant	Ferulic-acid; luteolin;vanillin
Antitaggregant	Ferulic-acid;
Tranquilizer	α -pinene; valeric-acid
Anticarcinogenic	Ferulic-acid; luteolin
Sedative	a-pinene; alpha-terpineol; valeric-acid

Source: Mahendra and Bist (2012)

Table 3. Different species of Asafoetida from India and Western Himalayas.

Sr No	Name of Species
India	
1	<i>Ferula narthex</i> (Falc.) Drude
2	<i>Ferula thomsoni</i>
3	<i>Ferula jaeschkeana</i> Vatke
Western Himalayas	
1	<i>Ferula baluchistanica</i>
2	<i>Ferula collina</i>
3	<i>Ferula costata</i>
4	<i>Ferula foetida</i>
5	<i>Ferula heuffellii</i>
6	<i>Ferula hindukushensis</i>
7	<i>Ferula jaeschkeana</i> Vatke
8	<i>Ferula karelini</i>
9	<i>F.kokanica</i> Rgl. et Schmalh.
10	<i>Ferula lehmanni</i>
11	<i>Ferula leucocarpum</i>
12	<i>Ferula macrocolea</i>
13	<i>Ferula microloba</i> Boiss.
14	<i>Ferula narthex</i> (Falc.) Drude
15	<i>F.oopoda</i> (Boiss. Et Buhse) Boiss.
16	<i>Ferula ovina</i> Boiss.
17	<i>Ferula propinqua</i>
18	<i>Ferula reppiae</i>
19	<i>Ferula stewartiana</i>

Source: Yaqoob and Nawchoo (2016)

resin. The latter two compounds had pesticidal properties (Takeoka, 2001). R-2-butyl-I-propenyl disulphide and 2-methyl-3-methylthio allyl disulphide were mainly responsible for the flavour of asafoetida.

The volatile oil contains terpenes, disulphide and pinene, which was mainly responsible for the therapeutic action of the species. The main constituent of the oil is isobutyl propenyl disulphide (C₆H₁₆S₂). Bahrami *et al.* (2012) studied the chemical composition of the essential oil of the fruit of *Ferula assa-foetida* L. and identified 54 compounds. The major constituents of the oil were epi- α -Cadinol (23.15 %), germacrene β (10.98%), α -gurjunene (6.18%), (Z)-1-propenyl sec-butyl disulfide (5.89%), 5-epi-7-epi- α -eudesmol (4.89 %), δ -cadinene (4.78%), γ -cadinene (3.36%) and germacrene D (3.09%) which constituted 96.9% of the total oil. Hadavand and Hasanloo (2014) reported thirty nine components in the essential oil of oleo gum resin of *F. asafoetida* obtained from Tabas and Yazd province of Iran. They found that E-1-propenyl sec-butyl disulfide (40-44%), Z-1-propenyl sec-butyl disulfide (24-28%), Guaiol (5.5 -3.14%) and carotol (5.14-1.63%) were the major components.

Moghaddam and Farhadi (2015) observed that (E)-

propenyl sec butyl disulfide (37.30-53.99%) and (Z)-propenyl sec butyl disulfide (12.10-23.10%) were the main constituents of the essential oil of *F. asafoetida* obtained from different rangelands in Kerman province of Iran. Hassanabadi *et al.* (2019) analysed fourteen accessions of asafoetida in which they discovered forty two components. In all the accessions, six compounds were largely available and these were (E)-1-propenyl sec-butyl disulfide (13.66-49.35%), α -pinene (1.06-21.18%), (Z)-1-propenyl sec-butyl disulfide (2.02-15.29%), α -pinene (2.04-17.61%), thiophene (0.03-36.81%) and thiourea (0.08-9.63%).

The essential oil content was directly and indirectly influenced by temperature, physical and chemical properties of soil and latitude, longitude and altitude, respectively. Karimi *et al.* (2020) identified chemotypes on the basis of essential oil obtained from the roots of ten Iranian accessions. The three chemotypes were attributed by mono terpenes and 2-1-propenyl sec butyl disulfide, eudesmane sesquiterpenoids and α agarofuran and Z and E-1-propenyl sec butyl disulfide. The amount of oleo gum resin and its oil content was also significantly influenced by collection time. Karimi-an *et al.* (2020) obtained the highest amount of oleo gum resin (OGR) in September (13.2g) while lowest amount of OGR was obtained in July (6.3g). The highest radical scavenging activity of OGR was observed in August. The total number of constituents present in OGR essential oil during July, August, September and October harvesting were 47, 47, 43 and 44, respectively. α -pinene, (Z)-propenyl-sec-butyl disulfide, β -pinene, bicyclogermacrene, (E)-propenyl-sec-butyl disulfide, germacrene D and (Z)- β -ocimene were main constituents of OGR essential oil.

Kavoosi and Rowshan (2013) also observed that the harvesting dates of oleo gum resin also influence the chemical composition of their essential oils. The essential oil obtained from OGR harvested on 15th June, 2011 constituted high levels of cyclic sulfur-containing compounds viz., (E)-1-propenyl sec-butyl disulfide and (Z)-1-propenyl sec butyl disulfide and bicyclic sesquiterpenes (10-epi-c-eudesmol). This essential oil also showed the highest radical scavenging and the lowest antibacterial and antifungal activities. While the essential oil obtained from OGR, harvested on 30th June also contained high levels of acyclic sulfur-containing compounds and bicyclic monoterpenes (β -pinene and α -pinene) but showed moderate radical scavenging, antibacterial and antifungal activities. On the other hand, the essential oil extracted from OGR obtained from third harvest (15th July) contain high levels of bicyclic monoterpenes (β -pinene and α -pinene) and heterocyclic disulfide (1, 2-dithiolane) and showed the lowest radical scavenging and the highest antibacterial and antifungal activities.

Traditional uses : Asafoetida has long been used in traditional medicine for the treatment of several diseases like epilepsy, paralysis, hysterias, depression,

intestinal parasites, flatulence, weak digestion, stomach ache, influenza, asthma, premature labour, unusually painful, difficult and excessive menstruation, leucorrhoea, infertility and influenza etc. (Kavoosi and Rowshan, 2013). In India, dried extract of *F. asafoetida* with *Brassica alba* and rock salt was diluted with vinegar and taken orally as an abortifacient (Venkataraghavan and Sundaresan, 1981). For chronic bronchitis, the hot water extract of dried gum was taken orally. It was used to cure cholera when consumed along with cayenne pepper and sweet flag (Subrahmanyam *et al.*, 1954). To avert the infection of guinea worm, the exudate of the dried gum resin was eaten (Joshi, 1991). It could be applied externally along with salt and the bark juice of *Moringa pterygosperma* for stomach aches (John, 1984). For curing the gallstones and kidney stones 200-300 g of asafoetida is mixed with *Lampyrus noctiluca* without head and was consumed in morning and evening. For old stones, potassium nitrate was added to the mixture (Tiwari *et al.*, 1979). The hot water extract of the dried resin is taken orally as an emmenagogue (Kamboj, 1988).

Nepali people also regularly consume it in their daily diets, and it was believed that asafoetida had aphrodisiac, sedative and diuretic properties. In Iranian folk medicine, asafoetida was also used as a medicine for the treatment of asthma. The most persistent uses of asafoetida was in upper respiratory diseases like asthma, bronchitis and whooping cough (Moghaddam *et al.*, 2020). In addition, it had been used in traditional medicine of other countries such as Malaysia, Nepal and Fiji. In Iran, China and Nepal, it was traditionally used for the treatment of intestinal parasites (Iranshahy and Iranshahi, 2011; Gundamaraju, 2013). Oleo Gum resin of asafoetida had therapeutic effects on different diseases as documented in the Chinese, European, Iranian and Indian traditional medicinal books. Therapeutic effects related to the diseases of the nervous system, such as hysteresis and convulsion, were also available (Moghaddam *et al.*, 2014). It is used to decrease parasites like blastocystis species when taken either in powder form or oil form (El-Deeb *et al.*, 2012). The extract of *F. asafoetida* and *Silybum marianum* reduce the symptoms of functional dyspepsia (Illuri *et al.*, 2019). Asafoetida and turmeric in combination were used for the treatment of various inflammatory diseases like ulcerative colitis (Gopi *et al.*, 2017). The *F. asafoetida*, *Syzygium aromaticum* and *Carum carvi* were used as potent molluscicides (Upadhyay *et al.*, 2017). It was a promising natural therapeutic and prophylactic agent against cryptosporidiosis (Abdelmaksoud *et al.*, 2020). Asafoetida mouthwash was recommended as an efficient herbal mouthwash for improving the indices of gingival health (Seyed Hashemi *et al.*, 2019).

Modern uses: According to Sultana *et al.* (2015), asafoetida was proven for its various pharmacological

and biological properties like antispasmodic, hypotensive, antinociceptive, antioxidant, anxiolytic, aphrodisiac, antiviral, antidiabetic, gastric, antiulcer, antiseptic, nephron protective, neuroprotective and anticancer in animals and humans. Mahendra and Bisht (2012) reported that it was the most important ingredient of digestive powders and the best remedy for flatulence. It should be dissolved in hot water and a pad of cloth steeped in it may be used for stimulating the stomach. It also had the ability to prevent the increasing incidences of cancer. As reported by Unnikrishn and Kuttan (1988) that the human lymphocytes activated when asafoetida was administered to humans at a concentration of 0.25mg/ml. The same authors in 1990 also reported that oral administration to mice increased the percentage of life span by 52.9%. Nigam and Sachan (2013) also concluded that the occurrence of the cancer was more in those countries which had very low usage of asafoetida either as a spice or as medication.

With reference to women, asafoetida proved useful in the treatment of several problems such as sterility, unwanted abortion, pre-mature labour, unusually painful, difficult and excessive menstruation and leucorrhoea. It stimulates the secretion of progesterone hormone when about 12 centigrams of gum are fried in ghee along with 120 grams of goat's fresh milk and a tablespoon of honey. It is also useful for women after childbirth due to its antifatulent and digestive properties (Mahendra and Bisht, 2012). Complete pregnancy inhibition was observed in Sprague–Dawley rats when methanol extract of the resin was given orally to these at a dose of 400 mg/kg daily for 10 days (Keshri *et al.*, 1999).

It also possesses antihypertensive activity as evidenced by various studies. When water extract of the dried gum resin was administered intravenously to dogs at variable doses, it lowers their blood pressure (Sarkisyan, 1969). In another study tincture of the gland, administered intravenously to rabbits, produced significant hypotensive effects (Boyd, 1928). It showed anticoagulant activity when water extracts of the gum were given intravenously to dogs and rats at variable doses (Mansurov, 1967).

Several studies had shown that the extract, oleoresin powder, essential oil of asafoetida had antifungal activity (Garg *et al.*, 1980; Dikshi and Husain, 1984; Soni *et al.*, 1992; Thayagaraja and Hosono, 1996). The volatile oils of the Pathani variety were effective antibacterial, whereas Irani varieties act as antifungal agents (Divya *et al.*, 2014). The essential oils obtained from seed and oleo gum resin of *F. asafoetida* showed antimicrobial effects against oral pathogens (Alireza *et al.*, 2019). It also induced hyperglycemia (Al-Awadi, 1985) and was highly effective in the treatment of Alzheimer disease (Shereen *et al.*, 2013). It had cardioprotective effects in low doses and cardiotoxic effects in higher doses (Mansour Esmailidehaj *et al.*, 2014). It had an-

tiulcer and hepatoprotective activity (Bagheri *et al.*, 2018). The minimum dose of 10 mg per 100 g bw gave maximum protection for colon cancer (Panwar *et al.*, 2015). The oleo gum resin was found effective against Rhinovirus and influenza A H1N1 (Dissanayake and Perera, 2020).

During storage to improve the oxidative stability of fatty foods, the essential oil obtained from the earlier stages of *F. assafoetida* was used as safe and effective natural antioxidants. The essential oil obtained from the later stages of *F. assafoetida* was used in the health industry as an antimicrobial agent (Kavoosi and Rowshan, 2013; Golmohammadi, 2016).

In organic farming, it was used for the control of several insect-pests. It was used by farmers for the control of termites (*Odontotermes obesus*). Its disagreeable odour repels termites and other insects (Meena *et al.*, 2013). The leaf decoction of nirgundi + 10g of Heeng mixed in 1litre of water followed by mixing with 5 litres of cow urine control various pests of wheat and paddy (Lal and Verma, 2006). It was also found efficient in reducing the sucking pests (Noorani *et al.*, 2016) in different crops.

Cultivars and varieties: Based on the relative flavour and quality there are various commercial varieties available. According to Peter (2004) the varieties are distinguished according to country of origin like Irani Hing from Iran and Pathani Hing from Afghanistan. The Irani and Pathani varieties have following properties:

Irani: In early stage, they appear dry, blackish brown or reddish brown or yellow in colour later they change their colour to deeper shades. The main varieties are Irani Ras, Irani Khada and Irani No. 1. They have sweet fetid odour, sweet taste and contain wood chips except in 'Irani Ras'. They contain 40 % resin and 5-10% volatile oil and 0.5-7.75% ash.

Pathani: They are reddish to blackish brown or yellow or white in colour and appear agglutinated and wet. They have bitter fetid odour and bitter taste. They contain 10-20% volatile oil and 40-60% resin and only 0.7 - 1.90% ash. The major varieties are Naya Chal, Hadda, Naya Zamin, Charas, Galmin, Khawlal, Kabuli and Shabandi.

Climate and Soil: It requires dry temperate conditions for best growth. It can be grown at an elevation ranging from 600 to 2400m above sea level. Heavy and continuous rainfall likely to affect crop growth adversely. It requires an annual average rainfall of 250-350 mm (Nadjafi *et al.*, 2006). This plant grows on all aspects having a slope gradient of more than 25% (Nadjafi *et al.*, 2006; Jafari *et al.*, 2019). The optimum temperature for its vegetative growth vary from 10-20°C. However, it can tolerate temperatures up to 35°C. The germination of *Asafoetida* is best at a temperature of 15°C. It requires abundant sunshine and cannot tolerate shady conditions (Parsa *et al.*, 2014; Zangoie *et al.*, 2012). According to Moghad-

dam and Farhadi (2015), the maximum accumulations of essential oil and sulphur compounds in asafoetida was associated with different mean annual temperatures and altitude. The contents of these parameters reduce with increasing altitude and decreasing temperature. However, the resin yield was positively correlated with the precipitation rate.

It prefers well-drained fertile sandy loam or clay soils (Ali, 2019). It can grow on poor soils with a light structure. It can tolerate pH ranging from acidic to basic soil types (Moghaddam and Farhadi, 2015). Jafari *et al.* (2019) observed that this plant grows well in soils where lime amount ranging from 55.92% to 58.27% and organic matter vary from 1.20% to 1.97%.

Cultivation

Seed Sowing: The best method of propagating the plant is a seed. It begins to germinate within 20 days of sowing. Pirmoradi *et al.* (2013) reported that the elimination of the seed coat in one-year-old seeds lead to 84% germination within 4 days even at 20°C while newly harvested seed exhibit dormancy and did not germinate under any treatment condition. The germination was completed within a month.

In a greenhouse, the seeds should be sown as soon as they are ripe during the autumn season. The seedlings should be pricked out into individual pots as soon as they are large enough to handle. Under open conditions, winter or spring (April) sowings are preferred. The seed sown during winters, i.e. December-January gave higher emergence percentage and more tuber yield than spring plantings, i.e. April (Mellati *et al.*, 2010; Varmazyar, 2013). During winters they should be given protective mulching. Varmazyar (2013) observed a higher emergence rate when seeds were sown 4 cm deep in rows as compared to sowing depth of 2 cm. Sowings done in rows make it possible to rogue out weak off-type seedling from the field.

The seeds of asafoetida have long dormancy and poor seed germination (Golmohammadi, 2016). Therefore, to improve seed germination, cold stratification is done. The duration and temperature of stratification influence the seed germination. In general, at 4°C for 60 days was sufficient to remove the embryo dormancy (Zare *et al.*, 2011). Otrshy *et al.* (2009) observed that when chilling treatment was given in combination with 6-benzylaminopurine (BAP), the germination percentage increases. For breaking dormancy of Tabas and Shirkooh populations of *F. assafoetida* on MS medium, seed treatment with chilling and cytokinins were most effective (Hassani *et al.*, 2009). Also washing and chilling (5°C) for a period of 14 days was found to be most effective (Nadjafi *et al.*, 2006). Seed vernalization at 4-5°C for two weeks also increased seed germination by 50% (Nowruzian *et al.*, 2017). In addition, washing seeds for 6 hours and applying GA₃ @10 ml/l also augmented germination percentage. The right combination of vernalization, washing time

and growth hormones was a prerequisite for proper germination of asafoetida.

According to Chittendon (1956), the vegetative propagation of the asafoetida plant can also be done by the root division method in the month of September. However, it was not an advisable method because plants dislike root disturbance.

Manures and fertilizers: In the first year, it was advised to apply 15-20 t/ha of farmyard manure. The recommended dose of chemical fertilizers consists of 20g N, 18g P₂O₅ and 25g K₂O per seedling. The dose was increased gradually up to ten years. Tenth year onward, a fertilizer dose of 200g N, 180g P₂O₅ and 200g K₂O per plant was applied. In zinc deficient soils, basal application of zinc sulphate @ 30 kg/ha should be applied for yield improvement. The intervention of earthing up should be followed after fertilizer application so that the fertilizer gets mixed in soil properly (Anonymous, 2020b).

Irrigation: Water stress reduces plant growth and productivity more than any other environmental factors (Tehri, 2016). The asafoetida prefers moist conditions only during germination. Waterlogging at later stages can be harmful. During summers, more number of irrigations were required (Anonymous, 2020b). According to Reza *et al.* (2015) irrigating the crop once in a week is sufficient. The resin yield, vegetative growth and % survival of asafoetida plants also depends on the number of irrigations. Since the crop grows in high mountains, melting of snow in spring can meet the growth needs. However, if drought conditions persist, then watering the seedlings with sprinkler or drip should be done. The relative moisture of soil should be 40-75%. Moghaddam and Farhadi (2015) also reported that resin yield was positively correlated with rainfall.

Interculture and weed control: During the early stages, asafoetida needs more care. Weeds which grow vigorously should be removed timely. Generally, two weedings in a year (June–July and October–November) and one digging of soil around the bushes during August–September were done (Anonymous, 2020b). After about four to five years, they do not need weeding.

Collection and harvesting: The crop grows into 2m tall trees in five years' time and latex gum material was obtained from the roots and rhizomes of the plants. The older plants were more productive. The time to start harvesting the gum from the succulent stem and the root was just before flowering. March and April were the best months for harvesting the crop (Golmohammadi, 2016). The incision was made vertically on the stem near the roots of the plant. The roots which had attained 6-10 cm diameter were recommended for the extraction of asafoetida (Omid Beygi and Pirmoradei, 2006). A milky liquid oozes from the exposed surface. This substance hardens when exposed to air and later scraped and extracted. This

process is repeated after every 4-5 days on the stems of asafoetida, till gum stops oozing (Shah and Zare, 2014; Giri *et al.*, 2008, Ali, 2019).

Gholami and Mahdi (2015) evaluated the effects of different cutting methods (conventional method, crown cutting, concave and surface cutting) and the number of cuts (5, 10 and 13 times) on the yield of asafoetida in its natural habitat in Mazar area in Badzhestan district, Iran. The yield of gum was determined by the number of cuts. They reported that the highest yields and the best plant regeneration were achieved using the concave method with 10 cuts. They also revealed that the conventional method of cutting destroys the buds in the crown, which causes the death of the plant. Traditionally it was collected from wild pasture by using sickles to cut the entire plant or branches without considering natural regeneration which leads to the extinction of this valuable plant (Ali, 2019). Damanch and Sharafatmandrad (2017) also observed that the traditional incision methods were fatal to the asafoetida. They recommended that the 45-degree cutting method and concave method were the best incision techniques. The highest gum yield and best plant regeneration rates were obtained by using a concave method with 10 cutting times (Gholami and Faravani, 2014). Omid Beygi and Pirmoradei (2006) also found pruning up to tenth level economical. The entire process took three months to complete and one plant can yield up to 900 g of gum (Shah and Zare, 2014). The resinous gum appears greyish-white when fresh, and darkens to a deep yellow/amber when dried. Chunks of asafoetida resin are broken off to be sold commercially. The gum is seldom sold in its pure form. It is often combined with Arabic gum, wheat/rice flour, turmeric, etc. and sold as Compounded Asafoetida (Peter, 2004, Anonymous, 2017).

Yield: On an average, a single plant yields around 40g to 900g of fresh gum (Shah and Zare, 2014; Moghaddam and Farhadi, 2015). The value of 1 kg dried gum in the global market is around 130-170\$USD (Golmohammadi, 2014). The essential oil yield varies from 2.53 to 20.85%. This high level of variation in yield occurs due to their place of cultivation (Hassanabadi *et al.*, 2019). The oil extracted from different parts of asafoetida is also sold at premium prices.

Processing: According to Shah and Zare (2014), the oleo gum resin was extracted from the stem and roots of different *Ferula* species. When fresh, the resin is greyish-white, but after some days dries to a dark amber colour. Ali (2019) found that the dried sap of asafoetida was difficult to grate and traditionally, it was crushed between stones or using a hammer. Anonymous (2017) and Shah and Zare (2014) reported that in India, the purest form was natively known as hing which was usually soft, transparent, and obtained from stem of *F. alliacea* while hingra obtained from *F. foetida*, was exported. It was powdered when excessively cold or by drying over freshly burnt lime or exposure to

Table 4. Quality attributes of different types of Asafoetida available in the market.

Quality Attributes	Heeng	Heengra	Compounded Asafoetida
Total ash max	15.0	20.0	10.0
Ash soluble in HCl % (Maximum)	2.50	8.00	1.50
Alcoholic extract % (90% alcohol)	12 (Max.)	50 (Max.)	5 (Min.)
Starch %	1	1	

Source: Shah and Zare (2014)

currents of warm air, and then it was reduced at low temperature. Starch or magnesium carbonate act as a diluent which maintains powdered form. According to Giri *et al.* (2008) the most commonly available form was compounded asafoetida, a fine powder containing 30% asafoetida resin, along with rice flour or *maida* (white wheat flour) and gum arabic. The compounded asafoetida was mostly sold in bricket form. It is also available in free-flowing (powder form) or in tablet forms. Different grades of resins, dried granules, chunks, or powders were sold. The quality attributes of different types of asafoetida available in the market are given in Table 4.

Generally, it was marketed in three forms-tears, mass and paste. The most common form of asafoetida in the market is mass. Tears or lumps were the purest forms. They were round or flat, about 15–30 mm diameter and had greyish or dull yellow colour. In contrast, the mass was agglutinated tears mixed with extraneous matters. On the other hand, the paste was semi-solid and it also contains extraneous matter (Javaid *et al.*, 2020).

Asafoetida was the most adulterated spice in the market. Besides being largely admixed with inferior qualities of asafoetida, it often had Gum Arabic, other gum resins, rosin, gypsum, red clay, chalk, barely, sand, stones, wheat flour, slices of potatoes etc. added to it to increase its weight (Peter, 2004; Ali, 2019; Javaid *et al.*, 2020).

Conclusion

Asafoetida is mainly grown for the oleo gum resin which is extracted from its roots. It is valued for its medicinal properties against respiratory, gastrointestinal, neurological and reproductive disorders. In India, there is no tradition of cultivation of asafoetida, but recently it was introduced at village Kwaring, Lahaul valley, Himachal Pradesh, India by the team of scientists of Council of Scientific and Industrial Research-Institute of Himalayan Bioresource Technology. They were of the opinion that the cold desert areas of India are suitable for its cultivation. In addition, cultivation of this crop in farmland will be beneficial for the resource-poor farmers of hill states. Thus, in view of the substantial economic importance of asafoetida, detailed studies on agrotechnology along with training and information sharing with the community, are required for its successful cultivation.

Conflict of interests

There is no conflict of interest regarding the publication of this article.

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