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Long pepper

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25.1 Introduction

Long pepper commonly called 'Pippal' in Sanskrit, is an important medicinal spice. The long pepper of commerce is derived from more than one species. The Indian long pepper is derived from *Piper longum* L and *Piper peepuloides* Wall. while the much longer Indonesian or Java long pepper is derived from *P. retrofractum* Vahl. The products of these species are used for the same purposes, though they vary in their effectiveness. The products of *Piper longum* and *P. retrofractum* are often not clearly distinguished in the spice trade. The spikes of *Piper peepuloides* and sometimes another related species with globose spikes *P. mullesua* Ham. occur mixed with commercial *P. longum* (CSIR, 1969; Pruthi, 1976).

25.1.1 Vernacular/regional names

English: Long pepper; Bengal pepper, Java pepper, Balinese pepper; Unani: Pipal; Amharic: Timiz; Arabian: Dardildil; Persian: Filfilidaraz, filfildray, Maghzpipal, Pilpil, Pipal; Nepalese: Pipal, Piplamol, Popal; Malaya: Pit poot; Burmese: Peik-khyen, Peikchin; Malay: Lada, Mula-gu, Cuttaterpali, Chabai; Hungarian: Bali bors, Bengali bors; Sinhalese: Tippali; Greek: Pepper makron; Italian: Pepe lungo; Indonesian (Java): Cabe bali, Cabe jawa; Lada panjang; Mexican: Tlathancuaye; Potuguese: Pimenta longa; Dutch: Langwerpige peper; Duk.: Pipaliana; Swedish: Lang peppar; German: Langer Pfeffer, Stangenpfeffer, Balinesischer Pfeffer, Jaborandi Pfeffer, Bengalischer Pfeffer; French: Poivre long, Racindes de; Spanish: Pimentera larga; Khmer: Morech ansai; Laotian: Sa li pi, I lo; Japanese: Hihatsu; Chinese: Pipo, Bi ba; Estonian: Pikk pipar; Thai: Dee plee, Phrik hang, Dipli chuak; Tibetan: Dro-sman; Hindi: Pipli, Pipal, Pimpli, Piplamul, Pipulmul; Sanskrit: Chanchala, Chapala, Granthika, Kana, Kati, Kola, Korangi, Krishna, Krishnapippali, Magadhi, Pippali, Tiktatandula, Vaidehi; Urdu: Pipul; Bengali: Piplamor, Piplamul, Pipli, Pipul; Assami: Pipoli; Gujarathi: Piper, Pipli, Pipara; Marathi: Pimpli, Mothi, Piple; Punjabi: Darfilfil, Filfildaraz, Maghzpipal, Pipal; Sindhi: Filfildray, Tippili, Fil; Uriya: Baihehi, Krykola, Mogodha, Pippoli; Santal: Ralli; Canarese (Kannada): Thippali, Hippali; Tamil: Argadi, Atti, Kalidi, Kaman, Kanna, Kindigam, Kolagam, Savundi, Sauyini; Telugu: Modi, Pippali; Malayalam: Chapal, Tippali (Singh *et al.* 2000). The roots have been described separately in Ayurvedic texts as granthika, Pippalimul, Ushna, Chatakashir, kolmul, Katugranthi, Chavikashir.

25.1.2 Origin and geographical distribution

Long pepper belongs to the family Piperaceae and is native to South and South East Asia. The three major species which constitute long pepper of commerce occur in three different geographical regions. *Piper longum* L. (Syn. *Chavica roxburghii* Miq.), commonly called Indian long pepper, occurs throughout India, Sri Lanka, Burma, Malaysia, Nepal, Singapore and other South Asian countries, but is most widely distributed in India and is a native of penisular India. It occurs from central Himalayas to Assam, Khasi and Mikir hills, lower hills of Bengal and evergreen forests of Western Ghats from Konkan to Kanyakumari as well as Nicobar Islands. Indian long pepper is mostly derived from the wild type mainly from Kerala, Assam, West Bengal, Nepal, Uttar Pradesh, North East region and Andhra Pradesh. It is also cultivated to a limited extent in parts of Bengal, Assam, Maharashtra, Tamil Nadu, Orissa, Andhra Pradesh, Arunachal Pradesh, Meghalaya and Manipur (Atal and Ojha, 1965). The chromosome number of *P. longum* varies from 2n = 24 to 2n = 96. The reported chromosome numbers of *P. chaba* are 2 n =24 and 104, *Piper peepuloides* 2n = 156 and *P. mullesua* 2n = 132. Many related species have been reported in India (Ravindran and Nirmal Babu 1994, Ravindran 2000).

Piper peepuloides Wall occurs mainly in North-Eastern India whereas *Piper retrofractum* Vahl (Syn. *P. chaba* Hunt), comes from South East Asia and is mostly cultivated in Indonesia and Thailand (Hooker, 1886).

25.1.3 Botanical notes and description

Family: Piperaceae.

Piper longum Linn.; syn.; *P. sarmentosum* Wall.; *P. latifolium* Hunter; *P. turbinarium* Noronha.; *Chavica roxburghii* Miq.; *C. sarmentosa* Miq.
Piper peepuloides Wall; Syn. *Chavica peepuloides* Miq.
Piper retrofractum Vahl: Syn. *P. chaba* Hunt,

Piper longum is a slender, aromatic, trailing, dioecious plant with perennial woody roots occurring in the hotter parts of India. It is a perennial creeping undershrub spreading on the ground. Stems creeping, jointed with erect fruiting branches, young shoots downy. Leaves are simple alternate, petiolate or sessile, distinctly dimorphic, 5–9 cm long, 3–5 cm wide, ovate, cordate with broad rounded lobes at base, sub-acute, entire, glabrous on creeping shoots; leaves on the fruiting branches oblong, lanceolate, base unequally cordate. Spikes cylindrical with peduncle, male longer and slender, female 1.3–2.5 cm long and 4–5 mm diameter, fruits ovoid, sunk in fleshy spike turns black from green when ripe. Flowering is throughout the year; flowers are dioecious. Inflorescence is a spike with unisexual, small or minute closely packed flowers and form small clusters of grey berries. The female spikes are with short thick stalk varying from 1.5 to 2.5 cm length and 0.5 to 0.7 cm thickness. The male spikes are slender and longer stalks (2.5 to 7.5 cm), slightly elongate. The fruits

are ovoid drupes, small and completely sunk in the fleshy spikes, fused laterally, pungent, aromatic, spicy, shining dark green when immature and blackish green when fully mature. Female spikes arising singly from leaf axil, is cylindrical, short and stout with multiple fruit. Male spikes also arise from the base of the leaf, is single, long cylindrical and of no economic value. The mature female spikes are collected and dried and this is the commercial form of pippali (Narayan Aiyer and Kolammal, 1966, Ravindran 2000).

The long peppers from Indonesia come from slender climbers rooting at nodes. The branches are swollen at the nodes and the leaves are alternate. Plants of *Piper retrofractum* and *P. peepuloides* are climbers with yellowish orange to red fruits. In addition *P. retrofractum* has reticulate leaves on its fruiting branches with much larger spikes. They have sparser-looking foliage than *P. longum*, the most noticeable difference between the two being that the fruits of Indian long pepper *(P. longum)* are smaller and more pungent than those of Javanese long pepper *(P. retrofractum)*. The spikes of *P. retrofractum* are conical while those of *P. longum* (Viswanathan, 1995) are cylindrical.

25.1.4 Economic parts and importance

Long pepper is so called because the fruits are long, cylindrical spikes 5 mm in diameter and 2.5 to 4 cm long. The economic parts are roots and dry spikes of female plants, which are generally used for its several medicinal and spicy properties. Long pepper has a sweet and fragrant aroma but the flavour is bitingly hot, lingering and numbing, belying its innocent smell. Long pepper probably came to Europe much before the now dominant black pepper. During the Roman Empire it was priced about three times that of black pepper. With its taste pungent and sweet at the same time, it was perfect for Roman cookery especially as they were fond of these two taste sensations. Since terpene components are missing in its aroma, long pepper cannot be substituted by ordinary black pepper. Its hot-and-sweet taste goes well with spicy cheese specialities.

The 'Pippalmul' are the roots of *Piper longum* which are sometimes adulterated with those obtained from other wild species of *Piper*. These are mostly dried bits of roots 4–6 cm in length of a dark grey or grayish brown colour with the surface slightly shrunken, and having distinct internodes and swollen nodes with a number of small rootlets and root scars. There is a general resemblance in the anatomical structure between these bits and those of *Piper longum*. The number of primary xylem groups may vary from five to seven, so also the number of radiating bands of vascular tissue. Small thickened cells occur in the cortex of the roots of *Piper longum* but are not evident in the dried specimens. The phloem appears narrower and the cork much darker in colour. The powder is reddish brown to creamish grey and under the microscope shows scalariform vessels, aspetate fibres, simple and compound starch grains measuring 3–14 μm in diameter (*The Ayurvedic Pharmacopia of India*. Parts I and II. Ministry of Health and Family Welfare. Dept of ISM&H. 133–134.)

25.1.5 Histology of *Piper longum* root

The histology of *Piper longum* root was studied by Narayan Aiyer and Kolammal (1966). A transverse section of the root about 4 mm diameter is almost circular and the outline regular. The outermost cork is made up of three-five rows of thin-walled,

elongated cells and appears as a very narrow strip slightly brown in colour and is not evident in many specimens. The cortex has round to oblong, large thin walled parenchymatous cells with large intercellular spaces. The cell walls of the peripheral rows are slightly thickened but not lignified. Most of these cells contain starch grains. A few cortical cells contain minute prismatic crystals of calcium oxalate. Many thick-walled cells and secretary cells are found scattered in the cortex. A wavy endodermis composed of one row of rectangular cells with their side walls slightly thickened. The pith is surrounded by four-six wedge shaped radiating strips of vascular tissue having their wider ends towards the periphery. The cells of the pith are similar to those of cortex. Six groups of evenly spaced primary stem bundles are present outside the pith. In each vascular strip the xylem is composed of xylem vessels, xylem parenchyma and wood fibres and its wider end is crowned with a hemispherical strip of phloem.

One or two rows of thin-walled rectangular cambial cells are present between the xylem and phloem. The phloem is composed of many sieve tubes and companion cells and phloem parenchyma. One or two groups of two to three stone cells are present at the peripheral region of the phloem. There are four to six broad wedge-shaped medullary rays extending from the pith up to the endodermis, with their wider ends at the periphery and alternating with the radiating bands of vascular tissues. The ray cells are all thin walled and heavily loaded with starch grains. Narayan Aiyer and Kolammal (1966) also studied the histology of market samples of long pepper root and found that many samples showed histological similarity to long pepper root with minor differences.

25.2 Chemical composition of long pepper

The constituents responsible for the spicy properties of plants are always secondary metabolism products, that is, they are not involved in primary metabolism hence not vital for the plant. In some cases, it is supposed that the aroma molecules are essentially byproducts of metabolism, in most cases, though, they play an important rôle in attracting pollinators or drive away herbivorous animals. It is somehow a paradox that plants are grown and spread word-wide as food enhancers, although their tasty constituents' intention is to discourage the consumption of the plant.

Fruits contain volatile oil, resin, alkaloids and terpenoids. The dried spikes of long pepper on steam distillation yield an essential oil (0.7%–0.8%). The flavour is characteristic of pepper in pungency and taste, the important flavour compounds being piperine, piperlongumine (present in the major alkaloid in addition to piperine) and pipelartine. These components are responsible for the important medicinal functions, *viz.*, laxative, carminative, thermogenic, anthelmintic, digestive, stomachic, emmenagogue.

Long pepper is similar to black pepper in composition but it is less expensive and used as an adulterant of ground black pepper. The approximate composition of the plant is:

Moisture	9.5%
Protein	12.2%
Starch	39.5%
Fibre	5.8%
Total ash	5.9%

Insoluble acid	4.2%
Volatile oil	1.5%
Fixed oil	6.6%
Piperine	4.5%

(All values except moisture are measured on dry basis.)

The active constituents of *P. longum* are the alkaloids. They exhibit characteristic mouthfeel, a pepper-like pungency and pronounced salivation and numbness. The highest content of piperine was found in the underground part of the stem and roots. Piperine content of fruits increases with maturity from 14–16 days (0.53%) to 40–45 days (0.9%).

Piperine is the active principle and principal alkaloid of long pepper (*Piper longum* L.) and constitutes 3–5% (on dry weight basis). The content of piperine (about 6%) is slightly higher than in black pepper and yields upon distillation with water, 1% of a bland, thickish, yellow-green oil of specific gravity 0.861, and resembling ginger in odour. The drug has a peculiar odour and a pungent bitter taste producing numbness on the tongue. It contains piperine (0.15–0.18%), piplartine (0.13–0.20%) and traces of yellow crystalline pungent alkaloid. Other constituents include triacontane, dihydrostigmasterol, a sterol, reducing sugars and glycosides (Pillai *et al.*, 2000).

Piperine increases micelle formation, stimulation of active transport of amino acids (gamma-glutamyl transpeptidase), and epithelial cell wall modification due to the affinity of piperine towards fats and fatty substances. In view of these findings it is proposed that piperine ingested in relatively small amounts would act as a thermonutrient. Localized thermogenic action on the epithelial cells would in turn increase the rate of absorption of supplemented nutrient(s).

25.2.1 Chemical composition of *P. longum* oil

Long pepper on distillation yields 0.7–1.5% of light green, viscous oil with a spicy odour resembling that of pepper and ginger and has the following characteristics:

D_{20}	0.8484
N_{20}	1.4769
[α]D	40.1
m.p.	–6 °C
Acid value	7.2
Saponification value	8.9
Saponification value after acetylation	12.8
n-hexadecane	0.7%
n-heptadecane	6.0%
n-octadecane	5.8%
n-eisocane	4.7%
n-heneicosane	2.5%
α-thujene	1.7%
terpinolene	1.3%
zingiberene	7.0%
ρ-methoxy acetophenone	trace
dihdrocarveol	4.3%
phenethyl alcohol	2.1%

25.2.2 Chemical constituents of fruits

The long pepper fruits contain Sylvatin, Sesamin, Diaeuolemin, Piperine, Piplartine, Asarinin, Pluviatilol, Fragenin (E) and (Z), Pipercide, Guineenside, Longamide, piplasterol, Dihudropiperonaline (Shoji *et al.*, 1986).

Fruits contain volatile oil, resin, alkaloids (4–5% piperine), a terpenoid substance, piplartine (m.p. 124–125°) and two liquid alkaloids. Sesamin ($C_{20}H_{18}O_6$, m.p. 122°), dihydrostigmasterol and piplasterol are also present. On the other hand, long pepper contains less essential oil than its relatives (about 1%), which consists of sesquiterpene hydrocarbons and ethers (bisabolene, *beta*-caryophyllene, *beta*-caryophyllene oxide, each 10–20%; *alpha*-zingiberene, 5%), and, surprizingly, saturated aliphatic hydrocarbons: 18% pentadecane, 7% tridecane, 6% heptadecane. Medicinal properties are attributed to the alkaloid piperine and piplartine (Atal and Ojha, 1965).

A sample of dried fruit of *P. longum* on steam distillation gave 0.7% of essential oil with spicy odour resembling that of pepper and ginger oils, and has the following characteristics: acid val. 7.2; sap. val. 8.9; sap. val. after acetylation 12.8; soluble in 20 vol. of 95% alcohol; specific gravity – 0.8484; refractive index: 1.4769; Optical rotation – 40.1°. The oil contained: *n*-hexadecane – 0.7; *n*-heptadecane – 6.0; *n*-octadecane – 5.3; *n*-nonadecane – 5.8; *n*-eicosane – 4.7; *n*-heneicosane – 2.5; α-thujene – 1.7; terpinolene – 1.3; zingiberene – 7.0; *p*-cymene – 1.3; *p*-methoxy acetophenone – trace; and a monocyclic sesquiterpene (Handa *et al.*, 1963).

25.2.3 Chemical constituents of leaves

Hentriacontane, β-sitosterol, hentriacontane-16-one, triacontanol (Purnima *et al.*, 1999).

25.2.4 Chemistry of Piplamool

Chemical constituents of roots

Piperine, Piperlongumine, Piperlonguminine, Piplasterol, Triacontane, Cepharanone B, Aristolactam AII, Piperolactam A, Piperlactam B, Cepharadione A, Cepharadione B, Norcepharadione B, Sesamin, 22,23 – dihrdostigmasterol, methyl-3,4,5-trimethoxy cinnamate, piperadione.

In *P. retrofractum*, piperine, piperlonguminine, sylvatine, guineensine, piperlongumine, filfiline, sitosterol, methyl piperate and a series of piperine-analog retrofractamides are reported. (Banerji *et al.*, 1985).

Two alkaloids piperlongumine (probably identical with piplartine; $C_{17}H_{19}O_5N$, m.p. 124°; 0.2–0.25%) and piperlonguminine ($C_{16}H_{19}O_3N$, m.p. 166–168°; 0.2%) have also been identified in the roots (Parthasarathy and Narasimha Rao, 1954; Atal and Ojha, 1965) Long pepper is rarely used medicinally in the United States. *King's American Dispensatory.* 1898.

25.2.5 Structure of piperine

Chemical names: 1-piperoyl piperidine; (E,E) 1-[5-(1,3-Benzodioxol-5-yl)-1-oxo-2, 4-pentadienyl]piperidine; Molecular weight: 285.33; Percentage composition: C = 71.55%, H = 6.71% N = 4.91% O = 16.82%.

25.2.6 Method of extraction

Piperine can be isolated from the oleoresin of *P. longum*. The powdered fruits of the plant are extracted with dichloromethane at room temperature with stirring for 12 hours. The extract is filtered, concentrated in vacuum, and then the residue is purified on an alumina column. Pure piperine can also be obtained by crystallization from ethanol, which may be required for food and/or medicinal usage. Piperine is obtained directly from the crude residue in lesser amounts by extraction in alcohol, filtration and successive crystallization. Alkaline hydrolysis of piperine gives two compounds, one an acid, viz., piperic acid and the other an alkaloid, viz., piperidine. This confirms that piperine is the amide formed between piperidine and piperic acid.

$$\underset{\text{Piperine}}{C_{17}H_{19}O_3N} + H_2O \xrightarrow{NaOH} \underset{\text{Piperidine}}{C_5H_{11}N} + \underset{\text{Piperic acid}}{C_{12}H_{10}O_4}$$

25.2.7 Structure of piperidine

Piperidine is well-known as the hexahydro derivative of pyridine. It is a simple organic heterocyclic nitrogen compound. The structure is shown in Fig. 25.2.

25.2.8 Structure of piperic acid

Qualitative tests confirmed that piperic acid contains one carboxyl, two olefinic double bonds and no free hydroxyl groups. Piperic acid on permanganate oxidation gives first the aldehyde piperonal and then the acid piperonylic acid. Piperonylic acid does not contain any free phenolic hydroxyl groups. On heating with HCl under pressure, it gives the diphenolic acid protocatechuic acid and formaldehyde. This shows that only one carbon is eliminated to give a diphenolic compound. It has previously been established that protocatechuic acid is 3,4-dihydroxybenzoic acid (Fig. 25.3.)

The structure of some of the other important constituents of long pepper are shown in Fig. 25.4.

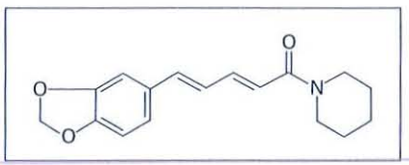
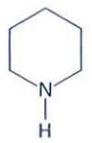
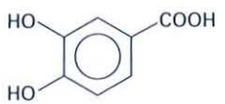


Fig. 25.1 Structure of piperine.



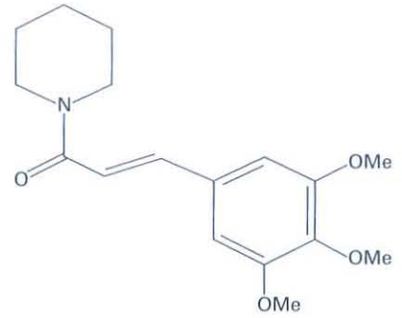
Piperidine

Fig. 25.2 Structure of piperidine.

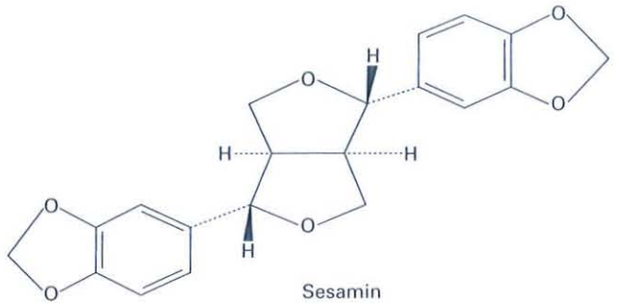


Protocatechuic acid

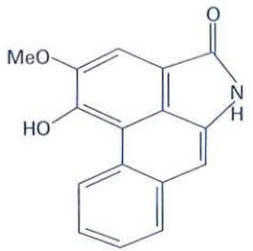
Fig. 25.3 Protocatechuic acid.



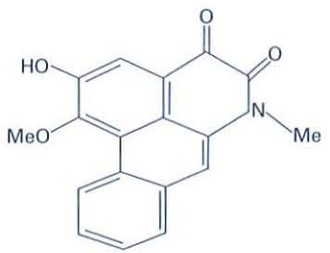
Piplartine (Piperlongumine)



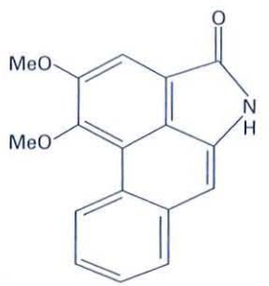
Sesamin



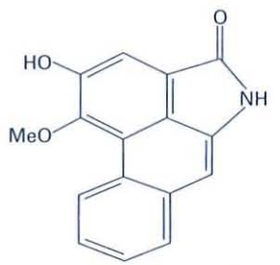
Piperolactam A



Piperadione



Cepharanone B



Aristolactam AH

Fig. 25.4 Structure of some of the other important constituents of long pepper.

25.3 Uses

The fruits are used as a spice and also in pickles, preservatives, foods, beverages, liquors and medicines. Rather remarkably, long pepper is also known and popular in parts of Africa, namely in the Islamic regions of North and East Africa, where it has been introduced by Arab traders therefore long pepper is sometimes found in the complex spice mixtures of Morocco. It is also of some importance for the cuisine of Ethiopia, where long pepper is usually found in the traditional meat stews (*wat*), mostly together with black pepper, nutmeg, clove and turmeric; the usage of turmeric exemplifies the Indian influence in Ethiopian cuisine.

The most important use of long pepper is as a medicinal ingredient in the Indian systems of medicine – Ayurveda, Sidha and Unani. Both fruit and dried roots are used. Besides the spikes thicker stem and roots are used in preparation of 'piplamool' in Ayurvedic Sidha and Unani medicines. The pungent root is considered as healing, stomachic, laxative, anthelmintic, carminative, improves the appetite, useful in bronchitis, abdominal pains, diseases of the spleen, tumour, ascites and relieves biliousness. The fruits as well as roots are attributed with numerous medicinal uses and may be used for diseases of respiratory tract, viz., cough, bronchitis, asthma, etc; as a counter irritant and analgesic when applied locally for muscular pains and inflammation; as snuff in coma and drowsiness and internally as carminative; as sedative in insomnia and epilepsy; as general tonic and haematinic; as cholagogue in obstruction of bile duct and gall bladder; as an emmenagogue and abortifacient; and for miscellaneous purposes as antihelmenthic and in dysentery and leprosy (Atal and Ojha, 1965; Atal *et al.*, 1981).

Used in many Ayurvedic traditional remedies, *Piper longum* has been intensively studied. A large number of traditional medicinal preparations have long pepper as one of their constituents. *Piper longum* differs little in its medicinal values from *P. nigrum* as it is less aromatic and more acrid. It is widely used in Ayurvedic and Unani systems of medicine in the prevention and treatment of respiratory congestion and bronchial asthma. Whole spike and piplamool (dried roots and thick stem) are used. Unripe fruit is used as an alternative analgesic for muscular pains and inflammations, vermifuge, carminative, sedative, anti-diarrhoeic, anti-dysenteric against fevers, leprosy, jaundice and as an immunostimulant and tonic; used after childbirth to check post-partum haemorrhage, treat respiratory tract diseases. The dry spikes of female types are used in the Ayurvedic preparations like Pipalarishta, Pipplayasava, Panchakola, Pippalayadiluha and Lavanabhaskar churnam. It is the major constituent of an Ayurvedic preparation, 'Trikatu' which is prescribed routinely for a variety of diseases. The root is used for bronchitis, stomachache, diseases of spleen and tumours. It improves appetite also.

An infusion of the root is prescribed after parturition to induce the expulsion of placenta. The fruits are also used as carminative, sedative in insomnia and epilepsy, as general tonic and haematinic, as cholagogue in obstruction of bile duct and gall bladder; as an enumenagogue and abortifacient; as anthelmintic and in dysentery and leprosy. Ripe fruit is sweetish, pungent, heating, stomachic, aphrodisiac, alternative, laxative and anti-dysenteric.

Pungent root is considered as warming, stomachic, laxative, anthelmintic, carminative, improves the appetite, useful in bronchitis, abdominal pains, diseases of the spleen, tumour, ascites and causes of biliousness. The roots and stems are used for diseases of the respiratory tract like cough, bronchitis, asthma, etc., as counter-irritant and analgesic when applied locally for muscular pains and inflammation; as snuff in coma and drowsiness.

The fruits contain volatile oil, resin, alkaloids (4–5% piperine) – a terpenoid substance, piplartine (m.p. 124–125°) and two liquid alkaloids. The first alkaloid is closely related to pellitorine producing marked salivation, numbness and a tingling sensation of mucous membranes of the mouth. It showed *in vitro* anti-tubercular activity against *Mycobacterium tuberculosis* H-37 Rv strain; inhibited the growth of the bacillus in 20 µg/ml concentrations (Pruthi, 1976). Piperine has diverse pharmacological activities including nerve depressant and antagonistic effect on electro-shock and chemo-shock seizures as well as muscular uncoordination. The alkaloids (Piperine, pipelartive and piper longument) present in long pepper proved to possess anti-tubercular activity. The fruits are also used as carminative, sedative in insomnia and epilepsy, as general tonic and haematinic, as cholagogue in obstruction of bile duct and gall bladder; as an enumenagogue and abortifacient; as anthelmintic in dysentery and leprosy. Alcoholic extracts of the dry fruits and aqueous extracts of the leaves showed activity against *Micrococcus phygenes* var. *aureus* and *Escherichia coli*. Ether extract of the fruits showed larvicidal properties (Pruthi, 1976). Alcoholic extracts of the dry fruits and aqueous extracts of leaves showed activity against *Micrococcus pyogenes* var. *aureus* and *Escherichia coli*. Ether extract of the fruits showed larvicidal activity (George *et al.*, 1947).

A decoction of immature fruits and roots is given for chronic bronchitis, coughs and colds. Fruits and roots are used in palsy, gout, rheumatism, lumbago, an antidote for snake-bite and scorpion sting, as counter-irritant and analgesic when applied locally for muscular pains and inflammation; internally as carminative; as sedative in insomnia and epilepsy; as general tonic and haematinic; and for miscellaneous purposes as anthelmintic, in dysentery and leprosy (Atal and Ojha, 1965). It forms one of the ingredients in various compound preparations used for anorexia, piles, dyspepsia and also in snuffs used in coma and drowsiness (CSIR, 1969). A compound preparation of *P. longum* is also said to be a good remedy for leucoderma. The plant is considered by tribals (Santals) to be useful in splenetic disorders, cholera, dysentery, consumption, puerperal fever and diarrhoea (Jain and Tarafder, 1970).

Experiments were conducted to evaluate the scientific basis of the use of the trikatu group of acrids (long pepper, black pepper and ginger) in the large number of prescriptions in Ayurveda. [3H] vasicine and [3H] sparteine were taken as test drugs. *Piper longum* (long pepper) increased the blood levels of vasicine by nearly 233%. Under the influence of piperine, the active principle of *Piper* species, sparteine blood levels increased more than 100%. The results suggest that these acrids have the capacity to increase the bioavailability of certain drugs. It appears that the trikatu group of drugs increase bioavailability either by promoting rapid absorption from the gastrointestinal tract or by protecting the drug from being metabolized/oxidized in its first passage through the liver after being absorbed, or by a combination of these two mechanisms (Atal *et al.*, 1981).

Components of the long pepper fruits have been shown to exert a significant level of protection against liver toxicity induced by tert-butyl-hydroperoxide and carbon tetrachloride by reducing *in vitro* and *in vivo* lipid peroxidation by decreasing the reduction of GSH (Koul and Kapil, 1993; Treadway, 1998).

Rasa (taste) is katu (pungent), Virya (energy) is ushna (hot) and Vipak (post digestive action) is madhura (sweet). The berries are a cardiac stimulant, carminative, tonic, laxative, digestive, stomachic and antiseptic. It is a mild diuretic, alterative,

hepatic and expectorant. The fruit contains volatile oil, starch, protein, alkaloids-piperine and piperlongumine, saponins and lignans. Pippali, like its relative Black pepper, is a powerful stimulant for the digestive and respiratory systems. It is strongly healing, removes colds, congestion and toxins and revives weak organ functions.

In an Indian study published in 1999, *Piper longum* was tested for its efficacy against experimental infection of *Giardia lamblia* in mice. *Piper longum* possessed a demonstrable immunostimulatory activity, both specific and non-specific. In another study, piperine, an active alkaloidal constituent of *Piper longum* was evaluated for its anti-hepatotoxic potential in order to validate its use in traditional therapeutic formulations. The alkaloid exerted a significant protection against tert-butyl hydroperoxide and carbon tetrachloride hepatotoxicity by reducing both *in vitro* and *in vivo* lipid peroxidation and by reducing the depletion of glutathione and total thiols. (Tripathi *et al.*, 1999). In an analogous way to the digestive tract delivering nutrients, air passages deliver the most important nutrient of all – oxygen. In fact, the main Ayurvedic formula for better delivery of nutrients at the gastrointestinal level is used in bronchopulmonary conditions as well.

Piper longum, traditionally known in Sanskrit as Pippali, has been used in Ayurveda and related Unani medicine in the prevention and treatment of bronchial asthma. In a study involving 20 children, five to twelve years old, suffering from bronchial asthma with confirmed sensitivity to house dust mite (HDM), long pepper fruits were administered in form of 150 mg (children five years old or younger) or 250 mg (children five to twelve years old) capsules for five weeks (week 1, one capsule a day, week 2, two, week 3, three, week 4, two, week five, one). At the end of five weeks all patients showed significant clinical improvement as assessed by the pulmonary functions tests and decrease in frequency and severity of asthma attacks and decreased sensitivity to HDM skin test. The FVC, FEV1 and MMEFR values were significantly ($p < 0.05$) increased: 1.2253 (before treatment)/1.5123(after); 852.17/1061; 48.88/73.38 respectively. The follow-up of the patients' status after one year found 11 patients with no recurrence of asthma attacks. *Piper longum* contains a minimum of 1% of alkaloid piperine, however, other yet to be identified components may be responsible for the therapeutic action in patients with asthma. (Muhammed and Vladimir 1997).

The dried spikes are thermogenic, carminative (cures flatulence), expectorant, drives off fever, laxative, digestive, antiseptic and tonic. Pippali finds usage in anorexia, indigestion, flatulence, cold, cough, bronchitis, and hiccups, fevers and stomach disorders. The root of long pepper is also attributed with several medicinal properties. The extract is used in cough syrups and as a counter-irritant in analgesics and for all other ailments where fruits are used.

Antiallergic activity of the fruit has been studied. It effectively reduced passive cutaneous anaphylaxis in rats and protected guinea pigs against antigen-induced bronchospasm; a 30% protection of mast cells was observed in an *in-vitro* study (Dahanukar *et al.*, 1984). Both alcoholic extract and piplartine extracted from the stems showed significant inhibition of ciliary movements of oesophagus of frog (Banga *et al.*, 1964). Piperine decreased the rate and amplitude of respiration and showed nonspecific blockade of acetylcholine, histamine and 5-hydroxytryptamine induced spasm on isolated guinea pig and rabbit intestine (Neogi *et al.*, 1971). The oil of fruit has been found to possess significant paralytic action on the nerve-muscle pre-paration of A. lumbricoides (D'Cruz *et al.*, 1980). The hepatoprotective effect has been shown in carbon tetrachloride-induced liver damage in rats (Rege *et al.*, 1984). A common use of the fruit is in the prevention of recurrent attacks of bronchial asthma (Pandeya, 1983).

Another important indication is in chronic malaria (Gogate, 1983). In a study of 240 children treated long-term with fruit 58.3% had decreased severity of attacks (Athavale, 1980). In another study 20 children were studied for one year with the same treatment. Eleven had no recurrence. All patients had a strongly positive skin test which became negative in six and decreased significantly in 12 after five weeks of treatment. Along with *Piper nigrum* and *C. officinale* it has been useful in viral hepatitis (Dahanukar and Karandikar, 1984).

25.3.1 Contraindication

Piper longum has been in widespread use for many centuries. The standard doses are well tolerated. No mortality was observed with the powder of the fruit boiled in milk and water administered orally to albino rats in a dose of 1 gm/kg. Acute toxicity studies with piperine, piperlongumine and piperlonguminine were carried out in mice, rats and dogs using oral and intraperitoneal routes. In mice, oral LD (50) was 56.2 + 8.0, 110.1 + 7.8 and 115.3 + 9.5 mg/kg with piperine, piper-lonigumine and piperlonguminine respectively (Singh *et al.*, 1973).

25.4 Cultivation

Long pepper is successfully cultivated in well-drained forest soils rich in organic matter. Laterite soils with high organic matter content and moisture holding capacity are also suitable for cultivation. Areas with high rainfall and high humidity with an elevation of 100–1000 m are ideal. It grows well under semi-shady conditions (25–50% shade) in irrigated coconut gardens.

In some hilly parts of Vishakapatnam district of Andhra Pradesh, long pepper is grown for its roots. It is grown as a perennial in small plots of 25–50% and the roots are collected for 10–30 years, the first harvest commencing from 18 months after planting. The stems close to the ground are cut and the roots dug up, cleaned and heaped in shade for a day, after which they are cut into pieces of 2.5–5 cm long. On an average 500 kg of roots are obtained per hectare (Parthasarathy and Narasimha Rao, 1954)

25.4.1 Varieties and cultivars

Viswam is the only released variety in the country so far. The variety was developed by Kerala Agricultural University, Thrissur, India, through clonal selection. It was recommended to grow as an intercrop in irrigated coconut and arecanut gardens. It has a prolonged flowering phase and bears stout, short and thick fruits. Unripened mature fruits are blackish green. The variety gives economic yield for about 240–270 days in a year. Fruits contain about 20% dry matter and 2.83% alkaloid.

25.4.2 Soil and climate

It is grown in the natural habitat and indigenous to wet and warmer parts of India and requires partial shade for ideal growth. It is cultivated as a rainfed crop in Assam and

Meghalaya and as an irrigated crop in other parts. The crop thrives in a variety of soils – fertile forest soil rich in organic matter, laterite soils with high organic matter content and water-holding capacity, limestone soil and well drained fertile black cotton soil. However, light, porous and well drained soil rich in organic content is most suitable for its cultivation. It requires high humidity, high rainfall or frequent irrigation and partial shade for good growth and can be cultivated up to 1000 m elevation.

25.4.3 Planting material

Propagation is through vine cuttings mainly by layering of mature branches or by suckers. Three to five noded cuttings, 15–20 cm long with three 5 cm nodes, taken from any part of the stem, serve as planting material. However, terminal shoots are usually used for planting. The cuttings can be easily rooted in pot mixture and planted in polythene bags or in nursery beds and irrigated on alternate days. Rooting takes about 15–20 days after planting. The rooted cuttings will be ready for transplanting in two months; 100% establishment of cuttings can be observed. March–April is the best time for raising the nursery. Cuttings can be directly planted in the field at the beginning of the rainy season or rooting can be initiated in the nursery before they are transplanted in the field. Mealy bugs attack the roots in the nursery. Spraying or drenching Aldrin 10% reduces Mealy bug attack (Philip *et al.*, 1991; Satyabrata Maiti and Presanna Kumari).

25.4.4 Land preparation and planting

With the onset of the monsoon in June, the field is ploughed well, levelled considering the slope of land to facilitate drainage of excess of water, and raised beds of convenient length and breadth are taken. On these beds, pits are dug at 60 × 60 cm spacing and well-decomposed organic manure at the rate of 100 g/pit is applied and mixed with soil. Rooted vine cuttings or suckers (two/pit) are then transplanted to these pits. The plant will trail on the ground or it can be staked for better yields. The crop cannot survive in waterlogged conditions. Hard wood cuttings of *Sesbania grandiflora* or *Erythrina varigata* or both are planted near the sprouted cuttings of long pepper for providing support and shade. In south India, it is also successfully cultivated as an intercrop in irrigated coconut and arecanut gardens.

25.4.5 Manuring and intercultural operations

Piper longum requires heavy organic manuring (20–25 tonnes of farmyard manure/ha/year) as split application will give a good yield during the economic period of three years. During the first year, organic manure can be applied in pits at the time of planting. In subsequent years, manuring is done by spreading in beds and covering with soil. Crop growth and spike production increases by the application of wood ash. There is no report so far about the use of inorganic fertilizers. No chemical fertilizer has been recommended so far for this crop. A study conducted at Kerala Agricultural University to find out the optimum spacing and manorial recommendation revealed that plant height, number of branches, number of leaves and total dry matter increased with a high dose of organic manure and 30:30:60 kg NPK/ha with an optimum spacing of 50 × 50 cm. In soils with low fertility the growth of the plant is very poor.

Regular interculture operations can be done as and when weeds grow in beds during the first year. Generally two or three weedings are sufficient. When the crop covers the broad interspaces at the time of manuring the weeds can be removed and manure can be spread in beds and earthed up. The crop should be irrigated during summer months once a week.

25.4.6 Irrigation

It is reported that an unirrigated crop after the onset of monsoon grows vigorously and shows more hardiness than the irrigated crop. But irrigation is most essential during summer months. One or two irrigations a week, depending upon the water-holding capacity of the soil, is needed. Even in the monsoon period, if there is a failure of rain for quite some time, irrigation needs to be given. In irrigated crops, fruit production continues even in summer months.

25.4.7 Diseases and pests

Bordeaux mixture can be applied in pits at time of field planting. Diseases reported are rotting of vine and leaves due to *Colletotrichum* during monsoon season and Necrotic spot and blight of leaves by *Colletotrichum* and *Cercospora* in summer months which sometime cause total or partial crop loss. This can be controlled by Bordeaux mixture (1%) spray during May and subsequently during rainy season. The crop is also affected by mealy bugs especially during summer. The mealy bug infected root of the crop shows stunted growth and yellowing. The insect attacks the healthy roots and sucks its sap. Application of systemic insecticides like Rogar, Nuvacron or Dimecron is recommended. Severe attack of *Helopeltis theivora* is also reported by feeding on tender foliage. Application of neem kernel suspension at 0.25% is recommended for controlling it. *Phytophthora* leaf and stem rot and anthracnose are important diseases of long pepper. Spraying of 0.5% Bordeaux mixture at 15 day intervals and soil drenching of 1.0% Bordeaux mixture at monthly intervals reduce the loss caused by these diseases effectively.

25.4.8 Harvesting

The vines start flowering six months after planting and flowers are produced almost throughout the year. The spikes are harvested, two months after flowering, when they are full-grown but yet unripe, as it is the most pungent stage, and are sun dried. If left without picking they ripen and their pungency is lost to a great extent. Harvesting over-matured or ripened fruits also reduces the quality of the produce and it does not break easily after full drying. Indian long pepper is usually cultivated as a four- to five-year crop as yield starts declining and gradually becomes uneconomic after the fifth year and should be replaced. In such cases fruits, roots and thicker basal stem portions are also collected before crop is abandoned. Stems and roots are cleaned, cut into cylindrical pieces of 2.5–5 cm length and 0.5–2.5 mm thickness, dried in shade and marketed as piplamool. This is not the case with other species (*Piper retrofractum* and *P. peepuloides*) of climbing long peppers which continue to give increased yields even after 15 years. The yield of pipalmul is much higher in these species depending on the year of harvesting.

25.4.9 Post harvesting operation

Harvested spikes are repeatedly exposed in the sun for four to five days until they are perfectly dry. The green spike to dry spike ratio is around 10:1.5. The dried spikes have to be stored in moisture-proof containers. Produce should not be stored for more than a year. Thicker parts of stems and roots are cut and dried for making piplamool and graded depending on the size of roots and stems (Parthasarathy and Narasimha Rao, 1954).

25.4.10 Yield

In Kerala, three to four pickings are made depending upon the maturity of the fruits. The yield of dry spike is 400 kg/ha during the first year when irrigated, increases to 1.0 to 1.25 t/ha in subsequent years and decreases thereafter. Rain-fed crop has a shorter flush of fruiting, resulting in reduced yield. Average yield is 500 kg dry roots/ha. Stems and roots are cleaned, cut into cylindrical pieces of 2.5–5 cm length and 0.5–2.5 mm thickness, dried in shade and marketed as piplamool. The market for medicinal plants is volatile and the economics may vary from year to year.

25.5 Quality specifications

There are three grades of *Piplamul*, Grade I with thick roots and underground stems fetching a higher price than Grade II or III, which comprise either thin roots, stems or broken fragments. Commercial drugs consist almost entirely of transversely cut pieces (length 5–25 mm, diam. 2–7 mm), which are cylindrical, straight or slightly curved, and some with distinct, swollen internodes showing a number of leaf and rootlet scars. Surface of the pieces is dirty light brown in colour.

25.6 Biotechnology

According to the World Health Organization 80% of the world population is dependent upon medicinal plants for primary health care, particularly in the developing economies where local communities are offered immediate access to safe and effective products so as to treat ill health through self medication (Akerele 1992). The popularity of traditional health care in most parts of the world has created a tremendous demand for medicinal plants, which are still collected from their natural habitats leading to their depletion and finally extinction. Medicinal and aromatic plants need to be multiplied faster to meet the demand, with minimum loss to their natural habitats. Micro-propagation technology for fast multiplication of required planting material could be very useful. The advent of molecular biology, gene technology and cell biology has helped understand diseases on the molecular/gene level. Novel target-directed screening assay, automation and miniaturization have resulted in high throughput screening (HTS) approaches thereby improving the industrial drug discovery process drastically (Grabley and Thiericke 1999). Moreoever, *in vitro* gene banks can play a very crucial role in providing the feedstock for this revolution.

Protocols were standardized for rapid clonal multiplication of *Piper longum* and *P. chaba* from shoot tip explants (Sarasan *et al.*, 1993; Nirmal Babu *et al.*, 1994).

Conversion of root meristem into shoot meristem and its subsequent development to plantlets was reported in *P. longum* (Nirmal Babu *et al.*, 1993b). Plants were regenerated from leaf and stem explants of *Piper longum*, *P. chaba*, through direct and indirect organogenesis (Bhat *et al.*, 1992, 1995; Sarasan *et al.*, 1993). In *P. longum*, root explants were directly regenerated into plantlets (Nirmal Babu *et al.*, 1993a).

Piper longum and *P. chaba* could be successfully micropropagated on McCown's Woody Plant Medium (WPM) supplemented with BAP and kinetin. WPM with 3 mgl^{-1} BAP and 1 mgl^{-1} kinetin was found to be ideal for shoot regeneration and their subsequent growth from both leaf and stem explants either with or without intervening callus phase in both the species. Within another 20–30 days, organogenesis in the form of numerous (10–100) shoot primordials could be obtained and over 40% of these primordials showed good elongation and continued normal development. These shoots developed good root systems when growth regulators were removed from the culture medium. When these rooted plantlets were grown in culture medium with 3 mgl^{-1} BAP and 1 mgl^{-1} kinetin there was conversion of root meristem to shoot meristem, which subsequently developed into shoots and then plantlets. Over 90% of the regenerated plantlets could be easily established in soil (Nirmal Babu *et al.*, 1993a,b; 1994; 1997; 1999; 2000).

Shoot tips could be conserved under minimal growth conditions with yearly subculture in WPM without any growth regulators. The plantlets could be multiplied normally after one year of storage and the rooted plantlets were successfully planted out. This helps in conservation of long pepper genetic resources in *in vitro* gene banks (Nirmal Babu *et al.*, 1999; Peter *et al.*, 2002).

Ajith (1997) used RAPD profiling to study the micropropagated plants of *Piper longum* and reported that they are genetically stable. Nirmal Babu *et al.*, 2000 and Parani *et al.*, (1997) have standardized RAPD fingerprinting for selecting micropropagated plants of *Piper longum* for conservation. Philip *et al.*, (2000) have studied RAPD polymorphism in three different collections of *P. longum*. Banerjee *et al.*, (1999) have developed RAPD markers to identify male and female lines of *P. longum*.

25.7 Future

Long pepper is an important medicinal plant used in many drugs and medicinal formulations. There is tremendous demand for commercial long pepper and pipalmul. In India, most of the long pepper is still collected from the wild leading to destruction of these populations in their natural habitats. It is important to encourage commercial cultivation on a larger scale to ensure a continous supply of genuine raw material. Adequate availability of planting material is also a limiting factor for commercial cultivation. Micropropagation supplemented with vegetative propagation can meet these lacunae. The pricing of medicinal plants is highly volatile due to unorganized marketing, discouraging farmers to take up cultivation of medicinal plants on a larger scale. A properly regulated market with guaranteed pricing would help in popularization and cultivation of these important plants.

Identifying genotypes which contain high amounts of the required drug/alkaloid is another area which needs intensified research. It is known that the environment adversely affects the quality parameters of many medicinal plants. Information on suitable soil nutrient and water requirements need to be generated for producing

high-quality products suitable for the pharmaceutical industry. Though some information is available, clinical validation of drugs from long pepper and identification of the new drugs are important areas, which need intensified research.

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