Chapter 15
Cultivation and Utilization of *Pandanus odorifer* for Industrial Application

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Abstract *Pandanus odorifer* (Forssk.) Kuntze (Kewda) is an industrially important aromatic plant currently having huge demand for the unique fragrance possessed by its essential oil. Phenyl ethyl methyl ether is the major component which imparts this exquisite odour to the kewda male flower essential oil. This distinctive aroma instigates its extensive usage in the cosmetic, pharmaceuticals and flavour and fragrance industries. Almost every part of the plant (flower, stem, root, leaves) possess numerous pharmacological and ethnic utilities. The plant propagation using elite genetic material is therefore imperative to produce improved quality kewda plants to meet the global need. The accelerated demand of kewda perfumes has resulted in a hike in the price of kewda oil. Hence, the farmers require its large-scale cultivation mainly in the coastal and sub-coastal regions. The present chapter focuses on the botanical, phytochemical, pharmacological, agronomical and biotechnological aspects of *Pandanus odorifer*. This comprehensive information will conclusively allow better utilization of this industrially important plant for various industrial uses and improve the socio-economic growth of low-income coastal villagers.

Keywords *Pandanus odorifer* · Essential oil · Perfume · Chemotype · Genotype · Pharmacology · Aromatic plant · Flavour and fragrance industry

15.1 Introduction

Since ancient times plants have been an exorbitant source of natural products and have been widely used to treat various health-related disorders; natural products include numerous pharmaceutical compounds, colouring agents, dyes, and aromatic essential oils. The essential oils are the secondary metabolites stored in the glandular trichomes or cavities and provide a defence system to the plant against herbivores (Glas et al. 2012). Several aromatic plants have been identified and explored for their therapeutic essential oils which are used extensively in the flavor and fragrance

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industry as well as the pharmaceutical industries (Mohanty et al. 2017; Stringaro et al. 2018; Hanif et al. 2019; Manilal et al. 2020). About 90% of the essential oil is consumed by the flavour and fragrance industry in the production of perfumes, cosmetics, food flavouring agents and other healthcare products (Swamy and Sinniah 2016).

Pandanus odorifer (Forssk.) Kuntze (kewda) is a perennial evergreen dioecious monocotyledonous aromatic plant native to South Asia (Nadaf and Zanan 2012; Solomon Raju and Lakshminarayana 2020). The plant sees flowering during the rainy season and is highly valued for its fragrant male flowers. The essential oil from the male flowers is isolated by the hydro-distillation method, which possesses a unique fragrance (Nasim et al. 2018). The phytochemical analysis of kewda essential oil has revealed phenyl ethyl methyl ether (PEME) as the major component that imparts the characteristic smell to the oil (Naqvi and Mandal 1996). Very limited reports are available for the GC-MS analysis to identify the phytochemical composition of kewda flower essential oil (Naqvi and Mandal 1996; Misra et al. 2000; Raina et al. 2004; Nasim et al. 2017a, 2018). Because of its distinct aroma, of kewda oil has a massive demand in pharmaceutical, cosmetic and flavour and fragrance industry.

15.1.1 Botanical Description

15.1.1.1 Taxonomic Position

Pandanus odorifer (Forssk.) Kuntze (kewda) belongs to an ancient family Pandanaceae (Gallaher et al. 2015). The taxonomic classification of *Pandanus odoriferis* as follows:

Kingdom	Plantae
Division	Angiospermae
Class	Monocotyledons
Order	Pandanales
Family	Pandanaceae
Genus	Pandanus
Species	*Pandanus odorifer*

The name Pandanus was derived from a Malayan vernacular name of the trees, "pandan" in 1743 by Rumphius (John 1960). In India, the genus is represented by 30–40 species, which are not well defined (Kirtikar et al. 1991). Among these, *P. odorifer* is a dominant species found mainly in Odisha's coastal regions (Nasim et al. 2017a). Commonly known as kewda, the plant has various synonyms (Table 15.1).

15.1.1.2 Morphological Description

The plant has a palm-like appearance, usually growing to a height of 3–5 m (Fig. 15.1A, B). The kewda leaves are deep green, glaucous, oblong, ensiform with coriaceous margins and tapering with spiny midribs, arranged spirally on the branches and measure 1–3 m long and 5–6 cm broad (Fig. 15.1C). The plant is dioecious with unisexual flowers. Male flowers appear as clusters with androecia having a unique fragrance and are surrounded by tender white bracts (Fig. 15.1 D). The male spadix is 25–50 cm in length and has numerous subsessile cylindrical spikes, which are 5–10 cm long (Padhy et al. 2016). The female flowers lack any fragrance and look like a pineapple. The female inflorescence consists of a single spadix (5 cm in diameter) and gynoecia without perianth and is made up of lots of carpels (Padhy et al. 2016). The male flowers last only a single day. The fruits of this plant are odourless with 15–25 cm width and are ellipsoid, ovoid, globose or subglobose. Unripen fruits are green, whereas mature fruits are yellow/red (Jose et al. 2016; Padhy et al. 2016). It has greyish- or reddish-brown smooth barks. Braches and stems are ringed with distinct leaf scars (Lim 2012). It has a spinous trunk (12–25 cm across) with the thick and strong prop or adventitious stilt roots that arise from the stems (Fig. 15.1E) (Panda et al. 2009). Ecologically, the plant has been reported to bear immense potential in its intricate root system, and thereby controlling soil erosion, fixing sand dunes and protecting from damage caused by tsunami (Tanaka et al. 2011; Thuy et al. 2018).

Table 15.1 Synonyms of *Pandanus odorifer*

Botanical	*Pandanus fascicularis Lam*
	Pandanus odoratissimus L.f
	Pandanus tectorius
English	Screwpine
	Umbrella tree,
Hindi	*Kewda*
	Kewra
Sanskrit	*Ketaka*
Urdu	*Keora*
Odiya	*Kiya*
	Ketki
Malayalam	Kaitha
Tamil	Kaida
Thai	Ka-Ra-Ket

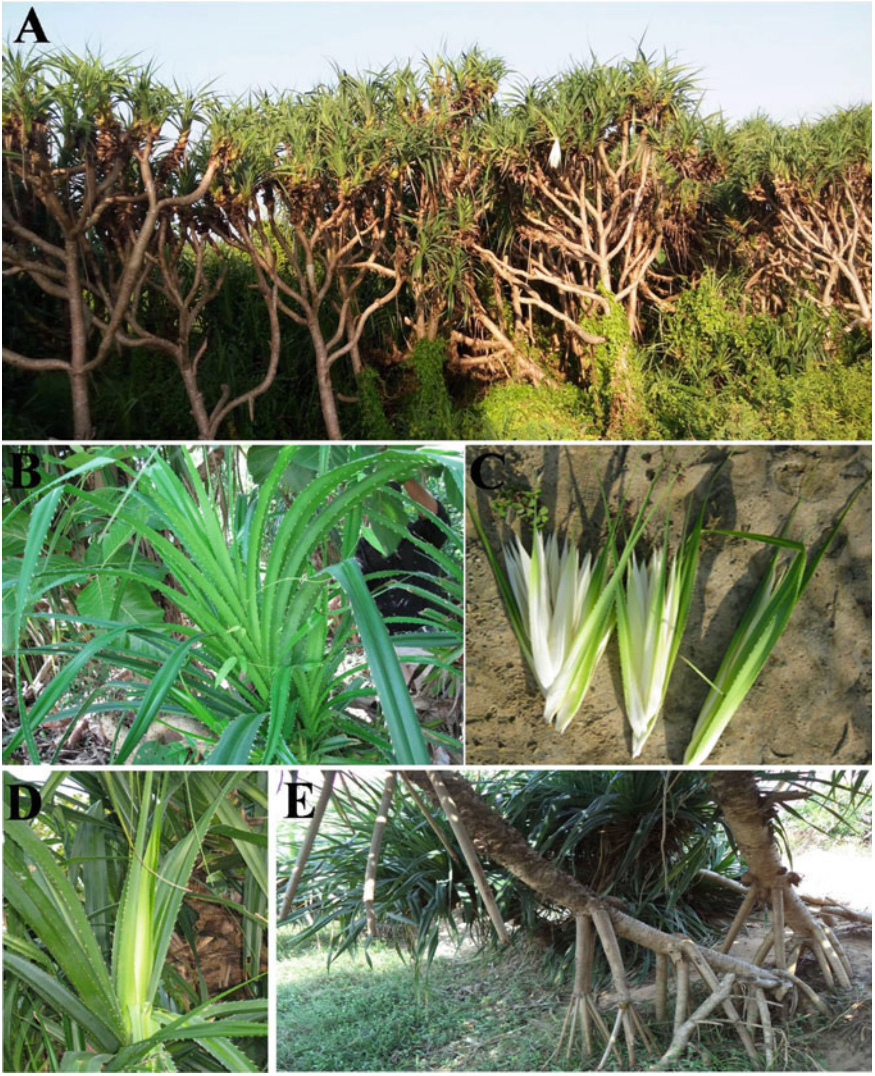

Fig. 15.1 Dense kewda plantation in Ganjam district of Odisha, (B) kewda plant, (C) kewda male flowers, (D) kewda spiny leaves, (E) stilt/prop roots of kewda

15.1.2 Industrial Importance of Pandanus Odorifer (Kewda)

Pandanus odorifer (kewda) is an industrially important essential oil-bearing plant with high priced flower essential oil. Economically, it is an important natural bio-resource for the perfumery industry due to its unique fragrance (Panda et al. 2009).

The characteristic smell of the male flowers owes their application to the manufacturing of various perfumery products through hydro-distillation. Three types of end products are produced from the hydro-distilled kewda flowers, i.e. kewda oil, kewda attar and kewda water. Kewda oil has substantial demand in the perfumery industry, whereas kewda attar and kewda water are predominantly used for flavouring purposes in the food and cosmetic industry (Panda et al. 2012).Ganjam district of Odisha has been reported to have a superior quality of kewda essence (Raina et al. 2004). Hence, it provides 85–90% of kewda essence in India and about 50% of the world with an approximate turnover of Rs. Fifty crores (Padhy et al. 2016). The kewda products have seen an upsurge in their price due to the prompt demand of kewda perfume in the national and international markets, especially in the Arab countries (Sahu and Misra 2007). Kewda essential oil is approximately priced to be 2.5 to 4 lakh per litre, kewda attar is 0.2 lakh per litre and kewda water is Rs 300 per litre (Padhy et al. 2016).

Pandanus odorifer plant parts have multipurpose industrial applications and a broad ethnic value. Though the male flowers are extensively used for perfumery production, they also have broad pharmaceutical properties. Other plant parts such as leaves, roots and fruits are also employed in the food, fibre, handcraft and pharmaceutical industries. Kewda leaves are rigid and spiny and often used as fences across the crop fields to protect them from livestock. The low-income coastal villagers also use them in making various handicraft products such as ropes, mats, baskets, table lamps, files and wall hangings. (Abral et al. 2012; Teli and Jadhav 2017). The leaf extracts are also used for food colouring purposes. In Sri Lanka, the leaves are used for cooking (Takeda et al. 2008). The pulp and polyester composites of the leaves are used in the paper and fibre industry. The fibre obtained from *P. odorifer* leaves also has excellent potential for being used as a textile and composite material. The thick and strong prop roots are used as supports and fabrication of houses. The spinous trunks of mature plants are used in building thatched roof. It is also used for preparing glue and making string. The branches are used to make compost and wood fuel. In India and Sri Lanka, the flowers are used for decoration and are offered to God. Fruits are used as firewood and foodstuff (Nadaf and Zanan 2012; Baba et al. 2016).

Hence, cultivation practice and the marketing of kewda products have become an additional source of income for the deprived coastal villagers, resulting in their socio-economic growth. Thus, the plant has become an essential bio-resource with a positive impact on the local economy of Ganjam district, Odisha, India (Panda et al. 2007; Panda et al. 2009; Panda et al. 2010b; Jose et al. 2016).

15.2 Geographic Distribution

15.2.1 Origin

Pandanus is a pleiotropic genus, belonging to an ancient family Pandanaceae, representing dioecious monocotyledons having Gondwanan origin (Gallaher et al. 2015). Among all the genera of the Pandanaceae family, Pandanus is the largest genus and has the broadest geographical distribution with immense economic and medicinal importance (Buerki et al. 2012). The diversity of habitats included by the genus occupies the tropical and sub-tropical zones, riversides, rocky or sandy coasts, swamp forests, mangrove forests, savannas, lowland dipterocarp forest and mountain forest (Susanti et al. 2012).

15.2.2 Distribution

In India, Pandanaceae family represents about 30–40 species under three genera *Pandanus, Benstonea* and *Freycinetia* (Table 15.2). *Pandanus odorifer* is an important member of the genus *Pandanus* with a higher concentration in Andaman and Nicobar Islands and Northern and Southern India. It is an aromatic monocot species, native to Australia, Indonesia, South Asia and Philippines. It is widely distributed in South America, Micronesia, Papua New Guinea, Melanesia, Polynesia, India and Pacific Islands (Nadaf and Zanan 2012; Adkar et al. 2014; Nasim et al. 2020). In India, it is massively distributed in the Western Ghats zone and the coastal zone of Odisha, Kerala, Tamil Nadu, West Bengal, Andhra Pradesh, Gujarat and Uttar Pradesh (Padhy et al. 2016; Nasim et al. 2017a). In Odisha, the plant is found in Ganjam, Cuttack, Khorda, Jagatsinghpur, Bhadark, Puri and Balasore. Although the plant covers the entire coast of Odisha, the Ganjam district is the only growth centre where the plant is cultivated for commercial purposes (Nasim et al. 2017a).

15.3 Brief Phytochemistry

Aromatic plants have a wide range of chemical components that seeks the attention of pharmaceutical industries. A large number of phytoconstituents have been identified in the flower essential oil of *Pandanus odorifer*. The available reports showed a diverse chemical profile with a broad range of chemical constituents with a wide range of volatility, including ethers, esters, aldehydes, alcohol, ketones, acids, sulphur and nitrogen-containing compounds. The major constituent identified in the kewda oil was 2-phenylethyl methyl ether (75.0%) which is the key component responsible for the distinct aroma of kewda (Naqvi and Mandal 1996). Terpinen-4-ol (15.2%)

Table 15.2 Distribution of some Indian *Pandanus* species

	Species	Distribution	References
1	*Pandanus odorifer*	Odisha, Andhra Pradesh, Kerala, Tamil Nadu, West Bengal, Uttar Pradesh, Gujarat	Nasim et al. (2020)
2	*Pandanus kaida*	Goa, Karnataka, Kerala, Tamil Nadu, Odisha,	Nadaf and Zanan (2012)
3	*Pandanus furcatus*	Maharashtra, Goa, Karnataka and Kerala	Zanan and Nadaf (2013)
4	*Pandanus thwaitesii*	Goa, Karnataka, Kerala, Maharashtra	Zanan and Nadaf (2011)
5	*Pandanus canaranus*	Goa, Karnataka, Kerala, Maharashtra	Zanan and Nadaf (2011)
6	*Pandanus dubius*	Kerala and Karnataka	Zanan and Nadaf (2013)
7	*Pandanus amaryllifolius*	Gujarat, Maharashtra, Goa, Karnataka, Kerala, Tamil Nadu, Orissa, and West Bengal	Wakte et al. (2012)
8	*Pandanus emarginatus*	Arunachal Pradesh	Nadaf and Zanan (2012a)
9	*Pandanus leram*	Andaman and Nicobar Islands	Nadaf and Zanan (2013)
10	*Pandanus nepalensis*	WB, Sikkim	Nadaf and Zanan (2013)
11	*Pandanus unguifer*	WB, Sikkim	Nadaf and Zanan (2013)
12	*Pandanus palakkadensis*	Palakkad, Kerala state	Nadaf et al. (2011)
13	*Pandanus mangalorensis*	Mangalore district, Karnataka state	Zanan and Nadaf (2012a)
14	*Pandanus martinianus*	Arunachal Pradesh, Assam	Zanan and Nadaf (2012b)
15	*Pandanus foetidus*	Kerala, Karnataka, Goa	Zanan and Nadaf (2011)
16	*Pandanus diversus*	Assam	Nadaf and Zanan (2012)
17	*Pandanus unipapillatus*	Maharashtra, Goa, Karnataka, Kerala	Nadaf and Zanan (2013)

was reported as the second major constituent for the first time by Naqvi and Mandal (1996). Raina et al. (2004) reported 2-phenyl ethyl methyl ether (37.7%), terpinen-4-ol (18.6%), α-terpineol (8.3%) and 2-phenyl ethyl alcohol (7.5%) as the dominating phyto-compounds in the hydro-distilled kewda flower oil obtained from Ganjam district of Odisha. The study also reported a comparative analysis of hydro-distilled kewda oil with oil purchased from the local market. Market kewda oil was reported to have 2-phenyl ethyl alcohol (33.2%) as the major compound followed by 2-phenyl ethyl methyl ether (16.1%), benzyl benzoate (11.0%), viridine (8.8%) and germacrene B (8.3%) (Raina et al. 2004). GC and GC-MS analysis of the kewda flower extract was reported by Rout et al. (2005). Rout et al. (2011) reported the chemical composition of the extract obtained by liquid CO_2 extraction of the kewda flowers. The above studies show the better quality of kewda essential oil from Ganjam district, but there was unpredictability for the oil quality from different zones of Ganjam.

In this context, a study was done by collecting kewda oil from twelve different zones of Ganjam district (Rushikulya River Bank, Kalipalli, Keluapalli, Markandi, Indrakhi, Mantridi, Kaliabali, Basanaputty, Chamakhandi, Podapadar, Chilika and Tampara) and GC-MS analysis was done. The study reported the PEME to be the major constituent highest in Rushikulya River Bank (81.86%) and lowest in Mantridi (58.03%). The second major compound reported was terpinen-4-ol (7.81–21.46%) (Nasim et al. 2018). The study also reported the role of soil factors for secondary metabolites of kewda. Among the five analysed parameters, i.e., soil pH, soil nitrogen (N), organic carbon (OC), potassium (K) and phosphorous (P), N was found to be the most influential factor for kewda oil yield and PEME content followed by OC, pH, P and K (Nasim et al. 2018). For a more detailed characterization of the volatile constituents present in kewda oil, GCxGC-TOFMS analysis was also done. The study identified 159 chemical compounds in kewda oil out of which kewda ether, *ortho*-cymene and terpinen-4-ol were the predominant constituents (Nasim et al. 2017a). The structures of some of the major chemical components found in kewda essential oil are shown in Fig. 15.2.

Other than *Pandanus odorifer*, very few reports are available on other *Pandanus* species (Table 15.3). MacLeod and Pieris (1982) analysed the essential oil of *Pandanus latifolius* leaves and reported the presence of mainly sesquiterpene hydrocarbons, and the only monoterpene that was reported was linalool. The chemical profile of the red fruit oil from *Pandanus conoideus* showed the presence of 1, 3-dimethylbenzene (27.46%), N-glycyl- L-alanine (17.36%), trichloromethane (15.22%) and ethane (11.43%) (Rohman et al. 2012). *Pandanus amaryllifolius* leaf oil

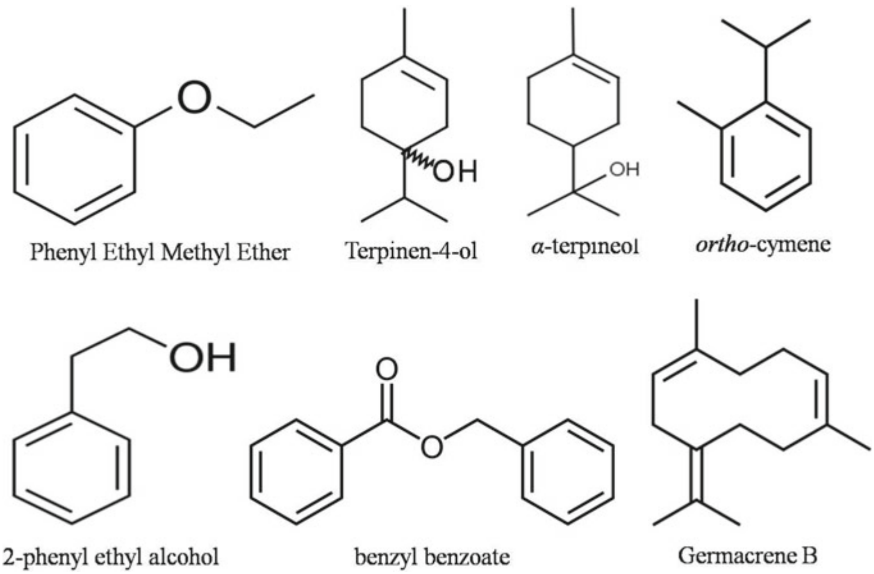

Fig. 15.2 Structures of chemical compounds found in *Pandanus odorifer* male flowers essential oil

Table 15.3 Analysis of essential oil constituents in different *Pandanus* species

S.No.	Pandanus species	Origin	Major constituents	Plant part	Analysis	References
1	*Pandanus latifolius*	Sri Lanka	Linalool (5.7%), beta-selinene (24.3%), beta-caryophyllene (10.8%), styrene (12%), formylthiophen (14.9%), 1,2 dimethoxybenzene (2.9%), beta-farnesene (3.6%)	Leaves	GC–MS	MacLeod and Pieris (1982)
2	*Pandanus conoideus*	Indonesia	1,3-dimethylbenzene (27.46%), N-glycyl- L-alanine (17.36%), trichloromethane (15.2%), and ethane (11.43%)	Fruit	GC–MS	Rohman et al. (2012)
3	*Pandanus amaryllifolius*	Singapore	3-Methyl-2-(5H)-furanone(73.07%),3-hexanol(7.09%), 4-methylpentanol(6.13%), 3-Hexanone (2.97%), 2-hexanone (2.65%)	Leaves	GC–MS	Jiang (1999)
4	*Pandanus tectorius*	Polynesia	Geranyl acetate(27.5%), 3-Methyl-3-buten- 1-yl cinnamate(17.1%), Ethyl cinnamate(10.2%), 3-Methyl-3-buten- 1-yl acetate(10.1%), Cinnamyl acetate(5.2%), 3-Methyl-2-buten- 1-yl acetate(4.7%), 3-Methyl-2-buten- 1-yl cinnamate(4.5%), 2-Phenylethyl acetate(2.9%), Linalool(1.9%), C15H24(1.8%),	Fruit	GC and GC–MS	Vahirua-Lechat et al. (1996)
5	*Pandanus Tectorius*	China	Asarone(26.7%),longipinocarvone(15.2%) and 2-methyl-6-(4-methylphenyl)hept-2-en-4-one(14.8%)	Root	GC and GC–MS	Liu et al. (2012)
6	*Pandanus fasciculuris*	India	2-phenylethyl methyl ether(75%), terpinen-4-ol (15.2%), p-cymene(1.8%), a-pinene(1.6%), sabinene(1.2%), linalool(1.1%), b-pinene(1%)	Flower	GC and GC–MS	Naqvi and Mandal (1996)
7	*Pandanus odoratissimus*	India	2-phenyl ethyl methyl ether (37.7%), terpinen-4-ol (18.6%), α-terpineol (8.3%) and 2-phenyl ethyl alcohol (7.5%),	Flowers	GC and GC–MS	Raina et al. (2004)

(continued)

Table 15.3 (continued)

S.No.	Pandanus species	Origin	Major constituents	Plant part	Analysis	References
8	*Pandanus fascicularis*	India	2-phenyl ethyl methyl ether, terpinen-4-ol and a-terpineol	Flower	GC and GC–MS	Rout et al. (2011)
9	*Pandanus fascicularis*	India	kewda ether, ortho-cymene and terpinen-4-ol	Flower	GCxGC-TOFMS	Nasim et al. (2017a)
10	*Pandanus odorifer*	India	Phenylethyl methyl ether (58.03–81.86%), terpinen-4-ol (7.81–21.46%)	Flower	GC and GC–MS	Nasim et al. (2018)
11	*Pandanus amaryllifolius*	Myanmar	Phytol (21.35%), α-thujaplicin (18.64%), dodecanol (12.55%), n-tetradecanol (8.93%), benzyl acetate (8.08%)	Leaves	GC–MS	Mar et al. (2019)

chemical composition was reported by Jiang (1999). About twenty-two compounds were identified and the major components were 3-methyl-2-(5H)-furanone, 3-hexanol, 4-methylpentanol, 3-exanone and 2-hexanone. Isopentenyl and dimethylallyl acetates and cinnamates were reported as the dominant phytoconstituents in the essential oil of ripe fruit of *Pandanus tectorius* (Vahirua-Lechat et al. 1996). *Pandanus tectorius* root oil was analysed by Liu et al. (2012) and major compounds reported were asarone, longipinocarvone and 2-methyl-6-(4-methylphenyl) hept-2-en-4-one. The leaf extract of *Pandanus odorus* was analysed with GC–MS and α-tocopherol, β-sitosterol, hexadecanoic acid, campesterol, squalene, stigmasterol and 9,12,15-octadecatrien-1-ol were identified as major components by Rahman et al. (1999).

15.4 Medicinal Properties and Usage

Pandanus odorifer has a broad range of pharmacological properties. Different parts of the plant have been used as one of the ingredients in several Ayurvedic formulations (Nasim et al. 2020). In Ayurveda, kewda has been used for treated many human health problems such as indigestion, headache, anorexia, constipation, leprosy and rheumatism. (Udupa et al. 2011). Since ancient times kewda oil has been used for healing skin diseases, small-pox, earache, rheumatoid arthritis, headache, spasms and leprosy and as a laxative for colic infections (Adkar et al. 2014). The fruit is an excellent source of carotenoids and has been used to treat vitamin deficiencies and certain heart-related infections (Lim 2012). As a traditional practice, tablets made up of kewda leaf extracts are used for getting relief from pain and inflammation (Panda et al. 2009). The leaves are also used for curing syphilis, leprosy, leucoderma, scabies and small-pox (Padhy et al. 2016). The plant extract also possesses diuretic and anti-spasmodic properties (Rajeswari et al. 2012).

The biological potencies of *Pandanus odorifer* were reported as anti-inflammatory (Del mundo et al. 2020), anti-oxidant (Londonkar and Kamble 2011), anti-diabetic (Kumari et al. 2012), anti-cancer (Gowtham et al. 2014), anti-bacterial and thrombolytic (Penu et al. 2020), anti-fungal (Rahayu et al. 2013), cardio-protective (Sobhana et al. 2014), cytotoxic activity (Jitu et al. 2017), hepato-protective (El-Shaibany et al. 2016), protective effect on UV-B-induced DNA damage (Kaewklom and Vejaratpimol 2011), anti-stress (Adkar et al. 2014), anti-ulcer (Abirami et al. 2015), neuro-pharmacological activities (Kuber and Santhrani 2010), etc. Comprehensive information regarding pharmaceutical properties present in extracts of different parts of kewda is summarized in Table 15.4.

Table 15.4 Biological activities reported in *Pandanus odorifer*

SI. No.	Activity	Extract	Active constituents	References
1	Anti-ulcer	Aqueous extract of leaves	Steroids, saponin, sterol,alkaloids, quinone, phenol, coumarin, glycosides	Abirami et al. (2015)
2	Anti-convulsant	Ethanol extract of leaves	Glycosides, flavonoids, alkaloids	Adkar et al. (2014)
3	Nocturnal enuresis	Methanolic peduncle extract	Flavonoids and phenolic compounds	El-shaibany (2014)
4	Anti-oxidant, anti-bacterial	Fruits extract	Phenolics, flavonoids, terpenoid, steroids, saponins and glycosides	Londonkar and Kamble (2011); Andriani et al. (2019)
5	Anti-inflammatory	Methanolic and aqueous extracts	Ethyl caffeate and dihydroconiferyl alcohol	Del mundo et al. (2020)
6	Neurobehavioral activity	Ethyl acetate fraction of leaves	Flavonoids	Bhatt and bhatt (2015)
7	Cytotoxic activity	Chloroform extract of fruits	Alkaloids, steroids, terpenoids, flavonoids, tannins, saponins	Jitu et al. (2017)
8	Anti-fertility	Hydroalcoholic leaves extract	Alkaloids, carbohydrates, flavonoids, saponins	Kumar et al. (2017)
9	Anti-microbial	Hydroalcoholic leaf extract	Alkaloids and flavonoids	Kumar et al. (2010)
10	Anti-diabetic	Methanolic extract of aerial roots	Flavonoids and phenolic compounds	Rajeswari et al. (2012)
11	Hepato-protective	Ethanolic extract of roots	Alkaloids, flavonoids, glycosides	Mishra et al. (2015)
12	Analgesis	Aqueous extract of prop roots	Carbohydrates, proteins, aminoacids, saponins, tannins, phenolic compounds, alkalodies and flavonoids	Rajeswari et al. (2011)
13	Anti-cancer	Aqueous extract of roots and leaves	Alkaloids, flavonoids, glycosides and phenolic content	Gowtham et al. (2014)

(continued)

Table 15.4 (continued)

SI. No.	Activity	Extract	Active constituents	References
14	Anti-hyperglycemic	Alcohol and aqueous root extracts	Phenolic compounds, tannins and flavonoids	Madhavan et al. (2008)
15	Anti-nociceptive	Chloroform extract of leaves	Steroids, terpenoids, flavonoids, saponins, tannins	Panda et al. (2008)
16	Wound-healing agent	Chloroform extract of leaves	Steroids, terpenoids, flavonoids, saponins, tannins	Panda et al. (2010b)
17	Anti-fungal activity	Ethanol extract of leaves	Alkaloids and tannins	Rahayu et al. (2013)
18	Anti-diarrheal activity	Methanol extracts of leaf and fruit	Flavonoids, saponins, alkaloids, steroids, terpenes	Rahman et al. (2014)
19	CNS depressant	Methanolic leaf extract	Steroids, saponins, terpenoids, glycosides, tannins, flavonoids and phenolics	Raju et al. (2011)
20	Cardio-protective activity	Hydroalcoholic leaves extracts	Flavonoids, tannins, saponins, proteins, aminoacids, alkaloidsglycosides, phenols, carbohydrates	Sobhana et al. (2014)

15.5 Agro-Technology/Cultivation/Domestication

15.5.1 Vegetative Propagation

Pandanus odorifer propagate by vegetative methods. The adventitious aerial roots and the branch cuttings are used widely for its propagation. About 60–80 cm long and 8–10 cm thick branch cuttings are implanted during the rainy season. The spacing between each plantlet is maintained at 3–7 m apart. It is highly salt-tolerant and can withstand strong winds (Rashmi and Nadaf 2017). The plant is adapted well to light and heavy well-drained soil. It is well acclimatized to saline, sandy and marshy wastelands. Among the different edaphic factors influencing the oil yield and PEME content of the kewda flower essential oil, nitrogen has been reported to be the most influential factor followed up by organic carbon, pH, phosphorous and potassium (Nasim et al. 2018).

15.5.2 Climate

The plant grows abundantly in high rainfall areas and is found profusely in a 45 × 15-km stretch in Ganjam district along the coast of the Bay of Bengal. The flowering starts after 3–4 years of the plantation and the rainy season (July to October) sees the maximum flowers. A mature kewda tress produces about 30–40 flowers spikes yearly. Branching, rainfall and nearness to the water body affect the flowering of the plant. The plant has a life span of 50–80 years which might last up to 100–150 years also. However, the fruiting stage is only for 20–25 years (Adkar et al. 2014).

15.5.3 Crop Nutrition

Nutritionally, the fruit of the plant is rich in provitamin A, vitamin C and total carotenoids. Foods rich in carotenoids are consumed to protect against anaemia, vitamin A deficiency and chronic diseases such as diabetes, cancer and heart diseases (Lim 2012). It is consumed in the form of a paste and contains protein, calcium, iron, thiamine and beta-carotene. The juice is also used in the form of a beverage (Englberger et al. 2009). The fruit seed oil has also been reported to be a promising source for non-edible biodiesel production (Mahlinda et al. 2017).

15.5.4 Diseases and Pests

The senescence of the plant is mainly due to the infection of insect pests such as bagworm, beetles and thrips causing economic losses. Diseases like foot rot of central shoot, leaf blight and fruit rot have also been reported in this plant (Jagadev et al. 2001).Arbuscular mycorrhizal fungi (AMF) association has also been reported in this plant which helps in strengthening the ecological efficacy in coastal regions (Kamble et al. 2013).

15.5.5 Harvesting

Kewda male flowers are the prime source of the essential oil and the harvesting time and extraction procedures of the essential oil play a significant role in maintaining its quality and yield. Depending on the flowering season which occurs thrice a year, the inflorescences are harvested. The male flowers are plucked manually early morning between 7–9 a.m. with the help of a long bamboo stick fitted with a hook and immediately subjected to essential oil extraction. Large quantities of flowers are collected and hydro-distilled by the traditional method of oil extraction employing copper vessel, copper lead and bamboo pipes. It has been reported that delay in the transportation of kewda flowers deteriorates the quality and aroma of kewda oil (Nasim et al. 2017a). This leads to decreased price of the oil and in turn causes a huge loss to the farmers. Hence, harvesting time and the extraction of essential oil have to be a rapid process to maintain the oil quality and quantity, thereby minimizing the loss to the kewda growers (Nasim et al. 2017a).

15.6 Biotechnological Approaches

15.6.1 Overview of Molecular Markers Technologies Employed in Kewda

Plant genetic resources are valuable and irreplaceable resources for current and future crop improvement strategies. Genetic diversity accounts for heritable genetic variability within and among populations of a species and forms the basis for survival, selection, adaptation and plant improvement (Rao and Hodgkin 2002; Laurentin 2009). Molecular markers have been extensively used to study genetic diversity (Agarwal et al. 2008; Omondi et al. 2016). Different types of molecular markers like RAPD, ISSR, AFLP, SSR and SNP have been developed and are being used for crop improvement (Nadeem et al. 2018). These molecular marker techniques can be employed to study genetic diversity within and among the species (Cervera et al. 2000; Zou et al. 2011). In comparison with other marker types, these DNA-based markers techniques can unmask the genetic diversity of almost all species at various developmental stages, remaining unaffected by environmental conditions (Shah et al. 2018). Molecular markers also provide information about the diversity at the nucleotide level (SNPs), population structure, frequencies of gene and allele (genotype information), distribution and range of genetic diversity. Besides, molecular markers can also be used for resolving taxonomic problems and help in providing exact taxonomic hierarchies important for phylogenetic studies (Sarwat et al. 2012). Characterization based on molecular markers is highly reliable and effective in studying variation in different genotypes (Kaur et al. 2015).

To date, there are only a few reports of the utilization of RAPD, ISSR and SSR for assessing genetic diversity in kewda. RAPD profile of three morphotypes (spinous, ketaki and spineless.) of *Pandanus fascicularis* was developed by Panda et al. (2007). Cluster analysis by the UPGMA method from their study resulted in a phylogenetic dendrogram which produced two groups, one separating ketaki morphotype while the second group was separating spinous and spineless morphotype suggesting ketaki as a distinct variety in the Pandanus genus. Panda et al. (2010a) utilized 30 RAPD primers to detect sex differences in *Pandanus tectorius* Parkinson (*P. fascicularis, P. odorifer)* from seven populations of Odisha. Dendrogram from their study divided the seven populations into two distinct groups of male and female plants. AMOVA show 3% molecular variance among populations and ~95% within populations. Molecular markers were also used for differentiating male and female genotypes in *Pandanus fascicularis.* Vinod et al. (2007) developed a male-specific SCAR marker for differentiating the sexes in Pandanus. Another report revealed a considerable amount of polymorphism at the interspecific level and a lower degree of polymorphism at the intraspecific level in the genus Pandanus when analysed by RAPD (Sarile and Menguito 2010). In a more recent study, genetic diversity analysis of *Pandanus odorifer* (Forssk.) Kuntze was carried out by utilizing 13 ISSRs and 30 SSRs (Nasim et al. 2020). A total of 84 accessions from different regions of Ganjam were utilized in the study which revealed SSRs being more effective than ISSR for genetic diversity evaluation in kewda accessions. Further studies in this direction will help in proper identification and characterization of kewda species and the data from genetic diversity analysis can be utilized for kewda improvement to meet its increasing demand in the perfumery industry.

15.6.2 Genomics Aspect of **P. Odorifer**

With the rapid advancement of genomics and transcriptomics, the identification of key genes involved in the synthesis of specialized metabolites in medicinal and aromatic plants has become much faster (Yamazaki et al. 2018). The next-generation sequencing strategies have enabled the researchers to sequence huge and complex genomes of medicinal plants effortlessly. Despite its medicinal and economic importance, there are only limited reports on the exploration of genes associated with *Pandanus odorifer'*s unique fragrance. Vinod et al. (2010) for the first time constructed a male-specific cDNA library in *P. odorifer* and identified specific transcripts involved in PEME biosynthesis. A total of 977 ESTs were generated from their study. Rashmi et al. (2019) utilized integrative transcriptomics and metabolomics approach for the understanding of salinity tolerance in *P. odorifer*. Results from their study revealed the up-regulation of Asparagine (Asn) biosynthesis genes. Higher transcript accumulation of genes, *viz. glutamine synthetase, glutamine synthase, aspartate kinase, pyruvate kinase, aspartate aminotransferase, phosphoenolpyruvate, carboxylase and asparagine synthetase* (AS) was observed under salt stress. Subsequently, the genomic resources generated from these studies will largely benefit our understanding of primary and secondary metabolite pathways and pave the way for metabolite engineering to increase essential oil yield and quality in *P. odorifer*.

15.7 Perspectives

In recent years, medicinal and aromatic plants have gained huge attention due to the stimulated demand from the pharmaceutical, cosmetic and aromatic industries in the local, national and international markets. *Pandanus odorifer* is an economically and industrially important aromatic plant. The exquisite fragrance owned by the kewda male inflorescence has captivated the perfumery industry. Different parts of the plant possess numerous pharmaceutical properties. It is an important natural bio-resource of Ganjam district, Odisha, and provides livelihood to the huge population there. The flower essential oil of kewda is in high demand for kewda perfumes, especially in the national and international markets, especially in the Arab countries.

In spite of so much economic value and numerous pharmaceutical properties in the oil and extracts, the plant still lacks proper exploration in the global market due to restricted plantation and high cost of kewda oil.

Use of elite chemotypes and elite genotypes of kewda is the need of the hour to improve the quality and quantity of kewda, thereby meeting the increased demand of this plant in the perfumery industry. Furthermore, future research is anticipated in developing efficient protocols for in vitro studies for maintaining the bioactive chemical entities naturally present in the essential oil. The plant is vegetatively propagated; hence, the development of different propagation strategies is needed for crop management with improved cultivation practices. Large-scale kewda cultivation can be achieved through the proper application of advanced biotechnological applications to study the genetic variation by various types of molecular markers to improve the quality of kewda cultivars and meet the global market requirement. Also, kewda growers should use high yielding kewda chemotypes as mass planting material and follow the rapid extraction of essential oil immediately after harvesting to improve the quality of different kewda products like kewda attar and kewda water. Different edaphic factors should also be taken care of with balanced nutrient application, weed control, timely planting, micronutrient use and timely harvesting to meet the future market demand.

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