High-Yielding Improved Varieties of Medicinal and Aromatic Crops for Enhanced Income

J. R. Bahl, A. K. Singh, R. K. Lal, and A. K. Gupta

Medicinal and aromatic crops are now being considered as important commercial items for sustainable economic development of the country. To meet the demand of prominent industries producing herbal drugs, pharmaceuticals, cosmetics, nutraceuticals, other confectionary items, etc., it has become imperative to produce the quality raw materials in significant quantities by evolving improved varieties through application of various breeding tools and developing improved agro-technologies and processing technological of the harvested produces. Presently, the medicinal plants and their various products/derivatives are looked upon not only as a source of affordable health care but also as an important commodity item of international trade and commerce. The medicinal plants-related trade is growing rapidly every year, but India's share in the global market is not very impressive (about 2%). This dismal situation warranted to further gear up research and development activities in the area of medicinal plants followed by dissemination of improved plant varieties and agro-technologies among the growers and entrepreneurs.

Wide variations prevailing in agroclimatic conditions in our country provide enough opportunity to grow and harvest such medicinal and aromatic crops in one or the other parts. Availability of improved varieties and agro-technologies developed by various R&D institutions, especially CSIR-CIMAP, has further enabled a large number of farmers to adopt these crops in the existing farming system for additional economic gains (Rahman et al. 2015; Anonymous 2016a). Being comparatively resistant in nature, many of these crops have also emerged as saviour of farmers in present times when production of food and vegetable crops are adversely affected by the change in climate and also due to natural calamities like drought, floods, etc. Several such medicinal and aromatic crops having potential for

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commercial cultivation in different parts of the country and their current status in terms of cultivated area, profitability and marketing are summarized below.

Ashwagandha (*Withania somnifera*)

Roots of Asgandh or Ashwagandha *(Withania somnifera*) are used in traditional system of medicines variously. This shrubby bush plant grows well in dry and subtropical regions, is a potential cash crop for the dry land zones and is also grown for beautifying the wasteland (Fig. 1a). It is cultivated in about 5000 ha area on marginal land in north-western region of Madhya Pradesh. It is also grown in Kota, Jaipur, Jodhpur districts of Rajasthan and Jammu forest. One hectare plantation of Ashwagandha yields on an average 8–10 q of dried roots which are sold at about Rs 10,000 per quintal giving a net return of Rs 75,000 from a 6- to 8-month crop. CIMAP's initiatives in popularizing this important crop in Anantapur district of Andhra Pradesh have shown a new hope of agri-economic development in otherwise dry land area. An annual requirement of dried roots is estimated to be around 7000 tonnes annually, whereas 1500 tonnes are being produced in India.

Poshita The variety Poshita of Ashwagandha developed by CSIR-CIMAP has the potential of producing dry root yield of 14 q/ha with total alkaloids and withanolide content (steroidal lactones) which are the major group of secondary metabolites of medicinal interest containing 1.292 and 3.469 kg/ha, respectively. The fresh and dry leaf yields are also high up to 2.83 and 0.50 q/ha with high withaferin content in dry leaves 0.528%. The variety developed by CSIR-CIMAP is presently grown in about 3000 ha of land due to the continued efforts made by CIMAP Research Centre, Hyderabad, under the institute's rural development programme.

NMITLI-118 The variety NMITLI-118 was developed jointly by CSIR-CIMAP and NBRI and was released in September 2009. The variety has uniform crop canopy, non-spreading plant architecture (more plant/unit area), high root yield and high withanolide yield per unit biomass, and phytochemically uniform and is the first pharmacologically validated variety. It has withanolide A and withanone in roots and high content of withaferin A (up to 2%) and no withanone in leaves. The variety is reported to give dry root yield of about 15 q/ha. Another variety of Ashwagandha named NMITLI-101 was also released in 2015 which has potential to yield up to 23 q dry roots under optimal agronomic conditions (Anonymous 2016b).

Sarpagandha (*Rauvolfia serpentina*)

More than 70 compounds are known in Sarpagandha, *Rauvolfia serpentina*, roots among which the reserpine and rescinnamine are used for control of high blood pressure, whereas ajmaline and ajmalicine are used for cardiac disease under modern

Fig. 1 (**a**) Ashwagandha, *Withania somnifera*; (**b**) Sarpgandha, *Rauvolfia serpentina*; (**c**) Kalmegh, *Andrographis paniculata*; (**d**) Satavar, *Asparagus racemosus*; (**e**) Quinghao, *Artemisia annua*; (**f**) Bhumyamalaki, *Phyllanthus amarus*

system of medicine (allopathy). It is an erect, evergreen 0.60–1.0-m high shrub found growing in the Himalayan region, Meghalaya, Assam, East UP, Bihar, Shimla, Uttaranchal and Southern India (Fig. 1b). Generally, it is being collected from wild, and its uncontrolled collection from wild has led to the inclusion of Sarpagandha in the list of threatened plant species. Its cultivation is on the limited scale and is currently being promoted by different organizations/institutes as the

plant has become rare in most of the accessible areas of its natural occurrence due to over exploitation.

CIM-Sheel To facilitate the quality production of this plant, CSIR-CIMAP has developed an improved variety 'CIM-Sheel' using directed breeding efforts having high root and alkaloid yields with defined reserpine content. CIM-Sheel plants grow up to the height of about 50–100 cm having green erect stem with soft branches and white-pink flowers. The roots go up to the depth of 40–60 cm, which are brittle in nature and bitter in taste with a peculiar smell. The plants raised from seeds give better yield of roots ranging from 100 to 400 gm per plant. Average root yield/ha under irrigated condition from 2-year-old plantation is about 1200 kg, and the roots are sold at about Rs 150/kg, so a grower can get a net return of Rs 150,000 from 1 ha land area.

Kalmegh (*Andrographis paniculata*)

Kalmegh is an important medicinal plant which is employed in Indian traditional system of medicine mostly to cure liver disorders. It is widely distributed throughout the plains of India (Fig. 1c). The plant has astringent, anodyne, antipyretic, anti-inflammatory, immunosuppressive and anthelmintic properties. Recently, its cultivation has been started in India due to efforts made by CSIR-CIMAP and other organizations. Considering its pharmaceutical potential, there is a need to increase its large-scale systematic cultivation in India.

CIM-Megha The variety CIM-Megha developed as seed progeny selection by CSIR-CIMAP consistently produces high herbage with major bitter principles diterpenoids – andrographolide and neo-andrographolides. The average dry herb, andrographolide and neo-andrographolide contents in the variety are 32 q/ha, 2.23%, 0.76%, respectively. A well-maintained crop grown in 1 ha area yields 2.5–3.0 tonnes of dried herb giving a net income of about Rs 45,000 from a 3-month crop.

Satavar (*Asparagus racemosus*)

Tuberous roots or rhizomes of satavar containing saponins and vitamins are highly valued in traditional system of medicine. These are also used as galactagogue and improve body weight and general health. It is estimated that in India, more than 500 tonnes of satavar roots are required every year for medicinal preparations. The cultivation of satavar by the farmers is increasing due to its rising demand in the country (Fig. 1d).

CIM-Shakti CSIR-CIMAP is promoting cultivation of satavar by providing seeds/saplings of the improved variety of 'CIM-Shakti', developed recently. It takes about 18–20 months for the crop to mature. However, better yield can be obtained after

2 years of planting. The crop should be harvested during October and December (dormancy period). On an average, 5–6 tonnes of dried root may be obtained from 1 ha and a net profit of about Rs 350,000 from a 2-year crop.

CIM-Sunehari Recently a new variety of yellow satavar named as CIM-Sunehari has been developed and released by CSIR-CIMAP (Anonymous 2016b). The average dry root yield was found to be 9 tonnes/ha containing 11% saponins in this variety.

Quinghao (*Artemisia annua*)

Artemisia annua, commonly known as quinghao, contains an active compound artemisinin used as antimalarial drug. The demand of this drug is on the rise due to World Health Organization (WHO) approving artemisinin combination therapy (ACT) for the treatment of cerebral malaria.

The manufactures of artemisinin derivative of the drug have been importing artemisinin from international sources, but the non-availability of sufficient raw material has forced Indian industry to depend on cultivation of this crop indigenously for self-reliance. It is estimated that to sustain >100 million doses requiring to meet global need of malaria affected people, the crop may need to cover an area of about 25,000 ha only, and with the current production levels, farmers may earn a profit of about Rs 60,000 per ha in a span of 6 months for single harvest. The pharma companies are coming forward to go for contract farming for the planned cultivation and sustained production of herbage for isolation of active compound artemisinin to meet the global demand and also the national need to combat this disease. The agrotechnology for cultivation of improved variety of *Artemisia annua* was licensed by CSIR-CIMAP to seven leading companies in India who promoted the cultivation of this crop involving farming community (Fig. 1e).

CIM-Arogya The variety of *Artemisia annua* 'CIM-Arogya', was developed by CSIR-CIMAP with characters like 280–305 cm plant height, oval growth habit, 0.9–1.0% artemisinin content and about 50 q/ha dry leaf yield.

CIM-Sanjeevani CSIR-CIMAP scientists have also developed genetically improved variety CIM-Sanjeevani of *Artemisia annua* with 1.2% artemisinin content (Anonymous 2016b). This variety has been developed using classical breeding method of polycrossing between two existing varieties, i.e. Jeevan Raksha and CIM-Arogya, followed by population enrichment with desirable genes. The plants of variety CIM-Sanjeevani have a yield potential of producing an average 50–55 kg of artemisinin from an average dry herb yield of 43–45 q/ha in a single harvest. The plants of this variety have intermediate morphology between Jeevan Raksha and CIM-Arogya. This variety is about 10 days late in flowering as compared to two earlier varieties and is, therefore, also suited for three harvests. This variety will benefit both farmers and industries involved in *Artemisia* cultivation/business.

Farmers can have an extra income of Rs 10,000–15,000 from 1 ha crop (giving 10–12% higher yield of dry leaves compared to CIM-Arogya).

Bhumyamalaki (*Phyllanthus amarus*)

The plant is valued for its antiviral properties used extensively in traditional formulations effective against liver infections such as hepatitis, diarrhoea, dysentery and urinogenital problems. The plant is found growing all over India and is being collected from wild to be used in medicinal preparation in which the chemical components vary leading to variation in quality (Fig. 1f). So the need was felt to develop a high-yielding cultivar for widespread cultivation on one hand and to conserve the wild germplasm on the other. The crop of *Phyllanthus* harvested after 60 days of planting gives 15–16 q of dried herb and a net profit of Rs 30,000 per ha.

CIM-Jeevan A high-yielding variety called CIM-Jeevan with defined marker chemicals like phyllanthin and hypophyllanthin (0.70–0.77% and 0.32–0.37%, respectively) was developed following planned breeding programme. The dry herb yield of the variety CIM-Jeevan was found to be 15–20 q/ha.

Isabgol (*Plantago ovata*)

Plantago ovata, commonly known as isabgol or Psyllium, is valued for its seeds and husk which have been used in medicine long since as laxative. It is particularly beneficial in habitual constipation, chronic diarrhoea and dysentery for centuries all over the world. India continues to rank first in its production and trade in the world market. It is also the sole exporter of isabgol to the world market, and about 80–90% produce is being exported. The export of husk and seed was valued at Rs 4650 and 6120 million. Isabgol can be grown on variety of well-drained soils having pH ranging from 7.2 to 7.9 and thrives well in warm temperate regions (Fig. 2a).

Niharika The variety Niharika was developed and released by CSIR-CIMAP, especially for north Indian conditions. One hectares crop may yield about 10–12 q of seeds giving a net profit of about Rs 40,000 from a crop of 4–5 months.

Mayuri The variety Mayuri was developed by mutation breeding and is propagated by seeds for commercial cultivation with yielding potential of about 13 q/ha seeds. It is an early maturing, higher seed and husk yielding variety of psyllium with distinct pigment marker of the panicles relatable to the maturing, thereby indicating the harvesting stage.

Fig. 2 (**a**) Isabgol, *Plantago ovata*; (**b**) Senna, *Cassia angustifolia*; (**c**) Aloe, *Aloe vera*; (**d**) Haldi, *Curcuma longa*; (**e**) Menthol mint, *Mentha arvensis*; (**f**) Peppermint, *Mentha piperita*

Senna (*Cassia angustifolia*)

Cassia angustifolia, a small leguminous shrub, is exclusively grown for its foliage and pods which contains glycosides having usefulness in a variety of ailments, such as liver complications and abdominal troubles (Fig. 2b). It is also used in modern medicine as a laxative because of its glycosides-sennoside A and B. Leaves and pods

from *Cassia angustifolia* Vahl and *Cassia acutifolia* Del are the commercial senna drug of the Unani system of medicine. Both species, *Cassia angustifolia* (native of South Arabia, West Asia) and *Cassia acutifolia* (Sudan, East Africa), are exotic to India. In their native lands, these species grow on arid tracts as perennial bushes. However, these are maintained as annual herb when cultivated. Now both the species are commonly known as *Cassia senna*. Although most plant parts contain sennosides (glycosides), but leaves and pod shells contain highest concentration described as sennosides A, B, C and D. The pods contain higher amount of total sennosides (3–5%) as compared to foliage (2.5–4%). Indian pharmaceutical industry uses about 100 tonnes of leaves and pods. The total world requirement is about 10,000 tonnes of leaves and pods. India is the major exporter and exports up to 5000 tonnes worth Rs 20 crores every year. Senna grows well on sandy loam and laterite soils with low to moderate fertility and pH ranging from 7.0 to 8.5. Dry summer with moderate temperature is the actual requirement of the crop. Fall in temperature, rain and water logging conditions are injurious to the plant. It is a 130–150 days summer crop in Northern India whereas winter crop in southern India.

Sona CSIR-CIMAP's variety Sona has become popular among the farmers of Rajasthan which covers huge area under cultivation. It has been observed that younger leaves and pods contain high sennoside content. To obtain desired level of biomass, first picking should be done between 70 and 90 days when sennoside content is optimum. The picking is done by hand so that most of the growing tops are removed to induce further better leafy growth and delay the flowering. Second picking can be done between 90 and 110 days and third between 130 and 150 days when entire plants are harvested to include both leaves and pods together producing dry leaves up to 8–10 q/ha and that of dry pods as 4–5 q/ha. Hence, 1 ha plantation of senna can give a net profit of about Rs 27,000–30,000 in a year.

Aloe (*Aloe vera*)

Aloe (Ghrit Kumari) is found in abundance throughout the world. The aloin group of glycosides are the major constituents of *Aloe* juice or pulp which are variously used in cosmetics and medicines for treatment of chronic constipation, burns and skin diseases. The plant can be grown easily in poor degraded soils with minimum irrigation in hot and dry climate (Fig. 2c).

CIM-Sheetal CSIR-CIMAP has developed CIM-Sheetal variety to provide a genetically defined planting material to the growers and has been released to farmers for cultivation. On an average about 50 tonnes of leaves can be obtained from 1 ha crop of aloe giving a net return of about Rs 1,25,000. The cultivation should be promoted only when processing units for aloe are located in the vicinity so that the fresh leaves can be sold for making sap, juice or gel.

Haldi (*Curcuma longa*)

Turmeric is not only one of the most popular spices for Indian cuisines; it is also one of the most valuable medicinal plants of traditional systems of Indian medicine due to its large repertoire of preventive and curative effects (Fig. 2d). The pharmaceutical importance of turmeric is due to its curcuminoids which are credited with anti-inflammatory, hypo-cholesterolemic, anti-oxidant, antiparasitic, antispasmodic, antimicrobial, antirheumatic, anti-ageing and anticancer properties. India is producing more than 80% of the total global turmeric production, and it is being cultivated over an area of 150,000 ha, Andhra Pradesh (70%) being the leader in turmeric production followed by Tamil Nadu, Odisha, Karnataka, West Bengal, Gujarat and Kerala.

CIM-Pitamber Extensive R&D efforts made at CSIR-CIMAP have resulted in the development of superior variety CIM-Pitamber, which can produce 60–65 tonnes fresh rhizomes/ha containing 12.5% curcuminoids in a relatively short span of 180–190 days (Anonymous 2016c). This variety has been developed using the method of clonal selection breeding method. The variety is also tolerant to leaf blotch disease of turmeric, and a farmer can get a net profit of Rs 1.25–1.50 lakhs/ha.

Menthol Mint (*Mentha arvensis*)

Menthol mint, *Mentha arvensis*, is grown for menthol used in pharmaceutical and flavour industry. India is a leading supplier of menthol mint oil to the world, and a large number of farmers in India are being benefitted by its cultivation. Generally, the crop is cultivated during January to July, either by suckers or transplanting plantlets for production of mint oil (Fig. 2e). Among different essential oils produced in India today, *Mentha arvensis* (menthol mint) oil holds prominent position in terms of acreage under the crop production and domestic consumption and export to the world market. Today India is the largest producer and exporter of natural menthol in the world. The annual turnover of the menthol industry has been in the range of Rs 3500–4000 crores during the past one decade. This has been possible due to the improved agro-technologies and plants varieties developed by CSIR-CIMAP coupled with extension of the crops in the farmers' fields with an active involvement of user industries, government departments, nongovernment organizations and traders and manufactures mainly from UP (Singh and Khanuja 2007).

Menthol mint is presently cultivated in more than 2.50 lakh hectares land of North India. It is believed that over 5 lakh farming families grow menthol mint crop contributing 75–80% global menthol mint oil produce. Pradesh contributes about 70–75% of the total national production of menthol mint oil. Taking the lesson of success of menthol mint cultivation from the farmers of UP, the area under mint is now spreading to other states in the country including Bihar, parts of Punjab,

Madhya Pradesh, etc. Menthol mint yields 130–150 kg mint oil/ha (single harvest) giving a net profit in the range of Rs 60–70,000 in about 3 and a half months.

Kosi The high-yielding variety Kosi developed through half-sib progeny selection is tall with robust growth and wider adaptability in different parts of the country. The variety is early maturing by about 10 days, and the essential oil is containing 75–78% menthol.

CIM-Saryu Another high-yielding variety developed with large canopy and huge biomass. The leaf fall is less as compared to other varieties and is also tolerant to sudden rainfall at maturity. The variety yields 140–150 kg essential oil per hectare containing 78–80% menthol.

CIM-Kranti The improved variety 'CIM-Kranti' of menthol mint has been developed through half-sib progeny selection (Bahl et al. 2013). The variety is cold and frost tolerant and has the potential to produce higher oil (≅100 kg/ha oil having 80% menthol) when grown in winter compared to all popular commercial varieties. However, during winter season (September to January) when all other varieties suffer senescence by the cold and frost conditions, 'CIM-Kranti' remain green in the field. During this period, the variety CIM-Kranti growing vigorously yields two to three times higher essential oil, compared to the popular commercial varieties 'Kosi' and 'CIM-Saryu'. The oil yield during the main summer crop from this variety is 10–12% higher compared to the best check varieties. Hence, this variety is suitable for commercial cultivation to generate additional income without any extra input during both winter and summer seasons.

CIM-Vishisht The variety 'CIM-Vishisht' rich in pulegone was developed through a half-sib progeny selection in menthol mint cultivar, 'Shivalik'. The new variety has the potential of yielding 60 kg/ha of essential oil rich in pulegone in the range of 65–68%. The pulegone has wide usage in aromatherapy, flavouring agents, perfumery, etc. and also can be chemically converted into some other important compounds like menthone, carvone or thymol and into high value commercially important menthofuran through biotransformation. Therefore, this new variety 'CIM-Vishisht' will be helpful in opening new avenues for industry and research**.**

Peppermint (*Mentha piperita*)

Peppermint, *Mentha piperita*, yields an essential oil which is known for its freshness and sweetness and finds its extensive use in food and flavour industries (Fig. 2f). The major use of the oil is for flavouring toothpastes and oral care products, candies and chewing gums, chocolates, ice creams, beverages, baked products, confectionary and pharmaceutical syrups. The crop can be profitably grown in hilly and/or plain areas by yielding essential oil ranging between 80 and 100 kg with a profit of about Rs 90,000–1,00,000/ha.

Kukrail This variety of peppermint was developed through mutation breeding and has erect plant habit with vigorous growth. It proved superior in oil yield over the local cultivars and has wider adaptability with low disease incidence.

Tushar A higher oil yielding variety called Tushar of *Mentha piperita* (peppermint) has been developed through mutation breeding which can produce 85–90 kg/ha oil having 27% menthone, 33% menthol, 2% menthofuran and 9% methyl acetate. The variety can also be grown in partial shading areas without affecting the yield.

CIM-Indus The variety CIM-Indus was developed among open-pollinated seed raised progeny of var. Kukrail of *Mentha piperita.* The essential oil obtained from var. CIM-Indus is rich in menthofuran (27%) and is an important compound in the formulation of certain synthesized essential oils. The variety has the potential of producing higher oil yield in comparison to var. Kukrail.

CIM-Madhuras CIM-Madhuras was selected among open-pollinated seed raised progeny of var. Kukrail of *Mentha piperita.* CIM-Madhuras has the potential of producing 20% higher oil yield in comparison to var. Kukrail, and the oil is sweet smelling which is useful for flavouring industry.

Indian Basil (*Ocimum basilicum*)

Indian basil (*Ocimum basilicum*) is a short-duration crop and is cultivated in India for its essential oil used extensively in flavour, fragrance, food, oral health, etc. (Fig. 3a). The crop thrives well on moderate fertile and well-drained sandy loam oil. It can be grown in subtropical and tropical climate conditions. Temperate climate is not suitable for this crop. CSIR-CIMAP has developed high-yielding varieties with chemical variability, namely, CIM-Saumya, CIM-Snigdha and CIM-Surabhi. The crop is propagated by seeds/seedlings during months of June and July, and it can yield about 80 kg oil giving a net profit of Rs 35,000–40,000 per ha in about 3 months.

CIM-Saumya The variety was developed through selection for uniformity of selected traits and their stability among seed raised progeny. It is a short-duration crop of 3 months and has the potential to produce about 80–100 kg/ha oil rich in methyl chavicol (62%) and linalool (25%).

CIM-Snigdha This variety developed by CSIR-CIMAP is distinct in leaf morphology and has unique aroma. The variety matures in 80–90 days yielding essential oil rich in methyl cinnamate content (78.7%).

CIM-Surabhi The essential oil of sweet basil with linalool, linalool acetate in desired combinations is used in various cosmetic and perfumery products. Intensive breeding techniques and selection process were undertaken at CSIR-CIMAP to

Fig. 3 (**a**) Indian basil, *Ocimum basilicum*; (**b**) Tulsi, *Ocimum sanctum*; (**c**) Chamomile, *Chamomilla recutita*; (**d**) Geranium, *Pelargonium graveolens*; (**e**) Rose, *Rosa damascena*; (**f**) Patchouli, *Pogostemon cablin*

develop this high oil-yielding variety (100–120 kg/ha) with a unique chemical composition having 70–75% (−) linalool with 99% purity. The (−) linalool obtained from this variety is superior to that obtained from lavender and will be a cheaper source of linalool for the industry.

Tulsi (*Ocimum sanctum*)

Tulsi is well known for its traditional medicinal values due to its anti-oxidant and anti-ageing properties. The decoction of leaves is effective for relief from seasonal cold and cough and stomach disorders. The crop is cultivated by a large number of farmers which can give a net profit of about Rs 70–80,000 per ha (Fig. 3b).

CIM-Ayu The variety CIM-Ayu developed by CSIR-CIMAP has the potential to produce 16 q dry leaf yield or 110 kg/ha oil rich in eugenol (83%) even in rainy season. The variety is being cultivated as annual crop in around 4000 ha in Mathura, Uttar Pradesh, Gujarat, Karnataka and Maharashtra states of India for its leaf oil and dry leaves for use in herbal tea.

CIM-Angna A new and distinct genotype was developed through half-sib progeny selection between the isolated single-plant progenies from the diverse germplasm. The plant morphology is distinct by having greyish purple stem with green leaves, which turn purplish in winter season. The variety is producing dry leaf herb yield (14 q/ha) or 90 kg/ha essential oil yield containing eugenol (40%) and germacrene-D (16%).

Chamomile (*Chamomilla recutita*)

The blue oil obtained from flowers of chamomile finds extensive applications in cosmetic and foods, and the active constituents α-bisabolol and chamazulene are reported to possess anti-inflammatory and antispasmodic activities (Fig. 3c). Its flowers are also in great demand owing to their extensive use in herbal tea and mouthwash, and a crop of chamomile from 1 ha land area can give a net profit of about Rs 40–50,000.

CIM-Sammohak The variety CIM-Sammohak has been developed through intensive mutation breeding with higher yield of dry flowers (7.5 q/ha) and oil yield of 6–7 kg/ha containing 12% chamazulene, 20% bisabolol oxide A and 11% bisabolol oxide B.

Geranium (*Pelargonium graveolens*)

The oil of geranium possesses a strong heavy rose-like odour with minty top note, which is as such used in high-grade perfumes and cosmetics. Geranium oil is produced by steam/hydrodistillation of fresh herb of *Pelargonium graveolens* belonging to the family Geraniaceae (Fig. 3d). Geranium oil is rich source of rose alcohols and is processed to isolate 1 citronellol (rhodinol) which is used very extensively in fine fragrances for its sweetness and delightful freshness. Current international demand of geranium oil is 600 tonnes and is largely met by China,

Egypt, Morocco, Reunion Island and South Africa. Presently, India's production is not more than 5 tonnes in a year against its annual requirement of around 150 tonnes. Considering the heavy demand of the cosmetic and perfumery industry, export promotion/import substitution, yield potential, quality standards and economics of its cultivation in India, this is high time to produce geranium oil. With good soil and better management, a yield of 20–25 tonnes of fresh herb is obtained. The herb is distilled fresh, and the 0.1% oil on commercial scale is obtained from the herb. Second harvest of 5–10 tonnes of herb is also available. Thus, a total of 30–35 kg oil/ha is obtained giving a net profit of Rs 60,000 per ha.

CIM-Pawan It is the result of selections from the somaclones of cv. Bourbon for higher oil content and subsequent yield evaluation. The variety CIM-Pawan possesses higher oil content (0.23%) and has the potential to produce about 30% higher essential oil yield as compared to cv. Bourbon. The major active constituents in the oil like citronellol and geranial are present with 25–33% and 21–26% contents, respectively.

Rose (*Rosa damascena*)

Rose oil is obtained from the flowers of *R. damascena* and is the costliest oil used in high-grade perfumes (Fig. 3e). The institute has developed improved technology for rose oil extraction. The recovery of oil varies from 0.025% to 0.03% as compared to 0.01% being obtained using country-made stills. A low-cost, directly fired field distillation unit has also been developed, and technology has been transferred to perfumery industry for commercialization. The area under rose cultivation in UP alone is estimated at 1500 ha where about 100 kg oil valued at about Rs 6 crores is produced annually. A Bulgarian strain of rose was introduced in Kashmir valley, which gave higher yields than those obtained in Bulgaria.

Noorjahan CIMAP has also developed a superior variety of Damask rose named 'Noorjahan' which is suitable for cultivation in the subtropical areas of Uttar Pradesh and the adjoining states. About 600 g rose oil valued at Rs 3 lakhs is obtained from 1 ha of rose plantation based on 0.025–0.030% oil content in subtropical regions and 0.035–0.040% in temperate regions. The oil of Noorjahan variety contains nearly 30% geraniol, 24% citronellol, 12% nerol and 1.3% rose oxide.

Ranisahiba This variety developed through half-sib selection with higher flower biomass up to 40 q/ha, which is available for longer period of about 3 months and is suitable for making rose water. The oil is reported to contain 35% geraniol, 7% geranyl acetate, 5% citronellol and 10% trans-rose oxide.

Patchouli (*Pogostemon cablin*)

Patchouli, *Pogostemon cablin* Benth, is an aromatic undershrub. The plant is cultivated on commercial scale for its essential oil which has traditionally been one of the most important natural base materials used in perfumery industry and as flavour ingredient in major food products (Fig. 3f). Further, patchouli oil is known to possess bacteriostatic properties. Patchouli oil is obtained from leaves of the plant and is used practically in most of the perfumes as base because of its fixative property. Indonesia and China are the major exporters of the oil to the world market. Indigenous agro-technology for cultivation has been developed at CIMAP Field Station, Bangalore, and it has been found that the crop could be grown in coastal areas as an intercrop in coconut plantation. India imports substantial quantities of patchouli oil to meet its requirement, and there is a good scope to produce patchouli oil in order to save valuable foreign exchange. Patchouli plantation raised in 1 ha gives generally about 40 kg oil valued at about Rs 80,000 − and a net profit of about Rs 60,000 can be expected.

CIM-Samarth CSIR-CIMAP has developed an improved variety called CIM-Samarth for cultivation in northern plains of India, which can produce 10–-15 tonnes/ha fresh herb giving 60–70 kg oil in two harvests. The variety is tolerant to all common diseases and insects and has better regeneration ability.

Lemongrass (*Cymbopogon flexuosus*)

The lemongrass oil as such is widely used in perfumery, soaps and cosmetics to obtain typical lemon note. Besides, it is an important source of citral, which is used in perfumery and medicine (Fig. 4a). While citral forms a significant raw material for confectionary and beverages, about 320 tonnes of the oil valued at about Rs 12 crores are being produced annually for internal consumption as well as for export. CSIR-CIMAP has developed improved agro-technology for the cultivation of this plant. A superior variety named 'Krishna' has the potential to yield up to three times more oil than the existing varieties. This variety is being popularized among the farmers for large-scale cultivation in different parts of the country. Lemongrass oil has very good demand in the world market. Guatemala, China, Sri Lanka and Brazil are the other major producing countries. The production of lemongrass oil in the country has declined in recent years, and there are immense possibilities for production of good quality lemongrass for the domestic market as well as for export. The slips of the lemongrass can be planted in February, March and June to September. The crop remains economically productive up till 5 years. One hectare plantation of lemongrass yields about 100–125 kg oil under unirrigated conditions and 200–250 kg under irrigated conditions giving a net profit of about Rs 60,000 and 1,00,000, respectively, per annum.

Fig. 4 (**a**) Lemongrass, *Cymbopogon flexuosus*; (**b**) Java grass, *Cymbopogon winterianus*; (**c**) Palmarosa, *Cymbopogon martinii*; (**d**) Khus, *Vetiveria zizanioides*

Krishna A high oil-yielding variety has been developed by CSIR-CIMAP suitable for South Indian to North Indian plains and hilly areas. The variety Krishna is a perennial crop and is very popular among farmers. The variety can produce up to 300 q/ha herb yield with 0.8–0.9% oil content and thus yielding 230–250 kg oil/ha containing 80–82% citral.

Nima This novel variety 'Nima' of lemongrass is a selection from the open-pollinated seed raised progenies obtained from *C. flexuosus* cv. OD-19. Nima is distinct having essential oil yield (250–260 kg/ha) rich in citral content (85–90%). The variety is salt tolerant and is suitable for usar land prevailing in Uttar Pradesh and other parts of northern India.

CIM-Shikhar This new variety is able to produce 20–25% more essential oil in irrigated conditions with around 80% citral content. The oil yield of this variety is more than 280 kg/ha, and an average oil content is 1.6% in herbage (Anonymous 2016b).

Java Grass (*Cymbopogon winterianus*)

Citronella oil of Java quality is obtained by steam distillation of leaves. It an important source of perfumery chemicals, such as citronellal, geraniol and hydroxyl-citronellal, which finds use in soap, perfumery, cosmetic and flavouring industries (Fig. 4b). The oil is also used as insect repellent. The oil is produced in Indonesia, China and Sri Lanka, which are the major suppliers of the oil in the world market. As a result of transfer of technology by CIMAP and RRL (Jorhat), more than 300 tonnes of citronella Java oil worth about Rs 7.5 crore is produced annually. The plant is grown in north-eastern states and in south India. However, it has been observed that slightly acidic soils are much more favourable for this crop. Newer areas are coming under citronella crop in the north Indian plains owing to popularization of the improved technologies and development of varieties by CIMAP. It has great potential for Uttar Pradesh, Madhya Pradesh and Maharashtra where good irrigation facilities are available. CIMAP has also developed several high-yielding varieties in citronella Java. These varieties, Manjusha, Mandakini, Manjari, Medini, Bio-13 and CIM-Jeeva, are becoming popular among citronella growers of the country. One hectare crop of citronella yields about 250 kg oil per year giving about Rs 185,000 net return.

BIO-13 The variety is suitable for North Indian plains and can produce an average of 250 kg/ha oil per year in four harvestings over the year under normal conditions. The oil contains 32–45% citronellal, 12–18% geraniol, 11–15% citronellol and 3–8% geranyl acetate. It is a perennial crop and is maintained for 6–7 years, and later it can be replaced with new plantation for better higher yields.

CIM-Jeeva The variety is high oil yielding and can produce oil yield up to 285 kg/ha with citronellal content of 41%. A better adaptability and establishment after plantation is observed in this variety and is also found tolerant to yellowing disease.

Palmarosa (*Cymbopogon martinii*)

Palmarosa oil is obtained from the flowering tops, leaves and above ground parts of the plant *C. martinii* variety *motia*. The oil is used in perfumery, cosmetic and flavour industries. Currently, it is cultivated to a great extent in Madhya Pradesh, Uttar Pradesh, Rajasthan, Maharashtra and Karnataka states of India (Fig. 4c). Indonesia and Guatemala are the major competitors to India in the world market. CSIR-CIMAP developed agro-technology and provides quality palmarosa seeds to the farmers in various parts of the country. It is estimated that 50–60 tonnes of palmarosa oil worth about Rs 5 crores is being produced annually in the country. Palmarosa oil is exported to France, Germany, the Netherlands, USA, etc., and ample opportunities are available for extending cultivation of the crop to areas where salt-affected, cultivable wastelands are available.

PRC-1 The seeds of palmarosa are sown in the nursery during May/June, and seedlings are planted in the month of July. One hectare crop of palmarosa gives about 80 kg oil under unirrigated conditions and 125–150 kg oil under irrigated conditions resulting into a net return of about Rs 60,000 and 1,00,000, respectively, per annum.

CIM-Harsh Recently, another high oil-yielding variety named CIM-Harsh has been released for commercial cultivation, which has the potential of producing up to 175–200 kg/ha oil containing 85% geraniol. The variety CIMAP-Harsh is fast growing and is tall with light yellow stem, higher number of tillers/plant and longer inflorescence.

Khus (*Vetiveria zizanioides*)

Vetiver (Khus) is cultivated for the production of essential oil derived from roots and is being used in high-grade perfumes, soaps, sherbets and cosmetic preparations. The total world production is estimated to be 600–700 tonnes per annum as compared to 20–25 tonnes produced annually in India. Therefore, khus cultivation in Indian context seems to be profit-driven with increasing oil demand for perfume and soap industries (Fig. 4d). Currently, about 20 tonnes of oil, valued at about Rs 30 crores, is produced annually. The crop offers immense possibilities for expansion, especially along the river beds. Whereas, CSIR-CIMAP has developed agro-technology and improved processing technology for vetiver oil production and several high-yielding varieties.

KS-1 The slips of this variety can be planted during February to March or July to August, and roots can be harvested after 12–18 months during December to January. The variety is tall and produces oil yield in the range of 18–20 kg/ha with traditional vetiver oil aroma.

CIM-Vridhi It is a short-duration variety having potential of producing 20–25 kg oil per ha in a span of 10–12 months and thus, giving a net profit of Rs 1,50,000/ha, has become very popular among a large number of farmers of UP, Bihar, Chhattisgarh, Jharkhand, Karnataka and Odisha states in recent years. In addition, cocultivation of khus with wheat, lentil, peas, mint, basil, etc. brings an additional profit of about Rs 30,000/ha.

CIM-Samriddhi A new variety is developed called CIM-Samriddhi with unique aroma of its essential oil containing major aroma ingredients as >30% Khusilal (*nor*-sesquiterpene (C_{14}) aldehydes) and >19% Khusol. This variety has the potential of producing 20% higher oil yield. Moreover, this variety can be grown in the unutilized or underutilized lands (Anonymous 2016c).

Opportunities Available and Challenges Ahead

Medicinal and aromatic crops offer several opportunities for entrepreneurship development and job creation especially in rural sector. These include cultivation, processing, value addition, product formulation, marketing, supply of seeds and propagules of high-yielding varieties and testing services for quality evaluation of the produce. Industries requiring quality raw material in bulk are approaching R&D institutions for cultivation technology(s) and farmers for contractual cultivation. In this way public-private partnership model has started taking shape which has been steered by CSIR-CIMAP adopting 'biovillage' approach based on antimalarial drug plant *Artemisia annua* (Khanuja and Singh 2007; Kumar et al. 2015). Similar approach can be explored for other medicinal and aromatic crops.

Though several high-yielding improved varieties were developed and popularized for cultivation of medicinal and aromatic crops during the last three and a half decades, there appears to be a continued need for such efforts due to frequent changes in the climate resulting into alarming decline in available resources such as water, land, manpower, etc. for growing such crops. R&D institutions are expected to formulate strategy for developing varieties which can be grown with comparatively lesser inputs under adverse climatic conditions and in stressed soils without affecting yield and quality of the produce. Integration of medicinal and aromatic crops with traditional food crops is another area requiring urgent attention. Though challenges on the R&D front are enormous, the future may hold great promise looking at the available gene pool of MAPs, scientifically trained manpower and research facilities available in the country.

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