Genetic Resources of Spices

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Spices play an important role in preservation, colouring and flavoring of food, cosmetics and medicine. India is the center of diversity for spices like black pepper, ginger, cardamom, turmeric, cinnamon, tamarind and has good collection of diverse germplasm. In introduced crops like nutmeg, clove, allspice, vanilla, seed and herbal spices though India has reasonable germplasm holdings the diversity is limited especially for quality and resistance to biotic and abiotic stresses. Introducing germplasm from the centers of diversity for general and specific characters is an important aspect to be considered in the latter group of crops.

Key words: Spices, Genetic resources, Conservation, Introduction

Spices played a major role in human life and history. Spices were used in preservation of food, religious ceremonies, cosmetics, dyes, medicines, embalming of the dead and folklore.

India is the land of spices and the lure of spices led many traders to India in the past. Many spices are native to India, and the most important of them are black pepper and cardamom followed by ginger, turmeric, cinnamon, tamarind and garcinia. India has a good amount of diversity in these crops. The other important spices relevant in Indian context are coriander, chili, fennel, fenugreek, cumin, nutmeg, clove and vanilla in addition to other minor spices. India is also a major producer and exporter of these spices. Being crops of exotic origin, except a few, the indigenous genetic diversity in these crops is narrow. Plant introduction from the centers of diversity has helped in broadening the genetic base, to a certain extent in coriander, chili, fennel, fenugreek and cumin. It is much needed in crops like paprika, nutmeg, clove, allspice and vanilla. In others, introduction of specific genotypes with special characters will augument our future breeding programmes.

Black Pepper (*Piper nigrum* L.)

Black pepper is the dried, mature fruit of *Piper nigrum* L. native to the South-Western India and the North-Eastern region from where it spread throughout the tropics. Though Central America is the centre of diversity of genus *Piper*, where over 2,000 species are known, the tropical forest of Malabar coast of India is the centre of diversity of *Piper nigrum*. About 110 species of *Piper* are reported from India and over 100 cultivars of black pepper are reported (Ravindran *et al.*, 2000). The diploid chromosome number of black pepper is 2n = 52. The major producing countries are India, Vietnam, Indonesia, Brazil, Sri Lanka, China and Thailand. In India, black pepper is cultivated in approximately 181,000 ha. The annual production is about 60-65,000 tons, out of which about 60% is exported.

India being the native home of black pepper, a very large collection of black pepper germplasm is conserved *ex situ* at Indian Institute of Spices Research (IISR), Calicut and at various centres of All India Co-ordinated Research Project on Spices (Table 1).

Local cultivar diversity is the richest in Kerala, followed by Karnataka. Unlike the wild forms of *P. nigrum* which are mostly dioecious, most cultivated ones are bisexual. Intra-cultivar variability was also reported in certain local cultivars grown extensively (Gopalam and Ravindran, 1986; Ravindran and Nirmal

Table 1. Collections of black pepper germplasm in India

Institution	Cultivated	Wild and related spp.	Total
Indian Institute of Spice Research, Calicut	2079	890	2969
NBPGR Regional Station, Thrissur, Kerala	417	341	758
Pepper Research Station, Panniyur, Kerala	167	72	289
Pepper Research Station, Sirsi, Karnataka	98	19	117
Regional Agricultural Research Station, Chintapalli, Andhra Pradesh	58	–	58
Horticultural Research Station, Yercaud, Tamil Nadu	122	10	132
Other AICRP Centres	83	–	83

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Babu, 1994; Ravindran *et al.,* 2006). There is good variability in germplasm with regard to morphological as well as yield attributes like spike length, number of bisexual flowers, fruit set, fruit size etc. The major quality parameters are volatile oil, oleoresin and piperine contents. Among the cultivars, the content ranges from 2.8-7.6% in piperine, 0.4-5.5% in volatile oil, 5.4-17.8% in oleoresin and 12.4-46.6% in starch. Gopalam and Ravindran (1986) categorised the common local pepper cultivars into high, medium and low quality classes based on the above parameters. The germplasm is utilized in various crop improvement programmes, which led to the release of about 16 elite varieties of pepper (Table 2).

Recently a few high yielding varieties of black pepper viz., IISR Girimunda, IISR Malabar Excel, Thevam, and Shakti were released from IISR. The first two are hybrids and are suitable for high elevations while the last two are selections, which are tolerant to *Phytophthora.*

Foot rot caused by *Phytophthora capsici,* is a major bottleneck in black pepper production and productivity. Resistance sources are not available in the indigenous germplasm but available in an exotic Central American species of Piper, *P. colubrinum.* This species is resistant to *Phytophthora capsici-* a fungal pathogen, pollu beetle – a major insect pest and *Radopholous similis* – a major nematode pest affecting black pepper. This indicates the availability of resistance genes in the primary centre of diversity of the genus. Identification and introduction of resistance sources from the Central and South American regions will be of great relevance in black pepper improvement.

The pepper growing countries have their own local diversity developed from segregating populations originally introduced from India. Introduction of some of the selections with special characters like resistance to *Phytophthora capsici* and *Radopholous similis* may be considered.

Cardamom - [*Elettaria cardamomum* (L.) Maton]

Elettaria cardamomum belongs to the family Zingiberaceae. Cardamom of commerce is the dried fruit of this rhizomatous, herbaceous perennial species. The centre of diversity of the genus *Elettaria* is the Malaysian-Indonesian region from where eight species are reported (Sakai and Nagamasu, 2000). The origin or phylogenetic

Table 2. High yielding black pepper varieties developed in India

Variety	Pedigree	Salient features
Panniyur 1	Hybrid between Uthirankotta x Cheriyakaniyakadan	Does not tolerate shade, moderately high oleoresin (11.8%), long spikes and bold berries.
Panniyur 2	Open pollinated progeny of Balankotta	Shade tolerant, rich in oleoresin, high piperine.
Panniyur 3	Hybrid between Uthirankotta x Cheriyankaniyakadan	Late maturing, suitable for all pepper growing regions, performs well under open situation. Long spikes and bold berries.
Panniyur 4	Clonal selection from Kuthiravally	Stable yielder, performs well under adverse conditions.
Sreekara	Selection from Karimunda	Suitable for all pepper growing regions.
Subhakara	Selection from Karimunda	High quality line (12.4% oleoresin), with wider adaptability to all pepper growing tracts.
Panchami	Clonal selection from Aimpiriyan	Late maturing variety with excellent fruit set.
Poumami	Clonal selection from Ottaplackal	High yielding variety, tolerant to root knot nematode.
Panniyur 5	Open pollinated progeny of Perumkodi	Suitable for both monocropping & mixed crop in coconut/ arecanut gardens. Long spikes.
PLD-2	Clonal selection from Kottanadan	High oleoresin line (15.5%), recommended for Trivandrum and Quilon districts of Kerala.
Panniyur 6	Clonal selection from Karimunda	Steady and stable yielder tolerant to drought and adverse climatic conditions. Suitable for open condition as well as partial shade.
Panniyur 7	Open pollinated progeny of Kalluvally	Vigorous, hardy and a regular bearer, long spike, high piperine (5.6%) tolerant adverse climatic condition suitable for open and shaded conditions.
IISR Thevam	Clonal selection from Thevanmundi	High yielding vigorous vine field tolerant to *Phytophthora.*
IISR Girimunda	Hybrid between Narayakodi X Neelamundi	High yielding vine suitable to high elevations and as a mixed crop.
IISR Malabar Excel	Hybrid between Cholamundi X Panniyur 1	High yielding vine suitable to high elevations and as a mixed crop.
IISR Shakti	OP progeny of Perambramundi	Moderate yielder but resistant to *Phytophthora.*

relationship of cardamom is not clearly known. Holttum (1950) felt that *E. cardamomum* and the Malaysian *Elettaria* represent parallel development from different points of origin in the *Alpinia* stock. Only one species occurs in India namely, *Elettaria cardamomum* and this is the only economically important species. Its closest species is the Srilankan wild cardamom *E. ensal* (Abheyv) (syn. *E. major* Thw). Cardamom has a somatic chromosome number of 2n = 48.

Cardamom occurs in its native state only in the tropical evergreen forests of the Western Ghats. The domestication of cardamom is relatively recent. Cultivated cardamom consists of three morphologically distinct types, namely Malabar, Mysore and Vazhukka. The wild populations of cardamom gradually declined as a result of disturbances in forest habitats. Currently in India, Cardamom is grown over an area of 72,000 ha and the annual production is around 6,000-8,000t. The major producer is Guatemala with an annual production of about 13,000t.

Cardamom is naturally cross-pollinated, the major pollinating agent is honey bee. It is propagated both by seed and suckers. Cardamom being a monotypic genus, general variability in the natural populations is restricted. Cardamom genetic resources are conserved at four centres (Table 3). The germplasm conservation is through field gene banks and *in vitro* gene banks.

Table 3. Holdings of cardamom germplasm in India

Institution	Cultivated	Wild and related spp.	Total
IISR, CRC, Apangala	423	13	436
ICRI, Myladumpara	600	12	612
AICRPS Centre, Pampadumpara	141	–	141
AICRPS Centre, Mudigere	132	–	132

IISR. CRC - Indian Institute of Spcies Research, Cardamom Research Centre, ICRI - Indian Cardamom Research Institute, AICRPS - All India Coordinated Research Project on Spices (Source: Annual Reports of IISR and AICRP on Spices)

Good variability exists in cardamom with regard to various morphological characters such as fruit (capsule) size, shape, leaf and plant pubescence and quality like characters such as essential oil and its components, 1,8-cineole and alpha-terperyl acetate (Zachariah and Lukose, 1992; Madhusoodanam *et al.* 1994; Zachariah *et al.* 1998; Padmini *et al.* 1999).

Utilization of germplasm for selection and hybridization led to the development and release of 12 high yielding varieties (Table 4). One of them (RR1) is tolerant to rhizome rot of cardamom.

Table 4. Released cultivars of cardamom

Cultivar	Pedigree	Mean yield (kg/ha)
Mudigere 1	Clonal selection in Malabar type with high yield.	275
PV 1	A selection in Walayar collection with long capsules	260
IISR Suvasini	Selection from open-pollinated progeny of CI. 37. Short statured plant	745
ICRI 1	Selection in Chakkupalam collection	325
ICRI 2	Clonal selection in germplasm collection	375
ICRI 3	Selection in Malabar type	440
Mudigere 2	Clonal selection in Malabar type	476
ICRI 4	Clonal selection in germplasm	455
IISR Avinash	Clonal selection of open-pollinated progeny of clone-37 with resistance to Rhizome rot	847
PV 2	OP selection from PV 1	982
IISR Vijetha	Clonal selection from katte resistant lines	643
Njallayani Green Gold	A farmers selection	1600

Two selections, tolerant to Katte virus, are also being released from IISR and another high yielding variety PV2 from Kerala Agricultural University (KAU).

In cardamom, there is reasonable amount of genetic variability in the indigenous sources. However, variability with regard to disease, viral and pest resistance is limited. Introduction of Srilankan wild cardamom *E. ensal* (Abheyv). (syn. *E. major* Thw) which is tolerant to stem borer is worth consideration. A look into genetic diversity of *Elettaria* in the Malaysian-Indonesian region from where, eight species are reported, is also needed.

Ginger (*Zingiber officinale* Roscoe)

Ginger (Zingiberaceae) is known to exist only under cultivation. Ginger is grown in most states in India, from Himachal Pradesh to Kerala. The total area under ginger is around 77,000 ha, the annual production is to the tune of 250,000 tons.

Zingiber is included in the tribe Hedychieae along with other genera such as *Curcuma, Hedychium* and *Kaempferia* (Holttum, 1950) and in the series Zingiberae which has only one genus *Zingiber.* Over 30 species were reported from Indo-Malayan region (Baker 1886, Fischer 1928). The species of *Zingiber* occurring in India are given in Table 5.

There is no conclusive evidence with regard to the origin of ginger. It is probably a sterile hybrid between two distant species that survived because of the successful

Table 5. Important *Zingiber* species occuring in India

S.No.	Species
1.	*Z. officinale* Roscoe
2.	*Z. zerumbet* (L.) Sm.
3.	*Z. purpureum* Roscoe
4.	*Z. roseum* (Roxb.) Roscoe
5.	*Z. wightianum* Thw.
6.	*Z. macrostachyum* Dalz.,
7.	*Z. cernuum* Dalz.
8.	*Z. capitatum* Roxb.
9.	*Z. cylindricum* Moon
10.	*Z. ligulatum* Roxb.
11.	*Z. spectabilis* Griff.
12.	*Z. clarkii* King ez Benth.
13.	*Z. marginatum* Roxb.
14.	*Z. intermedium* Baker
15.	*Z. chrysanthum* Roscoe
16.	*Z. rubens* Roxb.
17.	*Z. squarrosum* Roxb.
18.	*Z. elatum* R. Br.

vegetative mode of propagation. The chromosome number of the genus is 2n = 22 and all the Indian species studied so far have this number. It flowers under certain climatic conditions (as in Kerala), but does not set seed.

Variability in cultivated ginger exists mainly in the north-eastern region and Kerala. A botanically distinct variety *Z. officinale* var. *rubrum* with pink outer skin of rhizome is under cultivation in Malaysia.

There is moderate cultivar diversity in India, which is often named after the locality. Morphological variability is rather limited, however, chemical variations in essential oil content and components, are reported (Ravindran *et al.*, 1994; Zachariah *et al.*, 1998). Conservation of ginger germplasm is being done mainly in field gene bank (Table 6).

Table 6. Holdings of ginger germplasm in India

Institution	Accessions (No.)
Indian Institute of Spices Research, Calicut, Kerala	684
National Bureau of Plant Genetic Resources, Regional Station, Trichur, Kerala	173
Orissa University of Agriculture and Technology, High Altitude Research Station, Pottangi, Orissa	172
Y.S. Parmar University of Horticulture and Forestry, Solan, Hjmachal Pradesh	288
Rajendra Agricultural University, Dholi, Bihar	43
N.D. University of Agriculture and Technology, Faizabad, Uttar-Pradesh	45
Uttar Banga Krishi Vishwa Vidyalaya, Pundibari, West Bengal	38
Other Centres	44

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Seven high yielding and high quality varieties were released for cultivation so far (Table 7). All of them are clonal selections from the germplasm. Though variability for yield attributes and quality parameters are reported in ginger germplasm (Ravindran *et al.*, 1994; Sasikumar *et al.*, 1992) none of the cultivars possess resistance to the serious diseases such as *Pythium* rot and bacterial wilt.

Table 7. Released cultivars of ginger

Cultivar	Pedigree/Method	Mean yield (kg/ha)
Suprabha	Clonal selection in Kunduli local	16.6
Suruchi	Clonal selection in Kunduli local	11.6
Surabhi	Induced mutant in Rudrapur local	17.5
Himgiri	Clonal selection in Himacnal collection	13.5
IISR Varada	Selection in germplasm	22.6
IISR Rejatha	Selection from germplasm	22.4
IISR Mahima	Selection from germplasm	23.2

Ravindran *et al.*, 2006; Johny and Ravindran, 2006.

Though variability of ginger is reasonable in the country except for disease reistance, introduction of local varieties of ginger from South East Asian countries, China, Jamaica, Nigeria and Australia may yield varieties with less fibre and with resistance to rhizome rot which is the most important disease affecting ginger.

Turmeric (*Curcuma longa* L.)

Turmeric (Zingiberaceae) is one of the most ancient spices used in India and is part of Indian culture and the socio-religious practices. The processed and dried rhizomes of *C. longa* constitute the spice of commerce. India is the largest producer and exporter of turmeric. Turmeric is grown in most of the states in India, and the important states are Andhra Pradesh, Tamil Nadu, Maharashtra, Madhya Pradesh, Uttar Pradesh and Bihar. It covers an area of about 140,000 ha and has annual production of about 550,000 tons. A few cultivars such as Aleppey grown in central Kerala area are regarded as high yielding and of high quality. The cultivars are mainly known after the place where the particular type is grown traditionally.

The genus *Curcuma* is mainly distributed in the Indo-Malayan region and about 100 species are known. The most striking feature of turmeric is the bright yellow colour of the rhizome. Holttum (1950) reported that at least two other species, namely, *C. colorata* Val. and *C. xanthorhiza* Roxb. have equally deep yellow

rhizome colour but they never gained any prominence either as spice or as a source of colour. Very little is known about its ancestors and phylogenetic relationship. Turmeric is a triploid having chromosome number 2n (3x) = 63. A related species *C. aremali* has 2n = 84. It is generally propagated by rhizomes but it occasionally sets seed that have been used in breeding programmes (Ravindran *et al.*, 2006).

The distribution of *Curcuma* species in India is given in Table 8. Among the related species, *C. aromatica* is important in preparation of medicine and toiletry articles. The pale yellow rhizome of *C. aromatica* has a camphor-like odour. *C. amada* (mango ginger) is used as vegetable. *C. zedoaria,* is medicinal and is also a source of starch for tribal people in many parts of India.

Table 8. Distibution of *Curcuma* species in India

Sl. No.	Species without fingers or rhizome	Region of occurence
1.	*C. aeruginosa* Roxb.	North Eastern India
2.	*C. albiflora* Thw.	Karnataka
3.	*C. amada* Roxb.	Throughout India
4.	*C. amarassima* Rosc.	North Eastern India
5.	*C. aromatica* Salisb.	Karnataka/Kerala
6.	*C. aurantiana*	Kerala
7.	*C. brog*	North Eastern India
8.	*C. caesia* Roxb.	North Eastern India
9.	*C. cannanorensis*	Kerala, Ansari et al.
10.	*C. comosa* Roxb.	North Eastern India
11.	*C. coriaceae*	Kerala, Mangaly & Sabu
12.	*C. decipiens* Dalzell	Kerala
13.	*C. ecalcorata* Sivarajan and Indu.	Kerala
14.	*C. haritha* Sabu	Kerala
15.	*C. karnatakensis**	Karnataka
16.	*C. kudagensis**	Karnataka
17.	*C. latifolia* Rosc.	North EAstern India
18.	*C. longa* L.	Throughout India
19.	*C. lutea*	Kerala/Karnataka
20.	*C. malabarica*	Kerala/Karnataka
21.	*C. montana* Roxb.	Andhra Pradesh
22.	*C. nilamburensis**	Kerala
23.	*C. nilgherrensis* Wight	Sourth India
24.	*C. oilgantha* Trimen	Kerala
25.	*C. pseudomontana* Graham	South India & Maharashtra
26.	*C. raktakanta* Mangaly and Sabu	Kerala
27.	*C. soloensis*	North Eastern India
28.	*C. sylvatica*	North Eastern India/Kerala
29.	*C. thalakkaveriensis**	Karnataka
30.	*C. vamana* sabu & Mangaly	Kerala
31.	*C. vellanikkariensis**	Kerala
32.	*C. zedoaria* (Chistm.) Roscoe	Throughout India

* Velayudhan *et al.* (1999)

The status of turmeric germplasm in the country is given in Table 9. There is an urgent need for collecting and conserving many spices reported from North-eastern region of the country. Several species, such as *C. leucorrhiza, C. petiolata, C. angustifolia, C. montana,* etc., are to be collected.

Characterization of turmeric based on morphological characters was carried out at IISR and NBPGR. A total of 21 distinct morphotypes and six taxonomic groups were identified and reasonable variability for yield, yield attributes, quality attributes and dry recovery were observed (Velayudhan *et al.*, 1991, 1999, Nirmal Babu *et al.*, 1993b).

So far, 24 high yielding cultivars of turmeric were released for cultivation throughout India. Of these, only two were selected from the seedling progenies of turmeric and one is an induced mutant (Table 10).

Introduction of germplasm from exotic sources do not hold much promise in turmeric.

Seed Spices

The major seed spices grown in India are coriander, cumin, fennel, fenugreek, celery, ajwain, dill, caraway black caraway, black cumin (kala zira), white mustard, black mustard, and Indian mustard. The main seed spices growing states in India are Andhra Pradesh, Tamil Nadu, Gujarat, Rajasthan, Uttar Pradesh, Madhya Pradesh and

Table 9. Germplasm holdings of turmeric and their related species

Institution	Accessions (No.)
Field gene bank	1040
Indian Institute of Spices Research, Calicut, Kerala	
National Bureau of Plant Genetic Resources, Regional Station, Trichur, Kerala	954
Orissa University of Agriculture and Technology, Pottangi, Orissa.	193
Regional Agriculture Research Station, Jagtial, Andhra Pradesh	352
Y S Pawar University of Horticulture and Forestry, Solan, Himachal Pradesh	145
Rajendra Agricultural University, Dholi, Bihar	145
Indira Gandhi Agricultural University, Regional Station, Raigarh	42
N.D. University of Agriculture and Technolgy, Faizabad, Uttar Pradesh	114
Uttar Banga Krishi Vishwa Vidyalaya, Pundibari, West Bengal	140
Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu	255

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Table 10. Released varieties of turmeric

Cultivar	Pedigree/method	Mean yield (kg/ha)
CO-1	Induced mutant in Erode local	30.5
Krishna	Clonal selection in Tekurpeta collection	9.2
Sugandham	Clonal selection in germplasm	15.0
BSR.1	Induced mutant in Erode local	30.7
Roma	Clonal selection in T. Sunder	20.7
Suroma	Induced mutant (Clonal selection) in Tsundur	20.0
Rajendra Sonia	Selection in local germplasm	4.8
Suguna	Selection in germplasm	29.3
Suvarna	Selection in germplasm	17.4
Sudharsana	Selection in germplasm	28.8
Ranga	Clonal selection in Rajpuri local	29.0
Rasmi	Selection in germplasm	32.0
BSR.2	Clonal selection in Rajpuri local	32.7
IISR Prabha	Open-pollinated progeny selection	37.4
IISR Prathiba	Open-pollinated progeny selection	39.1
Megha turmerica 1	Selection in Lakadong type	23.0
Sobha	Clonal selection from local type	35.8
Pant Peethabh	Clonal selection from local type	20.0
Sona	Clonal selection from local type	7.0 (dry)
IISR Alleppey Supreme	Clonal selection from Alleppey	29.2
IISR Kedaram	Selection from germplasm	27.9
Varna	Clonal selection from local type	4.1 (dry)
Kanti	Clonal selection from Mudukur	5.2 (dry)
Suranjana	Clonal selection from local type	29.2

Ravindran *et al.*, 2006; Johny and Ravindran, 2006.

Haryana. Among them, only coriander, cumin, fennel and fenugreek are grown on a commercial scale. Cultivation of the remaining seed spices is limited.

Though not native to India, a good collection of seed spices germplasm is available in India (Table 11).

Coriander *(Coriandrum sativum,* Apiaceae) is the most important seed spice. It is native to southern Europe, Asia Minor and Caucasus where it also grows wild. This crop is commercially grown in Russia, Hungary, Poland, Romania, Czechoslovakia, Morocco, India, Mexico, Gautemala and also in USA. It was introduced into India from the Mediterranean region and now India is a major producer of coriander. It is cultivated on a large scale in the states of Rajasthan and Andhra Pradesh; and also in Gujarat, Madhya Pradesh, Uttar Pradesh, Bihar and Chattisgarh. Coriander is a major component of masala mixes and curry powders. The main chemical constituents of coriander essential oil are linalool (60-70%) and hydrocarbons (about 20%) such as dl α-pinene, β-pinene, dipentane, p-cymene and α-terpinene. In coriander germplasm, essential oil content varies from 0.17 to 0.26% (Sharma, 1994). A total of 1,767 accessions are being maintained at various research centres in India. The released varieties of coriander are given in Table 12.

Cumin is a member of family Apiaceae and probably a native of Turkistan or Upper Egypt. Cumin is cultivated in Ukraine, Morocco, Algeria, Syria, Malta and Cyperus. In India, it is cultivated in the states of Gujarat and Rajasthan. About 621 accessions of cumin are being maintained and 10 varieties were released (Table 13). Cuminaldehyde is the major component in cumin oil. Oil content is low in indigenous germplasm but high in exotic collections (Sharma, 1994). Hence introduction of cumin genotypes with high oil is important.

Fennel *(Foeniculum vulgare)* belongs to Apiaceae. It has two sub-species. *F. vulgare* ssp. *capillaceum* (garden fennel) and ssp. *piperitura* (wild fennel). Sub-species *capillaceum* comprises var. *vulgare* (bitter fennel), var. *dulce* (sweet fennel or French sweet fennel or Roman fennel) and var. *panmoriwn* (Indian fennel). Sharma (1994) reported that oil content ranges from 0.7 to 6% in fennel germplasm. Five research stations are maintaining 529 accessions of fennel and so far and 14 varieties have been released (Table 14).

Table 11. Seed spices germplasm collections in india

Centre	Accessions (No.)			
	Coriander	Cumin	Fennel	Fenugreek
Rajasthan Agricultural University, Jobner	885	376	187	353
Gujarat Agricultural University, Jagudan	120	226	115	63
Tamil Nadu Agricultural University, Coimbatore	274	–	3	255
Andhra Pradesh Agricultural University, Guntur	124	–	–	126
Rajendra Agricultural University, Dholi	85	–	31	109
Narendra Dev University of Agriculture and Technology, Kumarganj	75	19	39	63
Chaudhary Charan Singh Haryana Agricultural University, Hisar	204	–	94	134
Indira Gandhi Krishi Vishwa Vidyalaya, Raigarh, Solan, Himachal Pradesh	20	–	–	225
Total	**1767**	**621**	**469**	**1141**

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Table 12. Improved varieties of coriander

Cultivar	Pedigree/method	Mean yield (kg/ha)
Guj. Coriander-1	Selection in germplasm	1100
Co-1	Selection in Koilpatti local	440
Co-2	Selection in culture P2 of Gujarat	520
Guj. Coriander-2	Selection in Co-2	1450
Rajendra Swathi	Selection in Muzaffarpur collection	1300
RCr-41	Recurrent selection in local type	909
Sadhana	Mass selection in Alur local collection	1025
Swathi	Mass selection in Nandyal germplasm,	855
CS-287	Selection in Guntur collection	600
Co-3	Selection in Acc.695 of IARI type	650
Sindhu	Mass selection in local germplasm	1050
Hisar Anand	Mass selection in Haryana collection	1400
RCr-20	Recurrent selection in Jaipur local	900
RCr-435	Recurrent selection in local germplasm	1000
RCr-436	Recurrent selection in local germplasm	1200
RCr-684	Induced mutant in RCr-20	990
Co-4	Reselection from ATP-71	600
Rcr-446	Half sib selection from Jaipur local	1200
Hissar Suganth	Mass selection from germplasm	1400
Hissar Surabhi	Mass selection from germplasm	1800
Azad Dhania-1	Mass selection from germplasm	1000
Pant Haritima	Selection Pant Dhania	1200
DWA-3	Pure line selection	440 dry
CIMPOS-33	Selection from Bulgarian introduction	2100
NRCSS-ACR-1	Re selection from Russian introduction	1100

Table 13. Released varieties of Cumin

Cultivar	Pedigree/method	Mean yield (kg/ha)
Mc-43	Selection in germplasm	580
Guj. Cumin-1	Selection from Vijaypur-5	550
RZ-19	Recurrent selection in UC.19	560
Guj. Cumin-2	Induced mutant in NIC-49	620
Guj. Cumin-3	Recurrent selection from German germplasm EC-232689	620
S-404	Selection from germplasm	350
Guj. Cumin-4	Selection from germplasm	1250
RZ- 209	Recurrent selection from Jalore	650
RZ- 223	Mutant selection from UC -216	600
AC - 01-167	Re selection from EC- 243375	515

Johny and Ravindran, 2006

Bitter fennel is commercially cultivated in India, Romania, Russia, Hungary, Czech Republic, Germany, France and Italy. It grows wild in France, Spain, Morocco and Algeria. Sweet fennel is cultivated in France, Italy and Greece and has the best odour and flavour quality. The oil of fennel contains mainly anethole, α-pinene, α-phellandrene, dipentene etc. The bitter taste is due to presence of d-fenchone. Sweet fennel contains mostly anethole, and smaller quantities of d-phellandrene and d-limonene and no fenchone. Introduction of

Table 14. Released varieties of fennel

Cultivar	Pedigree/method	Mean yield (kg/ha)
PF-35	Selection in germplasm	1280
Co-1	Selection in PF35	570
Guj. Fennel-1	Pure line selection	1720
Guj. Fennel-2	Pedigree selection in local germplasm	1940
RF-101	Recurrent selection in local germplasm	1550
Guj. Fennel-II	Selection from local germplasm	2489
Co- 1	Re selection from PF-35	570
Hissar Swarup	Mass selection from germplasm	1600
Azad Sonuf-1	Selection from germplasm	1500
Pant Madhurika	Pure line selection	1200
Rajendra Sourabha	–	–
NRCSS-AF-1	Recurrent selection	1950
RF-143	Recurrent selection	1200

sweet fennel types from europion region is worth considering.

Fenugreek *(Trigonella foenum-graceum),* Fabaceae is native of eastern Mediterranean extending to central Asia. In addition, Ethiopia is also an independent centre of origin. In India fenugreek is grown in an area of about 38,500 ha, mainly in Rajasthan, Gujarat and Andhra Pradesh with an annual production of about 50,000 t. The seed is used as spice and leaf as vegetable. It is also grown in Argentina, Egypt, France, Morocco, Lebanon etc. It has bitter taste of seeds due to alkaloid trigonellin and steroid sapogenin (diosgenin), but in appropriate quantities, it adds a special taste and flavour to culinary dishes. It also has high medicinal and nutritive value. Conservation of fenugreek germplasm is being taken up at seven centers, with about 908 collections of which 7 were released as improved varieties (Table 15).

Celery (Apium graveolens), Bishops weed or Ajwain *(Trachyspermum ammi)* and Dill *(Anethum graveolens),* of the family Apiaceae, are other seed spices of importance. Celery is a native of Eastern Europe while Dill and Ajwain are native of the Mediterranean region, where they grow wild. The main celery producing countries are India, France and to some extent sub-tropical America. In India, celery is grown in about 2,000 ha, mostly in Punjab, mainly for seeds. The main chemical constituents are d-limonene, elimene, sedanolide and sedanonic anhydride. The characteristic flavour is due to selinene. Ajwain has two morphological types; a larger type is grown in most ajwain growing regions in Northern India

Table 15. Improved varieties of fenugreek

Cultivar	Pedigree/method	Mean yield (kg/ha)
Co-1	Selection in TG-2356	680
Rajendra kanti	Pure line selection in Reghimathpur local	1300
RMt-1	Pure line selection in Nagpur local	1400
Lam selection-1	Selection in germplasm collection	740
Hisar Sonali	Pure line selection in germpalsrn	1700
Co-2	Selection in CF 390	482
RMt-303	Mutation breeding in RMtl	1900
Gujarat Methi-1	Recurrent selection based on pure line selection in J. Fenu 102	1864
RF - 125	Recurrent selection from EC- 243382	1700
S-7-9	Selection from germplasm	1100

and a small form grown in Indore and adjoining regions. The larger type is used as a medicine and in the manufacture of curry powders and the smaller one is mainly exported. Other ajwain growing countries are Egypt and Iran. The most important constituent is thymol followed by carvaorol and hydrocarbons such as α-pinene, p-cymene, dipentene, γ-terpinene etc. Dill grows wild in parts of Europe, Africa and Asia. It is cultivated in USA, Hungary, Germany, India and in Eastern Europe. Dill seed oil contains carvone, d-limonene and phellandrene. Dill apiole, a poisonous component in oil, occurs in Indian dill but not in the European dill oil.

Anise or aniseed is yet another seed spice grown in India and countries like Egypt, Syria, Tunisia, Morocco, China, Chile, Mexico, USA etc. In India anise is grown in many North Indian states. The oil contains mainly anethole. It is extensively used in baked food industries.

The variability in the germplasm of seed spices in India is limited and does not represent the actual diversity available in these crops (Sharma, 1994). Careful and unbiased collections from the centers of diversity can enhance the utility of the collection for crop improvement especially in developing high quality disease resistant types.

Tree Spices

There are many tree spices grown in India, some native, others introduced and a few of them are cultivated commercially (Table 16). Of these, nutmeg, clove and cinnamon are widely grown in the states of Kerala, Karnataka and Tamil Nadu. Allspice is a recent introduction, but is less popular. Tamarind, curry leaf and *Garcinia* are indigenous to India and are grown widely.

Nutmeg (*Myristica fragrans* Houtt)

Nutmeg tree produces two separate spices, namely, nutmeg (kernel of the seed) and mace (aril covering the seed). Nutmeg belongs to Myristicaceae, one of the most primitive families of dicots. Indonesia, New Guinea and Grenada are the major producers. It originated in the Moluccas Islands of Indonesia.

The species occurring in India are *M. amygdalina* Wall., *M. andamanica* Hook, *M. attenuata* Wall., *M. dactyloides* Gaertn. (*M. laurifolia* Hook. f.), *M. beddomeii* King., *M. gibbosa* Hook., *M. glabra* Blume, *M.glaucescens* Hooker., *M. irya* Gaertn., *M. kingii* Hook., *M. longifolia* Wall. and *M. magnified* Bedd. Most of these are endemic to the Indo-Malayan region and the Western Ghat forests. The mace and seeds of *M. dactyloides* are used in tribal and indigenous medicine.

The IISR, Calicut, maintains 484 accessions of *M. fragrans* and related species. The genetic base of nutmeg germplasm in India is rather narrow as these are derived from a very few trees, originally introduced to India. But being a sexually propagated dioecious plant, some variability exists in these populations, especially for characters such as fruit size and shape, mace, seed volume and chemical composition (Gopalakrishnan, 1992). They also show quantitative variations for major quality components. The concentration of hallucinogenic principles (myristicin, elemicin, myristic acid) are reported high in Indian nutmeg (Gopalakrishnan, 1992). Two high yielding varieties namely Konkan Sugandha and IISR Viswasree were released for cultivation.

Cinnamon and Cassia (*Cinnamomum* spp.)

True cinnamon (C. *verum* Bercht & Presi) belonging to Lauraceae is indigenous to Sri Lanka and southern Western Ghats of India. Cassia cinnamon is obtained from various sources, the most important being *C. cassia* Bercht. & Presl. (Chinese cassia, Vietnam cassia or Saigon cassia). The other cassia cinnamons are: Indonesian (Javan) cassia (*C. burmanii* C.G. & Th. Nees), Saigon (Vietnam) cassia (*C. loureirii* Nees,) and Indian cassia (*C. tamala* Nees). Rich variability exists both in Western Ghat forest and the North-eastern region of India. Hooker (1886) reported 26 species from Indian subcontinent and adjoining areas. Only a few species are being exploited commercially. Apart from cinnamon and cassia, *C. tamala* (Indian cassia, Tejpat) leaves are

Table 16. Tree spices occuring in India

Botanical name	Common name	Family	Useful part
Cinnamomum bejholgota	Tejpat	Lauraceae	Leaf
C. cassia Brecht. & Presl.	Cassia	Lauraceae	Leaf bark
C. impressinervium	Tejpat	Lauraceae	Leaf
C. tamala	Tejpat, Indian Cassia	Lauraceae	Leaf
C.verum Brecht. & Presl.	Cinnamon	Lauraceae	Leaf, bark
Garcinia kowa	–	Clusiaceae	Fruit rind
G. gummi-gutta (L.) N. Robson	Gamboge	Clusiaceae	Fruit rind
G. indica Choisy	Kokum	Clusiaceae	Fruit (rind)
Murraya koenigii (L.) Sprengel	Curry leaf	Rutaceae	Leaf
Myristica fragrans Houtt. (introduced)	Nutmeg, mace	Myristi-caceae	Seed and aril
Pimenta dioeca (L.) Merr. (introduced)	Allspicae	Myrtaceae	Fruit
Syzgium aromaticum (L.) Merr. et Perry (introduced)	Cloves	Myrtaceae	Unopened flower bud
Tamarindus indica L.	Tamarind	Caesalpi-niaceae	Fruit pulp

Table 17. Germplasm holdings of Tree spices in India

Crop / center	Number of accessions
Nutmeg	
IISR	484
AICRP, Peechiparai	20
AICRP, Dapoli	95
Clove	
IISR	233
AICRP, Peechiparai	22
AICRP, Dapoli	3
AICRP, Yercaud	13
Cinnamon	
IISR	408
AICRP, Peechiparai	12
AICRP, Dapoli	49
AICRP, Yercaud	16
All Spice	
IISR	2
Garcinia	
IISR	86
NBPGR	71

extensively used in northern and North-Eastern India for flavouring various dishes. *C. impressinervium* and *C. bejholgota* are also used as Tejpat in the North-Eastern India, the latter is traded as the best quality tejpat The wild populations of cinnamon are in real peril because of the indiscriminate bark extraction from them. Species like *C. malabaricum, C. macrocarpum, C. riparium* and *C. pauciflorum* are also aromatic and are being used like *C. tamala* leaves.

Cinnamon trees are naturally cross-pollinated, and hence much variation exists in natural populations for morphological, chemical as well as bark characters among species (Krishnamoorthy and Rema, 1994). The quality of cinnamon depends on the essential oil content and composition of leaf and bark oil. The leaf oil contains eugenol as the chief component while the bark oil has cinnamaldehyde. So far 7 improved varieties were released in cinnamon (Table 18).

The Chinese cassia cinnamon is the dried bark of *C. cassia,* found in China, Vietnam, Thailand and up to the Malaysian region. China and Vietnam are the major producers. Indonesian cinnamon is the dried bark of *C. burmanii,* and is produced mainly in the Sumatra-Java region of Indonesia. At IISR, a small germplasm collection of Chinese cassia exists, which was derived from an earlier introduction in the Sri Kundra estate of Valparai, Tamil Nadu. Seed progenies from these trees were collected and raised at IISR to develop a small gene pool of this species. The genetic variability is very narrow. Since the cinnamon, we use in India, is actually Cassia, introduction of Cassia germplasm from the centers of diversity i.e. China and South East Asia will help in brodening the gene pool.

Clove *(Syzygium aromaticum* (L.) Merr. & Perry)

Clove, belonging to family Myrtaceae, is a native of Moluccas Islands (Indonesia) from where it has spread to many tropical countries. Britishers introduced clove to India. The clove buds contain around 15-17% volatile oil, the main component of which is eugenol. Clove is grown as inter-crop in many households in Kerala

Table 18. Released vareties of cinnamon

Cultivar	Pedigree/method	Mean yield (kg/ha)
Nithyasree	Open-pollinated progeny selection in Indian collection	200
Navasree	Open-pollinated progeny selection in Srilankan collection	250
YCD-1	Clonal selection in open-pollinated progeny	360
KonkanTej	Single plant seedling selection from Ceylon type	102
RKL(B)C-6	Selection from germplasm	250
PPI(C)1	Selection from op progenies of Sri Lankan type	980
Sugandhini	Single tree selection from waynad collection (Sri Lankan type)	640

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and Karnataka and in some pure plantations in southern Tamil Nadu and in Kerala. Though many species of *Syzygium* occur in India, but none of them are related to clove. Because of the limited introductions and self-pollinating nature of the species, the genetic base of clove in India is very narrow in any meaningful crop improvement programme. At IISR, 233 collections are maintained, the notable variants are a dwarf clove accession and a king clove, having bold flower bud. Introducing more variability in clove will help in clove breeding.

Garcinia spp.

The genus *Garcinia* belonging to Clusiaceae, is distributed in the tropics of the old world, chiefly Asia, with approximately 200 species. Malaysia and Africa with large number of endemic species appear to be the two main centres of diversity of the genus *Garcinia.* There are two major centres of diversity in the Indian sub-continent: the Northeastern region from Assam extending up to Burma, and the Western Ghats. In India, three important species, namely, .*G. gummi-gutta* (L). N. Robson (Malabar tamarind), *G. indica* (Thouars) Choisy (Kokam) and *G. mangostana* L. (Mangosteen) are cultivated. *Garcinia gummi-gutta* is wild in evergreen or semi-evergreen forests of Western Ghats up to 1800 MSL in Maharashtra, Goa, Karnataka, Kerala and also the Shola forests of the Nilgiris, Tamil Nadu. *Garcinia indica* occurs wild in the evergreen forests of Western Ghats in South Maharashtra extending southwards up to Kerala (Kasargod district). *Garcinia mangostana* is successfully cultivated in very small areas in Kerala and Tamil Nadu for its delicious fruits termed as 'queen of tropical fruits' and believed to have originated in West Malaysia. Overall, there is no large-scale cultivation of *Garcinia* and no released cultivar has been identified.

The dried fruit rind of *Garcinia* is the spice and is also used as a substitute for tamarind. They are also used (especially *G. indica)* to manufacture syrup and squash and in pharmaceutical industry as a source of hydroxycitric acid, an anti-obesity compound. Many species of *Garcinia* especially *G. morella,* are also the source of gamboge, a vegetable dye, used in earlier times for various purposes including hand painting clothes, potteries, etc.

Garcinia is a cross-pollinated species with separate male and bisexual trees. A few germplasm collections exist at IISR, NBPGR and KAU. At present 86 accessions of 4 species, namely, *G. gummi-gutta* (60 accessions), *G. indica* (6 accessions), *G. mangostana* (3 accessions) and *G. xanthochymus* (Mysore gamboge-2 accessions) are being maintained. There is considerable variation in yield, leaf, fruit and seed characters (Ravindran *et al.,* 2005).

Tamarind *(Tamarindus indica* L.)

Tamarindus is a monotypic genus and belongs to Caesalpiniaceae. Tamarind originated in tropical Asia (India) but also occurs in Central Africa. It is used both as spice and also is important in medicine. The main flavour component of the pulp is 2-acetylfuran. Major constituent is tartaric acid (8-18%). Kernel powder is an important sizing material for jute and textiles. The kernel powder contains xyloglycan, used as a gelling agent.

Limited work carried out on germplasm collection and evaluation, though, resulted in development of 5 released cultivars, namely, *Periakulam-1* (PKM-1), *Prathissthan,* DTS-1, No.263 and Yogeswari for cultivation. Two other well-known elite genotypes are *Urukumpuli* and *Kambum* Tamarind, very popular among growers. Being a crop native to India, priority must be given to collect and conserve indigenous genetic variability.

Curry Leaf [*Murraya koenigii* (L.) Sprengel]

Curry leaf, belonging to family Rutaceae is an essential leafy spice in South Indian food preparations. It had originated in India and cultivated extensively as a backyard plant in most households. The genus *Murraya* is represented by only three species in India. *Murraya koenigii* is distributed from the foot hills of Himalayas in the North to Kerala in the South, except in the arid regions. It also occurs in Andaman and Nicobar Islands, Myanmar (Indo-Burman region), Malaysia and Sri Lanka and in Pacific Ocean Islands. It is grown as a commercial crop in Tamil Nadu, Karnataka and Andhra Pradesh. Very little conservation and improvement work were undertaken in this crop. The type with pink midrib is usually preferred over green midrib and broad leaves over narrow leaves as the former has better aroma.

Small germplasm collections are being maintained at the University of Agricultural Sciences, Dharwad, Karnataka and Andhra Pradesh Agricultural University. A selection, namely, Suvasini was released for general cultivation. Much is not known about the genetic variability in quality characters. The studies revealed

more than 62 components, the important ones are phellandrene (2 to 4%), a-pinene (17.5%), 3-caiyophyllene (7.3%) and P-terpene-4-ol (6.1%). This essential oil has high antifungal and antibacterial activity. Curry leaf contains many alkaloids such as koenigicine, mahanimbine, koenine, koenigine, isomahanimbine, murrayccine etc. Curry leaf also has many medicinal properties and is being used in traditional medicine, as an ingredient in certain toothpastes, hair oil etc.

Vanilla *Vanilla planifolia* Andrews syn.*V. fragranse* (Salis.) Ames

V. planifolia, is the member of Orchidaceae, the only commercially important species in this family. It originated in Mexico but is grown in many pacific ocean islands, Indonesia and many African countries. It was introduced into India 100 years back but the interest in the cultivation is very recent. A small germplasm collection of about 93 collections exists with Spices Board and IISR, Calicut. The related species available in the collection are *V. andamanica* Rofle, *V. aphylla* Blume (syn. *V. vatsalana), V. pilifera* Holtt., *V. tahitensis* Moore and *V. wightiana* Li. The germplasm available in vanilla in India has very narrow genetic base for any meaningful crop improvement programme, and the base must be broadened. Since *Vanilla* is a cross-pollinated species in its native home, attempts are made to exploit variation in the segregating progenies. *Vanilla andamanica* is reported to be resistant to *Phytophthora meadii* and *Fusarium oxysporum* while *V. aphylla* is resistant to *F. oxysporum.* A few species are reported from Central America with resistance to major fungal diseases affecting vanilla. In view of the very narrow genetic base, vanilla is another crop where the plant introduction from centers of origin and diversity will help crop improvement programmes in India.

Future Strategies

India being the center of diversity of many spices the genetic variability in major spices like black pepper and cardamom followed by ginger, turmeric, cinnamon, tamarind and garcinia is quite reasonable. But other spices grown in India like coriander, chili, fennel, fenugreek, cumin, nutmeg, clove and vanilla are crops of exotic origin. The available genetic diversity in these crops in India is either very narrow and hence has to be augumented further. Plant introduction from the centres of diversity both in general as well as for specific characters will help in broadening the genetic base and in meaningful crop improvement programmes. Though this is presently being done in some of these crops like coriander, chili, fennel and fenugreek, introduction of genetic diversity from the centres of diversity is much needed in crops like paprika, nutmeg, clove, allspice and vanilla.

Also worth considering is introduction of other useful but at present not so popular spices and herbs like chives, lavender, anise, dill, rosemary, oregano, sage, marjoram, thyme etc. as they help in diversifying our spices production and introducing them to non traditional areas too.

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