Chapter 9
Diversity and Erosion in Genetic Resources of Spices

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Abstract Genetic resources are global assets of inestimable value to human kind, which holds the key to increasing food security. The loss of variation in crops due to the modernization of agriculture has been described as genetic erosion. The current status of the genetic diversity and erosion in spice crops is discussed in this chapter. Human intervention into the natural habitats of wild and related species in centers of diversity, diseases, and pests plays an important role in the loss of older species and varieties. This is further complicated by climate change and reproductive behavior of crop species. The Genetic erosion of cultivated diversity is reflected in a modernization bottleneck in the diversity levels that occurred during the history of the crop. Two stages in this bottleneck are recognized: the initial replacement of landraces by modern cultivars and further trends in diversity as a consequence of modern breeding practices. The factors contributing to erosion is due to the enormous diversity in cultivated plants, population growth, deforestation, erosion, changing land use, and climate factors are major threats to the existing biodiversity of the region. Urbanization is increasing and agriculture is changing from subsistence based on highly market-driven farming. Although

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these changes have increased incomes of the populations of wild habitants to certain extent, not all of them are for the good. In particular, biodiversity is declining as a result of some of these changes. It is mandate to conserve the vanishing plant genetic resources and to understand better the linkages between agricultural and economic system that affect diversity and sustainable production. Genetic erosion may occur at three levels of integration: crop, variety, and allele. Thus, genetic erosion is reflected in the reduction of allelic richness in conjunction with events at variety level. This requires immediate efforts to understand and implement the effective multiplication and conservation strategies using both conventional and modern technologies to save the loss of the valuable genetic resources and preserve them for posterity. An important aspect is also to include genetic resource conservation as an important part in our social life.

Keywords Genetic resources · Genetic erosion · Crop diversity · Black pepper · Spices · Cardamom · Ginger · Turmeric · Vanilla · Cinnamon · Nutmeg · Clove · Coriander · Cumin · Fennel · Fenugreek · GIS · In situ conservation · In vitro conservation · Cryo preservation · DNAbank · Pollen bank

9.1 Introduction

Plant genetic resources—constituting genotypes or populations of cultivars (landraces, advance/improved cultivars), genetic stocks, wild and weedy species which are maintained in the form of plants, seeds, tissues, etc.—hold key to food security and sustainable agricultural development (Iwananga 1994). Genetic diversity is an essential resource for crop breeding and reservoirs of identified and unidentified genes are essential for the study of the breeders of all generations. The primary and secondary centers of origin are the source for germplasm due to the natural hybridization and flow of genes throughout their existence. Detailed study on germplasm gives us the source material for resistance to biotic and abiotic stresses which can be further used in the improvement aspect.

India is the land of spices and is the primary or secondary center of origin to major spices especially black pepper, cardamom, ginger, turmeric, cinnamon, tamarind, and garcinia, where genetic diversity is rich and their wild forms still exist. In others, the diversity is limited. The important spices relevant in Indian context are black pepper, cardamom, ginger, turmeric, coriander, cumin, fennel, fenugreek, cinnamon, turmeric, cloves, allspice, garcinia, vanilla, and a few herbal spices (Ravindran et al. 2005b; Peter and Nirmal Babu 2006; Ravindran et al. 2006).

9.2 Origin, Distribution, and Diversity

9.2.1 Black Pepper

Black pepper one of the oldest spices known to the world (*Piper nigrum* L.) is a native of the humid tropical forests of the Western Ghats, from where it has spread throughout the tropics. *P. nigrum* L. belongs to the pepper family Piperaceae of the series Microembryeae of Monochlamydeae. The genus *Piper* is generally distributed in the tropical and subtropical regions of the world. The main centers of distribution are Central and South America and South Asia (Trelease and Yuncker 1950). The main center of distribution for Neotropical species is Central America. In the Central American forests, the genera are distributed in four different habitats, viz. edge of the semi-deciduous forests, inside the semi-deciduous forest, edge of the swampy forest, and inside the swampy forests. The greatest diversity of *Piper* species occurs in Tropical America with over 700 species followed by southern Asia with over 400 species (Fig. 9.1). Diversity of *Piper* is also occurring in South Pacific (40 spp.) and in the African tropics (15 spp.) (Jaramillo and Manos 2001).

About 114 species are reported from the Indian subcontinent (Table 9.1), of which about 18 species are found in sub-mountainous tracts of Western Ghats and adjacent peninsular and coastal region (Ravindran and Nirmal Babu 1994; Ravindran 2000; Ravindran et al. 2000, 2005; Tyagi et al. 2004; Ravindran and Kallupurackal 2012). In India, the north-eastern region and the south-western

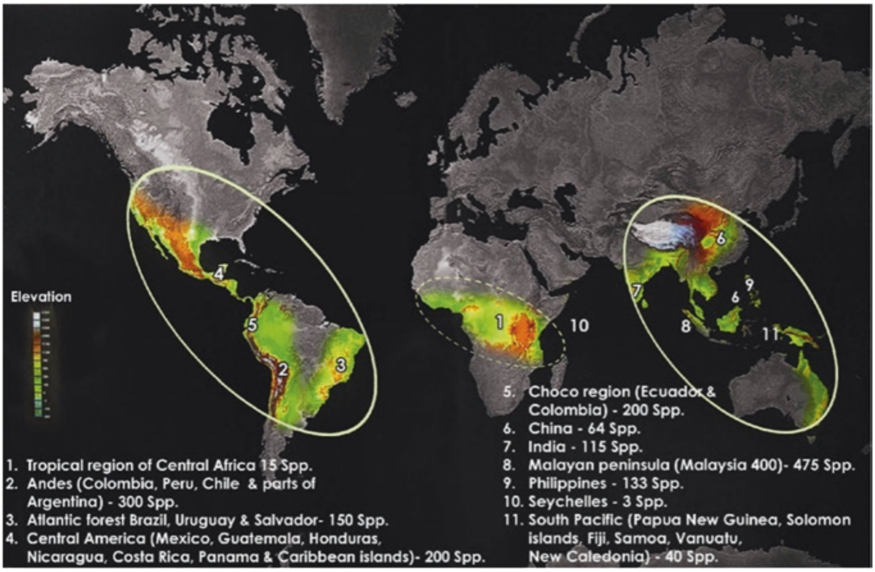

Fig. 9.1 The global geographical distribution of *Piper* and probable centers of origin of genus *Piper* (Saji 2006)

Table 9.1 *Piper* species reported from India

Sl. No.	Species	Sl. No.	Species	Sl. No.	Species
1.	*P. accrescens* Van Heurck & Müll.Arg.	39.	*P. gibsonii* C.DC	77.	*P. ovato-acuminatum* C.DC.
2.	*P. acutistigmum* C.DC.	40.	*P. glabramentum* C.DC.	78.	*P. ovatostemon* C.DC.
3.	*P. anisotis* Hook.f.	41.	*P. glabrirhache* C.DC.	79.	*P. pallidum* Van Heurck & Müll.Arg.
4.	*P. arborescens* Roxb.	42.	*P. grandipedun-culum* C.DC.	80.	*P. parvilimbum* C.DC.
5.	*P. arborigaudens* C.DC.	43.	*P. griffithii* C.DC.	81.	*P. pedicellatum* C.DC.
6.	*P. argyrophyllum* Miq.	44.	*P. guigual* Buch.-Ham. ex D.Don	82.	*P. peepuloides* Roxb.
7.	*P. arunachalensis* Gajurel, Rethy & Y.Kumar	45.	*P. hamiltonii* C.DC.	83.	*P. petiolatum* C.DC.
8.	*P. attenuatum* Buch. Ham. ex Wall.	46.	*P. hapnium* Buch.-Ham.	84.	*P. phalangense* C.DC.
9.	*P. aurantiacum* Wall.	47.	*P. haridasanii* Gajurel, Rethy & Y.Kumar	85.	*P. pseudonigrum* K.C.Velayudhan & V.A. Amalraj
10.	*P. aurorubrum* C.DC	48.	*P. hookeri* Miq.	86.	*P. puberulirameum* C.DC.
11.	*P. bababudani* Rahiman.	49.	*P. hymenophyl-lum* (Miq.) Wight	87.	*P. pykarahense* C.DC.
12.	*P. barberi* Gamble	50.	*P. isopleurum* C.DC.	88.	*P. retrofractum* Vahl.
13.	*P. bengalense* C.DC.	51.	*P. japvonum* C.DC.	89.	*P. rhytidocarpum* Hook.f.
14.	*P. betle* L.	52.	*P. jenkinsi*i C.DC.	90.	*P. ribesioides* Wall.
15.	*P. betleoides* C.DC.	53.	*P. kapruanum* C.DC.	91.	*P. sarmentosum* Roxb.
16.	*P. boehmeriaefolium* Wall.	54.	*P. khasianum* C.DC.	92.	*P. schmidtii* Hook.f.
17.	*P. brachystachyum* Wall.	55.	*P. laeve* Vahl	93.	*P. saxatile* Wall.
18.	*P. calvilimbum* C.DC.	56.	*P. lainatakanum* C.DC.	94.	*P. sikkimense* C.DC.
19.	*P. caninum* Blume	57.	*P. lanatum* Roxb.	95.	*P. silentvalleyensis* Ravindran, M.K. Nair & Asokan Nair
20.	*P. carnistigmum* C.DC.	58.	*P. laxivenum* C.DC.	96.	*P. siriboa* L.
21.	*P*. *caudilimbum* C.DC.	59.	*P. longum* L.	97.	*P. subpeltatum* Willd. –
22.	*P. chaba* Hunter	60.	*P. maingayi* Hook.f.	98.	*P. sugandhi* Babu et Naik
23.	*P. clarkei* C.DC.	61.	*P. makruense* C.DC.	99.	*P. suipigua* Buch.-Ham. ex D.Don

(continued)

Table 9.1 (continued)

Sl. No.	Species	Sl. No.	Species	Sl. No.	Species
24.	*P. clypeatum* Wall.	62.	*P. malamiris* L.	100.	*P. subrigidilimbum* C.DC.
25.	*P. cornilimbum* C.DC.	63.	*P. mannii* C.DC.	101.	*P. sylvaticum* Roxb.
26.	*P. crassistipes* C.DC.	64.	*P. meeboldii* C.DC.	102.	*P. sylvestre* Lam.
27.	*P. crenulatibracteum* C.DC.	65.	*P. mullesua* Buch.-Ham.	103.	*P. syringifolium* Vahl
28.	*P. cubeba* L. f.	66.	*P. muneypo-rense* C.DC.	104.	*P.t albotii* C.DC.
29.	*P. curtistipes* C.DC.	67.	*P. mungpooa-num* C.DC.	105.	*P. tenuibracteum* C.DC.
30.	*P. dekkoanum* C.DC.	68.	*P. nagaense* C.DC.	106.	*P. tenuiflorum* Vahl
31.	*P. diffusum* Blume ex Miq.	69.	*P. nepalense* Miq.	107.	*P. thermale* Vahl
32.	*P. exasperatum* Vahl	70.	*P. nigramentum* C.DC.	108.	*P. thomsoni* Hook.f.
33.	*P. falconeri* C.DC.	71.	*P. nigrum* L.	109.	*P. trichostachyon* C.DC.
34.	*P. filipedunculum* C.DC.	72.	*P. obtusistig-mum* C.DC.	110.	*P. trioicum* Roxb.
35.	*P. galeatum* C.DC.	73.	*P. oldhamii* C.DC.	111.	*P. tristachyon* C.DC.
36.	*P. gallatlyi* C.DC.	74.	*P. ootacamun-dense* C.DC.	112.	*P. voigtii* C.DC.
37.	*P. gamblei* C.DC.	75.	*P. opacilimbum* C.DC.	113.	*P. wightii* Miq.
38.	*P. gammiei* C.DC.	76.	*P. ovatistigmum* C.DC.	114.	*P. zuccarinii* C.DC.

(Western Ghats) region are recognized as two independent centers of diversity. *Piper* species occurring in India are unisexual, but the Central and South American species are generally bisexual types. However, the cultivated black pepper is bisexual. Probably, the bisexual types might have originated from the wild unisexual ones as a result of domestication and conscious and continuous selection for high-yielding types and their maintenance by vegetative propagation by people through the ages.

Over 100 cultivars of black pepper are known to India. The Dutch in the seventeenth and eighteenth centuries brought pepper cultivation on to Java, Sumatra, Borneo, Sarawak, the Malay Peninsula, Siam, Philippines, and later into the West Indies on a plantation scale. Black pepper is believed to be introduced to America during the middle of eighteenth century (Gentry 1955).

In addition to black pepper, the other economically important species of *Piper* are Indian long pepper (*P. longum* L), betel vine (*P. betle* L.), Java long pepper (*P. chaba* Hunter), tailed pepper (*P. cubeba* L.), Kawa pepper (*P. methysticum*

Forster), West African pepper (*P. clusi* C. DC.), Benin pepper (*P. guineense* Schum. & Thonn.) and Japanese pepper (*P. kadzura* (Choisy) Ohwi.).

The community composition, species richness, relative abundances of different species, and species diversity in a community were studied by Saji (2006) using Shannon diversity index (H) which indicated that the Western Ghats region of South India could be divided into seven, based on relative abundance of different species and species diversity in a community. Southern tip of India has highest diversity, while the coastal regions have low diversity. The hilly regions of Kerala and Tamil Nadu are the two regions with maximum diversity—especially the mountainous regions between the states (Fig. 9.2). The effort by the Government of India to protect these natural habitats as bio-parks is helping in conservation of biodiversity in these regions. This is helping many *Piper* species getting protected and they multiply into viable populations due to prevailing vegetative propagation. Because of these efforts, we find some endangered species like *Piper wightii* and *P. schmidtii* which are multiplying in Nilgiri reserves in Tamil Nadu and recently we discovered an ecological niche of *Piper barberi* a critically endangered species of *Piper* in the forest region of Idukki dist of Kerala, in India.

The cultivar diversity is very high in India where over 100 cultivars of pepper have been reported (Ravindran et al. 2000) from Western Ghats (Table 9.2). It is probable that the cultivated forms in different regions have originated from wild peppers of the same region.

India has assembled a world collection of black pepper germplasm with over 3500 accessions of cultivars, related species, land races, and maintains them in ex situ clonal field repositories. In addition, over 17 improved varieties are released for cultivation with good characters like high yield, bold berries, resistance to

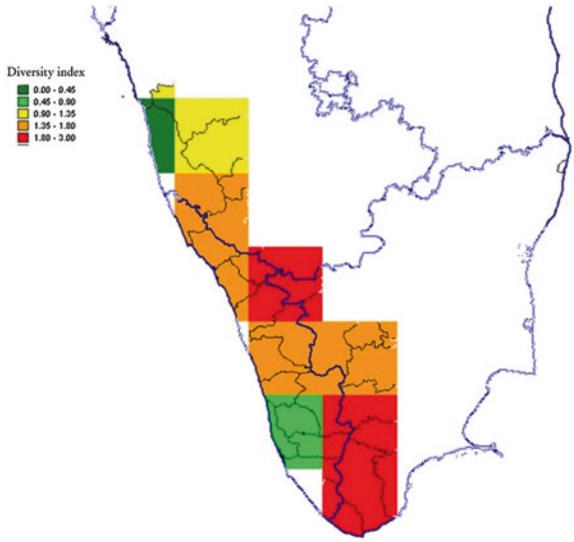

Fig. 9.2 Diversity indices of distribution of *Piper* species in Western Ghats of India

Table 9.2 Important cultivars of black pepper in India and other countries

Country	Name of the cultivar
India	Aimpiriyan, Arakkulam munda, Arimulaku, Aralumuriyan, Aranavalan, Arasinagunda, Arasinamuratta, Arikotta, Arivally, Balankotta, Cheppukulamundi, Cheriyakaniakkadan, Champakkara, Chankupazhuppan, Charadfupiriyan, Cheruvally (Cherukodi), Chettanvally, Cholamundi, Chumala, Doddigae,, Dadasinikulu, Doddalae, Ghantuvalli, Giddaghere, Irumaniyan, Jeerakamundi, Kalluvally, Karimkotta, Karimunda, Karimundi, Karivilanchi, Kottanadan, Kurimalai, Kuriyalmundi, Kuthiravally, Kallubalankotta, Kallumunda, Knajirakodan, Kanjiramundi, Kapplangamundi, Karimkodi, Karimuratta, Karivally, Konomkara, Kotta, Kottan, Kudirugunda, Kumbhachola (Kumbhakodi), Kumbhanadan, Kuppakkodi, Kuttiyanikodi, Kuzhuvelikodi, Malamundi, Maligesara, Mundi, Malanadan, Manjamundi, Marampadathi, Marankodi, Maeramodiyan, Motaghere, Munda, Murithothan, Narayakkodi, Nedumchola, Neelamundi, Nadesankodi, Nastigunda, Neyyattinkaramundi, Orumaniyan, Perambramunda, Perumkodi, Poonjaran munda, Padappan, Perumkarimunda, Pirimundi (Pirimunda), Ppunchakodi, Sagar Local, Shimoga, Sulla, Thevanmundi, Thommankodi, Thulamundi, Thekkan, Thippalimundi, Thottamundi, Uddaghere, Uthirankotta, Vadakkan, Valiakaniakkadan, Vattamundi, Vellanamban, Velliyaranmunda, Vally, Varikkakodi, Vellamunda, Veluthakaniakkadan, Vokkalginja, Vokkalu, Wynadan, Yohannakodi
SriLanka	Palulata, Panniyur 1, Kuching
Malaysia	Kuching, Semongok Perak, Semongok Emas
Indonesia	Belantung, Natar-1, Natar-2, Bulok Belantung, Jambi, Kerinci, Lampung Daun Lebar (LDL), Bangka (Muntok) and Lampung Daun Kecil (LDK), Petaling 1. Petaling 2, Choenuk, Bengkayang
Brazil	Chingapura, Bragantina, Iaçará and Guajarina,Panniyur 1

Phytophthora and nematodes, high dry recovery, high piperine, oleoresin and essential oil contents (Table 9.11). However, due to the preference of high-yielding varieties and debilitating diseases like *Phytophthora* foot rot, many of the old primitive cultivars are being replaced and are slowly disappearing from cultivation.

9.2.2 Small Cardamom

Small Cardamom is the dried fruit of *Elettaria cardamomum* Maton, belonging to Zingiberaceae. Cardamom occurs in its native state only in the tropical evergreen forests of the Western Ghats. The wild populations of cardamom gradually declined because of the large-scale destruction of forest habitats. *E. cardamomum* in India is monotypic genus with only one species. Its closest species is the Sri Lankan wild cardamom *E. cardamomum* namely, var. major. Seven other species of *Elettaria* were reported from southeast Asia.

The species *E. cardamomum* comprises a freely interbreeding population, and the genus *Elettaria* seems to be a "Cenospecies," in India, with a single "ecospecies" corresponding to the taxonomic species, *E. cardamomum* Maton. The ecotype can be divided into three mini local populations as local types they are '*Travancoria,' 'Oblongata,' and* '*Kanarensis.*' Cardamom consists of three morphologically distinct types, namely, Malabar, Mysore and Vazhukka. Cardamom being a cross-pollinated crop, a lot of phenotypic variants exists in nature. Some of exceptional variants in cardamom have panicles of various types, terminal panicle, branched raceme, female sterility and cleistogamy. Good variability exists in cardamom with regard to various morphological characters such as fruit (capsule) size, shape, leaf, and plant pubescence and quality characters, such as essential oil and its components, such as 1, 8-cineole and alpha-terperyl acetate. (Madhusoodanan et al. 1994, 2002) reported that a wide range of variation was observed between and within cultivars of small cardamom for economically important characters. In general, the 'Vazhukka' and 'Mysore' types are robust compared to Malabar types (Ravindran and Madhusoodanan 2002; Korikanthimath et al. 2006; Parthasarathy and Prasath 2012).

Over 900 accessions of cardamom germplasm are maintained as clonal repositories at various centers in India. The characters which are found to least occur are compound panicle, basal branching of panicles, and red pseudostem pigmentation. The diversity is very narrow with respect to biotic and abiotic stresses. In addition, over 10 improved varieties are released for cultivation with good characters like high yield, bold capsules, high-quality attributes, resistance to viruses, rhizome rot and drought (Table 9.11). However, due to the preference for newer high-yielding varieties and debilitating viral disease and fungal diseases like katte and rhizome rot, many of the low yielding cultivars are being replaced.

9.2.3 Ginger

Ginger (*Zingiber officinale* Roscoe) belongs to family Zingiberaceae. The north-eastern region is a major producer of ginger. Indo-Malayan region is the native home of this family. Ginger is not found in the truly wild state. It is believed to have originated in southeast Asia, but was under cultivation from ancient times in India (Purseglove et al. 1981; Mohanty and Panda 1994). There is no definite information on the primary center of origin or domestication. It was brought to the Mediterranean region from India by traders during the first century AD. During the thirteenth century AD, the Arabs took ginger to eastern Africa from India. Later, it was spread to West Africa by the Portuguese for commercial cultivation. Because of the ease with which ginger rhizomes can be transported long distances, it has spread throughout the tropical and subtropical regions in both hemispheres. The main areas of ginger cultivation are India, China, Nigeria, Indonesia, Jamaica, Taiwan, Sierra Leone, Fiji, Mauritius, Brazil, Costa Rica, Ghana, Japan, Malaysia, Bangladesh, Philippines, Sri Lanka, Solomon Islands, Thailand, Trinidad, Tobago, Uganda, Hawaii, Guatemala and many Pacific Ocean islands.

The genus *Zingiber*, consisting of about 150 species, is widely distributed in tropical and subtropical Asia. Some important species of *Zingiber* (Sabu and

Table 9.3 Species of *Zingiber* and their distribution

Species	Origin
Z. officinale Roscoe, Z. *zerumbet* (L.) Sm., *Z. purpureum* Roscoe, *Z. roseum* (Roxb.) Roscoe, *Z. wightianum* Thw., *Z. macrostachyum* Dalz., *Z. cernuum* Dalz., *Z. capitatum* Roxb., *Z. cylindricum* Moon, *Z. montanum* (Koenig) Link ex, *Z. intermedium* Baker, *Z. nimmonii, Z. odoriferum* Blume, *Z. ligulatum* Roxb., *Z. spectabilis* Griff., *Z. clarkii* King ez Benth, *Z. marginatum* Roxb., *Z. intermedium* Baker, *Z. chrysanthum* Roscoe, *Z. rubens* Roxb., *Z. squarrosum* Roxb, *Z. elatum* R. Br	India
Zingiber americanus Blume*., Zingiber argenteum* J. Mood & I. Theilade, *Z. acuminatum* Valeton, *Z. albiflorum* R.M. Sm., *Z. aurantiacum* I. Theilade, *Z. chlorobracteatum* Mood & Theilade, *Z. citrinum* Ridley, *Z. curtiisii* Holttum, *Z. flammeum* I. Theilade & J.Mood, *Z. fraseri* I. Theilade, *Z. georgei* J. Mood & I. Theilade, *Z. gracile* Jack, *Z. flagelliforme* J. Mood & I. Theilade, *Z. incomptum* Burtt & R.M. Sm., *Z. kuntstleri* Ridley, *Z. lambii* J. Mood & I. Theilade, *Z. latifolium* J. Mood & I. Theilade, *Z. leptostachyum* Valeton, *Z. malaysianum* C.K. Lim, *Z. martini* R.M. Sm., *Z. multibracteatum* Holttum, *Z. pendulum* J. Mood & I. Theilade, *Z. phillippsii* J. Mood & I. Theilade, *Z. pseudopungens* R.M. Sm., *Z. sulphureum* Burkill ex I.Theilade, *Z. velutinum* J. Mood & I. Theilade, *Z. vinosum* J. Mood & I. Theilade, *Z. viridiflorum* J. Mood & I. Theilade	Malaysia
Z.aromaticum Valeton	Tropical Asia
Z. bradleyanum Craib,, *Z.citriodorum* J. Mood & I. Theilade, *Z. corallinum* Hance, *Z. flavovirens* I. Theilade, *Z. larsenii* I. Theilade, *Z. longibracteatum* I. Theilade, *Z. newmanii* I. Theilade, *Z. peninsulare* Theilade, *Z. smilesianum* Craib, *Z. villosum* I. Theilade	Thailand
Z. mioga Roscoe	Japan
Z. barbatum Wall	Myanmar, Thailand
Z. chrysostachys Ridley, *Z. spectabile* Griffith, *Z. wrayii* Ridley, *Z. petiolatum* (Holttum) I. Theilade	Thailand, Malaysia
Z. collinsii I. Theilade & J. Mood	Vietnam
Z. eborium J. Mood & I. Theilade	Malaysia, Indonesia
Z. gramineum Noronha ex Blume	Thailand, Cambodia, Sumatra
Z. griffithii Baker	Malaysia, Thailand, Singapore
Z. junceum Gagnep	Cambodia, Thailand, Laos
Z. kerrii Craib	Thailand, Indochina
Z. koshunense C.T. Moo	Taiwan
Z. longipedunculatum Ridley	Australia
Z. neglectum Valeton, *Z. niveum* J. Mood & I. Theilade	United States
Z. ottensii Valeton	Southeast Asia
Z. pachysiphon B.L. Burtt & R.M. Sm.	Malaysia, Australia
Z. parishii Hook. f.	India, Myanmar, Thailand

(continued)

Table 9.3 (continued)

Species	Origin
Z. pellitum Gagnepo	Thailand, Laos, Malaysia
Z. puberulum Ridley	Malaysia, Thailand, Singapore
Z. rubens Roxb	India, Thailand, Vietnam, China
Z. squarrosum Roxb	India, Myanmar

Skinner 2005, Ravindran and Nirmal Babu 2005a) are given in Table 9.3. In India, variability for cultivated ginger exists mainly in the north-eastern region and Kerala. A botanically distinct variety *Z. officinale* var. rubrum having pink outer skin of rhizome is under cultivation in Malaysia. The genus *Zingiber* includes many species grown as ornamentals, but some are cultivated for valuable medicines. They bear showy, long-lasting inflorescences and often brightly colored bracts and floral parts; they are widely used as cut flowers in floral arrangements. Some of them are good foliage plants due to their arching form and shining leaves.

Cultivated ginger *Zingiber officinale* does not occur in wild but maintained only under cultivation. Ginger has no seed set and is only propagated vegetatively. There is moderate varietal/cultivar diversity in India. In India, over 1200 accessions are maintained in clonal repositories. The cultivars are often named after the locality. Good variation with respect to plant height, days to maturity, dry recovery, rhizome shape, size, yield, fiber content, color and quality attributes was observed (Ravindran et al. 2005a; Nirmal Babu et al. 2011a; Valsala 2012). This is due to accumulated natural mutations maintained in the population efficient vegetative propagation. Chemical variations in essential oil, oleoresin and gingerol, shogaol contents, have been reported. However, genetic diversity for biotic and abiotic resistances is almost absent making this crop susceptible for diseases and pests. In addition, over 12 improved varieties are released for cultivation with good characters like high gingerol and shogaol content and dry recovery. High/low fiber, plumpy rhizomes, vegetable types, and high dry recovery (Table 9.11). Rhizome rot caused by *Pythium* spp. and bacterial wilt caused by *Ralstonia* spp. are the most destructive diseases affecting ginger plantations. As no resistance source is reported so far in ginger or related species, many of the local cultivars are facing threat of elimination.

9.2.4 Turmeric

Turmeric *Curcuma longa* (L.) belongs to Zingiberaceae, and is one of the most ancient spices used in India. India is the largest producer and exporter of turmeric. Turmeric is believed to have originated in the Indo-Malayan region.

The genus *Curcuma* consists of about 70–110 (true identity is unclear) species distributed chiefly in southeastern Asia (Skornickova et al. 2007). In addition to *C. longa*, the other economically important species of the genus are *C. aromatica*, which is used in medicine and in toiletry articles; *C. kwangsiensis*, *C. ochrorhiza*, *C. pierreana*, *C. zedoaria* and *C. caesia*, which are used in folk medicines of the southern and southeastern Asian nations; *C. alismatifolia*, *C. elata* and *C. roscoeana*, with floricultural importance; *Curcuma amada*, which is used as medicine and in a variety of culinary preparations, pickles, and salads; *C. zedoaria*, *C. pseudomontana*, *C. montana*, *C. angustifolia*, *C. rubescens*, *C. haritha* and *C. caulina* which are all used in manufacturing arrowroot powder. The other species of minor importance are *C. purpurescens*, *C. mangga*, *C. heyneana*, *C. zanthorrhiza*, *C. phaeocaulis* and *C. petiolata* (Nirmal Babu et al. 1993; Rama Rao and Rao 1994; Velayudhan et al. 1999; Ravindran et al. 2007a, b; Skornickova et al. 2007).

The greatest diversity of the genus occurs in India, Myanmar and Thailand and extends to Korea, China, Australia and the South Pacific. This genus is also distributed in Cambodia, Indonesia, Malaysia, Laos, Madagascar and the Philippines. Many species of *Curcuma* are economically valuable and different species are cultivated in China, India, Indonesia and Thailand and throughout the tropics, including tropical regions of Africa, America and Australia. Genus *Curcuma* has about 42 species distributed in India, out of which *C. longa* is cultivated for turmeric, *C. aromatica* is grown for use in toiletry articles, and *C. amada* (mango ginger) is cultivated in limited areas for use as a vegetable. The country of origin of cultivated turmeric (*C. longa*) is presumed to be the southeast Asia. India is the single largest producer and exporter of turmeric in the world (Manohar Rao et al. 2006; Nirmal Babu et al. 2011b).

Different species of turmeric are used in folk medicine, as a spice, as a vegetable in a variety of culinary preparations, pickles, and salads, in the production of arrowroot powder, and in toiletry articles. Many *Curcuma* species are highly valued as ornamentals. Turmeric oil is also now used in aromatherapy and the perfume industry. Many *Curcuma* species were recognized by local and tribal people all over Asia as valuable sources of medicine. Distributions of *Curcuma* species in southeast Asia and India are given in Tables 9.4 and 9.5.

Good cultivar diversity occurs in India, with over 1500 accessions are conserved in various centers. In India, turmeric set seeds and seedling populations of over 300 progenies supplement the existing germplasm. There is a high variation with regard to morphology, yield, quality attributes, and dry recovery. In addition, over 34 improved varieties are released for cultivation with good characters like short duration, resistance to rhizome rot, plant height, high curcumin, and oleoresin content and dry recovery (Table 9.11).

Table 9.4 Distribution of *Curcuma* species in Indo—Malayan region

Curcuma species	Distribution
C. aeruginosa Roxb.	India, Thailand, Indochina, Malaysia, Indonesia, Sri Lanka, Myanmar
C. albiflora Thwaites, *C. oligantha* Trimen	Sri Lanka
C. alismatifolia Gagnep	Thailand, Laos, Cambodia
C. amarissima Roscoe	India, China
C. aurantiaca Zijp	India, Java, Thailand, Malaysia
C. australasica Hook. f.	Australia
C. bicolor Mood & Larsen, *C. burtii* K. Larsen & Smith, *C. ecomata* Craib., *C. glans* K. Larsen & Mood, *C. gracillima* Gagnep., *C. thorelii* Gagnep	Thailand
C. comosa Roxb., *C. cordata* Wall., *C. petiolata* Roxb., *C. sessilis* Gage, *C. strobilifera* Wall. ex. Baker	Myanmar
C. elata Roxb., *C. rubrobracteata* Skornick., M. Sabu & Prasanthk	India, Myanmar
C. exigua N. Liu & S.J. Chen, *C. kwangsiensis* S.G. Lee & C.F. Liang, *C. sichuanensis* X. X. Chen, *C. yunnanensis* N. Liu & S.J. Chen	China
C. ferruginea Roxb.	India, Bangladesh
C. flaviflora S. Q. Tong	China, Thailand
C. harmandii Gagnep	Thailand, Cambodia
C. larsenii C. Maknoi & T. Jenjittikul	Thailand, Laos, Vietnam
C. longa L.	Asia
C. mangga Valeton & Zijp	India, Malaysia, Indonesia
C. parviflora Wall	Thailand, Myanmar, Malaysia
C. picta Roxb. ex. Skornick	India, Thailand, Sri Lanka, Peninsular Malaysia
C. rhabdota Siriirugsa & M.F. Newman	Thailand, Laos
C. rhomba Mood & K. larsen	Vietnam, Thailand
C. roscoeana wall	India, Bangladesh, Myanmar, Thailand
C. rubescens Roxb.	India, Thailand, Bangladesh
C. sparganifolia Gagnep	Indochina, Cambodia, Thailand
C. viridiflora Roxb.	Indonesia, Malaysia, Thailand, China, Sumatra
C. zanthorrhiza Roxb.	India, Java, Peninsular Malaysia, Vietnam, China, Thailand, Philippines
C. zedoaria (Christm.) Roscoe	India, Myanmar, Thailand, Malaysia

9.2.5 Vanilla

Vanilla planifolia [syn. *Vanilla fragrans*) is a member of Orchidaceae, the only commercially important spice in this family. Vanilla is a crop of great commercial importance as the source of natural vanillin; a major component of flavor industry.

Table 9.5 Distribution of *Curcuma* species in India[a]

Sl. No.	Species	Region of occurence	Sl. No.	Species	Region of occurence
1.	*C. aeruginosa* Roxb.	NE	17.	*C. latifolia* Rosc.	NE
2.	*C. albiflora* Thw.	Ka	18.	*C. longa* L.	
3.	*C. amada* Roxb.	IND	19.	*C. lutea*	Ke/Ka
4.	*C. amarassima* Rosc.	NE	20.	*C. malabarica*	Ka/Ke
5.	*C. aromatica* Salisb.	Ka/Ke	21.	*C. montana* Roxb.	AP
6.	*C. aurantiana*	Ke	22.	*C. nilamburensis* Velayudhan et al.	Ke
7.	*C. brog*	NE	23.	*C. nilgherrensis* Wight	SI
8.	*C. caesia* Roxb.	NE	24.	*C. oligantha* Trimen	Ke
9.	*C. cannanorensis* Ansari et al.	Ke	25.	*C. pseudomontana* Graham	SI & M
10.	*C. comosa* Roxb.	NE	26.	*C. raktakanta* Mangaly and Sabu	Ke
11.	*C. coriaceae* Mangaly & Sabu	Ke	27.	*C. soloensis*	NE
12.	*C. decipiens* Dalzell	Ke	28.	*C. sylvatica*	NE/Ke
13.	*C. ecalcarata* Sivarajan and Indu.	Ke	29.	*C. thalakkaveriensis* Velayudhan et al.	Ka
14.	*C. haritha* Sabu	Ke	30.	*C. vamana* Sabu & Mangaly	Ke
15.	*C. karnatakensis* Velayudhan et al.	Ka	31.	*C. vellanikkariensis* Velayudhan et al.	Ke
16.	*C. kudagensis* Velayudhan et al.	Ka	32.	*C. zedoaria* (Christm.) Roscoe	IND

Ke Kerala, *Ka* Karnataka, *NE* North-eastern region *M* Maharashtra, *SI* South India, *AP* Andhra Pradesh, *IND* India
[a]Velayudhan et al. (1999)

It originated in Mexico but is grown in many Pacific Ocean islands, Indonesia and many African countries. The genus Vanilla comprises about 110 species, distributed in tropical parts of the world (Purseglove et al. 1981; Cuvelier and Grisoni 2010; De Guzman and Zara 2012). Few important vanilla species are *V. andamanica, V. aphylla* syn. *V. vatsalana, V. pilifera, V. tahitensis, V. pompon, V. wightiana, V. parishii,* and *V. walkeriae* (Table 9.6).

The germplasm available in vanilla in India is very narrow. The primary gene pool of *V. planifolia* is narrow and is evidently threatened due to destruction of its natural habitats making the secondary gene pool important as a source of desirable traits especially for resistance to diseases. The species diversity in the country is represented by five species, viz., *V. aphylla, V. walkeriae, V. wightiana, V. pilifera,* and *V. andamanica* and most of them are considered endangered. Intense works of selection, breeding, and conservation of genetic resources are required to overcome the narrow genetic base of this vegetatively propagated crop. Effective

Table 9.6 Some important species of Vanilla

Vanilla	*Vanilla abundiflora* J.J. Sm., *V. acuminata* Rolfe, *V. africana* Lindl., *V. albida* Blume, *V. mexicana* Mill., *V. aphylla* Blume, *V. andamanica* Rolfe, *V. angustipetala* Schltr., *V. annamica* Gagnep., *V. appendiculata* Rolfe, *V. vellozoi* Rolfe, *V. anomala (Ames & L.O.Williams)* Garay, *V. barbellata* Rchb.f., *V. bahiana* Hoehne, *V. bertoniensis* Bertoni, *V. bicolor* Lindl., *V. borneensis* Rolfe, *V. bradei* Schltr. ex Mansf., *V. calopogon* Rchb.f., *V. calyculata* Schltr., *V. gardneri* Rolfe, *V. chalotii* Finet, *V. chamissonis* Klotzsch, *V. claviculata* Sw., *V. cobanensis* Archila, *V. columbiana* Rolfe, *V. coursii* H.Perrier, *V. crenulata* Rolfe, *V. cribbiana* Soto Arenas, *V. cristagalli* Hoehne, *V. odorata* C. Presl, *V. dietschiana* Edwall, *V. dilloniana* Correll, *V. dressleri* Soto Arenas, *V. dubia* Hoehne., *V. dungsii* Pabst, *V. edwallii* Hoehne, *V. poitaei* Rchb.f., *V. fimbriata* Rolfe, *V. francoisii* H. Perrier, *V. gardneri* Rolfe, *V. giulianettii* F.M. Bailey, *V. griffithii* Rchb.f., *V. guatemalensis* Archila, *V. guianensis* Splitg., *V. hamata* Klotzsch, *V. hartii* Rolfe, *V. havilandii* Rolfe, *V. helleri* A.D.Hawkes, *V. imperialis* Kraenzl., *V. inodora* Schiede, *V. insignis* Ames, *V. kaniensis* Schltr., *V. kempteriana* Schltr., *V. kinabaluensis* Carr, *V. madagascariensis* Rolfe, *V. martinezii* Soto Arenas, *V. montana* Ridl., *V. moonii* Thwaites, *V. nigerica* Rendle, *V. organensis* Rolfe, *V. ovata* Rolfe, *V. palembanica* Teijsm. & Binn.,*V. parvifolia* Barb. Rodr., *V. perrieri* Schltr., *V. phaeantha* Rchb.f., *V. planifolia* Jacks. ex Andrews, *V. platyphylla* Schltr., *V. pompona* Schiede, *V. ramificans* J.J. Sm., *V. ramosa* Rolfe, *V. ribeiroi* Hoehne, *V. roscheri* Rchb.f., *V. savannarum* Britton, *V. seretii* De Wild., *V. somae* Hayata, *V. sprucei* Rolfe, *V. trigonocarpa* Hoehne, *V. utteridgei* J.J. Wood, *V. walkeriae* Wight, *V. wariensis* Schltr., *V. wightii* Lindl. ex Wight, *V. zanzibarica* Rolfe, *V. yersiniana* Guillaumin & Sigaldi

Source Vanilla Species [*Catalogue of Life: 22nd December 2014, Integrated Taxonomic Information System (IT IS)*]

procedures for micropropagation and in vitro conservation by slow growth in selected species of vanilla are available.

Although vanilla is cultivated throughout the tropics, its natural populations in Southern Mexico—the most critical sources of novel genetic diversity—are on the verge of disappearing due to deforestation and over collection (Lubinsky 2003). Since the narrow primary gene pool is evidently threatened, the secondary gene pool comprising the close relatives of *V. planifolia*, which is also equally threatened, becomes important as a source of desirable traits—especially for self-pollination, higher fruit set, and disease resistance (Minoo 2002; Minoo et al. 2006; Bory et al. 2010). Many species of vanilla are considered endangered (Table 9.6) and there is urgent need to conserve them. The recent International Congress on vanilla emphasized the need to conserve these species before they go extinct (International Congress on Vanilla 2003). Thus a major challenge is to conserve the vanilla gene pool from the onslaught of habitat destruction, over collection, climate changes and destructive diseases in monocultures.

Recent advances in conservation have paved the way to safeguard plant biodiversity with a biotechnological approach, which can be regarded as complementary to the traditional clonal orchards and seed banks. Traditionally, Vanilla germplasm is conserved in clonal repositories belonging to botanical gardens and in scientific institutions. However, the high costs of this traditional conservation system limit the number of accessions that can be preserved. In order to stem the flow of loss of biodiversity, an attempt to conserve *Vanilla* species, in vitro has been made (Minoo et al. 2006).

9.2.6 Tree Spices

There are many tree spices which are important. The most important ones, in Indian context, are cinnamon (*Cinnamomum verum syn: Cinnamomum zylanicyum*), nutmeg (*Myristica fragrans*), clove (*Syzygium aromaticum Syn: Eugenia Cariophyllus*), and garcinia (*Garcinia* sp.) (Ravindran et al., 2004a, b, 2005a), some of which are native and others introduced (Krishnamoorthy and Rema 1994).

9.2.6.1 Nutmeg

Nutmeg tree is the only plant that produces two separate spices, namely nutmeg (kernel of the seed) and mace (aril covering the seed). Nutmeg belongs to Myristicaceae and the species is believed to have originated in the Moluccas Islands of Indonesia. The important species occurring in India are *M. amygdalina, M. andamanica, M. attenuata, M. dactyloides, M. beddomeii, M. gibbosa, M. glabrae, M. glaucescensr., M. irya Gaertn., M. kingii., M. longifolia.,* and *M. magnifica.* Being a dioecious plant, good variability exists in nutmeg, especially for characters such as fruit size and shape, mace, and seed volume. (Krishnamoorthy et al. 1996). The chemical composition also shows quantitative variations for major quality components. Myristicin, elemicin, and 1,8-cineole are the important constituents in nutmeg. There is an increase in genetic diversity in cultivated nutmeg due to variation through segregating progenies. But the nutmeg population (nutmeg swamps) are slowly disappearing. Over 475 accessions are maintained at various centers in India. About six varieties of high-yielding, high-quality cultivars were recommended for release in India (Table 9.11).

9.2.6.2 Cinnamon

True cinnamon is obtained from *C. verum* belonging to Lauraceae; indigenous to Sri Lanka and Southern Western Ghats of India. Cassia cinnamon is obtained from various sources, the most important being *C. cassia* (Chinese cassia, Vietnam cassia or Saigon cassia). The other cassia cinnamons are Indonesian (Javan) cassia (*C. burmanii*), Saigon (Vietnam) cassia (*C. loureirii*), and Indian cassia (*C. tamala*). The genus is a native of south-western tropical India and SriLanka, consisting more than 250 species distributed in southeast Asia, China and Australia. Seychelles and Malagay Republic are the major cinnamon-producing countries besides Sri Lanka. Some important species of *Cinnamomum* are given in Table 9.7. Over 26 species occur in India. Endemic species are *C. macrocarpum* Hk. F., *C. malabathrum* Bl., *C. nicolsonianum* Manilal and Shylaja, *C. riparium* Gamble, *C. keralaense* Kosterm, *C. travancoricum* Gamble, *C. wightii* Meiss., *C. heyneanum* Nees, *C. gracile* (Miq.), and *C. chemungianum* Mohan and Henry. Non-endemic species are *C. citriodorum*Thw., *C. filipedicellatum* Kosterm., *C. goaense* Kosterm, *C. perottetii* Meiss., *C. sulphuratum* Nees, and *C. walaiwarense* Kosterm (Haldankar et al. 1994; Krishnamoorthy et al. 1996; Tyagi et al. 2004; Ravindran et al. 2004a, b).

Cinnamon trees are naturally cross-pollinated and as a result much variation exists in natural populations for morphological, chemical as well as bark characters. 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. Over 430 accessions are maintained at various centers in India. About six varieties of high-yielding, high-quality cultivars were recommended for release in India (Table 9.11).

9.2.6.3 Clove

Clove, belonging to the family Myrtaceae, is a native of Moluccas Islands and was introduced to India. Because of the limited introductions that have taken place and due to self-pollinating nature of the species, the genetic base of germplasm available in India is very narrow for use in any meaningful crop improvement program. The spice is dried, mature, unopened flower buds (Nurdjannah and Bermawie 2012). The clove buds contain around 15–17 % volatile oil, the main component of which is eugenol (about 70–90 %). There are many species of *Syzygium* occurring in India. Over 250 accessions are maintained at various centers in India.

9.2.6.4 Garcinia

The genus *Garcinia* of the family Clusiaceae is a large genus of evergreen polygamous trees, shrubs, lianas, and herbs. It consists of over 200 species distributed in the tropics of the world chiefly in Asia, Africa, and Polynesia. *Garcinia* is native to old world tropics and maximum concentration of *Garcinia* species occurs in Asian countries. It is hypothesized that the genus *Garcinia* has originated before the continental drift followed by separate diversification in canters in the Afro-Madagascar and Indo-Malayan areas. About 35 species occur in India, many of which are endemic and economically important including *G. mangostana, G. indica G. gummi-gutta, G. cowa, G. pedunculata, G. xanthochymus* Hk.f, with immense medicinal properties. *Garcinia* is the source for a natural diet ingredient hydroxy citric acid (HCA) which is an anti-obesity compound. However, lack of awareness coupled with habitat destruction, is leading to genetic erosion of this forest resource and many species are threatened.

Table 9.7 Species diversity in tree spices

Genus	Species
Cinnamomum	*Cinnamomum alainii (C.K. Allen) A.H. Liogier, C. alexei Kosterm., C. alternifolium Kosterm., C. altissimum Kosterm., C. amoenum (Nees) Kosterm., C. amplexicaule* (Cham. & Schltdl.) Kosterm., *C. anacardium* Kosterm., *C. angustitepalum* Kosterm., *C. antillanum* (Meisn.) Kosterm., *C. appelianum* Schewe in Hand.-Mazz., *C. arbusculum* Kosterm., *C. archboldianum* C.K. Allen, *C. areolatum* (Lundell) Kosterm., *C. arfakense* Kosterm., *C. arsenei* (C.K. Allen) Kosterm., *C. asomicum* S.C. Nath & Baruah, *C. aubletii* Lukmanoff, *C. aureofulvum* Gamble, *C. auricolor* Kosterm., *C. austrosinense* Hung T. Chang, *C. austroyunnanense* H.W. Li, *C. baileyanum (*F. Muell. ex F. M. Bailey) Francis, *C. balansae* Lecomte, *C. bamoense* Lukmanoff, *C. barbeyanum* (Mez) Kosterm., *C. bejolghota* (Buch.-Ham.) Sweet, *C. bhamoensis* M. Gangop., *C. bhaskarii* M. Gangop., *C. bintulense* Kosterm., *C. birmanicum* A.J.G.H. Kostermans, *C. bishnupadae* M.Gangop., *C. blandfordii* M.Gangop., *C. bodinieri* H. Lév., *C. bonii* Lecomte, *C. borneense* Miq., *C. brachythyrsum* J. Li, *C. bractefoliaceum* F.G. Lorea-Hernandez, *C. breedlovii* (Lundell) Kosterm., *C. brenesii* (Standley) Kosterm., *C. brevifolium* Miq., *C. burmannii* (Nees & T. Nees) Bl., *C. calciphilum* Kosterm., *C. calyculatum* Miq., *C. cambodianum* Lecomte, *C. camphora* (L.) J. Presl, *C. cappara-coronde* Bl., *C. caratingae* I. de Vattimo-Gil, *C. carolinense* Koidz., *C. caryophyllus* (Lour.) S. Moore, *C. cassia* (L.) Presl, *C. caudifolium* Kosterm., *C. cebuense* Kosterm., *C. celebicum* Miq., *C. champokianum* Baruah & S.C. Nath, *C. chartophyllum* H.W. Li, *C. chavarrianum* (Hammel) Kosterm., *C. chemungianum* M. Mohanan & A.N. Henry, *C. chiapense* (Lundell) Kosterm., *C. citriodorum* Thw., *C. clemensii* C.K. Allen, *C. concinnum* F.G. Lorea-Hernandez, *C. contractum* H.W. Li, *C. cordatum* Kosterm., *C. coriaceum* Cammerloher, *C. corneri* Kosterm., *C. costaricanum (*Mez & Pittier) Kosterm., *C. crenulicupulum* Kostermans, *C. crispulum* Kosterm., *C. culilaban* (L.) Kosterm., *C. cupulatum* A.J.G.H. Kostermans, *C. curtisii* Lukmanoff, *C. curvifolium (*Lour.) Nees, *C. cuspidatum* Miq., *C. cyrtopodum* Miq., *C. damhaensis* Kosterm., *C. daphnoides* Sieb. & Zucc., *C. dasyanthum* Miq., *C. degeneri* C.K. Allen, *C. dictyoneuron* Kosterm., *C. doederleinii* Engl., *C. dubium* Nees, *C. durifolium* Kosterm., *C. ebaloi* Kosterm., *C. effusum (Meisn.)* Kosterm., *C. ehrenbergii (Mez)* Kosterm., *C. ellipticifolium* A.J.G.H. Kostermans, *C. elongatum* (Nees) Kosterm., *C. endlicheriicarpum*Kosterm., *C. englerianum* Schewe, *C. erythropus* (Nees & Mart.) Kosterm., *C. eugenoliferum* Kosterm., *C. falcatum* (Mez) R.A. Howard, *C. filipedicellatum* Kosterm., *C. filipes* (Rusby) Kosterm., *C. fitianum* (Meisn.) A. C. Sm., *C. floccosum* van der Werff, *C. formicarium* van der Werff & Lorea-Hern., *C. fouilloyi* Kosterm., *C. foveolatum* (Merr.) H.W.Li & J.Li, *C. frodinii* Kosterm., *C. fruticosum* (Lundell) Kosterm., *C. glanduliferum* (Wall.) Nees, *C. glaucescens* (Buch.-Ham. ex Nees) Hand.-Mazz., *C. glaziovii* (Mez) Kosterm., *C. glauciphyllum* A.J.G.H. Kostermans, *C. goaense*Kosterm., *C. glossophyllum* F.G. Lorea-Hernandez, *C. gracillimum* Kosterm., *C. grandiflorum* Kosterm., *C. grandifolium* Cammerloher, *C. grandis* Kosterm., *C. grisebachii* F.G. Lorea-Hernandez, *C. hartmannii* (Johnston) Kosterm., *C. hatschbachii* Vattimo, `*C. haussknechtii* (Mez) Kosterm., *C.helferii* Lukmanoff, *C. heterantherum* (Ruiz & Pav.) Kosterm., *C. heyneanum* Nees, *C. hkinlumense* A.J.G.H. Kostermans, *C. ilicioides* A. Chev., *C. impressicostatum* Kosterm., *C. impressinervium* Meisn., *C. inconspicuum* Kosterm., *C. iners* Reinw. ex Bl., *C. inunctum* (Nees) Meisn., *C. japonicum* Sieb. ex Nakai, *C. javanicum* Bl., *C. jensenianum* Hand.-Mazz., *C. johnstonii* (C.K. Allen) Kosterm., *C. kami* Kosterm., *C. keralaense* Kosterm., *C. kerangas* Kosterm., *C. kerrii* Kosterm., *C. kinabaluense* Heine, *C. kingdon-wardii* A.J.G.H. Kostermans, *C. kotoense* Kaneh. & Sasaki, *C. kruseanum* O. Téllez-Valdés & J.L. Villaseñor, *C. kunstleri* Ridl., *C. kwangtungense* Merr., *C. lampongum* Miq., *C. lanaoense* Kosterm., *C. lanigerum* van der Werff, *C. lanuginosum* Kosterm., *C. laubatii* F. Muell., *C. lawang* Kosterm., *C. ledermannii* Schewe, *C. leptophyllum* F. G. Lorea-Hernandez, *C. leptopus* A.C. Sm., *C. litseifolium* Thw., *C. lohitensis* M.Gangop., *C. longepedicellatum* Kosterm., *C. loureiroi* Nees, *C. macrophyllum* Miq., *C. mairei* H. Lév., *C. malabatrum* (Burm. f.) Presl, *C. mathewsii* (Mez) Kosterm., *C. melastomataceum* Kosterm., *C. microphyllum* Ridl., *C. molle* (Mez) Kosterm., *C. oblongum* Kosterm., *C. osmophloeum* Kaneh., *C. parthenoxylon (*Jack) Meisn., *C. polyadelphum* (Lour.) Kosterm., *C. quadrangulum* Kosterm., *C. racemosum* Kosterm., *C. rigidum* Gillespie, *C. sessilifolium* Kanehira, *C. stenophyllum* (Meisn.) I. de Vattimo, *C. subsessile* (Meisn.) Kosterm., *C. tamala* (Buch.-Ham.) Th. G.G. Nees, *C. tazia* (Buch.-Ham.) Kosterm. ex M. Gangop., *C. tenuifolium* J. Sugimoto, *C. velveti* F.G. Lorea-Hernandez, *C. verum* J.S. Presl, *C. xylophyllum* Kosterm., *C . wightii* Meisn., *C. yabunikkei* H.Ohba, *C. zapatae* F.G. Lorea-Hernandez

(continued)

Table 9.7 (continued)

Genus	Species
Myristica	*Myristica acsmithii* W.J.J.O. de Wilde, *M. acuminata* (Lam.) Warb.,*M. fatua subsp. affinis* (Warb.) de Wilde, *M. agusanensis, M. alba* W.J.J.O. de Wilde, *M. hollrungii* Warb., *M. fragrans* Houtt., *M. bancana* (Miq.) J. Sinclair, *M. andamanica* Hook. fil., *M. archboldiana* A. C. Sm., *M. argentea* Warb., *M. basilanica* W.J.J.O. de Wilde, *M. beddomei, M. beccarii* Warb., *M. bialata* Warb., *M. bifurcate, M. brachypoda* W.J.J.O. de Wilde, *M. brassii* A. C. Sm., *M. brevistipes* W.J.J.O. de Wilde, *M. cagayanensis* Merr., *M. carrii* J. Sinclair, *M. cerifera* A. C. Sm., *M. ceylanica* A. DC., *M. chartacea* Gillespie, *M. chrysophylla, M. cinnamomea* King, *M. clemensii* A.C.Sm., *M. concinna* J. Sinclair, *M. corticata* W.J.J.O. de Wilde, *M. crassa* King, *M. cucullata* Markgra, *M. cumingii* Warb., *M. elliptica* Wall. ex Hook. fil. & Thoms., *M. ensifolia* J. Sinclair, *M. extensa* W.J. de Wilde, *M. fallax* Warb., *M. fasciculata* W.J.J.O. de Wilde, *M. firmipes* J. Sinclair, *M. garciniifolia* Warb., *M. gibbosa* Hook. fil. & Thoms., *M. gracilipes* J. Sinclair, *M. grandifolia* A. DC., *M. guatteriifolia* A. DC., *M. hollrungii* Warb., *M. impressa* Warb., *M. iners* Bl., *M. ingrata subsp. Ingrate, M. inopinata* J. Sinclair, *M. johnsii* W.J.J.O. de Wilde, *M. kalkmanii* W.J.J.O. de Wilde, *M. koordersii* Warb., *M. laevifolia* W.J.J.O. de Wilde, *M. macrantha* A. C. Sm., *M. maingayi* Hook. fil., *M. malabarica* Lam., *M. maxima* Warb., *M. mindanaensis* Warb., *M. nana* W.J.J.O. de Wilde, *M. neglecta* Warb., *M. ornata* W.J.J.O. de Wilde, *M. pachyphylla* A. C. Sm., *M. pedicellata* J. Sinclair, *M. petiolata* A. C. Sm., *M. philippensis* Lam., *M. pumila* W.J.J.O. de Wilde, *M. rubrinervis* W.J. de Wilde, *M. rumphii* (Bl.) Kosterm., *M. sarcantha* W.J. de Wilde, *M. schleinitzii* Engl., *M. smythiesii* J. Sinclair, *M. sphaerosperma* A. C. Sm., *M. subalulata* Miq., *M. sumbawana* Warb., *M. trianthera* W.J.J.O. de Wilde, *M. tubiflora* Bl., *M. umbrosa* J. Sinclair
Syzygium	*Syzygium abbreviatum*Merr., *S. aborense* (Dunn) Rathakr. & N.C.Nair, *S. abortivum* (Gagnep.) Merr. & L.M.Perry, *S. abulugense* Merr., *S. aciculinum* Merr. & L.M.Perry, *S.* acre (Pancher ex Guillaumin) J.W.Dawson, *S. acrophilum* (C.B.Rob.) Merr., *S. acuminatissimum* (Blume) DC., *S. acuminatum* (Roxb.) Miq., *S. acutangulum* Nied., *S. acutatum* (Miq.) Amshoff, *S. adelphicum* Diels, *S. adenophyllum* Merr. & L.M.Perry, *S. aegiceroides* (Korth. ex Miq.) Korth., *S. aemulum* (Blume) Amshoff, *S. aeoranthum* (Diels) Merr. & L.M.Perry, *S. affine* Merr., *S. agastyamalayanum* M.B.Viswan. & Manik., *S. aggregatum* J.W.Dawson, *S. aksornae* Chantaran. & J.Parn.,*S. alatoramulum* B.Hyland, *S. alatum* (Lauterb.) Diels, *S. albayense* Merr., *S. album* Q.F.Zheng, *S. alternifolium* (Wight) Walp., *S. alutaceum* (Diels) Merr. & L.M.Perry, *S. alyxiifolium* (Ridl.) I.M.Turner, *S. amieuense* (Guillaumin) J.W.Dawson, *S. amplifolium* L.M.Perry, *S. ampullarium* (Stapf) Merr. & L.M.Perry, *S. andamanicum* (King) N.P.Balakr., *S. angkae* (Craib) Chantaran. & J.Parn., *S. angulare* (Elmer) Merr., *S. anisatum* (Vickery) Craven & Biffin, *S. anisosepalum* (Duthie) I.M.Turner, *S. anthicoides* P.S.Ashton, *S. antonianum* (Elmer) Merr., *S. apiarii* P.S.Ashton, *S. arboreum* (Baker f.) J.W.Dawson, *S. argyrocalyx* (Warb.) Merr. & L.M.Perry, *S. aromaticum* (L.) Merr. & L.M.Perry, *S. assamicum* (Biswas & Purkay.) Raizada, *S. attenuatum* (Miq.) Merr. & L.M.Perry, *S. aurantiacum* (H.Perrier) Labat & Schatz, *S. auriculatum* Brongn. & Gris, *S. avene* Miq., *S. barnesii* (Merr.) Merr., *S. bartonii* (F.M.Bailey) Merr. & L.M.Perry, *S. beddomei* (Duthie) Chithra, *S. benjaminum* Diels, *S. bicolor* Merr. & L.M.Perry, *S. blumei* (Steud.) Merr. & L.M.Perry, *S. borbonicum* J.Guého & A.J.Scott, *S. brachiatum* (Roxb.) Miq., *S. brachybotryum* Miq., *S. brackenridgei* (A.Gray) Müll.Stuttg., *S. bracteosum* Merr. & L.M.Perry, *S. brevifolium (A.Gray) Müll.Stuttg., S. bruynii* (Diels) Merr. & L.M.Perry, *S. bujangii* P.S.Ashton, *S. cacuminis* (Craib) Chantaran. & J.Parn.,*S. calcicola* (Merr.) Merr.,*S. calyptrocalyx* P.S.Ashton, *S. cameronum* I.M.Turner, *S. capillaceum (*Brongn. & Gris) J.W.Dawson, *S. capitatum* (Merr.) Merr. & L.M.Perry, *S. capituliferum* Merr. & L.M.Perry, *S. caryophyllatum* (L.) Alston, *S. caryophylloides* (Lauterb.) Merr. & L.M.Perry, *S. caudatum* (Merr.) Airy Shaw, *S. cephalophorum* (Ridl.) Merr. & L.M.Perry, *S. christmannii* Merr. & L.M.Perry, *S. cinctum* Merr. & L.M.Perry, *S. circumscissum* (Gagnep.) Craven & Biffin, *S. clementis* (C.B.Rob.) Merr.,*S. coccineum* J.W.Dawson, *S. cordatum* Hochst. ex Krauss, *S. cordifoliatum* (Ridl.) I.M.Turner, *S. cormiflorum* (F.Muell.) B.Hyland, *S. cornifolium* (Blume) Merr. & L.M.Perry, *S. corymbosum* (Blume) DC., *S. cumini* (L.) Skeels, *S. curtiflorum* (Elmer) Merr., *S. cylindricum* (Wight) Alston, *S. dansiei* B.Hyland, *S. dealbatum* (Burkill) A.C.Sm., *S. diffusiflorum* Merr., *S. durifolium* Merr. & L.M.Perry, *S. duthieanum* (King) Masam., *S. ebaloii* Merr., *S. elegans (*Brongn. & Gris) J.W.Dawson, *S. emirnense*

(continued)

Table 9.7 (continued)

Genus	Species
	(Baker) Labat & Schatz, *S. endophloium* B.Hyland, *S. eucalyptoides* (F.Muell.) B.Hyland, *S. eugenioides* (F.Muell.) Biffin & Craven, *S. eximiiflorum* (Diels) Merr. & L.M.Perry, *S. faciflorum* P.S.Ashton, *S. filiforme* Chantaran. & J.Parn., *S. ischeri* (Merr.) Merr.,*S. formosum* (Wall.) Masam., *S. frutescens* Brongn. & Gris, *S. fruticosum* DC., *S. gardneri* Thwaites, *S. gigantifolium* (Merr.) Merr., *S. glabratum* (DC.) Veldkamp, *S. glaucum* (King) Chantaran. & J.Parn.,*S. grande* (Wight) Walp., *S. grijsii* (Hance) Merr. & L.M.Perry, *S. guineense* (Willd.) DC., *S. halophilum* (Merr.) Masam., *S. handelii* Merr. & L.M.Perry, *S. hebephyllum* Melville, *S. heloanthum* Diels, *S. hoseanum* (King) Merr. & L.M.Perry, *S. hughcumingii* Merr., *S. ilocanum* (Merr.) Merr., *S. inasense* (King) I.M.Turner, *S. inophyllum* DC., *S. inopinatum* Amshoff, *S. isabelense* (Quisumb.) Merr.,*S. jaffrei* J.W.Dawson, *S. jasminifolium* (Ridl.) Chantaran. & J.Parn., *S. kanarense* (Talbot) Raizada, *S. kanneliyensis* Kosterm., *S. koordersianum* (King) I.M.Turner, *S. lacustre* (C.B.Rob.) Merr., *S. lakshnakarae* Chantaran. & J.Parn., *S. lamii* Merr. & L.M.Perry, *S. latifolium* (Poir.) DC., *S. leptoneurum* Diels, *S. leucanthum* L.M.Perry, *S. longifolium* (Brongn. & Gris) J.W.Dawson, *S.* longipedicellatum (Merr.) Merr., *S. luteum* (C.B.Rob.) Merr., *S. macgregorii* (C.B.Rob.) Merr., *S. macranthum* Brongn. & Gris, *S. macrocalyx* Merr. & L.M.Perry, *S. makul* Gaertn., *S. megacarpum* (Craib) Rathakr. & N.C.Nair, *S. melanophilum* H.T.Chang & R.H.Miao, *S. micrandrum* (Ridl.) Merr. & L.M.Perry, *S. mimicum* (Merr.) Merr.,*S. muelleri* (Miq.) Miq.,*S. mulgraveanum* (B.Hyland) Craven & Biffin, *S. myrtoides* (A.Gray) R.Schmid, *S. nanum* J.W.Dawson, *S. nitidum* Benth., *S. oblanceolatum* (C.B.Rob.) Merr., *S. occlusum* Miq., *S. odoratum* (Lour.) DC., *S. ovale* Korth., *S. palembanicum* Miq., *S. pallens* Merr. & L.M.Perry, *S. paniculatum* Gaertn., *S. parkeri* (Baker) Labat & Schatz, *S. patens* Korth., *S. pendulinum* J.W.Dawson, *S. perryae* I.M.Turner, *S. platypodum* Diels, *S. polyanthum* (Wight) Walp., *S. pondoense* Engl., *S. pseudojambolana* Miq., *S. pseudomolle* (M.R.Hend.) I.M.Turner, *S. pullei* Diels, *S. purpuriflorum* (Elmer) Merr., *S. quadratum* (King) I.M.Turner, *S. ramiflorum* Airy Shaw, *S. rehderianum* Merr. & L.M.Perry, *S. rigidifolium* Merr., *S. robustum* Miq., *S. rubens* (Roxb.) Walp., *S. rugosum* Korth., *S. salicifolium* (Wight) J.Graham, *S. samoense* (Burkill) Whistler, *S. setosum* (King) I.M.Turner, *S. squamatum* Merr. & L.M.Perry, *S. steenisii* Merr. & L.M.Perry, *S. subcapitulatum* Miq., *S. subnodosum* Miq., *S. sulitii* Merr., *S. taeniatum* Diels, *S. tahanense* (Ridl.) I.M.Turner, *S. tectum* (King) I.M.Turner, *S. tenuifolium* (Ridl.) Airy Shaw, *S. thomsenii* (Diels) Merr. & L.M.Perry, *S. tolypanthum* Diels, *S. trachyphloium* (C.T.White) B.Hyland, *S. tricolor* (Diels) Merr. & L.M.Perry, *S. triste* (Kurz) N.P.Balakr., *S. umbilicatum* (Koord. & Valeton) Amshoff, *S. vaccinifolium* Merr., *S. vaupelii* Whistler, *S. venosum* DC., *S. viburnoides* Diels, *S. virotii* J.W.Dawson, *S. waterhousei* Merr. & L.M.Perry, *S. xanthophyllum* (C.B.Rob.) Merr., *S. xylopiaceum* (Diels) Merr. & L.M.Perry, *S. zeylanicum* (L.) DC., *S. zollingerianum* (Miq.) Amshoff
Garcinia	*Garcinia acuminata* Planch. & Triana, *G. acutifolia* N. Robson, *G. afzelii* Engl., *G. amabilis* Kanehira & Hatusima, *G. andamanica* King, *G. angustifolia* A. C. Sm., *G. apetala* Pierre, *G. aphanophlebia* Baker, *G. aristata* (Griseb.) A. Borhidi, *G. balansae* Pierre, *G. balica* Miq., *G. basacensis* Pierre, *G. benthamii* Pierre, *G. blumei* Pierre, *G. brasiliensis* C. Martius, *G. caloneura* Boerl., *G. calophylla* Pierre, *G. caudiculata* Ridl., *G. cordata* Merrill, *G. cuspidata* King, *G. dioica* Bl., *G. echinocarpa* Thw., *G. elliptica* Choisy, *G. emarginata* Lauterb., *G. esculenta* Y.H. Li, *G. fabrilis* Miq., *G. fruticosa* Lauterb., *G. grandifolia* (Choisy) Pierre, *G. gummi-gutta* (L.) N. Robson, *G. hanburyi* Hook. f., *G. holttumii* Ridl., *G. indica (*Thouars) Choisy, *G. kingaensis* Engl., *G. korthalsii* Pierre, *G. leptophylla* Bittrich, *G. lucida* Vesque, *G. macrantha* A. C. Sm., *G. macrophylla* Mart., *G. mangostana* L., *G. microcarpa* Pierre, *G. morella* (Gaertn.) Desr., *G. neglecta* Vieill., *G. oligantha* Merr., *G. pachyantha* A. C. Sm., *G. pacifica* Merrill, *G. parvifolia* (Miq.) Miq., *G. prainiana* King, *G. smithii* A.J.G.H. Kostermans, *G. speciosa* Wall., *G.versteegii* Lauterb., *G. volkensii* Engl., *G. xylosperma* Pierre, *G. zeylanica* Roxb.

Source Species [*Catalogue of Life: 22nd December 2014, Integrated Taxonomic Information System (IT IS)*]; The Plant List http://www.theplantlist.org/browse/A/Myrtaceae/Syzygium/

Parthasarathy et al. (2013) reported that using GIS technique mapping of potential distribution of wild species of *Garcinia* of Western Ghats with the help of GIS techniques was done. Collection sites were plotted on map with the help of ArcGIS software. Based on the GIS prediction surveys, the authors found that *Garcinia cambogia* is distributed throughout the Western Ghats, whereas *G. indica* is predominantly seen in the northern parts of Western Ghats. This indicated that their distribution and population size is reduced to dangerous levels. Unless located and preserved, these species may quickly become endangered. There is considerable variation in yield and other characters studied.

9.2.7 Seed Spices

The major seed spices grown in India are coriander, cumin, fennel and fenugreek which are grown on a commercial scale. Cultivation of the remaining seed spices is limited to certain areas only. Three of the major seed spices, coriander (*Coriandrum sativum* L.), cumin (*Cuminum cyminum* L.), and fennel (*Foeniculum vulgare* Mill), belong to family Apiaceae, whereas fenugreek (*Trigonella foenum-graecum* L.) belongs to Fabaceae. Most of the seed spices cultivated in India are Mediterranean in origin. In none of the seed spices, wiled relatives, which could contribute by way of hybridization to cultivated forms, are known to exist in India. Most of the germplasms, therefore, exist in the form of traditional varieties. Most of such varieties have been subjected to natural selection for local adaptation and therefore, these are expected to pose valuable genes for resistance against biotic and abiotic stresses. Good collections are also maintained in China (Coriander-99, Fennel-35)2, Australia (coriander and fenugreek), Germany (Coriander and fennel), Netherlands (Coriander and Fennel), USA (Coriander, fenugreek, fennel, and cumin), as well as the countries of Mediterranean region namely Morocco, Egypt, Iran, as well as horn of Africa (Ethiopia). Most of the European and North American as well as Australian collections are the introductions from either India or Mediterranean countries. Cumin is a major crop in Syria, and hence the country is expected to have good genetic diversity in cumin. (Sharma 1994; Malhotra and Vijay 2003; Singhania et al. 2005a, b, c; Sastry 2009, Agarwal and Sharma 1990).

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9.2.7.1 Coriander

Coriander is native to southern Europe, Asia Minor, and Caucasus where it also grows wild. Now India is a major producer of coriander. The diversity of coriander is rather limited in India. *C. sativum* var *indicum* belongs to India. The small fruited types are recognized as C. *sativum* L. var. *microcarpum* and the large fruited one are described as *C. sativum* L. var. *vulgare* (Diederichsen and Hammer 2003). The sub-species of *C. sativum* Subsp. *Sativum* are var. *sativum* and var. *africanum* Stolet. The Subsp. of *C. sativum* Subsp. *asiaticum* are var. asiaticum, var. *anatolicum* and var. *afghanicum.* The other sub-species are *C. sativum* Subsp. *vavilovii* var. *vavilovii* and *C. sativum* Subsp. *pygmaeum* Stolet.

Dried ripe coriander seeds contain both steam volatile oil and fixed oil. The aromatic odor and taste of coriander fruit is due to its volatile oil, which is a clear, colorless to light yellow liquid. The flavor of the oil is warm, spicy aromatic, sweet and fruity. The oil contents of seeds vary widely with geographical origin. Higher volatile oil content is found in Norwegian coriander (1.4–1.7 %) followed by Bulgarian coriander (0.1–0.5 %). Indian seeds are poor in volatile oil content (0.1–0.4 %) (Agrawal and Sharma 1990). Major components of essential oil are linalool (67.7 %), followed by α-pinene (10.5 %), γ- terpinene (9.0 %), geranyl acetate (4.0 %), camphor (3.0 %) and geraniol (1.9 %). Minor components in the oil are β-pinene, camphene, myrcene, limonene, *p*-cymol, dipentene, α- terpinene, *n*-decylaldehyde, borneol, and acetic acid esters.

There is good generic diversity in coriander with respect to morphological characters, quality attributes, and resistance to biotic and abiotic stresses. Over 2130 accessions are maintained at various centers in India (Karla et al. 2006; Sharma and Sharma 2012).

Thirty-five high-yielding coriander cultivars are released for cultivation in India (Table 9.8). These varieties exhibit diversity for fruit shape, size, and plant type. Many of them are resistance to biotic and abiotic stresses like wilt, powdery mildew, stem gall, grain mold, tolerance to drought, field tolerance to white fly, mites and aphids early maturity, dual-purpose types, resistant to lodging and shattering, etc.

9.2.7.2 Cumin

Cumin is native to Egypt and Syria, Turkistan and Eastern Mediterranean region. Cuminaldehyde is the major component in cumin oil. Oil content is low in indigenous germplasm but high in exotic collections (Sharma 1994). Cumin is an aromatic spice with stimulating properties. It has a characteristic strong flavor and is slightly bitter in taste. Seeds contain 2–5 % volatile oil of which 40–65 % is cuminaldehyde (cuminic aldehyde). Over 590 accessions are maintained at various centers in India (Patel et al. 2006; Amin 2012).

Fourteen high-yielding cumin cultivars are released for cultivation in India (Table 9.8). The cv. RZ-19 is moderately resistant to wilt, having attractive fruits. Gujarat cumin-4 is wilt resistant and is the most important variety in India. Diversities for high yield, fruit shape and size, high quality, tolerance to *Fusarium* wilt, *Alternaria* blight and powdery mildew and rich in essential oil content exist among these improved varieties.

Table 9.8 Species diversity in seed spices

Genus	Species
Coriandrum	*Coriandrum didymum* Stokes, *C. diversifolium* Gilib., *C. globosum* Salisb., *C. latifolium* Crantz, *C. majus* Garsault, *C. melphitense* Ten. & Guss., *C. radians* Prantl, *C. sativum* L., *C. seselifolium* DC. ex DC., *C. setifolium* Koso-Pol., *C. testiculatum* Lour., *C. tordylium* (Fenzl) Bornm.
Cuminum	*Cuminum aegyptiacum* Mérat ex DC., *C. aethiopicum* Royle, *C. borszczowi Koso-Pol., C. brevisetum Koso-Pol., C. crinitum Koso-Pol., C. cuminodes Kuntze, C. cyminum* L., *C. hispanicum Mérat ex DC., C. maroccanum P.H.Davis & Hedge, C. minimum Steud., C. odorum Salisb., C. officinale Garsault, C. ramosissimum Koso-Pol., C. regium Royle, C. sativum J.Sm., C. setifolium Koso-Pol., C. sudanense H. Wolff*
Foeniculum	*Foeniculum capense* DC., *F. divaricatum* Griseb., *F. dulce* Mill., *F. giganteum* Lojac., *F. graecum* Calest., *F. kraussianum* Meisn., *F. luteum* Fisch. ex Sweet, *F. multiradiatum* K.Koch, *F. peucedanoides* Benth. & Hook.f., *F. piperitum* J.Presl, *F. rigidum Brot.* ex Steud., *F. salsum* Calest., *F. scoparium* Quézel, *F. subinodorum* Maire Weiller & Wilczek, *F. tortuosum* Benth. & Hook.f., *F. virescens* Benth. & Hook.f., *F. vulgare* Mill., *F. webbii* Benth. & Hook.f.
Trigonella	*Trigonella adscendens* (Nevski) Afan. & Gontsch.,*T. afghanica* Vassilcz., *T. anguina* Delile, *T. aphanoneura* Rech.f., *T. arabica* Delile, *T. aristata* (Vassilcz.) Sojak, *T. astroides* Fisch. & C.A.Mey., *T. badachschanica* Afan, *T. balachowskyi* Leredde, *T. balansae* Boiss. & Reut.,*T. berythea Boiss. & Blanche, T. bicolor* (Boiss. & Balansa) Lassen, *T. cachemiriana Cambess, T. caelesyriaca* Boiss., *T. caerulea (L.) Ser., T. capitata Boiss., T. calliceras* Fisch., *T. carica* Hub.-Mor., *T. cariensis* Boiss., *T. cassia* Boiss., *T. cedretorum* Vassilcz., *T. cephalotes* Boiss. & Balansa, *T. coerulescens* (M.Bieb.) Halacsy, *T. cretica* (L.) Boiss., *T. cylindracea* Desv, *T. dasycarpa* (Ser.)Vassilcz., *T. elliptica* Boiss., *T. emodi* Benth., *T. esculenta* Willd., *T. edelbergii* (Sirj. & Rech.f.) Rech.f., *T. falcata* Balf.f., *T. filipes* Boiss., *T. fimbriata* Benth., *T. foenum-graecum* L., *T. freitagii* Vassilcz., *T. geminiflora* Bunge, *T. gharuensis* Rech.f., *T. glabra* Thunb., *T. gladiata* M.Bieb., *T. gontscharovii* Vassilcz., *T. gracilis* Benth., *T. graeca* (Boiss. & Spruner)Boiss., *T. grandiflora* Bunge, *T. griffithii* Boiss., *T. halophila* Boiss., *T. hamosa, T. heratensis* Rech.f., *T. hierosolymitana* Boiss., *T. ionantha* Rech.f., *T. iskanderi* Vassilcz., *T. isthmocarpa* Boiss. & Balansa, *T. kafirniganica* Vassilcz., *T. koeiei* Sirj. & Rech.f., *T. korovinii* Vassilcz., *T. kotschyi* Benth., *T. laciniata* L., *T. latialata* (Bornm.)Vassilcz., *T. laxiflora* Aitch. & Baker, *T. laxissima* Vassilcz., *T. lilacina* Boiss., *T. linczevskii* Vassilcz., *T. lipskyi* Sirj., *T. lunata* Boiss., *T. lycica* Hub.-Mor., *T. macroglochin* Durieu, *T. macrorrhyncha* Boiss., *T. marco-poloi* Vassilcz., *T. maritima* Poir., *T. media* Delile, *T. mesopotamica Hub.-Mor., T. spicata* Sm., *T. spinosa* L., *T. obcordata* Benth., *T. zaprjagaevii* Afan. & Gontsch

Source Species [*Catalogue of Life: 24th November 2014, Integrated Taxonomic Information System (IT IS)*]

9.2.7.3 Fennel

Fennel belongs to Apiaceae. It has two sub-species: *Foeniculum vulgare* sp. *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). The oil content ranges from 0.7 to 6 % in fennel germplasm. The oil of fennel contains mainly anethole, α-pinene, β-phellandrene, dipentene, etc. Over 629 accessions are maintained at various centers in India.

Twenty-one high-yielding fennel cultivars are released for cultivation in India (Table 9.8). These cultivars posses among themselves high yield, high quality, fruit shape and size, tolerance to leaf spot, leaf blight and sugary diseases, shattering of grains, suitability for drought, water logged and saline and alkaline conditions.

9.2.7.4 Fenugreek

Fenugreek belongs to the family Fabaceae, and is native of eastern Mediterranean. Rich diversity exists for fenugreek in Turkey. The seed is used as spice and leaf as vegetable. It has bitter taste of seeds due to alkaloid trigonelline and steroid sapogenin (diosgenin), but in appropriate quantities, it adds a special taste and flavor to culinary dishes. It also has high medicinal and nutritive value (Kakani and Anwer 2012). Over 1118 accessions are maintained at various centers in India.

Twenty-one high-yielding fenugreek cultivars are released for cultivation in India (Table 9.8). These cultivars in addition to high yield, high quality, grain size and color, dual-purpose types, with tolerance to downy mildew, powdery mildew, root rot, high diosgenin content, and medium duration types.

9.3 Genetic Erosion

Due to destruction in their natural habitats, climate change, over exploitation, preference to better yielding varieties many of the species, wild forms and primitive cultivars are slowly disappearing. Some of the important species which were classified by IUCN as rare, endangered and threatened (RET) are given in Table 9.9.

All the spices crops like any other plant follow either vegetative or sexual reproduction. While many crops show strict self or cross pollination, yet, there are no fixed borders. Because of the sampling errors, the genetic structure of the population is affected; hence, there is danger of loss of valuable alleles in the collections due to the sampling procedures. Similarly, even during the regeneration and multiplication of the samples in germplasm collections also genetic erosion sets in. Before we understand the genetic erosion in nature and in germplasm collection, it is essential that we understand the reproduction in plants and its relation to population structure.

The genetic erosion can only be monitored when we are aware of the genetic resources of the area. The selection pressure on crops for yield has resulted in the erosion of land races which may be the allelic source of adaptability to a particular region. 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 and garcinia is quite reasonable. The natural variability has to be preserved

Table 9.9 Rare, endangered, and threatened (RET) species among spice crops

Genus	RET species
Piper	*Piper cordulatum* C. DC., *Piper fimbriulatum* C. DC., *Piper lucigaudens* C. DC., *Piper verrucosum* Sw., *Piper hylebates* C.DC., *P. hylophilum* C.DC., *P. lineatipilosum Yunck., P. napo-pastazanum* Trel. & Yunck., *P. nebuligaudens* Yunck., *P. schuppii* A.H. Gentry, *P. sodiroi* C. DC., *Piper subaduncum* Yunck., *Piper supernum* Trel & Yunck, *P. seychellarum* J.Gerlach, *Piper achupallasense* Yunck., *P. azuaiense* Yunck., *P. baezense* Trel., *P. begoniiforme* Yunck., *P. brachipilum* Yunck., *P. brachystylum* Trel., *P. campii* Yunck., *P. chimborazoense* Yunck., *P. coeloneurum* Diels., *P. cutucuense* Yunck., *P. densiciliatum* Yunck., *P. diffundum* Yunck., *P. disparipilum* C. DC., *P. dodsonii* Yunck., *P. eriocladum* Sodiro., *P. fallenii* A. H. Gentry., *P. huigranum* Trel. & Yunck., *P. longicaudatum* Trel. & Yunck., *P. mendezense* Yunck., *P. nanegalense* Trel. & Yunck., *P. perstrigosum* Yunck., *P. prietoi* Yunck., *P. productispicum* Yunck., *P. puyoense* Yunck., *P. regale* C. DC., *P. saloyanum* Trel. & Yunck., *P. skutchii* Trel. & Yunck., *P. valladolidense* Yunck., *P. zarumanum* Trel., *Piper angamarcanum* C.DC., *P. baezanum* C. DC., *P. bullatifolium* Sodiro., *P. clathratum* C.DC., *P. entradense* Trel & Yunck., *P. eustylum* Diels., *P. gualeanum* C.DC., *P. guayasanum* C. DC., *P. hydrolapathum* C. DC., *P. manabinum* C. DC., *P. mexiae* Trel. & Yunck., *P. molliusculum* Sodiro., *P. platylobum* Sodiro., *P. poscitum* Trel & Yunck., *P. stipulosum* Sodiro., *P. subnitidifolium* Yunck., *P. trachyphyllum* C. DC., *P. wibomii* Yunck.
Curcuma	*Curcuma alismatifolia* Gagnep., *Curcuma sparganiifolia* Gagnep, *Curcuma candida* (Wall.) Techaprasan & Škorničk., *Curcuma pseudomontana* J.Graham, *Curcuma rhabdota* Sirirugsa & M.F.Newman, *Curcuma caulina* J.Graham, *Curcuma coriacea* Mangaly & M.Sabu, *Curcuma vitellina* Škorničk. & H.Đ.Tran
Zingiber	*Zingiber fragile* S.Q.Tong., *Zingiber collinsii* Mood & Theilade, *Zingiber monophyllum* Gagnep.
Cinnamomum	*Cinnamomum japonicum* Siebold ex Nakai., *Cinnamomum capparu-coronde* Blume, *Cinnamomum litseifolium* Thw., *Cinnamomum macrostemon* Hayata, *Cinnamomum mathewsii* (Meisn.) Kostermans, *Cinnamomum mercadoi* Vid., *Cinnamomum osmophloeum* Kaneh., *Cinnamomum parviflorum* (Nees) Kosterm., *Cinnamomum perrottetii* Meissner, *Cinnamomum reticulatum* Hayata, *Cinnamomum riparium* Gamble, *Cinnamomum balansae* Lecomte, *Cinnamomum brevipedunculatum* Chang, *Cinnamomum chemungianum* Mohan & Henry, *Cinnamomum citriodorum* Thwaites, *Cinnamomum filipedicellatum* Kosterm, *Cinnamomum kanahirae* Hay., *Cinnamomum mairei* Leveille, *Cinnamomum kotoense* Kaneh. & Sas., *Cinnamomum rivulorum* Kosterm., *Cinnamomum walaiwarense* Kosterm
Syzygium	*Syzygium beddomei* (Duthie) Chithra, *Syzygium microphyllum* Gamble, *Syzygium parameswaranii* Mohanan & Henry, *Syzygium bourdillonii* (Gamble) Rathakr. & Nair, Syzygium chavaran (Bourd.) Gamble, *Syzygium caryophyllatum* (L.) Alston, *Syzygium fergusoni* Gamble, *Syzygium spathulatum* Thwaites, *Syzygium turbinatum* Alston, *Syzygium umbrosum* Thwaites, *Syzygium discophorum* (Koord. & Valet.) Amshoff, *Syzygium minus* A.C.Sm., *Syzygium myhendrae* (Beddome ex Brandis) Gamble, *Syzygium parvulum*Mildbr., *Syzygium pendulinum* J.W. Dawson, *Syzygium veillonii* J.W. Dawson, *Syzygium stocksii* (Duthie) Gamble

Table 9.9 (continued)

Genus	RET species
Myristica	*Myristica magnifica* Bedd., *Myristica teijsmannii* Miq., *Myristica yunnanensis* Y.H. Li
Garcinia	*Garcinia acutifolia* Robson, *Garcinia afzelii* Engl.,*Garcinia brevipedicellata* (Bak.G.) Hutch. & Dalz., *Garcinia clusiaefolia* Ridley, *Garcinia costata* Hemsley ex King, *Garcinia holttumii* Ridley, *Garcinia Montana* Ridley, *Garcinia decussate* Adams, *Garcinia epunctata* Stapf, *Garcinia kola* Heckel, *Garcinia quaesita* Pierre, *Garcinia rubro-echinata* Kosterm, *Garcinia travancorica* Bedd., *Garcinia semseii* B. Verdcourt, *Garcinia staudtii* Engl., *Garcinia wightii* T. Andr., *Garcinia bifasciculata* N. Robson, *Garcinia imberti* Bourd., *Garcinia kingie* Pierre ex Vesque, *Garcinia linii* C.E.Chang, *Garcinia paucinervis* Chun & How, *Garcinia thwaitesii* Pierre, *Garcinia zeylanica* Roxb.
Vanilla	*V. andamanica* Rolfe, *V. pilifera* Holtt, *V. aphylla* Blume; *Vanilla wightiana* Lindl. ex Hook. F, *Vanilla griffithii* Rchb.f.,*Vanilla calopogonRchb.f.*, *Vanilla somai*

in the place of primary origin as well as in secondary origin by conservation as to escape the risk of extinction of the genetic variability. The wild species presumably became extinct because of over collection. Owing to the strong commercial pressure of food and pharmaceutical industries of today, unregulated gatherings have led to severe genetic erosion of a range of herbs and spices. The status of genetic erosion will be likely speeded up during the process of development of economy. The forest fire causes erosion of wild species and it results in the spread of rhizomatous crops present in the forest fire-infected region, as the aerial shoots get affected by this natural calamity, underground parts escapes the disaster, and further regenerate vigorously as there will be no competition (Table 9.9).

9.4 Conservation Strategies

Many wild and related species of spices still occur in the wild and are severely affected by both natural and manmade ecological disturbances. Identifying and demarking the ecological niches as protected biosphere reserves will help in in situ conservation of these valuable genetic resources for posterity. Most of the cross-pollinated tropical spices are either vegetatively propagated or have recalcitrant and heterozygous seeds. Spices like black pepper, cardamom, ginger, turmeric, and vanilla are essentially vegetatively propagated. Although essentially seed propagated, many tree spices like nutmeg, clove, cinnamon, and garcinia have efficient vegetative propagation methods. Hence, ex situ conservation in clonal repositories or in field gene banks (Fig. 9.3) is essential if we are to conserve these valuable genetic resources especially the cultivated types.

In many crop species like seed spices, conventional seed storage can satisfy most of the conservation requirements. Seed spices, except fenugreek, are highly cross-pollinated and if sufficient population (Oka 1975) and isolation distance is not maintained, the purity of the variety will get eroded and there will be a genetic drift. In them, maintaining an individual collection in small quantities always

Fig. 9.3 Clonal repositories of **a** black pepper, **b** cardamom, **c** ginger, **d** turmeric, **e** vanilla, and **f** nutmeg germplasm

poses a problem and theoretically it will be very difficult to eliminate genetic erosion even on small scale. Another approach is to use the gene pool approach. In this, composites are synthesized so that all the genes belonging to constituent lines are conserved in at intermediate gene frequencies. This approach can be applied to annual cross-pollinated spice crops. So its important controlled pollination of minimum population is required to ensure generic purity in subsequent generations. Storing a population of seeds, depending upon the diversity and breeding behavior, in low-temperature seed storage will help in augmenting the seed storage. Because of the heterozygous and heterogeneous nature, the populations of seed spices are particularly vulnerable to changes in gene and genotype structure throughout breeding and selection. Hence, in order to maintain the proper genetic structure of a given collection, the following care should be taken (Breese 1989).

1. Avoid contamination by foreign pollen or seed through proper isolation and seed handling techniques (Fig. 9.4).

Fig. 9.4 Field gene bank of seed spices (*Inset* bagging to maintain purity of genotype)

2. Minimize the genetic drift by ensuring sufficient population size and reducing opportunities for natural selections.
3. Securing effective random mating through appropriate pollination techniques.

Ex situ conservation is ideal as it maintains the population structure and allows the evolutionary forces to modify the population for better adaptation. Farmer's fields also can be used for conservation Altieri and Merrick 1987; Brush 1991) of cultivars and varieties of seed spices, since we are dealing with cultivated species. Further, even now, farmers are still growing their traditional varieties.

However, crops with recalcitrant seeds and those having conservation needs cannot be satisfied by seed storage, which have to be stored in clonal repositories and in vitro *gene* banks. Most field gene banks are prone to high labor cost, vulnerable to hazards like natural disasters, pests, and pathogens attack (especially viruses and systemic pathogens), to which they are continuously exposed and require large areas of space. This supports in vitro and cryoconservation. In addition, other resources like continuous supply of standard stock cultures for experiments to examine physiological and biochemical processes, cell and callus lines developed for in vitro synthesis of valuable secondary products, flavors, and other important compounds will benefit strongly from in vitro cultures.

Many spices are plagued by destructive and epidemic diseases caused by viruses, bacteria, and fungi. This makes germplasm conservation in field gene bank risky. Thus in vitro (Fig. 9.5) and cryostorage system becomes important in the overall strategy of conserving genepool. Each technology should be chosen on the basis of utility, security, and complementarily to other components of the strategy. A balance needs to be struck between seed, field gene bank, in vitro and cryoconservation of propagules, tissues, pollen, cell lines, and DNA storage for overall objective of conserving gene pool (Adams 1997; Nirmal Babu et al. 2007, 2012).

Pollen storage can be considerable value supplementing the germplasm conservation strategy by facilitating hybridisation between plants with different times of flowering and to transport pollen across the globe for various crop improvement programs in addition to developing haploid or homozygous lines. Cryopreservation of pollen (Fig. 9.6) might represent an interesting alternative for the long-term conservation of problematic species (IPGRI 1996).

Consequent with the advancements in gene cloning and transfer has been the development of technology for the removal and analysis of DNA. DNAs from the nucleus, mitochondrion, and chloroplast are now routinely extracted and immobilized onto nitrocellulose sheets where the DNA can be probed with numerous cloned genes. These advances, coupled with the prospect of the loss of significant plant genetic resources throughout the world, have led to the establishment of DNA bank for the storage of genomic DNA. The advantage of storing DNA is that it is efficient and simple and overcomes many physical limitations and constraints that characterize other forms of storage (Adams et al. 1994).

Fig. 9.5 In vitro gene bank of vegetatively propagated spices (*Inset* Ginger cultures under slow growth regime)

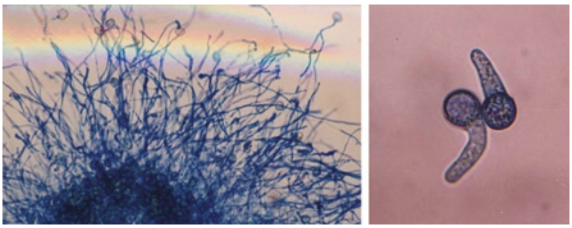

Fig. 9.6 Viability and germination of cryo-preserved pollen in vanilla

Table 9.10 Genetic resources of major spices conserved at various centers in India

Crop/Center	Indigenous accessions		Exotic accessions
	Cultivated	Wild and related sp	
Black pepper	1952	1300	13
Cardamom	900	13	–
Ginger	1200	15	40
Turmeric	2500	27	9
Clove	250	10	2
Nutmeg	475	34	–
Cinnamon	430	30	75
Coriander	1986	–	124
Cumin	577	–	13
Fennel	629	–	22
Fenugreek	1106	–	12
Garcinia	190	28	2

At present, the germplasm collection of spices available in India is the largest in the world comprising cultivars, wild relatives and genotypes having special characteristics (Table 9.10). These are maintained at various research centers. The germplasm conservation is through field gene banks, seed banks supplemented by in vitro, cryogene banks and DNA storage, where ever possible, depending upon the crop involved.

The existing germplasm available at various centers in India was effectively utilized in selection, hybridization, and mutation breeding programs and over 150 varieties of spices with high yield and resistance to biotic and abiotic stresses were released (Table 9.11).

9.5 Information System Support

The distribution of the wild species in the wild cannot be manually evaluated as it requires intensively more skilled personnel. GIS analysis of the germplasm data helps to better understand and develop new strategies for exploiting geographic diversity and to predict where species naturally occur or may be successfully introduced. Habitat loss and fragmentation are among the most common threats facing endangered species, making GIS-based evaluations an essential component of population viability analysis.

Table 9.11 Improved varieties of spices in India and their important characters

Sl. No.	Crop	Variety with salient features
1.	Black pepper	Panniyur 1(highest yield potential, Long spikes & bold berries, adopted to all regions except shade and high oleoresin); Panniyur 2 (Shade tolerant, rich in piperine); Panniyur 3. (Long spikes & bold berries;) Panniyur 4 (Stable yield); Panniyur 5 (Suitable for both mixed cropping); Panniyur 6 (Vigorous vine, rich in high piperine; Panniyur 7(wide adaptability); Panniyur 8 (tolerant to drought); Sreekara (wide adaptability and high volatile oil); Subhakara(wide adaptability and high volatile oil); Panchami (rich in oleoresin); Pournami (tolerant to root knot nematode); IISR Sakthi (Tolerant to *Phytophthora capsici);* IISR Thevam (field tolerant to *Phytophthora);* IISR Girimunda (suitable for high elevation); IISR Malabar Excel (suitable for high elevation); PLD –2 (rich in oleoresis); Arka Coorg Excel; Vijaya (tolerant to *Phytophthora*)
2.	Cardamom	Mudigere 1 (suitable for high density planting, moderately tolerant to thrips); Mudigere 2(early maturing, bold capsules); PV 1 (long, bold capsules); PV 2 (long panicle, long bold capsules, high dry recovery, field tolerant to stem borer and thrips); ICRI 1 (round extra bold dark green capsules); ICRI 2 (parrot green capsules); ICRI 3 (pubescent leaves, tolerant to rhizome rot, oblong, bold parrot green capsules); ICRI 4 (round bold capsules.); ICRI 5 (bold capsules, moderately tolerant to drought); ICRI 6(bold capsule); ICRI 7(Angular bold capsules, rich in oleoresin); IISR Suvasini (short plant type, suitable for high density planting); IISR Avinash (tolerant to rhizome rot); IISR Vijetha (tolerant to *katte*); Appangala 2 (First *katte* tolerant hybrid, high α-terpinyl acetate); S1 (PV 3) (Moderately tolerant to drought)
3.	Ginger	Suprabha (plumpy low fiber rhizomes); Suruchi (Early maturing, bold rhizomes); Suravi (Plumpy rhizomes); Himgiri (best for green ginger, less susceptible to rhizome rot); IISR Varada (Low fiber, high quality, tolerant to diseases); IISR Mahima (Plumpy extra bold rhizomes, Resistant to *M. incognita and M. javanica* pathotype 1); IISR Rejatha (High yielder, plumpy-bold rhizomes); Aswathy (suitable for green with high recovery of volatile oil and oleoresin, field tolerant to *Phyllosticta* leaf spot); Athira (High-yielding high-quality clone with high zingiberence); Karthika (High pungency clone with high gingerol, low infestation of shoot borer); Subhada (Suitable for hills and plains)
4.	Turmeric	Co.1 (Suitable for drought, water logged, saline and alkaline areas); BSR 1 (Suitable for drought prone areas); BSR 2 (High yielding, short duration, resistant to scale insects); Krishna (Plumpy rhizomes); Sugadham (Short internodes, Moderately tolerant to pest and diseases); Roma (Suitable for rainfed and irrigated condition); Suroma (field tolerance to leaf blotch, leaf spot and rhizome scales); Ranga (Moderately resistant to leaf blotch and scales); Rasmi (Bold rhizomes, suitable for early and late sown season); Rajedra Sonia (Bold and plumpy rhizome); Megha turmeric 1 (High curcumin content, bold rhizomes); Pant Peetabh (Resistant to rhizome rot); Suranjana (Tolerant to rhizome rot and leaf blotch, resistant to rhizome scales, suitable for open and shaded condition); Suvarna (Bright orange, slender fingers); Suguna (Early maturing, field tolerant to rhizome rot); Sudarsana (Early maturing, field tolerant to rhizome rot); IISR Prabha (High yielding); IISR Prathibha (High yielding); IISR

(continued)

Table 9.11 (continued)

Sl. No.	Crop	Variety with salient features
		Kedaram (Resistant to leaf blotch); IISR Alleppey Supreme (Tolerant to leaf blotch); Kanthi (Big mother rhizomes, medium bold fingers, closer internodes); Sobha (High yielding, high curcumin content—7.39 %, big mother rhizome and more territory rhizomes); Sona (Field tolerant to leaf blotch); Varna (closer internodes, field tolerant to leaf blotch); Narendra Haldi—1 (high-yield potential, high curcumin and essential oil); Duggirala Red (High yielding, long and plumpy rhizomes); Narendra Haldi-2 (High-yield potential); Narendra Haldi—3 (Root knot nematode resistant); Surangi (Suitable for hills and plains)
5.	Cinnamon	YCD 1 (Good bark recovery); PPI (C)—1 (Suitable for cultivation in high rainfall zones); Konkan Tej (Superieor quality); Sugandhini (Dense foliage, Suitable for leaf oil production); RRL (B) C-6 (High quality, sweet pungent bark); IISR Nithyashree (Good regeneration capacity, bark and leaf oleoresin content is high); IISR Navashree (Good aroma and taste, high shoot regeneration)
6.	Nutmeg	Konkan Sugandha (No incidence of major pests and diseases); Konkan Swad (Erect canopy, Warm, humid and shaded conditions are suitable); IISR Viswasree (Low incidence of fruit rot, suitable for mixed cropping); IISR Keralashree (High yield, high quality and extra bold fruit, mace and nut)
7.	Coriander	Gujarat coriander 2 (Suitable for early sowing, moderately tolerant to wilt and powdery mildew); Co. 1 (Dual-purpose variety, Small grains); Co. 2 (Dual-purpose variety, Suitable for saline, alkaline and drought prone areas); Co. 3 (Dual-purpose variety, Field tolerant to powdery mildew, wilt and grain mold); Co.4 (Early maturing, field tolerant to wilt and grain mold); Gujarat coriander 2 (Semi spreading, tolerant to powdery mildew, shattering resistant); Rajendra Swathi (Aromatic round grains, suitable for intercropping, field tolerant to aphids); Sadhana (Dual-purpose variety, field tolerance to white fly, mites and aphids, withstands moisture stress); Swathi (Field tolerant to white fly, escapes powdery mildew disease); CS 287 (Early maturing, field tolerant to wilt and grain mold); Sindhu (Tolerant to wilt, powdery mildew as well as drought condition); Hisar Anand (Dual purpose, Spreading type so resistant to lodging); Hisar Sugandh (Resistant to stem gall disease); Hisar Surabhi (Tolerant to frost, medium duration); Azad Dhania—1 (Tolerant to moisture stress, powdery mildew and aphids); Pant haritima (Dual-purpose type, Smaller seeds with high oil content, resistant to stem gall); DWA 3 (Dual-purpose variety, Moderately tolerant to powdery mildew); CIMPO S-33 (Grains small and bold, suitable for oil production); ACR-01-256 (NRCSS ACR-1) (Dual purpose, resistant to stem gall and wilt); RCr 20 (Early maturing, bold grains, moderately tolerant to stem gall); RCr 41 (Small seeded, resistant to stem gall and wilt); RCr 435 (Resistant to root knot nematode and powdery mildew); RCr 436 (Semi dwarf, bushy type, resistant to root rot and root knot nematode); RCr 446 (Moderately resistant to stem gall); RCr 684 (Bold seeds, resistant to stem gall); LCC-234 (High yielding leafy variety suitable for off season production in Andhra Pradesh); Hisar Bhoomit (Small seeded, high oil content, suitable for leaf production); UD-475 (RCr-475) (High-yield potential, suitable for grain purpose); Narendra Dhania 2 (Dual purpose)

(continued)

Table 9.11 (continued)

Sl. No.	Crop	Variety with salient features
8.	Cumin	Mc.43 (Semi spreading, withstand lodging and shattering); Gujarat cumin 1 (Bushy plants, withstand shattering and lodging, moderately tolerant to wilt, powdery mildew and blight); RZ-19 (tolerant to wilt and blight); Gujarat cumin 2 (tolerant to wilt and blight); Gujarat cumin 3 (Resistant to frost and wilt, seeds are pungent with high essential oil content); RZ-19 (Pink flowers, tolerant to wilt and blight); RZ-209 (Resistant to blight and wilt); RZ-223 (Wide adaptability, resistant to wilt); Ac-01-167 (Bold seeds resistant to wilt)
9.	Fennel	PF-35 (Moderately tolerant to leaf spot, leaf blight and sugary disease); Co-1 (Suitable for intercropping, Suitable for drought prone, water logged, saline and alkaline conditions); Gujarat Fennel – 1 (Tolerant to drought moderately tolerant to sugary disease); Gujarat Fennel 2 (Rich in volatile oil); S-7-9 (Moderately tolerant to blight); RF 125 (Tolerant to sugary disease); Hisar Sawrup (Spreading, resistant to lodging and shattering of grains); Azad Saunf 1 (Resistant to root rot and blight, early maturing so escapes attack of aphids); Pant Madhurika (Sweet in taste); RF 143 (Medium tall); HF 33 (High yielding); JF-444-1 (Compact seeds in umbellate, synchronous maturity)
10.	Fenugreek	Co.1 (Dual-purpose variety, tolerant root rot); Co. 2 (Short duration, dual purpose, field tolerant to *Rhizoctonia* root rot); Rajendra kanti (Bushy plant, suitable for intercropping, field tolerant to *cercospora* leaf spot, powdery mildew and aphids); RMt.1 (yellow colored grains, moderately resistant to root knot nematode, powdery mildew and aphids); Lam sel.1 (Dual purpose); Hisar Sonali (Dual purpose, moderately resistant to root rot and aphids); Hisar Suvarna (Dual purpose, moderately resistant to *Cercospora* and powdery mildew); Hisar Madhavi (Dual purpose, resistant to powdery mildew and Downey mildew); Hisar Muktha (Wide adaptability); RMt 303 (Yellow color seeds); RMt 305 (First determinant type, multipodant, resistant to powdery mildew and root knot nematodes); Gujarat Methi 1 (Dwarf plants); RMt 143 (Moderately resistant to powdery mildew, seeds bold yellow color, suitable for heavier soils); Pant Ragini (Dual purpose, resistant to downy mildew and root rot); NRCS-AM -1 AM-01-35 (Dual purpose, tolerant to powdery mildew); LFC-103 (Suitable for both rainfed and irrigated conditions)

(*Source* Johny et al. 2006)

9.6 Conclusion and Prospects

The genetic resources which are the reservoirs of identified and unidentified different genes are always the source for study for the breeders of all generations. The primary and secondary centers of origin are the source for different germplasms due to the natural hybridization and flow of genes throughout their existence. Detailed study on germplasm gives us the source material for resistance to biotic and abiotic stresses which can be further used in the improvement aspect.

The factors contributing to erosion due to the enormous diversity in cultivated plants, population growth, deforestation, erosion, changing land use and climate factors are major threats to the existing biodiversity of the region.

Natural productivity of any given species is always less, as the survival and continuation of a species is more important in nature than productivity. However, under domestication, the crops have shown the reverse. Due to the efforts of the human being, the productivities of all the crops have constantly raised, and in turn the survival mechanisms of the crops have been put to stake. Thus, the natural balance of maintenance of different forms has been disturbed.

The wild species presumably became extinct because of over collection. Owing to the strong commercial pressure of food and pharmaceutical industries of today, unregulated gatherings have led to severe genetic erosion of a range of herbs and spices. The status of genetic erosion will be likely speeded up during the process of development of economy. The forest fire causes erosion of wild species, and it results in the spread of rhizomatous crops present in the forest fire-infected region, as the aerial shoots get affected by this natural calamity, underground parts escapes the disaster, and further regenerate vigorously as there will be no competition. Preserving the biodiversity hot spots as natural sanctuaries will certainly help in slow in the gene erosion.

Large-scale cultivation is one practice that can take the pressure off wild stocks. This can be possible only by identifying the commercial importance of the wild species and exploring the rare information in the wild species which helps in domestication of the plant genes by the farmers which are possible. Thus it becomes a valid concern to evaluate and utilize the materials.

In many spices, conventional seed storage can satisfy most of the conservation requirements. However, crops with recalcitrant seeds and those having conservation needs cannot be satisfied by seed storage, which have to be stored in vitro. Most field gene banks are prone to high labor cost, vulnerable to hazards like natural disasters, pests and pathogens attack (especially viruses and systemic pathogens), to which they are continuously exposed and require large areas of space.

Most of the spice crops are either vegetatively propagated or have recalcitrant seeds. The spices germplasm is mostly conserved in field gene banks. Most of the spices are plagued by destructive and epidemic diseases caused by viruses, bacteria, and fungi. This makes germplasm conservation in field gene bank risky. Thus in vitro and cryostorage system becomes important in the overall strategy of conserving gene pool. Each technology should be chosen on the basis of utility, security, and complementarily to other components of the strategy. A balance needs to be struck between seed, field gene bank, in vitro and cryoconservation of propagules, tissues, pollen, cell lines, and DNA storage for overall objective of conserving gene pool. The genetic resources of black pepper, cardamom, ginger, turmeric, and vanilla are best conserved in field clonal repositories supplemented in vitro gene banks of active germplasm, while field gene banks are sufficient for perennial tree spices. However, for seed spices, field gene banks field with controlled pollination to maintain the pollution structure is essential with annual resurrection. This should be supplemented by long-term storage of base germplasm in low-temperature seed banks, which is ideal. For all these crops, DNA and pollen storage will supply the conservation methods mentioned above. Certainly, this does not mean to say that in situ conservation through protection of their natural habitats is less important. In fact, all the native genes for crop improvement are in the wild populations and hence have to be protected under biosphere reserves for posterity.

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