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Genetic Resources of Black Pepper

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1. INTRODUCTION

Black pepper is the oldest and world's most important spice. Christened as the 'King of Spices', black pepper is the dried mature fruit of the perennial climber *Piper nigrum* L. which is a native of the humid tropical forests of the Malabar coast of peninsular India, from where it has spread throughout the tropics. It is known to be in India since time immemorial and was one of the first to be taken to Europe. For centuries, until recently India had the monopoly on the production and export of black pepper. The annual production of black pepper in India is between 40,000 and 60,000 tonnes, more than 95% of which comes from the State of Kerala. The other main pepper producing countries are Indonesia, Sarawak (Malaysia), Brazil, Malagassey Republic, Cambodia and Sri Lanka.

2. SYSTEMATICS

2.1 Origin and Distribution

Piper nigrum belongs to the family Piperaceae, which is pan-tropical in distribution, concentrated mainly in South and Central America and South Asia. Over 1000 species were reported from the genus *Piper* of which about 110 are of Indian origin. In India, the Transgangetic region and the Sub-mountainous South-western region were recognised as two independent centres of distribution for *Piper* (Hooker, 1886; Gamble, 1925).

Some of the economically important species of *Piper* along with black pepper are, *P. betle* L. (betelvine), cultivated extensively in India where the leaves are used as masticatory; *P. longum* L. (Indian long pepper) *P. retrofactum* Vahl. (Java long pepper), and *P. mullesua* Ham. the fruits and roots of which are used in indigenous medicine and *P. cubeba* L.f. (cubebs or tailed pepper) used in indigenous medicine.

The earliest record of the descriptions of *Piper* spp. of Indian sub-continent was by Van Rheede (1678) in his '*Hortus Indicus Malabaricus*', the first printed document on the plants of Malabar Coast of India. He has described five types of wild peppers including the black pepper and long pepper. Linneaus (1753) included 17 species from India in his *Species Plantarum*. Roxburgh (1832) described seven species of *Piper* from Indian peninsula. Miquel (1843) included seven wild species in his monograph on *Piper*.

Wight (1853) in his *Iconas Plantarum Indiae Orientalis* illustrated 15 species from Indian peninsula. De Candolle (1869) included 52 species from India in his monographic work on Piperaceae.

The first major study on the Indian *Piper* was done by Hooker (1886) in his Flora of British India. He divided the genus into six sections viz., Muldera, Cubeba, Chavica, Pseudo chavica, Eupiper and Heckeria. He reported 45 species under these six sections of which 29 species are from India. He also gave a list of undeterminable species.

Cooke (1906) in his flora of the Presidency of Bombay reported five species of *Piper*. Burkill (1923) included 13 species of *Piper* in his Flora of Abhor Hills of North-eastern India, while Kanjilal *et al.* (1940) in their flora of Assam region reported three species. Duthie (1960) in his flora of Upper Gangetic plains and the adjacent Siwalic and Sub-Himalayan tracts included *P. longum, P. betle, P. mullesua, P. nepalense* and *P. nigrum*. Haines (1924) in his Botany of Bihar and Orissa reported five species of *Piper* viz., *P. longum, P. peepuloides, P. chaba, P. attenuatum* and *P. nigrum*. Rama Rao (1914) in his 'Flowering Plants of Travancore' listed 14 species of *Piper* from Western Ghats. They are *P. galeatum, P. trichostanchyon, P. longum, P. betel, P. hapnium, P. brachystachyum, P. hookeri, P. nigrum, P. sylvestre, P. hymenophyllum, P. argyrophyllum, P. wightii, P. subpeltatum* and *P. longicaule*. Fisher (1921) described six species from Anamalai hills. Fyson (1932) in his Flora of Nilgiris and Pulney hill-tops reported four species of *Piper* which includes *P. schmidtii* and *P. wightii*. The most authoritative floristic study of the Western Ghats was that of J.S. Gamble (1925), who in his 'Flora of the Presidency of Madras' has included 14 species of *Piper* along with keys. The species reported by him are *P. galeatum, P. trichostachyon, P. longum, P. hapnium, P. brachystachyum* (syn. *P. mullesua*), *P. hookeri, P. barberi, P. nigrum, P. hymenophyllum, P. attenuatum, P. argyrophyllum, P. schmidtii, P. wightii* and *P. betle*. The other floristic enumerations of *Piper* species were those of Santapau (1960), Parker (1924), Sharma and Tiagi (1979), Saldanha and Nicolson (1976), Rao and Razi (1981) and Rahiman (1981).

Recently Ravindran *et al.* (1987) Velayudhan and Amal Raj (1992) and Nirmal Babu *et al* (1993) have reported four new taxa from Kerala. They are *P. silentvalleyensis P. nigrum* var. *hirtellosum P. pseudonigum* from Silent Valley biosphere reserve and *P. sugandhi, P. sungandhi* var. *brevipilis* from Sugandhagiri cardamom plantations, Wynad, Kerala.

The details of the more important species of *Piper* and their areas of distribution are given in Table 1.

2.2 Cytology

Cytology of *Piper* has been studied by various workers and most of them are confined to the determination of chromosome numbers (Janaki Ammal, 1945; Mathew, 1958; Sharma and Bhattacharya, 1959; Dasgupta and Datta, 1976; Jose and Sharma, 1985; Samuel and Bavappa, 1981; Rahiman and Nair, 1986; Stella Bai and Subramanian,

Table 1 : Major species of *Piper* occurring in India and their distribution (based on J.D. Hooker, 1896; J.S. Gamble, 1925; and on the collection surveys of the authors (unpublished)

Sl. No.	Species name	Area of distribution
1	2	3
1.	*Piper galeatum* Cas. DC.	Western Ghats from Coorg to Travancore, Wynad, Annamalais, Hills of Courtallam, in forests at low levels upto 2500 ft.
2.	*P. trichostachyon* Cas. DC.	Western Ghats, Konkan, Canara, Coorg, Wynad, Sivagiri Hills of Tirunelveli and Nilgiri Hills—in forests upto 2500 ft.
3.	*P. sumatranum* Cas. DC.	Andaman Islands.
4.	*P. griffithi* Cas. DC.	Assam.
5.	*P. canium*, Blume var. *glabra*, Helfer.	Andaman Islands.
6.	*P. muricatum*, Blume. var. *glabrata Giffith.*	Mishmi hills in upper Assam.
7.	*P. longum* Linn.	Hotter Parts of India from Central Himalayas to Assam, Khasi and Mikir hills, lower hills of Bengal, ever-green forests of Western Ghats from Konkan to Kanyakumari and Carnicobar Islands at lower elevations.
8.	*P. peepuloides* Roxb.	Tropical Himalayas from Nepal to Bhutan, Assam, Khasi and Mikir hills upto 3000 ft.
9.	*P. Chaba* Hunter.	Cultivated in various parts of North Eastern India.
10.	*P. sylvaticum* Roxb.	Upper and lower Assam in marshy districts.
11.	*P. petiolatum* Hook.	Upper Assam, Mishmi hills.
12.	*P. betle* Linn.	Cultivated in hotter and damper parts of India—Kerala, Karnataka, West Bengal, Tamil Nadu and Assam etc.
13.	*P. boehmeriaefolium* Wall. Cat.	Tropical Eastern Himalayas, Sikkim ascending to 5000 ft., Assam, Silhet and Khasia mountains.
14.	*P. anisotis* Hook.	Upper Assam.
15.	*P. aurantiacum* Wall.	Assam.
16.	*P. hapnium* Ham.	Western Ghats—in the hills of Kerala, Courtallam, (Very rare, endangered species).
17.	*P. mullesua* Ham. (*P. brachystachyum* Wall.)	Sub-tropical Himalayas from Simla to Bhutan—2000-5000 ft., Khasia mountain—3000-5000 ft., Western Ghats—Nilgiri hills, Annamalais, Pulneys and hills of Kerala in Shola forests about 5000 ft., Bababudan hills of Karnataka.
18.	*P. thomsoni* Hook.	Himalayas—Sikkim at 7000 ft., Khasia mountain from 3000-4000 ft.
19.	*P. hamiltonii* Cas. DC.	Sikkim, Assam, Silhet and Khasia mountains.
20.	*P. hookeri* Miq.	Konkan and Canera—Mahabaleshwar and Bababudan hills of Karnataka.
21.	*P. schmidtii* Hook f.	Western Ghats : Silent Valley, Nilgiri hills about 5000 ft. (rare, endangered species).
22.	*P. nepalense* Miq.	Sub-tropical Himalayas 3000-5000 ft. from Garhwal, Bhutan and Mishmi hills, Khasia mountain 3000-5000 ft.

(Contd.)

Table 1 : *Contd.*

1	2	3
23.	*P. khasianum* Cas.	Sikkim, Himalayas at 2000-6000 ft., Upper Assam Khasia mountains at 3000-5000 ft.
24.	*P. nigrum* Linn.	In the ever-green forests of Western Ghats well distributed upto 5000 ft. and largely cultivated in the States of Kerala, Karnataka, and Tamil Nadu.
25.	*P. nigrum* var. *hirtellosum* Asokan & Ravindran.	Silent Valley forests of Kerala.
26.	*P. rhytidocarpum* Hook.	Assam—Silhat and Khasia mountains ascending to 4000 ft. Very common.
27.	*P. attenuatum* Buch. Ham.	Eastern tropical Himalayas—Sikkim, Assam—Silhet and Khasia mountains, Western Ghats—Nilgiris, Thirunelveli in ever-green forests at low levels. Shevroy and Kolli hills and hills of A.P. and Orissa upto 3000 ft.
28.	*P. sylvestre* Lamk.	Assam—Silhat and Courtallam.
29.	*P. hymenophyllum* Miq.	Western Ghats from Mysore and Nilgiris South-wards in ever-green forest at 1500 to 5000 ft.
30.	*P. argyrophyllum* Miq.	Wester Ghats—Coorg, Nilgiris South-wards, upto 5000 ft.
31.	*P. wightii* Miq.	Nilgiris and Palney hills of Western Ghats above 6000 ft. in Sholas (rare, endangered species).
32.	*P. barberi* Gamble.	Hills of Tirunelvely and Breymore (Trivandrum) (very rare, endangered species).
33.	*P. silentvalleyensis* Ravindran, Nair and Asokan.	Silent Valley forest, Kerala (very rare, endangered).
34.	*P. sugandhi* Ravindran, Babu and Naik.	Ever-green forests of Western Ghats, Sugandhagiri Project area of Wynad.
35.	*P. sugandhi* var. *brevipilis*, Ravindran, Babu and Naik	Ever green forests of Western Ghats, Sugandhagiri Project area of Wynad.
36.	*P. pseudonigrum* Velayudhen at Amal Raj	Silent Valley forests of Western Ghast.

1975; and Samuel, 1986). The various species of *Piper* and their chromosome reports are given in Table 2. Mathew (1958, 1974) studied eleven cultivated and six wild types of *P. nigrum* and found the somatic chromosome number 2n = 52 in all the cultivated and wild except two in which the chromosome number was 2n = 104. According to him the chromosome length ranged from 1-3 μ.

The reported chromosome numbers 2n = 24, 26, 36, 39, 40, 48, 52, 60, 64, 65, 68, 78, 80, 96, 104, 132 etc. (Table 2) point to the existence of a polyploid series in the genus *Piper*. All the species studied from South India and Sri Lanka could be traced to a common basic number x = 13 while the North Indian species seem to have a basic number x = 12. The haploid number n = 12 as seen in *P. cubeba* may represent comparatively a primitive number from which x = 13 might have evolved. It has been suggested that x = 13 reported consistently should be taken as the valid basic number of the genus (Jose and Sharma, 1985). The species with 2n = 26 are then diploids those

Table 2 : Contd.

1	2	3	4
		52	NRCS*
		78	Nair *et al* (1993)
		104	Jose and Sharma (1985)
14.	*P. schmidtii*	96	Stella Bai and Subramanian (1985)
15.	*P. wightii*	(n = 24)	Stella Bai and Subramanian (1985)
		52	NRCS*
16.	*P. sugandhi*	52	NRCS*
17.	*P. trichostachyon*	52	Rahiman and Nair (1986)
		52	NRCS*
18.	*P. hapnium*	52	Rahiman and Nair (1986)
19.	*P. mullesua* Syn.	132	Stella Bai and Subramanian (1985)
	P. trichystachyum	132	NRCS*
20.	*P. attenuatum*	156	Jose and Sharma (1985)
21.	*P. betlehmeriaefolium*	52	Jose and Sharma (1985)
22.	*P. barberi*	52	Nirmal Babu *et al* (1992)
		52 (n = 26)	Mathew & Mathew (1992)

*Unpublished data from NRCS.

with 2n = 52 may be considered tetraploids and 2n = 104 types are octaploids. The chromosome number reported in *P. mullesua* as 2n = 132 may be a decaploid. Lack of uniformity in the reports of chromosome number by different workers indicate the existence of many cytotypes in this taxa. These cytotypes are being maintained in the population by the predominant vegetative propagation.

3. GERMPLASM COLLECTION

3.1 History

The hot and humid tropical evergreen forests of Western Ghats in South India is considered to be the centre of origin of *P. nigrum* where it still occurs wild in large populations. Though in earlier times black pepper was collected as a forest produce, the vines of black pepper have been domesticated many centuries ago in the upland and coastal areas of Western Ghats comprising the states of Kerala and Karnataka. From here it is presumed to have spread to countries like Sri Lanka, Malaysia, Indonesia, Philippines, Brazil etc. Black pepper being a crop of humid tropics requires heavy and well distributed rainfall. A rainfall of 2500 mm or more is ideal. Though virgin soils rich in humus is most suitable for pepper, they come up well in red lateritic or alluvial soils with high humus and good drainage.

Piper nigrum is mostly dioecious in its wild state while most of the cultivated types are bisexual. The bisexual nature seen in many of the present day cultivated types might have been the result of domestication and continuous conscious selection for high

yielding types from the wild types and their maintenance by vegetative propagation (Ravindran and Babu, 1988).

3.2 General Morphology

Piper nigrum is a perennial glabrous woody climber growing upto a height of 15 m or more. The height of the vine depends on the height of the support it climbs. Under cultivation as a monocrop, the height is restricted to about 4-6 m having a columnar appearance. They are trailed on either living or non-living standards (Fig. 1). In India, pepper is cultivated mostly in homestead gardens on living standards and fast growing trees like *Erythrina, Grevelia robusta, Ailanthus, Garuga pinnata* etc. are the most commonly used support trees. Pepper is also cultivated as a mixed crop in coconut, arecanut, coffee and tea plantations in many parts of Kerala, Karnataka and Tamil Nadu.

The pepper vine has two types of branches, the orthotropic climbing branches and the plagiotropic fruiting branches. The orthotropic branches are vegetative and have monopodial growth habit. After climbing a support they become woody with a thick bark which form the central axis of the column. The nodes are swollen and each node has a cordate or ovate leaf. At each node there may be 8-15 short adventitious clinging

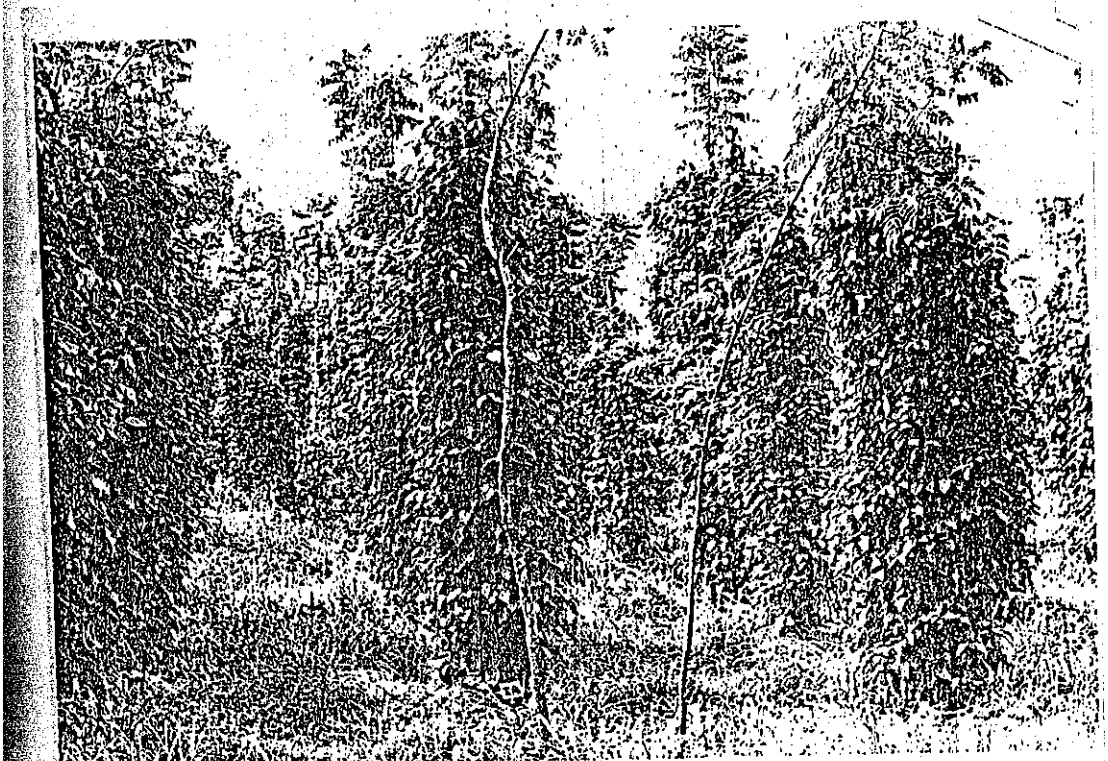


Fig. 1 : A black pepper plantation on *Erythrina* standards.

roots which adhere firmly to the support while climbing. At the axil of each leaf there is an axillary bud which can develop into plagiotropic branches which produce flowers and fruits. Both type of shoots branch but only orthotropic shoots produce further climbing shoots with roots at every node which are used for propagation of pepper vines. The sympodially growing fruiting branches when rooted and planted will grow into short pepper bushes (Fig. 2). These pepper bushes are ideal for growing in pots for terrace gardens. They can also be planted in field in hedge planting.

A mature pepper vine has 10-20 main adventitious roots 2-3 m long from the base of the stem and there is an extensive mat of surface feeding roots. About 80-90 per cent of the feeding roots are in the upper 40 cm of soil.

Leaves are simple alternate and often unequal sided. Leaf petiole is 1-5 cm long and grooved above. At the vegetative node the petioles are sheathed enclosing the developing shoot tip. Leaves are coriacedus, dark green and shiny above, pale and gland dotted below, cordate to ovate in orthotropic shoots ovate to ovate—elliptic on plagiotropic shoots. Lamina is entire with 5-7 veins arising from the leaf base or slightly above the

Fig. 2 : A bush pepper of cv. Panniyur-1 pot culture.

base which is round, acute or cordate, leaf tip usually acuminate. Leaf size varies with cultivars and may be 3-20 cm or more long and 3-15 cm or more broad.

The inflorescence is a filiform, pendant spike borne opposite to the leaves on fruiting branches. The spikes are terminal in development but pushed aside by the new shoot developing from the axillary bud, so as to make it appear opposite to the leaf. The spikes are 2-17 cm or more long bearing 5-100 or more minute flowers borne in the axils of ovate, fleshy and cupular bracts. Majority of the cultivated types are monoecious, exhibiting great variability in the composition of male, female and hermaphrodite flowers in the spike. Most of the high yielding cultivars have as much as 70-100 per cent bisexual flowers indicating that higher percentage of bisexual flowers results in greater productivity. Under intense shade conditions some of the varieties with bisexual flowers produce more of female and less of hermaphrodite flowers, and sometimes the anthers fail to emerge out of the bracts or emerge out belatedly. The sessile flowers have no perianth. The flowers exhibit extreme reduction of floral parts. The male flower is represented by two naked anthers, the female flower by single ovary and the hermaphrodite flower by an ovary with two anthers, one on either side of the ovary. The flowers are subtended by cupular bracts. Anthers 2 in number, two celled, 1-2 mm in size with short filaments. The globose ovary is one celled, sessile with a single orthotropous ovule. Stigmas 3-5, fleshy, papillose, white when receptive, later turn black. They may be receptive upto ten days with peak receptivity from third to fifth day. The pollen grains are small and usually in small aggregates. Self pollination is predominant in most of the cultivars and there is no active pollen transfer mechanism. In bisexual types the presence of anthers on either side of the gynoecium ensures effective self pollination especially in types where both male and female flowers mature at the same time, exhibiting synchrony of male and female phases. Though there is protogyny in many cultivars, in most of them the female phase coincides with the male phase at least at some stage so that the female flowers are exposed to the pollen from the same spike. Geitenogamy is the major mechanism effecting pollination. The presence of dew or water drops on the spike may further enhance dispersal of pollen grains. Cross pollination may also occur to a limited extent aided by either insects or wind.

The fruit, though known as a berry, is a sessile globose drupe with a pulpy pericarp. The green unripe fruit turns red upon ripening and turns black after drying. The size and number of drupes per spike varies with different cultivars. The seed has a minute embryo with little endosperm and copious perisperm.

3.3 Germplasm Collection

The fundamental requirement of any crop improvement programme is the genetic variability available within the species and in the closely related species. The tropical forests of the Western Ghats in Southern India, being the native home, is the centre of diversity of black pepper.

P. nigrum in its wild state still occurs throughout the Western Ghats in the periphery of dense forests. The rapid deforestation and the frequent forest fires are

causing considerable damage to the flora in this region. The species of *Piper* are one of the most affected. Many of the related species of *Piper* are now confined only to a few specific locations and may soon be extinct if not collected and conserved. Species like *P. barberi*, *P. hookeri* and *P. silentvalleyensis* are extremely rare and could be collected only from one or two locations. Similarly, *P. schmidtii* and *P. wightii*, which occur only at elevations above 6000 ft. are also becoming quite scarce occurring only at a very few locations around Ooty and Kodaikanal. Others like *P. longum*, *P. attennuatum*, *P. argyrophyllum*, *P. galeatum*, *P. trichostachyon* etc. have much wider distribution and occur at lower elevations throughout the states of Kerala and Southern Karnataka bordering the forests.

There are about hundred cultivars of black pepper still under cultivation. Many of them are named either after the place of popularization or the persons who popularised them. Sometimes the names are based on some important identifying character. For example 'Malabarvally' is a vine from Malabar; 'Natesankodi', 'Balankotta', 'Chettanvally' may have been named after a person; 'Aimpiriyan', a variety having five spiral rows of fruits; 'Vokkalu' a variety which has only one or two fruits in the spike; 'Doddele' has big leaves and so on. Many of the existing varieties are products of domestication and continuous selection and are being maintained by vegetative propagation. Sometimes seedling progenies were also raised by the earlier farmers and used as planting material. Both these factors might have contributed to the existing variability in the black pepper cultivars.

The collection, conservation, cataloguing and evaluation of genetic resources of black pepper is given high priority at the National Research Centre for Spices, Calicut, a constituent body of the I.C.A.R. Systematic surveys of all the pepper growing areas in India as well as the forests of Western Ghats have been conducted to collect the available variability of cultivated as well as wild types of *P. nigrum* and related species. The clonal material of these collections are maintained at the germplasm conservatory of this Centre. At present the germplasm holding of black pepper at the National Research Centre for Spices is perhaps the largest in the world with 474 accessions of cultivated, 281 accessions of wild types of *P. nigrum* and related species, 213 accessions of Karimunda, 75 accessions of Kottanadan and over 2000 inter-cultivar hybrid lines (Table 3). There are four exotic cultivars available at NRCS germplasm collection, namely 'Kuching', the famous Malaysian pepper cultivar and LDK 'Djambi' and 'Belantung', both from Indonesia.

4. EVALUATION AND DOCUMENTATION

The germplasm is being evaluated and described based on the standard descriptor developed at National Research Centre for Spices.

4.1 Morphological Characters

There is considerable variability among the accessions with regard to various morphological as well as floral characters like leaf shape leaf size, spike length, spiking

intensity, composition of male, female and bisexual flowers in the spike, fruit set, shape, weight and volume of the fruit and time taken for maturity etc. The extent of variability for some of the characters are given in Table 4, Fig. 3 and 4.

The leaf size varies from 8-19 cm in length and 4.7-10.2 cm in breadth. Cultivars like Doddele, Balankotta, Karimkotta etc. and the hybrid Panniyur-1 have large leaves while those of Jeerakamundi, Nedumchola, Cholamundi etc. have small leaves and Neelamundi, Karimunda, Kottanadan, Arakkulammunda, etc., have medium sized leaves. The large leave varieties usually grow into vines with bigger canopy whereas the smaller leave types have smaller canopy.

Table 3 : Details of germplasm holding of black pepper and related species in India

Sl. No.	Species name	No. of accessions	
		NRCS	Pepper R.S. Panniyur
1.	*Piper nigrum* L.		
	(a) Cultivated types		73
	(i) Indigenous	471	
	(ii) Exotic	3	
	(iii) Selections of cv. Karimunda	213	
	(iv) Selections of cv. Kottanadan	75	
	(v) Inter-cultivar hybrids	over 2000	
	(b) Wild types	69	127
2.	*P. longum*	18	
3.	*P. betle*	12	
4.	*P. chaba*	1	
5.	*P. attenuatum*	44	
6.	*P. argyrophyllum*	34	
7.	*P. hymenophyllum*	19	
8.	*P. mullesua*	4	
9.	*P. barberi*	2	
10.	*P. weightii*	2	
11.	*P. trichostachyon*	12	
12.	*P. galeatum*	15	
13.	*P. sugandhi*	2	
14.	*P. sugandhi* var. *brevipilis*	2	
15.	*P. colubrinum* (Exotic)	2	
16.	*P. magnificum* (Exotic)	1	
17.	*P. schmidtii*	1	
18.	*P. arborium*	1	
19.	Doubtful *Piper* entries	40	
	Total accessions	3043	200

Table 4 : Spike and berry (fruit) characters of black pepper cultivars

Sl. No.	Cultivars	Spike length (mm)	Peduncle length (mm)	L.L.*/Sp.L.*	Spike shape	Berry shape	Berry size
1.	Aimpiriyan	115.60	12.20	1.20	Curved	Round	Bold
2.	Arakkulamunda	114.00	13.10	1.34	Straight	"	Medium
3.	Arimulaku	80.35	13.23	1.20	"	"	Small
4.	Balankotta	127.40	17.20	1.55	"	"	Bold
5.	Billimalligesara	105.60	8.60	1.13	"	"	Medium
6.	Cheriyakaniakkadan	105.40	9.20	1.13	"	Obovate	Small
7.	Cheppukulamundi	120.30	19.00	1.21	"	Round	Medium
8.	Cholamundi	111.30	6.40	1.24	"	"	Small
9.	Jeerakamundi	103.60	6.00	1.16	"	"	"
10.	Karimunda	78.00	10.00	1.51	"	"	Medium
11.	Kaniakkadan	92.50	9.00	1.38	"	"	"
12.	Karuvilanchy	104.30	10.00	1.21	"	Oblong	Bold
13.	Karimkotta	156.30	21.00	0.88	"	Round	"
14.	Kalluvally 1	69.17	12.00	2.05	Curved	"	Small
15.	Kalluvally 2	124.90	10.60	1.90	Straight	"	Medium
16.	Kallubalancotta	136.36	10.50	1.02	"	"	"
17.	Kottanadan	106.90	11.10	1.20	"	"	"
18.	Kuching	91.00	9.70	1.51	"	Oblong	"
19.	Kuriyalmundi	53.20	10.10	2.22	Curved	Round	Small
20.	Kuthiravally	171.60	10.50	0.67	Straight	"	Medium
21.	Kurimalai	126.13	14.73	1.03	"	"	"
22.	Malamundi	96.70	7.90	1.34	"	"	"
23.	Mundi	86.30	9.10	1.56	"	"	Bold
24.	Narayakkodi	82.30	7.90	1.25	Curved	Obovate	Small
25.	Neelamundi	96.97	7.90	1.60	Straight	Round	Bold
26.	Nedumchola	51.70	9.60	1.71	"	Obovate	Small
27.	Neyyatinkaramundi	71.00	7.00	1.26	"	Round	"
28.	Ottaplackal 1	113.80	12.40	1.03	"	"	Medium
29.	Panniyur 1	140.00	13.70	1.02	"	"	Bold
30.	Perambramunda	119.00	10.00	1.25	"	Oblong	Medium
31.	Perumkodi	117.60	13.10	1.30	Straight	Round	Bold
32.	Poonjaranmunda	163.90	12.20	0.81	"	"	"
33.	Sagar local	90.00	10.80	1.70	"	"	"
34.	Thevamundi	96.50	8.71	1.46	"	Oblong	Medium
35.	Thomankodi	127.60	15.50	0.80	"	Round	"
36.	Thulasi	95.00	10.60	1.30	"	Oblong	Medium
37.	Udakkere	128.80	11.65	1.17	"	"	Bold
38.	Uthirancotta	105.60	12.60	1.35	"	"	"
39.	Vadakkan	117.30	14.60	1.41	Straight	Round	"
40.	Valiakaniakkadan	97.50	13.80	1.77	"	Oblong	"
41.	Vattamundi	99.70	12.45	1.14	"	Round	"
42.	Vellanamban	122.40	9.60	0.84	"	"	"
43.	Velliyaranmunda	100.06	8.46	1.45	"	"	Medium
44.	Vokkalu	33.70	5.30	2.12	"	"	"

*L.L.—Leaf length; Sp.L.—Spike length.

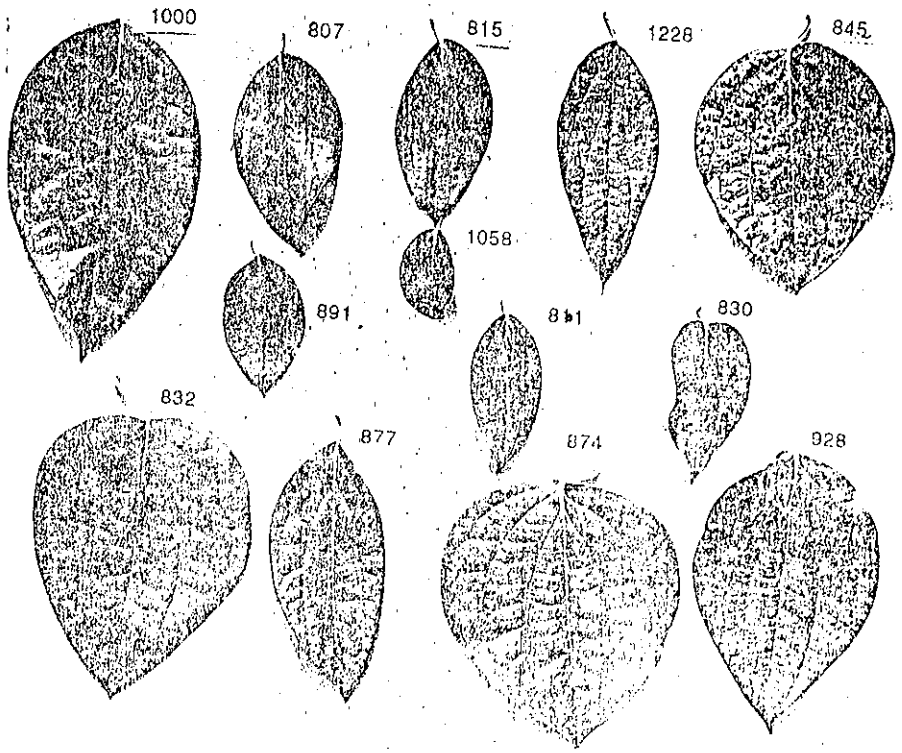


Fig. 3 : Variability in size & shape of the leaf among black pepper cultivars, (numbers at the side of each leaf give their collection numbers).

Accessions of Panniyur-1, Poonjaranmunda, Kuthiravaly; Balankotta, and Thommankodi have long spikes, whereas accessions like Neelamundi, Kalluvally, Arakkulammunda, Aimpiriyan, Kaniakkadan, Malligesara etc. have medium spikes and varieties like Kurialmundi, Jeerakamundi, Nedumchola, Thippalimundi have small spikes. Cultivar Vokkalu has the smallest spike of about 2-3 cm and has only one or two fruits. The spiking intensity is high in cultivars like Muttayaramundi, Jeerakamundi, Cholamundi, Karimunda and some accessions of Kalluvally where there is a tendency for clustering of spikes at the terminal ends of lateral branches. This clustering is due to the extreme shortening of internodes and lack of leaves at these nodes during peak flowering season. But most of them are rather poor yielders as the fruit set is poor except in some cultivars like Karimunda and Kalluvally.

Fruit set is very high (above 75%) in cultivars like Pulpally Kalluvally, Narayakodi, Kurielmundi, Pirimundi, Aimpiriyan, Karuthapirimunda, Karimunda etc. whereas Irumanian, Jeerakamundi, Uthirankotta, Cholamundi etc. have low fruit set. Cultivars of Panniyur and Vadakkan have large berries while cultivars Nedumchola, Jeerakamundi, Kurialmundi have very small berries. The berry size ranges from 90-264 cc for 1000 berries. The

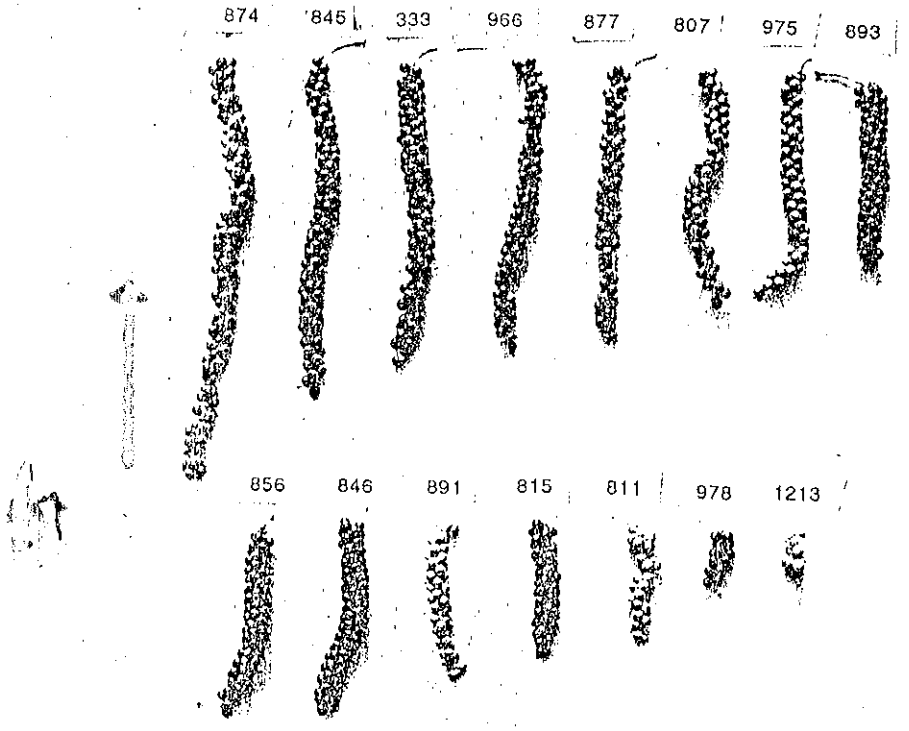


Fig. 4 : Variability in spike length among black pepper cultivars (numbers at the side of each spike give their collection numbers).

fruits are usually globose in most of the cutivars. Cultivars Karivilanchy and Perambramunda have oblong fruits. The fruits of Narayakodi have persistent stigma which gives a conical appearance.

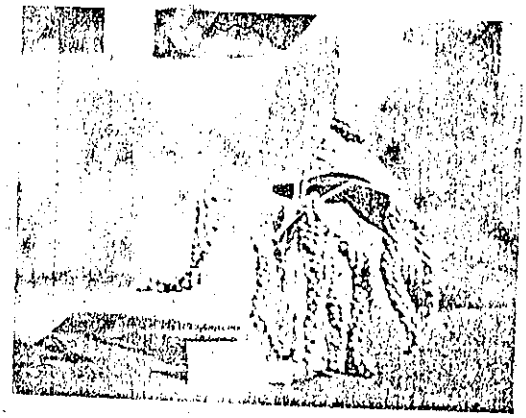
The cultivars show great variability in the composition of bisexual, female and male flowers in their spikes. Cultivars like Narayakodi, Uthirankotta and Karuvilanchy produce predominantly female flowers. On the other hand, Karimunda, Panniyur-1, Aimpiriyan, Kuthiravaly and Kalluvally have predominantly bisexual flowers. The climatic conditions seems to affect the nature of the flowers. For example the cultivar Cholamundi produces spikes with only female flowers in June-July, produces spikes with bisexual flowers in October-November. In Panniyur-1, the anther emergence is inhibited at high elevations and under heavy shade.

Arakulammunda is an early maturing variety and it takes about 6 months from flowering to the ripening of the fruits whereas Karimunda takes about 7 months and Aimpiriyan and Kambhakod takes 8 months as they matures late.

4.2 Yield

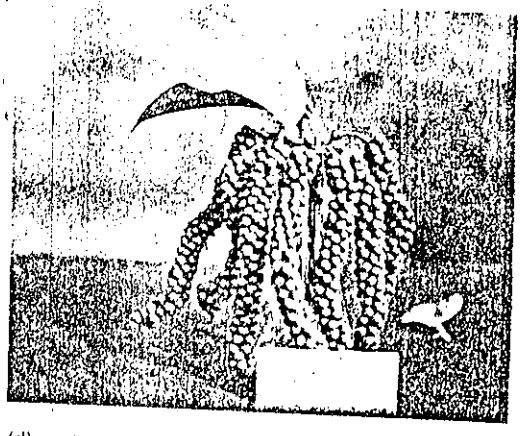
There is considerable variation in the yields of black pepper cultivars. Cultivars Karimunda, Aimpiriyan, Kottanadan, Kuthiravaly, Neelamundi, Balankotta, Pulpally Kalluvally, Karutha Pirimunda, etc., are some of the high yielding types (Fig. 5) whereas Vokkalu, Jeerakamundi, Maramonakki, Irumaniyan etc. give very low yields. Many of the varieties are location specific and their yield performance depends upon the agro-

(a)



(c)

(b)



(d)

Fig. 5 : Promising cultivars of black pepper
(a) Kuching
(b) Aimpiriyan
(c) N.T. line
(d) CLT-P-125

climatic situation where they are cultivated and the conditions like elevation, rainfall and shade seem to affect their performance (Ravindran and Babu, 1988). Cultivar Karimunda is the most popular and it is known to give consistent yields under varying climatic conditions and hence is grown throughout the State of Kerala. It is known to perform reasonably well even under moderate shade and hence most preferred for planting as mixed crop in coconut, arecanut, coffee, tea and cardamom plantations. Karimunda along with Kalluvally and Neelamundi are preferred in areas prone to drought.

4.3 Resistance to Pests and Diseases

The variability with regard to resistance to pests and diseases is limited. Almost all the cultivars are susceptible to *Phytophthora capsici*, the causal organism of the dreaded *Phytophthora* foot-rot'; *Radopholus similis* and *Meloidogyne incognita*, the causal organisms of the 'pepper yellows' and pollu beetle (*Longitarsus nigripennis*) which damage the fruits. Only a South American species *P. colubrinum* is resistant to *P. capsici* as well as *R. similis*. Cultivar Ottaplackal-1 released under the name 'Pournami' is found to be tolerant to *M. incognita*. Twelve accessions of cultivars, 12 inter-cultivar hybrids and 50 open pollinated progenies were found to have relative tolerance to *P. capsici* (unpublished data from NRCS). These are under field evaluation.

4.4 Quality Attributes

In black pepper, quality is as important as the yield. The major quality components are piperine, which contributes to the pungency and essential oil, which is responsible for the characteristic flavour of black pepper. Oleoresin contains both components. Hence, the quality parameters are usually expressed in terms of the percentage of oleoresin, essential oil and piperine. The variability in quality characters among some of the important cultivars is given in Table 5. Kottanadan, Kumbhakodi and Aimpiriyan are cultivars with high quality pepper.

4.5 Characterisation of Wild and Related Species

Very little work was done in systematic characterisation and evaluation of wild and related species of *Piper*. The study at NRCS indicate that most of the wild types of *P. nigrum* have medium to large leaves, with long spikes and are dioecious. The fruit set is very poor with about 3-10 fruits per spike. The fruits are globose, bigger and are less pungent compared to most of the cultivars.

Among the related species of *Piper*, which occur in India only the recently described *P. pseudonigrum*, *P. sugandhi* and *P. pseudonigrum* have fruits that are spicy in taste and having flavour similar to those of *P. nigrum*. Most of the *Piper* species give bitter fruits, except *P. longum*, *P. chaba*, *P. mullesua* and *P. peepuloides* whose fruits are commonly marketed as long pepper. They are more pungent with numbing taste and are used mostly in indigenous medicine. Some accessions of *P. attenuatum* have recorded the longest spike, about 25-30 cm with small conical or oval fruits which taste bitter (Fig. 6). The fruits of *P. galeatum* and *P. trichostachyon* resemble those of *P. nigrum*

Table 5 : Quality composition of important pepper cultivars* (Values on dry weight basis).

Sl. No.	Cultivar	Volatile oil % (v/w)	Oleoresin % (w/w)	Piperine % (w/w)	Starch % (w/w)
1.	Arikottanadan	4.75	12.90	4.50	24.66
2.	Arakkulamunda	4.75	9.84	4.40	36.18
3.	Balankotta	5.12	9.35	4.26	25.20
4.	Ceylon	3.75	13.50	7.60	15.66
5.	Cheriyakaniakkadan	3.75	9.05	3.95	24.84
6.	Chumala	2.25	5.45	3.30	46.62
7.	Doddigya	2.50	7.10	2.85	36.00
8.	Kalluvally	3.25	8.80	4.24	31.50
9.	Kalluvally (PTB)	0.40	10.90	4.65	29.00
10.	Kalluvally Type I	3.00	8.44	5.40	20.70
11.	Kaniakkadan	4.75	11.60	6.00	12.42
12.	Kottanadan	2.50	17.80	6.60	23.40
13.	Karimunda	4.00	11.00	4.40	39.60
14.	Karuvilanchy	3.50	9.70	4.30	27.00
15.	Kumbhakodi	4.50	14.90	7.60	18.20
16.	Kuthiravally	4.50	14.90	5.97	14.04
17.	Munda	4.75	7.00	5.60	22.70
18.	Mundi	3.50	7.50	3.60	23.40
19.	Narayakkodi	4.00	10.85	5.40	24.50
20.	Nilgiris	5.50	15.50	6.05	23.60
21.	Palulauta	3.00	7.60	3.60	19.26
22.	Panniyur-1	3.50	9.52	3.60	35.10
23.	Perumkodi	3.00	8.60	4.00	28.80
24.	Perumunda	4.00	8.00	7.40	26.64
25.	Shimoga	2.50	7.20	4.56	17.64
26.	Sullia	4.00	6.80	3.60	20.70
27.	TMB II	2.50	10.80	5.80	32.60
28.	Uthirankotta	4.75	8.55	3.92	28.80
29.	Vally	2.50	6.53	4.90	16.02
30.	Aimpiriyan	2.63	15.70	4.69	—
31.	Udhakara	3.82	8.61	2.36	—
32.	Thommankodi	5.98	13.77	2.77	—
33.	Sreekara**	7.00	13.00	5.10	—
34.	Subhakara**	6.00	12.40	3.40	—
35.	Panchami**	3.40	12.50	4.70	—
36.	Pournami**	3.35	13.80	4.10	—

*Raju *et al.* (1983); **New varieties released by NRCS.

but are larger and bitter. They are usually adulterated with those of *P. nigrum* especially when collected from forests, thus bringing down the quality of the spice. *P. barberi* is another distinct species with characteristic reticulately veined leaves and juvenile shoots with only scale leaves. The spikes are also distinct in that the peduncles are unusually longer (about 10 cm long). *P. mullesua* is the only south Indian species having globose spikes; while P. silentvalleyensis has fileform, erect or flexuous spike, and this also the only bisexual species occurring in south India. Some of the important spike and berry characters of different species of *Piper* are given in Tables 6 and 7.

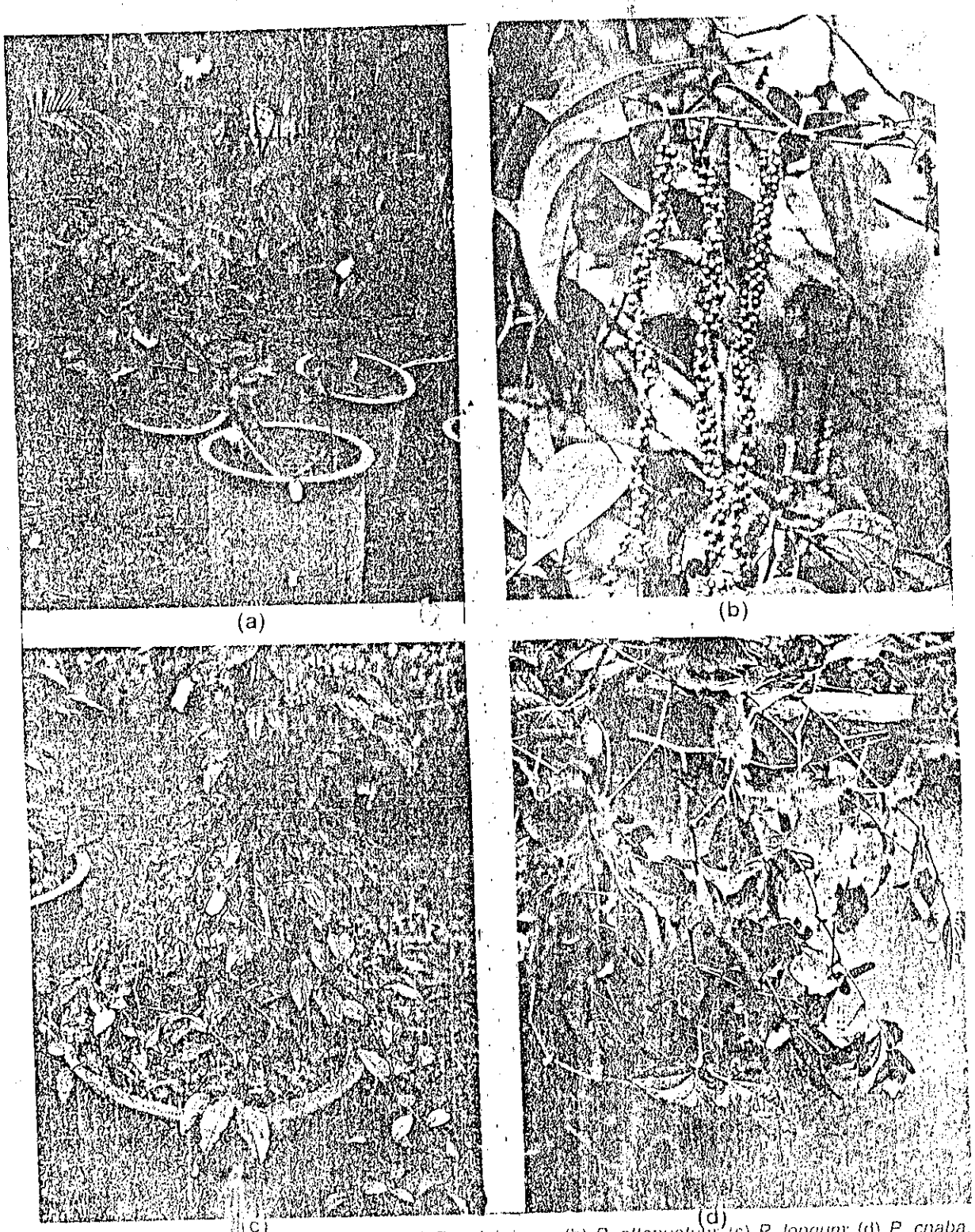


Fig. 6 : Related species of *Piper nigrum*. (a) *P. colubrinum*; (b) *P. attenuatum*; (c) *P. longum*; (d) *P. cnaba*.

Table 6 : Spike characters of *Piper* spp.

Species	Spike length (mm)	Peduncle length (mm)	Spike shape	Spike orientation	Spike texture	Bract type
P. attenuatum	120.0	20.0	Filiform	Pendulous	Glabrous	Adnate
P. argyrophyllum	83.0	25.2	"	"	"	"
P. hymenophyllum	73.0	22.0	"	"	"	"
P. galeatum	105.0	17.4	"	"	"	Connate fleshy cup
P. longum	38.0	14.0	Cylindrical	Erect	"	Stalked, peltate, orbicular
P. mullesua	9.0	3.0	Globose	"	"	"
P. schmidtii	125.0	20.0	Filiform	Pendulous	"	Obconical, angular free margins
P. silentvalleyensis	40.0	2.5	"	Ascending	"	Stalked, peltate, orbicular
P. sugandhi	71.0	14.6	"	Pendulous	Glabrous	Deeply cupular
P. sugandhi var. *brevipilis*	69.0	14.6	"	"	Hirtellous	"
P. trichostachyon	76.0	15.3	"	Pendulous	Hirtellous	Fleshy cup
P. wightii	65.0	12.0	"	"	Glabrous	"
P. nigrum	105.0	10.7	"	"	"	Shallow cup under the ovary
P. barberi	50.2	100.0	"	"	"	Peltate, orbicular
P. chaba	45.0	9.6	Conical	Erect	"	"

Table 7 : Fruit (berry) characters of *Piper* spp.

Species	Berry nature	Berry shape	Berry taste
P. attenuatum	Free	Ovate-oblong	Bitter
P. argyrophyllum	"	"	"
P. hymenophyllum	"	"	"
P. galeatum	"	"	"
P. longum	Fused	Elliptical	Spicy
P. mullesua	Free	"	"
P. schmidtii	"	Ovate-oblong	Bitter
P. silentvalleyensis	"	Obovate	Spicy
P. trichostachyon	"	Spherical	Bitter
P. sugandhi	"	Ovate-oblong	Pungent
P. sugandhi var *brevipilis*	"	"	"
P. wightii	"	Conical	Bitter
P. nigrum	"	Spherical	Pungent
-do- var. *hirtellosum*	"	"	"
P. barberi	"	Round	Seed slightly pungent
P. chaba	Fused	"	Spicy

5. CONSERVATION

Black pepper being a vegetatively propagated crop, its germplasm is maintained in clonal repositories as well as in field gene banks. Furthermore pepper seed is recalcitrant and hence cannot be stored for long, and the seedling progenies show variations when compared to the mother plant. At the National Research Centre for Spices the entire germplasm is maintained in three different stages viz.,

i) In the nursery each accession is trailed on bamboo splits in serial order and are under continuous multiplication.

ii) In the clonal repository 10 rooted cuttings of each cultivar are maintained, under extreme care.

iii) In the field gene bank, five vines of each accession are planted and are under continuous evaluation.

This three stage conservation serves as a precaution against inherent problems of loss of accessions due to epidemic diseases like *Phytophthora* foot rot. The diseased material from any one location/stage is immediately replaced by planting material from the other. In addition, this makes available, to a limited extent planting materials of any accession at any given time. Recently work on *in vitro* conservation of pepper germplasm has been initiated at NRCS, Calicut.

Rapid changes that are taking place in the bio-ecological structure of Indian forests are accelerating the genetic erosion. This calls for urgent steps to collect and conserve the bio-diversity of the economically useful plants. *Piper* is no exception. Species like *P. hapnium, P. barberi* and *P. silentvalleyensis* are on the verge of extinction and *P. schmidtii* and *P. wightii* are closely behind. The NRCS is now playing the key role in the collection and conservation of valuable *Piper* germplasm in collaboration with the various State Agricultural Universities. *In vitro* techniques have great potential for safe conservation of pepper germplasm in *in vitro* repositories.

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