

**2.9.1.6. Sample Size.** It has been suggested that 50-100 plants should be collected from each sample site. In addition, at least 50 seeds should be collected from each plant. Thus each sample should consist of 2,500 to 5,000 seeds.

**2.9.1.7. Field Records.** Adequate field records must be maintained during collection. For this purpose, minimum data sheets have been proposed, which can be used with some modifications, if necessary.

Indian scientists have undertaken several explorations. In 1955, the Botanic Survey of India sent a team to Bomdila, NEFA. In 1961, an expedition to central Nepal between Butwal and Pokhra and Muktinath was undertaken. Collections made during this expedition included cultivars of cereals, millets, pulses, mustards, etc. Wild species related to wheat, oat, barley, linseed, okra, and several other crops were also collected. Dr. H.B. Singh toured the country extensively in connection with germplasm collection. In addition, explorations were organised in tribal areas of Bihar, Orissa, Andhra Pradesh, in Lahaul and Spiti, in rainfed areas of Madhya Pradesh, Rajasthan and Gujarat, in the North-East region, in Indonesia and in certain parts of U.S.S.R.

**2.9.1.8. Merits of Exploration.** The chief merits of plant exploration are listed below.

1. It is the source of virtually all genetic diversity stored in gene banks.
2. It is the only means of collecting and conserving the threatened genetic diversity.
3. It often provides access to materials of special interest, e.g., new genes (= alleles), new species, etc.

**2.9.1.9. Limitations of Plant Explorations.** The chief limitations of plant explorations are given below.

1. It is tedious, time-taking and expensive.
2. It poses various hardships to the collectors, e.g., in boarding, transportation, etc., especially in remote areas.
3. There may even be a threat to life, especially from wild animals.

## **2.9.2. Procurement from other Agencies**

Germplasm can be obtained from other agencies concerned with germplasm conservation, from research institutions, individuals or companies. Generally, this involves an import of the germplasm; it is therefore considered in a greater detail under plant introduction (Chapter 3).

## **2.10. CENTRES OF ORIGIN**

There is considerable evidence that the cultivated plants were not distributed uniformly throughout the world. Even today, certain areas show far greater diversity than others in the forms of certain cultivated crops and their wild relatives. In 1926, N.I. Vavilov proposed that *crop plants evolved from wild species in the areas showing great diversity and termed them as primary centres of origin*. Later, crops moved to other areas primarily due to the activities of man. These latter areas generally lack the richness in variation found in the primary centres

of origin. But in some areas, certain crop species show considerable diversity of forms although they did not originate there; such areas are known as secondary centres of origin of these species.

The concept of centres of origin was given by Vavilov based on his studies of a vast collection of plants at the Institute of Plant Industry, Leningrad. He was director of this institute from 1916 till 1936. He also postulated the *Law of Homologous Series in Variation*; this law states that characters found in one species also occur in other related species. Thus diploid (2x), tetraploid (4x) and hexaploid (6x) wheats show a series of identical contrasting characters. Similarly, genus *Secale* duplicates the variation found in genus *Triticum*. Thus a character absent in a species, but found in a related species, is likely to be found in the collections of that species made from the centre of its origin.

Eight main centres of origin were originally proposed by Vavilov in 1926; these centres are (1) China, (2) Hindustan, (3) Central Asia, (4) Asia Minor, (5) Mediterranean, (6) Abyssinia, (7) Central and (8) South America (Table 2.6). Later, in 1935, Vavilov divided the Hindustan Centre of Origin into two centres, viz., *Indo-Burma* and *Siam-Malaya-Java Centres of Origin*. Similarly, the South American Centre was divided into three centres, namely, *Peru*, *Chile* and *Brazil-Paraguay Centres of Origin*. Thus the eight main centres were regrouped into 11 centres of origin. At the same time, he introduced a new centre of origin, the *U.S.A. Centre of Origin*. Two plant species, sunflower (*Helianthus annuus*) and Jerusalem artichoke (*Helianthus tuberosus*), are believed to have originated in the U.S.A. Centre of Origin.

### 2.10.1. The China Centre of Origin

This centre consists of the mountainous regions of central and western China and the neighbouring lowlands. It is the largest and the oldest independent centre of origin. The crops that originated in this area (*primary centre of origin*) are, soybean (*Glycine max*), radish (*Raphanus sativus*), *Colocasia antiquorum* (bunda), *Panicum miliaceum* (proso millet) and some other species of millets, buckwheat (*Fagopyrum esculentum*), *Papaver somniferum* (opium poppy), several species of *Brassica* and *Allium*, *Solanum melongena* (brinjal), some species of *Cucumis* and *Cucurbita*, pears (*Pyrus communis*), peaches (*Prunus persica*), apricots (*Prunus armeniaca*), plums (*Prunus divaricata*), orange (*Citrus nobilis*), Chinese tea (*Camellia sinensis*) and naked oats (*Avena nuda*).

In addition, it is *secondary centre of origin* for several crop plants, e.g., *Zea mays* (maize), *Phaseolus vulgaris* (rajma), cowpea (*Vigna anguiculata*), turnip (*Brassica rapa*) and sesame or til (*Sesamum indicum*).

### 2.10.2. The Hindustan Centre of Origin

This centre includes Burma, Assam, Malaya Archipelago, Java, Borneo, Sumatra and Philippines, but excludes North-West India, Punjab and North-Western Frontier Provinces. It is the *primary centre of origin* of rice (*Oryza sativa*), arhar or pigeonpea (*Cajanus cajan*), gram or chickpea (*Cicer arietinum*), cowpea, mung (*Vigna radiata*), brinjal, *Cucumis sativus* (cucumber), *Lactuca indica* (Indian lettuce), certain species of *Dioscorea* (yams), *Raphanus indicus* (Indian radish), *Saccharum officinarum* (noble canes), several species of cotton

(particularly, *Gossypium arboreum*), hemp (*Cannabis indica*), black pepper (*Piper nigrum*), indigo (*Indigofera* sp.), mango (*Mangifera indica*), orange, sour lime and some other *Citrus* species, coconut (*Cocos nucifera*), banana (*Musa sapientum*) and turmeric (*Curcuma domestica*).

**TABLE 2.6**  
The centres of origin as proposed by N.I. Vavilov (1926, 1935)

Centre of origin	Primary centre of origin	Secondary centre of origin
Abyssynian Centre	Barley, <i>Triticum</i> spp., jowar, bajra, gram, lentil, sem ( <i>Dolichos</i> sp.), pea, khesari, linseed, safflower, sesame, castor, coffee, onion, okra, etc.	Broad bean ( <i>Vicia faba</i> )
Asia Minor Centre (Syn., Near East or Persian Centre)	<i>Triticum</i> spp., rye, alfalfa, carrot, cabbage, oat, lettuce, apple, <i>Pyrus</i> spp., <i>Prunus</i> spp., grape, almonds, chestnut, pistachio nut, persian clover, etc.	<i>B. campestris</i> , <i>B. nigra</i> , turnip, apricot, etc.
Central American Centre (Syn., Mexican Centre)	Maize, rajma ( <i>P. vulgaris</i> ), lima beans, melons, pumpkin, sweet potato, arrowroot, chillies, <i>G. hirsutum</i> , papaya, guava, avacado, etc.	
Central Asia Centre (Syn., Afghanistan Centre)	<i>T. aestivum</i> , pea, mung, linseed, sesame, safflower, hemp, <i>G. herbaceum</i> , radish, musk melon, carrot, onion, garlic, spinach, pear, almond, grape, apple, etc.	Rye ( <i>Secale cereale</i> )
China Centre	Soybean, radish, bunda ( <i>Colocasia</i> sp.), proso millet, buckwheat, opium poppy, brinjal, pear, peach, apricot, plum, orange, chinese tea, etc.	Maize, rajma, cowpea, turnip, sesame (til)
Hindustan Centre [Divided into: (1) Indo-Burma, and (2) Siam-Malaya-Java Centres]	Rice, pigeonpea, chickpea, cowpea, mung, brinjal, cucumber, Indian radish, noble canes, <i>G. arboreum</i> , mango, orange, coconut, banana, etc.	
Mediterranean Centre	<i>Triticum</i> spp., barley, <i>Avena</i> spp., lentil, pea, broad bean, lupins, <i>Lathyrus</i> spp., chickpea, clovers, <i>Brassica</i> spp., onion, garlic, beets, lettuce, asparagus, lavender, peppermint, etc.	
South American Centre [Divided into: (1) Peru, (2) Chile, and (3) Brazil-Paraguay Centres]	Potato, maize, limabean, peanut, pineapple, pumpkin, <i>G. barbadense</i> , tomato, tobacco, guava, quinine tree, cassava, rubber, etc.	
U.S.A. Centre	Sunflower, Jerusalem artichoke	



**FIG. 2.1.** Centres of origin of cultivated plant species. 1. The China Centre, 2. The Hindustan Centre, 3. The Central Asia Centre, 4. The Asia Minor Centre, 5. The Mediterranean Centre, 6. The Abyssinian Centre, 7. The Central American Centre, and 8. The South American Centre (8. Peru, 8a. Brazil—Paraguay, and 8b. Chile).

### 2.10.3. The Central Asia Centre of Origin

It includes North-West India (Punjab, The North-West Frontier Provinces and Kashmir), all of Afghanistan, the Soviet Republics of Tadjikistan and Uzbekistan and Tian-Shan. It is also known as the *Afghanistan Centre of Origin*. The crops that originated in this centre (*primary centre of origin*) are, wheat (*Triticum aestivum*), club wheat (*Triticum compactum*), pea (*Pisum sativum*), broad bean (*Vicia faba*), mung, linseed (*Linum usitatissimum*), sesame, safflower (*Carthamus tinctorius*), hemp, cotton (*Gossypium herbaceum*), radish, musk melon (*Cucurbita moschata*), carrot (*Daucus carota*), onion (*Allium cepa*), garlic (*Allium sativum*), spinach (*Spinacea oleracea*), pistachio nut (*Pistacia vera*), apricot, pear, almond (*Prunus amygdalus*), grape (*Vitis vinifera*) and apple (*Pyrus malus*). It is *secondary centre of origin* of rye (*Secale cereale*).

### 2.10.4. The Asia Minor Centre of Origin

This is also known as the *Near East* or the *Persian Centre of Origin*. It includes the interior of Asia Minor, the whole of Transcaucasia, Iran and Highlands of Turkmenistan. The crop species that originated in this region (*primary centre of origin*) include nine species of *Triticum*, rye, alfalfa (*Medicago sativa*), Persian clover (*Trifolium resupinatum*), carrot, cabbage (*Brassica oleracea*), oat (*Avena sativa*), species of *Allium*, lettuce (*Lactuca sativa*), fig (*Ficus carica*), pomegranate (*Punica granatum*), apple, several species of *Pyrus*, *Prunus*, grape, almonds, chestnuts (*Castanea* sp.) and pistachio nut. It is the *secondary centre of origin* of rape (*Brassica campestris*), black mustard (*Brassica nigra*), leaf mustard (*Brassica japonica*), turnip (*B. rapa*) and apricot.

### 2.10.5. The Mediterranean Centre of Origin

Many valuable cereals and legumes originated in this area. The species that originated in this centre (*primary centre of origin*) are, durum wheats (*Triticum durum*), emmer wheats (*Triticum dicoccum*), and other *Triticum* species, several species of *Avena*, barley (*Hordeum vulgare*), lentil (*Lens esculenta*), several species of *Lathyrus*, pea, broad bean, lupins (*Lupinus* sp.), chickpea, clovers (*Trifolium* sp.), vetch (*Vicia sativa*), several species of *Brassica*, such as, rape, black mustard, cabbage and turnip, onion, garlic, beets, lettuce (*Lactuca sativa*), artichoke, asparagus (*Asparagus officinalis*), lavender, peppermint (*Mentha* sp.) and sage.

### 2.10.6. The Abyssinian Centre of Origin

It includes Ethiopia and hill country of Eritrea. It is the *primary centre of origin* for *H. vulgare* (barley), *Triticum durum*, *Triticum turgidum*, *Triticum dicoccum*, jowar (*Sorghum bicolor*), bajra (*Pennisetum americanum*), gram, lentil, sem (*Dolichos lablab*), pea, khesari (*Lathyrus sativus*), linseed, safflower, sesame, castor (*Ricinus communis*), coffee (*Coffea arabica*), onion and okra (*Abelmoschos esculentus*). It is the *secondary centre of origin* for broad bean (*Vicia faba*).

### 2.10.7. The Central American Centre of Origin

This includes the region of South Mexico and Central America. It is also referred to as the *Mexican Centre of Origin*. The plants that originated (*primary centre of origin*) here are, maize, rajma (*P. vulgaris*), lima bean (*Phaseolus lunatus*), melons, pumpkin (*Cucurbita melanosperma*), sweet potato (*Ipomoea batatas*), arrowroot (*Canna edulis*), chillies (*Capsicum annum*), cotton (*G. hirsutum* and *G. purpureascens*), papaya (*Carica papaya*), guava (*Psidium guajava*) and avacado (*Persea americana*).

### 2.10.8. The South American Centre of Origin

This centre includes the high mountainous regions of Peru, Bolivia, Ecuador, Columbia, parts of Chile and Brazil, and whole of Paraguay. The crops that originated in this centre (*primary centre of origin*) are many species of potatoes, maize, lima bean, peanut (*Arachis hypogaea*), pineapple (*Ananas comosa*), pumpkin (*Cucurbita maxima*), Egyptian cotton (*Gossypium barbadense*), tomatoes, guava, tobacco (*Nicotiana tabacum* and other species), quinine tree (*Cinchona calisaya*), cassava (*Manihot utilissima*), and rubber (*Hevea* sp.).

### 2.10.9. Centres of Diversity

The concept that centres of diversity represent centres of origin has been seriously questioned. Plants of a species growing in different environments are likely to be different, *i.e.*, diverse. Thus a plant species is likely to show a greater variation in a region with varied climatic and other ecological conditions. Areas with mountains and valleys show considerable variation in the prevalent environment. Therefore, plant species would show a great variation in such areas. Interestingly, the centres of origin are situated in such mountain-valley areas. Further the centres of diversity of many species have shifted with time. This shift in diversity was brought about by a shift in the area of the greatest cultivation and due to the introduction of the concerned species into an area with a greater ecological diversity than where they existed before. These processes have given rise to the *secondary centres of diversity*. Consequently, several species have two or more centres of diversity and it is often difficult to determine, which one of them is the real centre of origin.

Thus the centres of origin may be more appropriately called *centres of diversity*. Zhukovsky, in 1965, recognized 12 mega-gene centres of crop plant diversity (Table 2.7), and a number of microgene centres of wild growing species related to our crop plants. The cultivated forms are believed to have first originated in these microgene centres. These centres may not be the centres of origin of the species concerned, but they are the areas of the maximum diversity of these species. This serves as an extremely useful guide to plant explorers as to where to search for variation in a given species. Within the large centres of diversity, small areas may exhibit a much greater diversity than the centre as a whole; these areas are known as *microcentres*. The crop evolution appears to proceed at a more rapid rate in such microcentres. The microcentres are important for plant collection as well as for an experimental study of the evolution of plants.

TABLE 2.7

The 12 regions of diversity of crop plants (based on Zeven and Zhukovsky, 1975, and Zeven and de Wet, 1982)

Centre of diversity	Crop plant
Chinese-Japanese region	Soybean, Adzuki bean, proso millet, fox tail millet, naked oat, leafy mustard, orange/ <i>Citrus</i> , peach apricot, litchi, bamboo, tea, etc.
Indochinese-Indonesian region	Rice, rice bean, winged bean, cucurbits/ash gourd, mango, banana, <i>Citrus</i> /lime, grape-fruit, bamboos, nutmeg, clove, ginger, taros and yams, betel nut, coconut, etc.
Australian region	<i>Eucalyptus</i> , <i>Acacia</i> , <i>Macadamia</i> nut
Hindustani region	Rice, little millet, black gram, green gram, moth bean, rice bean, <i>Dolichos</i> bean, pigeonpea, cowpea, chickpea, horse gram, jute, eggplant, okra, cucumber, taros and yams, <i>Citrus</i> , banana, mango, sesame, ginger, turmeric, cardamom, sugarcane, black pepper, etc.
Central Asian region	Wheat (bread/club/shot), rye, <i>Allium</i> /onion, garlic, spinach, peas, beetroot, faba bean, lentil, chickpea, apricot, plum, pear, walnut, almond, melon, grape, carrot, sesame, etc.
Near-Eastern region	Wheat (einkorn, durum, bread), barley, rye, faba bean, chickpea, French bean, lentil, pea, <i>B. oleracea</i> , <i>Allium</i> , melon, grape, apple, safflower, sesame, flax, lupins, etc.
Mediterranean region	Wheat (durum, turgidum), oats, <i>B. oleracea</i> , lettuce, beetroot, faba bean, radish, olive, berseem, lupins, grape, fennel, cumin, linseed, celery, <i>Crocus</i> , colza
African region	Wheat (durum, emmer, bread), African rice, sorghum, pearl millet, finger millet, cowpea, bottle gourd, okra, cucumber, yams, castor, sesame, niger, oil palm, safflower, cotton, coffee, groundnut, date palm, melons, etc.
European-Siberian region	Peach, pear, plum, apricot, apple, almond, walnut, pistachionut, cherry, <i>cannabis</i> , black mustard, chicory, hops, lettuce
South American region	Potato, sweet potato, Lima bean, amaranth, <i>Chenopodium</i> , <i>Cucurbita</i> , tomato, tobacco, lupin, papaya, pineapple, groundnut, Egyptian cotton, cassava, cacao, rubber tree
Central American and Mexican region	Maize, French bean, potato, <i>Cucurbita</i> , pepper/chilli, amaranth, <i>Chenopodium</i> , tobacco, sisal hemp, upland cotton
North American region	Jerusalem artichoke, sunflower, plum, raspberry, strawberry

## 2.11. GERmplasm CONSERVATION

The germplasm has to be maintained in such a state that there is minimum risk for its loss and that either it can be planted directly in the field or it can be prepared for planting with relative ease; this is called *germplasm conservation*. Germplasm can be conserved either (1) *in situ* or (2) *ex situ*.