FLORA II. IN PERSIA
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With approximately six thousand recorded species of ferns and flowering plants, Persia harbors one of the richest floras of the Near Eastern countries, which is surprising, given that more than two-thirds of the country’s surface consists of deserts, semideserts, and steppes. Equally surprising is the great diversity in vegetation cover: subtropical forests on the southern Caspian coastal plain and the northern foothills of the Alborz (q.v.), dry-adapted woodlands in the western Persian mountain ranges, dwarf shrubs and thorn cushion formations in the central areas, and semidesert shrublands (including numerous species derived from a xero-tropical African flora) in the coastal areas along the Persian Gulf. This varied geobotanical landscape reflects the great contrasts of climate (q.v.) within the country and the evolution of the flora. Many plant genera evolved or diversified primarily on Persian territory, particularly in the mountain regions; examples of such indigens include taxa of *Astragalus*, *Acantholimon*, *Acanthophyllum*, *Nepeta*, *Onosma*, and *Cousinia*. The flora and vegetation of Persia are also enriched by remnants of floras that were once far more widespread.

Since the 16th century many investigators have collected and described plants from the Near East. Among the earliest pioneers in Persia were Samuel Gottlieb Gmelin and Peter Simon Pallas (1770-72), André Michaux (1782), Guillaume Antoine Olivier and Jean Guillaume Bruguière (1796-97), Pierre

Margin Rémi Aucher-Eloy (1835-38), Theodor Kotschy (1841-42), and especially Engelbert Kaempfer (1864-68). Edmond Boissier, in his *Flora Orientalis* (1867-88), not only made full use of observations and collections from his own journey to Egypt, Sinai, and Palestine in 1846 but also drew on previously scattered reports of existing collections. The reports of Joseph Friedrich Nicolaus Bornmüller, who traveled widely and published extensively, substantially increased knowledge of the flora of the Near and Middle East. In the years 1943-60 the Persian botanist Ahmad Parsa published an eight-volume flora of Persia. Aside from expanding botanical knowledge, his great contribution was the translation of Boissier's Latin identifications into French. The collections made by Paul Allen, Mogens Køie, Ian Charleson Hedge, and Per Wendelbo have contributed significantly to knowledge of Persian flora. Their works have provided a valuable foundation for the monumental *Flora Iranica* (q.v.) of Karl Heinz Rechinger, the leading expert on the flora of Persia. Rechinger, who carried out a number of field studies, has undertaken to publish the first comprehensive flora of the Persian highlands and adjoining areas, fulfilling an important prerequisite for geobotanical research in the country. So far, 172 fascicles have appeared. More recently, Jean Joseph Léonard (1981-92) published a flora of the central desert region.

Although the flora of Persia is thus fairly well known, there are still very few works on the overall vegetation. Alexander Gilli pioneered research on plant commun ities in the Alborz range (1939). Harry Bobek pursued diverse geographical studies in Persia, including fundamental work on plant geography. Most notable is his work on natural woodlands (Bobek, 1951). Michael Zohary (1963), and Sadegh Mobayen and Viktor Tregubov (1970) were the first to undertake comprehensive descriptions; Zohary dealt in detail with the vegetation of Persia in *Geobotanical Foundations of the Middle East* (1973), which provides an excellent general survey and a number of detailed studies. From 1972 to 1985 the vegetation of Persia has been studied within the framework of Special Research Area 19 of the Tübinger Atlas des Vorderen Orients (TAVO; Wolfgang Frey, Wolfgang Kramer, Harald Kürschner, Wilfried Probst). Recently, Jean Claude Klein (1982-94) published several phytosociological studies on the high mountain vegetation of the Alborz.

Climate. The only humid areas in Persia are the southern Caspian (q.v.) coastal plain and the northern foothills of the Alborz range. The main ridge of the Alborz separates this humid region from the arid plateau. The mountain chains on the Turkish-Persian border and the Zagros receive relatively high precipitation in winter and early spring, but the summer dry period has a decisive effect on the vegetation there, which is dominated by sparse deciduous woodlands. The rest of the country is extremely dry, as precipitation declines sharply between the mountains and the central areas. The desert regions of Dašt-e Kavīr and Dašt-e Lūt receive less than 100 mm a year. The coastal areas along the Persian Gulf and in Baluchistan and Sīstān are also very dry, with annual precipitation of less than 200 mm. North of the Alborz, where the Caspian Sea has a moderating effect, the winters are very mild. The temperature rarely drops below -5° C. Northwestern Persia, the Zagros chains, and the adjacent interior basins are characterized by harsh winters, when temperatures frequently drop below -25° C. Although the barren areas in the south (Dašt-e Lūt) belong to the torrid subtropical deserts, there are frequent night frosts, occasionally even snowfalls. During the summer months daily temperatures often rise above 50° C. Along the Gulf coast Persia is close to the boundary of the tropical zone; night frosts no longer occur and annual temperatures are more stable.

Plant Geography. Armen L. Takhtajan (1986) distinguished six phytogeographical regions (floral kingdoms): the Holarctic Kingdom or *Holarctis*, the Paleotropical Kingdom or *Paleotropis*, the Neotropical Kingdom or *Neotropis,* the Cape Kingdom or *Capensis*, the Australian Kingdom or *Australis*, and the Antarctic Kingdom or *Antarctis*. The greater part of Persia is included in the Holarctic kingdom, but the Persian Gulf coast belongs to the *Paleotropis*. The boundary between the two floral kingdoms passes through the southernmost part of the country.

CHARACTERISTICS OF HOLARCTIC FLORA

The Euro-Siberian floral region. The Hyrcanian subprovince, the eastern portion of the Euxino-Caucasian-Hyrcanian province, which is part of the larger Euro-Siberian floral region, extends into northern Persia. It encompasses the southern Caspian coastal plain and the northern foothills of the Alborz mountains. Arāk represents its western boundary; the eastern boundary lies west of Bojnūrd, and its upper limit lies on the northern slopes of the Alborz at an elevation of about 2,500 m. This subprovince is characterized by deciduous forests, and in peripheral areas by deciduous scrub. Forest species are *Parrotia persica*, the characteristic tree of the southern Caspian lowland forest, as well as *Acer velutinum*, *Alnus subcordata*, *Amygdalus spinosissima subsp. turcomanica*, *Acer monspessulanum subsp. turcomanicum*, *Quercus castaneifolia*, *Fraxinus excelsior* subsp. *coriariifolia*, *Lonicera floribunda*, *Malus orientalis*, *Pyrus boissieriana*, *Sorbus orientalis*, *Ilex spinigera*, *Ruscus hyrcanus*, *Gleditsia caspica*, *Buxus hyrcana*, and *Hedera pastuchovii*. The Hyrcanian subprovince includes remnants of a former Arcto-Tertiary flora and an Indo-Malaysian flora, which was driven south by the advance of continental glaciation in the Pleistocene and survived the Ice Age in this region.

The Irano-Turanian floral region. This region, characterized by a continental climate with low precipitation, extends from Central Asia across the Near East to include the Mauritanian steppe province in North Africa (Zohary, 1973). The Irano-Anatolian province encompasses central and eastern Anatolia, large parts of Persia (about two thirds), Afghanistan, and Pakistani Baluchistan. Hot, dry summers and cold winters predominate; precipitation falls in the winter and early spring, reaching substantial levels only in the mountains. Characteristic vegetation consists of dwarf scrub and thorn cushion formations in the Persian highlands, halophytes in the interior basins, and sparse woodlands and scrub on the mountain ranges. A large number of genera and species evolved and spread from this province, such as the species-rich genera *Amygdalus*, *Astragalus* (supposedly with more than 600 species in Persia alone), *Onobrychis*, *Haplophyllum*, *Pistacia*, *Ferula*, *Ferulago*, *Nepeta*, *Phlomis*, *Verbascum* (originating in Anatolia), *Acanthophyllum*, *Dionysia*, *Acantholimon*, *Echinops*, *Cousinia*, and *Eremurus*.

The Turanian, or Central Asian, province of the same floral region encompasses the wide desert and steppe areas between the Caspian and Aral seas and the western and southwestern spurs of the Central Asian mountain ranges. It includes northeastern Persia (Khorasan). Many small areas of the Irano-Anatolian province include large admixtures of Turanian species, as in the salt depressions and dunes of the interior Persian basin. Species of the genera *Ephedra* (e.g., *Ephedra strobilacea*), *Calligonum*, *Salsola*, *Haloxylon* (e.g., *Haloxylon persicum*), *Ferula*, *Eremostachys*, and *Stipa* belong to this group.

The Saharo-Arabian floral region. According to some authors, the Saharo-Arabian floral region stretches from the Sahara across Egypt, the Sinai, Arabia, and Mesopotamia into southern Persia and Sind, but in view of the present flora and its evolution, Zohary's argument (1973) that the southernmost regions of Persia, Pakistan, and western India belong to the *Paleotropis* seems more convincing. According to his classification only the areas of Īlām (Pošt-e Kūh) and Ḵūzestān belong to the Saharo-Arabian floral region, with a noteworthy component of Irano-Turanian and Nubo-Sindian species. The lowland areas receive less than 300 mm of annual precipitation, which falls in the winter months. The winters are short and mild; the summers long, dry, and hot. Among Saharo-Arabian species found in Persia are *Gymnocarpos decandrum*, *Moricandia sinaica*, *Diplotaxis harra*, *Anastatica hierochuntica*, *Astragalus kahiricus*, *Fagonia bruguieri*, *Althaea ludwigii*, *Lasiopogon muscoides*, *Gymnarrhena micrantha*, and *Centaurea sinaica* (Zohary, 1973).

Characteristics of the paleotropical flora. The northern margins of the *Paleotropis* in North Africa and southwestern Asia are considered part of the Nubo-Sindian province of the Sudanian floral region. The location of its boundary with the Saharo-Arabian floral region of the Holarctic kingdom is controversial. In Persia it coincides approximately with the northern limit of *Ziziphus* and *Acacia*. In contrast to the species of the Irano-Anatolian and Turanian provinces, those of the Sudanian floral region are sensitive to cold. They can grow only in low-lying regions on the Persian Gulf and along the *wādī*s or dry watercourses between ridges in the Zagros foothills. In Sīstān and Persian Baluchistan the Nubo-Sindian region extends inland as far as southwestern Afghanistan, and in Pakistan to the base of the western Himalayas. The flora consists of xerophytes adapted to very high temperatures, and is associated with hot, humid summers and winters without frost. Sparse semidesert scrub is very widespread. Among characteristic species are *Capparis decidua*, *Capparis spinosa* var. *mucronifolia*, *Acacia sejal*, *Acacia flava*, *Cleome brachycarpa*, *Cleome oxypetala*, *Tephrosia persica*, *Geranium trilophum*, *Tribulus longipetalus*, *Euphorbia larica*, *Euphorbia tirucalli*, *Salvadora persica*, *Ziziphus spina-christi*, *Stocksia brahuica*, *Tamarix dioica*, *Olea aucheri*, *Periploca aphylla*, *Calotropis procera*, *Pentatropis spiralis*, *Caralluma edulis*, *Pergularia tomentosa*, *Convolvulus acanthocladus*, *Convolvulus turrilianus*, *Convolvulus virgatus*, *Heliotropium laricum*, *Anthemis fungosa*, *Senecio flavans*, *Pennisetum divisum*, and *Lasiurus scindicus*.

EVOLUTION OF THE FLORA OF THE PERSIAN HIGHLAND

The evolution of the flora before the Tertiary. The present-day terrestrial flora of Persia consists overwhelmingly of angiosperms, which have evolved and proliferated since the Lower Cretaceous. In the Middle Cretaceous arctic, tropical, and antarctic floras had become differentiated worldwide. In the Upper Cretaceous, at least in the northern hemisphere, a definite regional differentiation emerged in addition to this latitudinal differentiation. There were no large continents: only island archipelagos in the Tethys Sea, which at that time extended as far as northern China. These islands were in the areas of present-day southern Europe, North Africa, and western Asia. Lithic finds suggest that they had an arid climate. It is possible that the first xerophytes originated in this period, in what is now Central Asia. This nucleus could later have colonized the arid regions of Asia and North Africa (Zohary, 1963; idem, 1973).

In the Upper Cretaceous a genuinely homogeneous flora predominated the northern part of the *Holarctis* (central and northern regions), the characteristic genera being *Acer*, *Betula*, *Alnus*, *Cocculus*, *Corylus*, *Credneria*, *Fagus*, *Quercus*, *Grewiopsis*, *Lindera*, *Platanus*, *Sassafras*, and *Viburnum*. In the south it adjoined a flora ranging from subtropical to tropical, with a high proportion of evergreen trees and shrubs, originating, as in the north, from the tropical Indo-Malesian flora. This flora, known from Egypt, Syria, Iraq, and Persia, had spread from southeast Asia along the northern and southern coasts of the Tethys Sea in the early Cretaceous. While purely tropical flora was mainly limited to the southern coast, the subtropical and temperate floras occured along the northern rim of the Tethys as far as central Europe.

Evolution in the Tertiary. The evolution of vegetation in Europe, northern Asia, and North America during the Tertiary is relatively well known, due to the abundance of fossils from these areas. They indicate a general worsening of the climate, from a tropical or subtropical type in the Eocene to extreme cold in the Pleistocene. One result of these changes was the disappearance of tropical and subtropical species, or rather their shift toward the south. The Near East was equally affected by the broad climatic changes, but, due to the absence of fossil finds and pollen analyses, very little is known about the evolution of flora in the region during the Tertiary. All conclusions are extrapolated from fossil finds outside the region, from considerations of plant geography and analyses of recent flora, especially indigenous species. The descriptions here are based on Zohary’s pioneering work (1973).

ELEMENTS OF THE FLORA

The Arcto-Tertiary element. Certain genetic elements of the flora must have been decisive for the plant colonization of the Near East. One of them was the Arcto-Tertiary flora, which apparently spread over the entire temperate zone of the northern hemisphere in the Pliocene. It must have retreated toward the south as the continental glaciers advanced in the Pleistocene. Today, many plants that died out in Europe and northern Asia during the Ice Age have survived in refuges in the southern Caspian lowlands and on the northern foothills of the Alborz mountains, as well as in the forested areas of Ṭāleš, the Caucasus, and the southern coast of the Black Sea (Probst, 1981). Examples include *Parrotia persica* (the last representative of a widespread and species-rich genus in the Tertiary), *Celtis australis*, *Pterocarya fraxinifolia*, and *Zelkova carpinifolia*. During the late Tertiary forests of Euxino-Hyrcanian type must have been widespread in the Near East, as is suggested by the presence of *Cedrus*, *Abies*, and *Ostrya* in modern Lebanon. Beside this mesophytic component of the Arcto-Tertiary element there was a xerophytic component, to which the many native Persian species of *Crataegus*, *Amygdalus*, *Cerasus*, *Prunus*, *Pistacia*, and *Rhamnus* and the species-aggregate related to *Quercus brantii* are to be traced. These xerophytic descendants of the Arcto-Tertiary flora conquered the arid mountain ranges on the interior of Persia. Today, they belong to Irano-Anatolian elements.

The Indo-Malesian element. A second genetic element was the tropical Indo-Malesian flora, which started spreading from southeast Asia in the Cretaceous, and in the early Tertiary had reached as far north as the fiftieth parallel in Europe (e.g., the Paleocene flora of London). Evidence of a Near Eastern distribution of this element has been found only in Lower Egypt and the Negev. It is nevertheless quite probable that a group of plants found today in the Euxino-Caucasian-Hyrcanian province are relics of this tropical flora, for example, *Diospyros lotus*, *Albizia julibrissin*, the genus *Buxus*, *Nelumbo speciosum*, and *Dioscorea caspica*. A few genera that are naturalized in the Near East and the Mediterranean basin also belong to the xerophytic descendants of the tropical Indo-Malesian flora, for example, *Ceratonia siliqua*; *Cercis siliquastrum*; *Laurus nobilis*; *Myrtus communis*; species of *Olea*, *Tamus*, *Smilax*, and *Ruscus*; and *Danae racemosa*. The westernmost traces of this element today are the laurel forests of the Canary Islands.

The Paleo-African element. It is not entirely certain whether or not there was a third, also tropical, Tertiary genetic element, but a series of plant-geographical discoveries supports such an identification. The Tertiary flora of Africa can be divided into two categories, the rain-forest flora of the Congo basin and the Paleo-African flora, which consists for the most part of xerophytic vegetation. Species of the latter spread across Ethiopia and Arabia into the Near East. For example, of twenty-five species of *Acacia* known in the Near East most occur in southwestern Arabia. However, only a few have reached Persia; they probably migrated across the Eritrean-Arabian land bridge in the early Tertiary.

The Mesogean element. Finally, the term Mesogean refers to the flora of a territory that encompasses the three hot and mostly arid regions constituting the eastern *Holarctis*: the Mediterranean, Saharo-Arabian, and Irano-Turanian floral regions. This element seems quite heterogeneous today, yet it includes a large number of common genera, which suggests a fairly uniform evolution of the flora over the entire area. Of more than ten thousand species found there more than two-thirds are indigenous. Zohary (1973) considered this flora an independent element, for it seems improbable that such numerous and richly differentiated taxa developed from Indo-Malesian and Arcto-Tertiary stock in the comparatively short span of time after the Tethys Sea receded. The distribution of numerous xeromorphic genera like *Eurotia*, *Artemisia*, *Fagonia*, *Suaeda*, *Kochia*, and *Tamarix*, which are at home in the band of deserts encircling the Old World, is evidence of a pre-Tertiary origin for this element. During the Tertiary, the Mesogean flora split into different components: the Central Asian, the Turanian, the Irano-Anatolian, the Paleo-Saharan, and the Mediterranean. The Turanian and Irano-Anatolian components have further evolved into a large number of species.

Differentiation and migration. The Tertiary orogenesis began in the Miocene, producing a fundamental change in the division between land and sea in the Near East. The result was extensive ecological differentiation within the area, which in turn strongly influenced the evolution of species. At first the Mesogean element must have played a greater role in the emerging and increasingly arid regions. Species of the Paleo-African element could have migrated to the Near East over the land bridges between Asia and Africa, which still existed at that time, and could have colonized the Persian Gulf region and part of present-day Baluchistan. The worsening of the climate led to a retreat of the Indo-Malesian flora, while the Arcto-Tertiary flora advanced. Nevertheless, the shrinking Tethys left behind a great basin stretching from Syria across Iraq and Persia as far as Afghanistan, which served as a barrier to the further penetration of the Arcto-Tertiary flora in the Tertiary. The boundary between the Holarctic and Paleotropical kingdoms was probably established at that time (Zohary, 1973); it still runs through southern Persia.

As fossils indicate in the Pliocene, the Arcto-Tertiary flora was distributed somewhat farther south than it is today. It was also richer in species, as can be seen from fossils of *Dicksonia*, *Ginkgo*, *Glyptostrobus*, and *Libocedrus*. In Persia, however, the nucleus was probably limited to the Hyrcanian district in the Pliocene. Today xerophytic descendants of the Arcto-Tertiary flora are considered Irano-Turanian species and are distributed over the arid parts of the Euxino-Caucasian-Hyrcanian subprovince and the mountain chains of the Zagros and Kurdistan (species of *Quercus*, *Pistacia*, *Rhamnus*, *Prunus*, *Cerasus*, *Amygdalus*, and *Acer*). The Indo-Malesian flora did not retreat entirely. A few species survived in the warm and protected coastal regions of the Black and Caspian Seas. With the further retreat of the Tethys, an Irano-Turanian flora of Mesogean origin was introduced into the Near and Middle East, spreading to newly emerging arid, often saline areas. A distinct evolution of species within the Irano-Anatolian stock, mostly colonized from Persia, ensued.

THE ICE AGE AND THE POSTGLACIAL ERA

At the end of the Tertiary the vegetation of Persia and the entire Near East was probably very similar to the present vegetation, leaving aside the strong influence of human beings during the last two or three thousand years. The boundaries of individual floral regions were practically identical with those today.

One major question is to what extent the climate on Persian territory was affected by the Ice Age and consequently how climatic changes affected the flora. Whether there was a pluvial period in the Near East or whether the climate differed only slightly from today’s arid conditions is still a matter of heated debate. The evidence suggesting extensive glaciation of the central Persian mountains is very slight. Hopefully, on the botanical side, palynological research will provide some clarification. For the time being, however, all claims for a fundamentally different distribution of forests and scrub during a few epochs of the Pleistocene are purely speculative. The same is true for the period from the great thaw about 30,000 years ago to the end of the last Ice Age and through the postglacial period. So far, the scant evidence derived from investigations (e.g., Zeist, 1967; idem and Wright, 1963) does not permit general conclusions.

Clarification of the evolution of vegetation on the Persian highland in the postglacial period is a pressing problem for future research. Such studies could reveal the extent to which human intervention has altered the ecosystems of Persia, and could provide information crucial for the regeneration of the damaged environment.

Evolution of new species and centers of diversity in Persia. According to Zohary (1963; 1973), 20 to 25 percent of Persian flora consists of indigenous (endemic) species. Many of them form the nuclei of large genera, with clusters of closely related species that probably appeared relatively recently. Genera with especially large numbers of endemic Persian species include *Silene*, *Acanthophyllum*, *Alyssum*, *Amygdalus*, *Trigonella*, *Medicago*, *Astragalus*, *Onobrychis*, *Euphorbia*, *Acantholimon*, *Convolvulus*, *Heliotropium*, *Onosma*, *Salvia*, *Nepeta*, *Phlomis*, *Stachys*, *Scrophularia*, *Asperula*, *Helichrysum*, *Achillea*, *Echinops*, *Cousinia*, *Eremurus*, *Tulipa*, and *Allium*. The genus *Astragalus* alone supposedly includes about 400 species endemic to Persia, an estimate that would probably be somewhat reduced after a critical review. The middle elevations of the peripheral mountain ranges and the massifs of the central Persian highland are especially rich in endemic species.

Most favourable for the adaptive evolution of a taxon are areas where a genus or a group of genera have limited competition and varied living conditions. Frequently described examples include island flora and fauna (e.g., in the Galapagos or Hawaiian islands). As the Tethys receded, the newly exposed land was colonized mainly by species of Mesogean stock. The uniform conditions on the plains with their extremely arid continental climate, permitted only a few forms of life. Hence the variety of biotopes, which might have allowed a further subdivision of species, is low. Conditions in the mountain systems are much more diverse and favourable, especially at higher altitudes, which receive more annual precipitation and are subject to lower average summer temperatures. The isolated locations of these mountain stocks makes possible, as with island floras, a further subdivision of species.

Many of the genera named above have evolutionary centers in Persia, which may coincide with the centers where the respective taxa originated (Nikolay Vavilov's gene-center theory), or they may represent secondary centers of evolution. At least they testify that in the named taxa an adaptive radiation occurred on Persian territory.

THE VEGETATION OF PERSIA

Nine different climatic zones, or large ecosystems (zonobiomes; Walter, 1973), can be distinguished between the equator and the poles. For each there is a typical zonal vegetation. The northern region of Persia, encompassing Azarbaijan, Gīlān, and Māzandarān, falls in the zone of deciduous forests (zonobiome VI, the typical temperate zonobiome with short periods of frost).

The interior Persian highland belongs to the desert and semidesert zone (zonobiome VII, with cold winters). In humid mountain areas it borders on the zone of mixed sclerophyllous woodlands and conifers (zonobiome IV, e.g., *Juniperus* and *Quercus* woodlands) with winter rains; in the south it adjoins low-lying hot deserts and semideserts (zonobiome III, encompassing, for example, subtropical or semidesert scrub in the Persian Gulf region).

Sometimes, less because of climate than because of special soil parameters (e.g., a high water table or ion richness) an "azonal vegetation" can be observed in a different climatic zone. In Persia the extensive endorheic salt marshes in the arid basins are host to such azonal vegetation (e.g., *Haloxylon* and *Tamarix* scrub). The mangroves at a few places on the Persian Gulf coast should also be considered azonal vegetation. Zonal vegetation can also appear outside the characteristic climatic zone if specific local conditions of a biotope duplicate those of another climatic zone. For example, predominantly calcareous soils and a southern exposure frequently lead to the appearance of "extrazonal vegetation" from a warmer, dryer climatic zone, such as cypress groves in a few hot, dry valleys of the northern Alborz forming islands in the zone of deciduous forests.

In the mountains the climate changes much more rapidly than on the plains, owing to rising altitudes. For that reason a clearer and sharper delineation of vegetation zones can be observed. From low to high altitudes hill, mountain, subalpine, alpine, and nival belts can be distinguished. In the northern mountains of Persia, the Alborz, the nival belt terminates in the area of Damāvand and possibly Taḵt-e Solaymān. The alpine belt in the Alborz extends down to about 3,200 m. It is also present in the central area of the Zagros, between Hamadān and Shiraz (probable lower limit: 3,500 m). Another high mountain area with a broad alpine belt is the Šāh Kūh between Sīrjān, Bam, and Kermān.

GENERAL CHARACTERISTICS

The description of Persian vegetation is a classification based on a combination of physiognomic and ecological factors proposed by Frey and Probst (1977) for the Near East.

Forests. Deciduous forests of the Hyrcanian type are limited to the southern Caspian lowlands and the adjacent northern foothills of the Alborz. The forested area extends from Ṭāleš in the west to Golestān National Park east of

Gorgān, though isolated patches of such forests occur as far east as Mehmānak, west of Bojnūrd. Today the lowest belt of this Caspian *jangal* (forest) has retreated before a vast area of cultivation, mainly of rice, cotton, and tea. The forested area encompasses the greater part of the Hyrcanian subprovince, which also includes some scrub form ations. These forests are relics of the Arcto-Tertiary and Indo-Malesian floras of the Tertiary. During the Ice Ages the region obviously served as an area of refuge, where Pliocene forests managed to survive, though less varied in species.

The forest area can be subdivided into cold-deciduous lowland and cold-deciduous montane forests, the dividing line marked by the upper limits of a few frost-sensitive species like *Pterocarya fraxinifolia*, *Diospyros lotus*, *Albizia julibrissin*, and *Parrotia persica*. Characteristic lowland species are *Quercus castaneifolia*, *Parrotia persica*, *Zelkova carpinifolia*, *Carpinus betulus*, *Carpinus orientalis*, *Albizia julibrissin*, *Gleditsia caspica*, *Acer velutinum*, *Fraxinus excelsior*, and beside rivers *Pterocarya fraxinifolia*, *Alnus subcordata*, and *Populus caspica*. The physiognomy of this kind of forest is partly determined by evergreens, which predominate in the undergrowth in some areas. *Buxus hyrcana* is common in the west, as are *Laurocerasus officinalis*, *Ilex spinigera*, *Ruscus hyrcanus*, *Hedera pastuchovii*, and *Danae racemosa*. A great abundance of epiphytes is characteristic of both lowland and montane forests. Pleurocarpous mosses, especially the endemic *Leucodon immersus*, *Palamocladium euchloron*, and *Pseudoleskeella laxiramea*, often cover completely the trunks and branches of trees and shrubs (PLATE I).

The forests are subject to moist sea winds throughout the year, but circulation of air masses between land and sea is especially strong in the summer period. Together with the high temperatures it ensures permanent high atmospheric humidity. Annual precipitation reaches nearly 2,000 mm in the west, at Bandar-e Anzalī, but decreases steadily toward the east, totaling only about 700 mm at Gorgān. In summer there is a gradual increase in the length of the dry season from Rāmsar eastward. The maximum precipitation falls in autumn.

Cold-deciduous montane forests (Hyrcanian montane forest; (PLATE II) are generally located at elevations between 700 and 1,000 m. The most important difference from the lowland forests is the decline or disappearance of various cold-sensitive tree species; the upper limit for *Pterocarya* is 500 (700) m, for *Albizia* 700 m, for *Diospyros* and *Gleditsia* 800 m, and for *Ficus*, *Tamus*, and *Vitis* 1,000 m. *Parrotia* can be found above 1,000 m but appears more frequently below 600 m. A second difference is the predominance of beeches (*Fagus orientalis*) in the montane forests (*Fagetum hyrcanum*, Mobayen and Tregubov, 1970; *Fagetea hyrcanica,* Zohary, 1973).

The most abundant and best preserved remnants of the southern Caspian forests are found at the lower levels of the mountain zone. In rainy areas there are almost pure stands of *Fagus orientalis*. These beech forests stand more than 25 m high. In dry areas, places with southern exposure, and river valleys subject to dry autumn winds from the highland the beeches are replaced by *Quercus castaneifolia*, *Carpinus betulus*, and *Carpinus orientalis,* or the forest disappeared. For that reason Mobayen and Tregubov (1970) have subdivided these forests into *Querco-Carpinetum* and *Fagetum hyrcanum* communities. *Fagus orientalis* occurs up to about 2,400 m, but the beech forests basically disappear above 2,000 m. Between 2,000 and 2,500 m (maximum elevation 3,000 m) *Quercus macranthera* dominates, frequently associated by *Carpinus orientalis* (the *Carpinetum orientalis* of Mobayen and Tregubov, 1970). The timberline on the northern slopes of the Alborz consists almost exclusively of *Quercus macranthera*, though it has been disturbed in many places as a result of intensive grazing. These woodlands have been studied in detail by Jean Claude Klein (Klein and Lacoste, 1989), who distinguished two types, depending on climatic conditions: the Aceri-Quercetum macrantherae, typical of the central Alborz between 2400-2800 m, under damp and temperate climate, and a floristically impoverished type, that spread out in the eastern Alborz under a more dry and continental climate. Most striking is the absence of subalpine Vaccinio-Piceetea communities in the Alborz, which are typical of the European Alps, but replaced here by these oak forests. Other trees of the montane forests are *Acer platanoides*, *Acer cappadocicum*, *Fraxinus excelsior*, and *Sorbus orientalis*. In the undergrowth such shrubs as *Mespilus germanicus*, several species of *Crataegus*, *Sorbus orientalis*, and *Virburnum lantana* occur. In the most favored locations the annual rainfall is about 2,000 mm. The foothills facing south receive less. Between 2,400 and 2,600 m there is a clear break in climate. The humid Caspian air masses press up to this level, but above it dry southern winds prevail. The tree line on the northern side of the Alborz is determined by aridity, not by cold; its course is very uneven.

Mangroves. Mangrove forests are occasionally found along the shores of the Persian Gulf: west of Bandar-e ʿAbbās, on the mudbanks between the island of Qešm and the mainland, and in several places on the Baluchistan coast (Frey and Probst, 1986). The predominant and most distinctive species is *Avicennia* *marina*. In a few places isolated *Rhizophora mucronata* trees occur. At higher elevations within the mangrove belt there are salt marshes dominated by *Halocnemum strobilaceum*.

Woodlands. Remnants of cold-sensitive evergreens (*Cupressus sempervirens*, *Thuja orientalis*) are found in the valleys cutting across the northernmost Alborz chains (PLATE III). Groves of *Cupressus sempervirens* also occur at Fīrūzābād in southern Persia and in the Taftān mountains in the southeast. Some of the Alborz valleys, for example the regions around Marzānābād in the Čālūs valley and Rūdbār in the valley of the Safīdrūd, lie in the rain shadow of the mountain chains and receive annual precipitation of about 500 mm. In a few valleys east of Gorgān *Thuja orientalis* replaces *Cupressus semperviren*s. Because both species are sensitive to cold, they are absent from the highlands. It was Zohary's opinion that these woodlands are relics of a period of aridity in the early Tertiary, representing a forest type that had largely disappeared from Persia with the shrinking of the Tethys.

Extensive woodlands of cold-resistant conifers such as *Juniperus excelsa* (PLATE V). The southeastern boundary is in the highlands at Shiraz. In the lowlands of Mesopotamia and along the Persian Gulf a belt of scrub encircles and encroaches upon this oak forest. The variety of species decreases as precipitation declines toward the southeast. On the Persian highland the oak forest gradually gives way to a dry type with a high admixture of *Juniperus excelsa*, then to *Astragalus* scrub, and finally to the dwarf scrub formations of the plateau. Among trees oaks predominate. In the northwest, beside *Quercus brantii*, *Quercus infectoria, Quercus boissieri,* and *Quercus libani* occur, whereas in the central Zagros only *Quercus brantii* is found; as the species most resistant to aridity, it also extends farthest to the southeast. Associated tree species include *Fraxinus rotundifolia*, *Acer monspessulanum subsp. cinerascens*, *Pistacia khinjuk*, *Amygdalus communis*, and *Pyrus syriaca*, the last of which predominates in a few locations.

Above 1,500 m the oak forest is a cold-adapted montane woodland, with an upper limit at 2,100-2,200 m, where it gives way to subalpine oak scrub. The lower limit is at about 800 m, where in humid areas the forest is intermingled with drought-adapted species (e.g. *Myrtus communis*, *Nerium oleander*). Oak forests require annual precipitation of more than 500 mm; it can rise to more than 1,000 mm in the mountain chains. Another prerequisite is fairly regular summer precipitation, which alone ensures regeneration; winter lows must be higher than those in the juniper woodlands. Zohary (1973) named this type of woodland “Kurdo-Zagrosian oak steppe-forest” (Quercetea brantii) and Bobek (1951) suggested “oak forest of the Zagros chain.”

Scrublands.Coniferous scrub is known only from the subalpine levels of the Alborz. It consists of *Juniperus excelsa* and *Juniperus communis subsp. communis*. Elsewhere cold-adapted deciduous scrub prevails. On the northern slopes of the Alborz the Hyrcanian forests give way gradually to deciduous scrub, and then either to the dwarf scrub and herbaceous formations characteristic of high mountain elevations or, in the east, to the juniper woodlands of Khorasan. Because of declining precipitation at higher elevations and farther east, the rich array of Hyrcanian forest species disappears. *Zelkova carpinifolia*, *Carpinus orientalis*, *Carpinus betulus*, and *Quercus macranthera* can advance farther in shrub form and thus form components of the scrublands, as do many shrubs that are characteristic of the distinctive eastern scrub. They include *Acer monspessulanum* subsp. *turcomanicum*, *Acer cappadocicum*, *Acer campestre*, various species of *Crataegus*, *Mespilus germanica*, *Prunus divaricata*, *Cerasus microcarpa*, *Pyrus boissieriana*, *Colutea persica*, *Celtis caucasica*, and species of *Berberis*. Species of *Pistacia* and *Amygdalus* have not been observed in these scrub complexes (Frey, 1980). Deciduous shrubs are associated with regular summer precipitation, which can be interspersed with long dry periods. The total annual rainfall must be around 500 mm. Also characteristic are extreme winter lows.

Open xeromorphic scrub is associated with forests of *Quercus brantii* on the southwestern slopes of the Zagros range as far as the Mesopotamian lowlands and the plains along the Persian Gulf (PLATE VI). After the oak forests peter out, this scrub continues in the southern and southeastern mountain chains and massifs. Its last outposts are found at 27° N and as far east as the Taftān range south of Zāhedān. In the latter region, however, there is frequently a transition to very open xeromorphic scrub formations. Bobek (1951) identified these formations as “pistachio-almond-maple dry forest”; Zohary (1973) as “*Juniperus–Pistacia–Amygdalus* steppe scrub” (*Junipero-Pistacietea*). Particularly diagnostic are *Amygdalus scoparia* and other species of *Amygdalus*, *Acer monspessulanum subsp. cinerascens* and *Acer monspessulanum subsp. persicum*, *Pistacia khinjuk*, and *Pistacia atlantica*. Other plants include species of *Ephedra* and *Rosa*, *Amygdalus haussknechtii*, *Amygdalus kotschyii*, *Amygdalus elaeagnifolia*, *Amygdalus erioclada*, *Amygdalus eburnea*, *Amygdalus lycioides*, *Cerasus brachypetala*, *Cerasus* *microcarpa*, *Cotoneaster persica*, *Crataegus azarolus*, *Prunus divaricata*, *Colutea persica*, *Rhamnus pallisii*, *Rhamnus kurdicus*, species of *Berberis*, *Ficus carica*, *Lonicera nummulariifolia*, *Daphne angustifolia*, species of *Lycium*, and *Juniperus excelsa*. Although the species of *Acer* and *Pistacia* frequently grow as trees, in this zone they are considered scrub in the physiognomic sense. In the east and southeast, where stands of pistachio trees are often even sparser, their cover is so thin that they can be classified neither as woodlands nor as scrub. Such stands of mountain almond and pistachio trees (Bobek 1951) must be considered part either of the very open xeromorphic scrub or of the dwarf scrub formations.

In the northwest, where scrub gives way to oak forests and the demarcation line is often not clear, the scrub is very rich in species, but their number declines toward the southeast, reflecting decreasing annual and summer precipitation. At Shiraz, where annual precipitation is ca. 400 mm, a large proportion of the scrub species has already disappeared. The last, most dry-resistant survivors are *Zygophyllum atriplicoides*, *Pistacia khinjuk*, *Acer monspessulanum subsp. persicum*, and species of *Amygdalus*, which constitute very sparse complexes of open xeromorphic scrub.

The lower limit of the scrublands is determined by the amount of precipitation, an annual minimum of 400-500 mm being necessary. They rise to an elevation of 3,000 m. Zohary (1973) was probably incorrect in grouping together juniper woodlands and *Pistacia–Amygdalus* scrub as *Juniperus–Pistacia–Amygdalus* steppe scrub (*Junipero-Pistacietea*). The ecological requirements and species composition characteristic of these two vegetation units are so different that they must also be separated in terms of plant sociology. Pure *Juniperus* woodlands are connected with areas of very low winter temperatures (-20° or -25° degrees C.) and irregular summer precipitation, while *Amygdalus–Pistacia* scrub demands higher winter temperatures and fairly regular summer precipitation.

As already mentioned, the species of *Crataegus*, *Amygdalus*, *Cerasus*, *Prunus*, *Pistacia*, *Rhamnus*, and *Acer* are xeromorphic descendants of the Arcto-Tertiary flora. They have spread over the southwestern Persian mountain ranges and evolved there. Also to be classified with the open xeromorphic scrub is the tamarisk scrub of the salt deserts on the southern and eastern highland and in the Persian Gulf region, where *Tamarix aphylla* can also form imposing thickets in dry watercourses.

As annual precipitation declines to 300 mm in the south and southeast, open xeromorphic scrub (PLATE VII) gives way to very open xeromorphic, or semidesert, scrub. Most resistant to aridity are species of *Amygdalus*, *Zygophyllum atriplicoides*, and *Pistacia khinjuk*. Little is known about the regional distribution of this kind of vegetation. In the warm areas of the Persian Gulf region semidesert scrub is quite widespread. The characteristic species are intruders from the Nubo-Sindian flora, for example, *Acacia nubica*, *Acacia sejal*, *Euphorbia larica*, *Periploca aphylla*, shrubby species of *Ziziphus*, *Stocksia brahuica*, and *Salvadora persica*. The Gulf region is noteworthy for frost-free winters; winter rains; long, hot, dry summers; and high atmospheric humidity. The annual precipitation in the mountain ranges is about 200-300 mm.

Complexes of dwarf scrub and thorn cushion formations characterize much of the interior Persian highland and the slopes of the peripheral mountain ranges that face the central highland. The two vegetation units are found over the larger part of Persia. It is surprising that they, along with the halophytes, are the least known and studied on the Persian highland (Frey and Kürschner, 1983). Often only the steppes and deserts are mentioned in the literature. Zohary (1963; 1973) was the first to undertake a more precise classification. A great number of genera originally developed in this region, among them *Astragalus*, *Acantholimon*, *Acanthophyllum*, *Artemisia* and other dwarf shrubs and thorn cushions. Associated with them are numerous genera with herbaceous representatives, like *Salvia*, *Nepeta*, *Phlomis*, *Onosma*, *Ferula*, *Dionysia*, *Echinops*, and *Cousinia*.

The flora of the basins and low-lying areas is often very poor in species, while on the mountain heights and hills it is quite rich. The major endemic species occur in the latter areas. The highlands and the lower elevations of the massifs are more favorable to formations of dwarf scrub. Thorn cushions are the characteristic vegetation at subalpine elevations and in degraded *Juniperus* woodlands (PLATE VIII). Both types have different ecological requirements. Thorn cushions occur in regions where winter temperatures reach extreme lows and there are long periods of snow cover (Kürschner, 1986; Klein, 1987).

Dwarf scrub is rich in species and highly differentiated, as Zohary (1963; 1973) was the first to establish. He distinguished a large number of associations between the predominant dwarf shrubs and accompanying species, for example, *Artemisia fragrans* and *Atraphaxis spinosa*, *Artemisia herba-alba* and *Stipa hohenackeriana*, *Artemisia herba-alba* and *Ephedra intermedia*, *Artemisia* *herba-alba* and *Zygophyllum atriplicoides*. Some of the associations serve as transitions to associations with thorn cushions: Zohary mentioned among others Artemisietum herbae-albae astra galetosum glaucacanthi, Astragaletum phyllokentri, and Artemisietum herbae-albae astragaletosum gossypini. Within *Artemisia* the species *Artemisia fragrans* and *Artemisia herba-alba* predominate (for the large number of species in this genus, see Zohary, 1963, 1973).

Dwarf scrub formations are subject to heavy grazing and use as fuel. As a result, thorny plants can be equally dominant or even predominant (e.g., *Astragalus glaucacanthus*, *Astragalus phyllokentrus*, and *Astragalus squarrosum*). A special feature of the Irano-Anatolian vegetation zone at the subalpine and lower alpine belts of the Alborz and Zagros mountains between 2000 and 3000 m are tall umbelliferae communities (*Prangetea ulopterae*) and xerophytic orophilous thorn cushions (*Onobrychidetea cornutae*), which seem to proceed from thermophilous pleistocene juniper stands after their destruction by man. Common discriminant factors for their development are a level of precipitation between 900 and 1300 mm, 50% of which falls in spring; a summer period of four months almost totally free from precipitation; and a rather cold thermal regime (Kürschner, 1986). They have been studied in detail by Klein (1987, 1988). Especially in Khorasan, the degraded *Juniperus* woodlands were obviously invaded by thorn cushions, an indication that these extensive units of thorn cushions are often secondary and would inhabit much smaller areas under natural conditions.

Terrestrial herbaceous communities. Herbaceous meadows play an important role in the mountains, especially in the subalpine and alpine belts. Although they do not cover such large surfaces as the dwarf scrub, they encompass a large number of endemic species of the genera *Salvia*, *Phlomis*, *Nepeta*, *Eryngium*, *Ferula*, *Euphorbia*, *Rheum*, *Cousinia*, *Onopordon*, and others. In the highlands herbs frequently occur in association with dwarf scrub, for example *Rheum ribes* in the area between Kermān and Sīrjān. Originally, grasses probably played a greater role in the vegetation units of the Persian highland than they do today. They have been sharply reduced through millennia of overgrazing. In formations of dwarf scrub species of *Stipa* and *Stipagrostis* can predominate. The semidesert scrub of the Persian Gulf region turns green during the heavy rainfalls of late winter and spring; annual grasses play the most important role in this greening.

Herbaceous and semi-woody salt swamps (PLATE IX). Characteristic of the extensive saline depressions in Persia are plant communities of *Halocnemum strobilaceum*, species of *Salsola*, *Salicornia europaea*, *Halocharis sulphurea*, *Cressa cretica*, *Halopeplis pygmaea*, *Noaea mucronata*, species of *Anabasis* and *Suaeda*, *Spergularia marina*, *Bienertia cycloptera*, and species of *Aeluropus*, *Frankenia*, and *Juncus*. Shrubs such as *Tamarix aphylla*, *Tamarix passerinoides*, *Tamarix hispida*, *Tamarix laxa*, *Prosopis farcta*, species of *Haloxylon*, and *Seidlitzia rosmarinus* also play an important role.

The distribution of plants on the salt plains differs greatly. This vegetation complex is still one of the least known on the Persian highland. According to geographic and climatic data, four types of biotopes can be distinguished: the salt flats (*kavīr*s) of the central Persian endorheic basin; the shores of the salt lakes; the coastal areas along the Persian Gulf with marked tides and a hot, dry climate; and the southern Caspian coast, characterized by a generally constant water-level and a fairly humid climate. The salt concentration in these habitats is different, which is reflected in a marked succession of vegetation zones. One example from each of the four main biotopes for halophytes will serve as a brief illustration. The characteristic zonal division of the vegetation on the margins of the Dašt-e Qazvīn has been described by Mobayen and Tregubov (1970). The innermost zone includes only *Halocnemum strobilaceum*. It is succeeded by a mixed formation of that species and *Limonium carnosum*. Next is a band of *Limonium carnosum*, *Atriplex verruciferum*, and *Salsola incanescens*, then plants of the surrounding dwarf-scrub formations, like *Artemisia herba-alba* and *Alhagi camelorum*. On other salt flats the zone of *Halocnemum* is succeeded by a zone of tamarisks and small *Seidlitzia rosmarinus* bushes. On the shores of the Maḥarlū salt lake near Shiraz Reinhold Carle and Wolfgang Frey (1977; cf. also Frey, 1982; idem and Kürschner, 1983) established the following sequence of vegetation zones: *Salicornia europaea* and *Halopeplis pygmaea* on the innermost edge; next a band with such additional halophytes as species of *Suaeda*, *Spergularia marina*, *Cressa cretica*, *Polypogon monspeliensis*, species of *Cyperus*, *Aeluropus littoralis*, *Frankenia persica*, and *Frankenia pulverulenta*; and on the outer margins *Juncus rigidus* and *Juncus subulatus*.

Extensive salt marshes occur along the Persian Gulf coast, owing to the influx of seawater and salt deposits on shore. Determining factors in the distribution of the halophyte vegetation are the warm, dry climate and the influence of the tides. A typical zonal organization can be described here from Bandar-e Ḵamīr (Frey and Probst, 1986; Frey et al., 1985). In the tidal area there is a narrow band of *Avicennia marina* mangroves, with marked regional differences. The adjacent zone, underwater only during the spring tides, is characterized by a very strong concentration of salt and is thus without vegetation. Next is a belt of *Halocnemum strobilaceum*, which, in the areas farthest from the coast, is bordered by scant salt-resistant shrubbery and herbs (*Chenopodiaceae* and species of *Zygophyllum*, *Frankenia*, *Spergularia*, and *Atriplex*). The adjacent open dwarf-scrub formations, rich in therophytes with isolated bushes and trees (species of *Acacia*, *Prosopis spicigera*), are largely unaffected by the influx of salt water.

The southern Caspian coastal zone has a very humid climate in the west. The annual precipitation declines toward the east, and in Gorgān there is a dry period in the summer. Correspondingly, the salinity of the soil is higher in the eastern coastal lands (e.g., the gulf of Gorgān) than in the west, where there are low-lying plains with tamarisks and species of *Halocnemum*, *Salsola*, *Atriplex*. The estuary of the Gorgān River at the southwestern corner of the Caspian Sea is typically occupied by salt marshes.

Annual communities. In general, wherever growing conditions, especially aridity, are so severe that dwarf scrub and perennial grasses can no longer flourish or occur only in very sparse clumps, annuals determine the character of vegetation after rainfall. Particularly prominent among these species-rich annual communities are representatives of the genera *Clypeola*, *Aethionema*, *Erophila*, *Medicago*, *Trigonella*, *Cerastium*, *Spergularia*, *Spergula*, *Arenaria*, *Silene*, *Erodium*, *Papaver*, *Glaucium*, *Hypecoum*, *Roemeria*, *Filago*, *Anthemis*, *Senecio*, *Gnaphalium*, *Lactuca*, *Sonchus*, and *Plantago*.

Vegetation on the dunes of the interior highland. Dune vegetation, like that near Yazd or between Bīrjand and Mašhad in Khorasan, has still not been sufficiently studied. Characteristic species are *Stipagrostis pennata*, *Calligonum stenopterum*, *Calligonum bungei*, species of *Heliotropium* and *Salsola*, *Carex physodes*, and *Ephedra strobilacea* (Zohary, 1963).

Deserts. The definition of “desert” varies among geobotanists. Various Russian botanists identify as desert any area that receives less than 150 mm of annual precipitation. According to that definition, the greater part of the central Persian highland is desert. It seems more reasonable to adopt Zohary’s definition (1973), according to which deserts are areas in which direct precipitation does not suffice to support plant growth. The vegetation in these areas is very diffuse, limited to depressions, funnels, and dried-up watercourses. In the two largest endorheic basins of the Persian highland the two great deserts of Persia have developed. In the north is the Dašt-e Kavīr, an immense salt desert entirely without vegetation in its center, and in the south the Dašt-e Lūt, one of the hottest deserts on earth, with summer temperatures above 50° C.

The vegetation of the Dašt-e Lūt was studied by Mobayen (1975) and Léonard (1991-92). Species of tamarisk (e.g., *Tamarix aphylla*, *Tamarix macrocarpa*, *Haloxylon ammodendron*, *Prosopis spicigera*, species of *Calligonum*, and *Seidlitzia rosmarinus*) press to the very edge of the vast unvegetated area. According to Zohary, vegetation is entirely lacking in salt deserts which receive less than 100 mm annual rainfall and have no additional sweet water. Around them a characteristic zonal arrangement of vegetation can frequently be observed: on the outer margins tamarisk bushes along with *Seidlitzia rosmarinus*, *Prosopis farcta* and *Artemisia herba-alba* (of which there is a halophytic variety); then a zone of *Halocnemum strobilaceum*, which extends to the edge of the barren salt surfaces.

Alpine vegetation. There is still insufficient information on the plant formations at alpine levels. In the Alborz the lower boundary of the alpine belt lies at about 3,200 m, in the Zagros at 3,500 m. The species and the ecology of the alpine plant formations, including communities of alpine herbaceous plants, areas of permafrost, cliffs, rocks, and scree were studied only by Gilli (1939) and recently by Klein (Klein, 1982; Klein and Lacoste, 1994). In the Alborz, at 2400 m subalpine meadows consisting of typical Euro-Siberian taxa such as *Alchemilla plicatissima, Tanacetum coccineum, Ranunculus buhsei, Trifolium canescens, Silene tenella, Erigeron caucasicus*, and *Veronica rechingeri* often replace the destroyed beech forests. They belong to the *Alchemilletum plicatissimae* and are intermixed with thorn cushions. They are replaced above 3500 m by the chionophilous communities (Oxytropidetea persicae) which correspond to the climatic climax of the lower alpine belt.

GEOPHYTES

In the present description of vegetation units only plant forms like trees, shrubs, dwarf scrub, thorn cushions, herbaceous plants, and annuals have been considered. So far the geophytes, which propagate by means of underground buds, have not been mentioned, for there are no tracts of purely geophytic vegetation. However, they do play an important role in the vegetation of the Near East and Central Asia, as they are particularly well acclimated to the harsh summer droughts and cold winters. Hoarded nutrients permit geophytes to propagate and bloom very quickly in spring, taking full advantage of the short periods favorable to vegetation. Thus on the southern Caspian coast *Scilla hohenackeri*, *Crocus caspicus*, *Galanthustrans caucasicus*, and *Gagea reticulata* bloom in very early spring. At higher elevations species of *Erythronium* are the early bloomers of the beech forests. Cliff-sides and other exposed locations are inhabited by *Muscari chalousicum*. Indigenous to the arid uplands are species of *Eremurus*, *Colchicum*, *Tulipa*, *Fritillaria*,and *Iris*, as well as *Merendera caucasica* and *Merendera persica*. In April innumerable *Eremurus giselae* burst into bloom between Sīrjān and Neyrīz.

In the Zagros and in Ḵūzestān various wild tulips bloom in spring. *Fritillaria imperialis*, frequently grown in Europe as a decorative plant, also comes from this region. In the lowlands, geophytes grow in the cultivated areas: most common are the species of *Ornithogalum*, *Bellevalia* and *Ixiolirion*, as well as *Bongardia chrysogonum*, a plant with potato-sized bulbs that grow at a depth of 40 cm and are valued as a remedy for epilepsy.

HUMAN ACTIVITY AND VEGETATION

The initial phase of anthropogenic influence. Finds at ʿObaydīya in the upper Jordan valley show evidence of human habitation in the Near East in the early Pleistocene (Zohary, 1973). Hundreds of thousands of years intervened between that period and the first attested cultures of the early Stone Age in the Near East. Owing to their constant need for edible plants, the early humans must have exhausted certain species in the main settlement areas along the partly wooded margins of the steppes. Such edible species would have been replaced by inedible ones. Therefore humans must have been an important factor in the natural selection of plant species since the earliest phase of their development and distribution. The gradual disappearance of edible plants around human settlements must have led fairly early to efforts to encourage and introduce plants that would serve human needs: “Indeed, a wealth of edible plants, that grow as ruderals and camp followers in the close vicinity of man, could have taught primitive man the technique of sowing” (Zohary, 1973, p. 610).

The introduction of agriculture. With the beginning of agriculture, attested in Mesopotamia and the “Fertile Crescent” before 10,000 B.C.E., humanity entered a new phase in its development. From that time onward human influence on nature sharply increased. First, agriculture itself meant active modification of the vegetation and often irreversible changes in the natural ecosystem (from burning off, soil depletion, erosion, etc.). One result of cultivation was the creation of new plant communities. Those in the Near East today consist largely of species that are no longer known in their natural environments, for example, *Ridolfia segetum*, *Coriandrum sativum*, *Daucus aureus*, *Conringia perfoliata*, *Neslia apiculata*, and *Heliotropium villosum* (cf. Zohary, 1973, p. 648). Many of the weeds dispersed throughout the world probably originated in this region as well, for example, *Convolvulus arvensis* and *Sinapis arvensis*. Second, the introduction of agriculture brought a sharp increase in human food supply. Human activity altered the balance of biological species in the environment, increasing the presence of edible plants beyond the numbers they would have reached under "natural" circumstances.

The physical conditions of the Near East, especially the edge of the "Fertile Crescent" bordering the Zagros between Mesopotamia and present day Persia, must have been conducive to the development of agriculture. Conditions for human life were favorable in the sparse, parklike oak forests of this region that also harbors crops like Einkorn wheat (*Triticum monococcum*), Emmer (*Triticum turgidum*), wild barley (*Hordeum spontaneum*), and pulses (lentil, chickpea, fava bean, common vetch, etc.; Zohary and Hopf, 1988) This, and the growth of early spring annuals in particular, may have called man's attention to the connection between sowing seeds and growing plants.

Grazing. Livestock has been pastured in present-day Persia since the 7th-6th millennium B.C. (Zohary, 1973). Today, owing to overgrazing of grasslands, as well as scrub, woodland, and densely forested areas, the vegetation has changed: the ground cover has partially disappeared and a strong selection of species can be observed. In fact, over the millennia a change of species composition has occurred. Originally, human influence must have been limited mainly to the settled areas, inhabited by agriculturally advanced peoples. The shift to seminomadic and nomadic ways of life made it possible to exploit the entire region. The nomadic grazing of herds over millennia has markedly changed the face of the vegetation of Persia. The present broad distribution of vegetation units dominated by thorn shrubs, dwarf scrub, or thorn cushions must have resulted from overgrazing. The original vegetation was driven back, leading to the dominance of poisonous and unpalatable species like thorn cushions (antipastoralism, antipyrism). These plants were able to spread from the areas where they originated over an enormous territory in a comparatively short time.

Destruction or alteration of the woodlands. In many parts of Persia single large shade trees and sacred groves can be found in cemeteries or seen in tomb paintings in otherwise deforested areas, where the present-day condition of the soil would hardly permit trees to grow. They often are remnants of an earlier vegetation and invite speculations about the extent of the woodlands in the past. Such open groves of trees probably represent the natural tree growth of favored settlement areas in the Near East; therefore human activity must have changed the vegetation of these areas drastically, pushing back the woodlands and scrub. Encouraged by soil erosion, the degradation of the densely forested areas of the Zagros and the humid Hyrcanian forests has progressed quite far (PLATE X, PLATE XI). The species composition in these forests must have changed, since plants which can adapt to frequent pruning and grazing have a clear advantage in the natural selection. Today many tree species like *Carpinus betulus*, *Carpinus orientalis*, *Quercus macranthera*, *Juniperus*, and *Quercus brantii*, are distributed over broad expanses as low bushes and often even as thorny dwarf shrubs. Pristine forests remain only in places too remote for economic exploitation, or inaccessible for goats.

Human impact on the vegetation of Persia can be summarized as follows. In many peripheral sites of tree growth, forest formations were destroyed and replaced mainly by thorn cushions or communities of annuals (e.g., on the southern slopes of the Alborz, on the outer Zagros chains, in large areas of the province of Fārs, and on mountain slopes with a favorable climate). The degraded forests have been invaded by secondary communities consisting mainly of thorny shrubs and thorn cushions like *Crataegus*, *Prunus*, *Cerasus*, *Amygdalus*, *Rhamnus*, *Paliurus*, *Astragalus*, *Ebenus*, *Acantholimon*, *Acanthophyllum*, and *Convolvulus*, and are thus no longer of value for economic exploitation. The array of plant species other than trees and bushes has also changed. For example, *Artemisia herba-alba* has been largely replaced in northeastern Persia by communities of *Peganum harmala* and *Dorema ammoniacum*. In other parts of the Persian highlands grasses have been replaced by dwarf shrubs and thorn cushions. As thorn cushions have often been used for fuel, degradation or alteration is greater near settlements, where species not suitable for burning (certain succulents, like species of *Anabasis*) have replaced the dwarf shrubs and thorn cushion formations.

See also ENVIRONMENTAL PROTECTION.

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