

Chapter **51**

**Plant Genetic
Resources Unit -
NCARTT, Jordan**



Sobhia Saifan

Plant Genetic Resources Unit, National Center for
Agricultural Research and Technology Transfer
(NCARTT), P.O. Box 639 Baqa' 19381, Jordan

Summary

Although Jordan is a small country, 90,000 km², it hosts about 1% of the total world Flora including wild progenitors and relatives as well as land races of globally important field crops and fruit trees. Comprising a sizable part of the fertile crescent, Jordan harbours a tremendous plant genetic variability across its four bio-geographical regions. The main goal of NCARTT is to conduct and/or coordinate research mandated to manage and improve agriculture. The Plant Genetic Resources Unit, established in 1993, is one of the major executing programs at NCARTT and aims to study biodiversity and to conserve (*in situ* and *ex situ*) plant genetic resources from deterioration and make them available to users. The main activities are: (1) collection, characterization, documentation and the *ex situ* and *in situ* conservation of genetic resources, including germplasm and herbarium specimens; (2) biodiversity studies of the populations using visual and molecular techniques; and (3) coordination with local, regional and international institutions and traditional users, through the exchange of information and plant materials. The Plant Genetic Resources Unit is divided into a gene bank (seed and field gene banks; > 2,243 accessions, representing crops, fruit trees and range land shrubs), a biotechnology laboratory, the national herbarium (> 4,000 specimens), and a Documentation Unit. The unit is looking to improve its capabilities and manpower through capacity building, equipment acquisition, implementation of modern documentation systems for both the gene bank and herbarium, and information exchange with international organizations.

Introduction

Since ancient history, Jordan was a birthplace for several civilisations. It was a pathway for caravans traversing Arabia and India and received caravans coming from Yemen and Hijaz. The Kingdom of Jordan, which is a Middle Eastern country and part of the so-called 'fertile crescent', lies between longitudes 33° and 22° E, and between latitudes 29° and 11° N. The total area of Jordan is computed as nearly 90,000 km², of which, well over half is "Badia" or desert. It is bordered by Syria to the north, Iraq to the east, Saudi Arabia on both eastern and southern borders, and Palestine to the west.

Topography of Jordan

Jordan can be subdivided into three main physiographic regions, namely: The Jordan Valley and Wadi Araba, the Highlands, and the eastern desert of Badia. Along the western edge of Jordan is the Jordan valley, a major part of the Levant Rift valley, which includes the lowest point on Earth, reaching 396 m below sea level along the shores of the Dead Sea. The Wadi Araba extends from the south of the Dead Sea to the Gulf of Aqaba on the Red Sea. It is considered a part of the Great Rift Valley. The highlands extend from Um Qais in the north, passing through the Ajlun Mountains going up to 1,250 m. The southern highlands (up to 1,700 m) are higher than those in the north while established reserves contain a rich variety of vegetation types. The Highlands harbour the natural forests in the Kingdom; however, these make up less than 1% of the total land area. Unfortunately, the mismanagement of these environmental resources is noticeable year after year. The Badia region (eastern desert) comprises the eastern Plateau of Jordan, which occupies about 85% of the country at an elevation between 800–900 m. It is a flattened area, subjected to flash floods. The Badia contains the so-called Azraq Depression, which formed the permanent Azraq Oasis. This is currently named as a wetland reserve.

Biogeography of Jordan

Jordan forms part of the Mediterranean region and has an Eastern Mediterranean climate, characterised by a mild and moderately rainy winter and a hot, rainless summer. Four different bioclimatic or biogeographically regions are recognized in Jordan (Kasapligil, 1956; Long, 1957; Qrunfleh *et al.*, 1962; Poore and Robertson, 1964; Beskok, 1971; Madany, 1978; Al-Eisawi, 1985). These are: Mediterranean, Irano-Turanian, eastern desert (Badia) and Sudanian or tropical penetration.

1. Mediterranean Region

This region comprises the most fertile part of Jordan and the best climate for forest ecosystems such as *Pinus halepensis* (Aleppo pine). This region is restricted to the highlands of Jordan with elevation ranges from 700–1,750 masl. The rainfall ranges from 300–600 mm. The mean minimal annual temperature ranges from 5–10°C and the mean maximum annual temperature ranges from 15–20°C. Soil types are dominated by the red Mediterranean soil (Rendzina). This region has the most diversified plant species, including the majority of orchids, bulbs and annual showy herbs.

2. Irano-Turanian Region

This is a narrow strip of variable width that surrounds all the Mediterranean ecozone, except at the north. It is characterized by the absence of forest cover. The vegetation is mainly one of small shrubs and bushes like *Anabasis syriaca* and *Artemisia herba-alba*. Altitudes range from 500–700 m and rainfall from 150–300 mm per annum. The mean annual minimal temperature ranges from 2–5°C, and the mean annual maximum temperature ranges from 15–25°C. Soil is mostly calcareous or transported by wind; vegetation is mostly dominated by Chamaephytes.

3. Eastern Desert or (Badia) Region

It is also called the Saharo-Arabian ecozone. It forms around 80% of the total surface area of the country. The annual rainfall in the northern part is around 100 mm and in southern part is around 50 mm per annum. The soil is generally very poor, which results in poor vegetation. Most of the vegetation cover is in the dry river beds or “Wadies” (Al-Eisawi, 1985). The Arabic term for the north-eastern desert is Badia, which is a more appropriate term than desert, because it is capable of supporting vegetation and animal life. The limiting factor here is rainfall. Altitude ranges between 500–700 mm, although a few places on the north-eastern borders of Jordan are recorded with an elevation reaching 1,200 m. The mean annual rainfall ranges from 50–200 mm; mean annual minimum temperature ranges from 5–15°C and the mean annual maximum temperature ranges from 15–25°C. Soils are mostly poor and of either a clay, saline, hammada, sandy or calcareous type. Small shrubs and annual herbs dominate this vegetation. However, there are hundreds of well-adapted plant species growing there, including genetic resources for valuable crops like *Aegilops* spp. Also many of the plants are used by human beings as medicinals (like *Achillea fragrantissima* and *Seriphidium inculcum*), as ornamentals, or they are edible, provide forage or wood.

4. Sudanian or Tropical Penetration Region

This region starts at Al-Karamah in the north and continues to the south through the Dead Sea depression and the Wadi Araba, which ends at the tip of the Gulf of Aqaba. Moreover, this ecozone includes the southern Jordan and southern Edom mountains. The vegetation is related to tropical varieties such as *Acacia* spp. (Al-Eisawi, 1985). The ecological pyramids and climatic conditions in the northern Jordan Valley, “Ghor”, are different from those of southern Ghor and Wadi Araba. In effect, the northern Ghor is considered part of the Mediterranean ecozone. The most important characteristic of this region is its altitude, considered the lowest point on earth (-396 m below sea level), providing a unique environment and thus a unique ecosystem. Annual rainfall ranges from 50 to 100 mm. The only inland sand dunes in Jordan are

restricted to this region. Vegetation is characterized by the presence of tropical tree elements such as *Ziziphus spina-christi*, in addition to some shrubs and annual herbs.

The borders of the four ecozones are not stable and are not well defined because of the integration of ecological elements between the two adjacent ecozones. Moreover, the climatic conditions, which vary considerably from year to year, affect the stability of these borders.

Value of Jordanian Biodiversity

Variation in climate and topography in Jordan has led to a wide diversity in ecological habitat and subsequently in flora. This flora was indirectly studied in works related to the area such as Flora Orientalis (Boissier, 1867–1883), the Flora of Syria, Palestine and Sinai (Post, 1932–1933), and Flora Palestina (Zohary, 1966–1982). In addition, many floristic studies were published during the past three decades (e.g., Boulos and Al-Eisawi, 1977a, 1977b; Al-Eisawi, 1983, 1988; El-Oqlah, 1976).

The vegetation types of Jordan exhibit an amazing variation considering the small land area of the country. Thirteen vegetation types were recognized by Al-Eisawi (1985) – see Box 51.1.

Box 51.1 Vegetation types of Jordan as described by Al-Eisawi (1985)

- Pine forest (*Pinus halepensis*)
- Evergreen Oak forest (*Quercus calliprinos*)
- Deciduous Oak forest (*Quercus ithaburensis*)
- Juniper forest
- Mediterranean non-forest region
- Steppe vegetation (*Ziziphus lotus*, *Ferula communis*)
- Halophytic (*Haloxylon persicum*, *Arthrocnemum* spp.)
- Sandy dunes
- Hammada (*Retama raetam*, *Artemisia herba-alba*, *Tamarix* spp. *Astragalus* spp., *Anabasis* spp.)
- Tropical
- Acacia and rocky vegetation
- Hydrophytes
- Mud flats

The Flora of Jordan is rich and diverse compared to the total number of recorded vascular plant species on earth (250,000–300,000). Jordan hosts approximately 2,500 species, included within 152 families and 700 genera (Jordan country study, 1998). This is about 1% of the total world flora. These species are ecologically and genetically adapted to local conditions and many of them are even adapted to the drier parts in the country, like the desert. The species growing in this vast area are valuable as the primary vegetation element and for their uses as a food source for humans, as grazing for animals, as medicines, as soil and nitrogen fixers, as sources of disease resistance, and as parents of cultivated, drought- and saline-resistant plants.

The importance of endemic species, such as black iris (*Iris nigricans* Dinsm.), is clear since they comprise about 2.5% (100 species) of the total Jordanian flora. Many species are known to be rare or endangered, such as the orchids, ornamental bulbous plants, and some edible or medicinal plants. However, the status of many species is unknown.

The Jordanian flora includes important ornamental plants, such as *Iris*, tulip, *Allium*, *Crocus* and *Colchicum*. In addition, it includes wild progenitors, relatives and landraces of globally-important field crops (e.g., wheat, barley, oats, lentil, vetch, peas). Harlan, (1970) indicated that the general location for wheat and barley domestication seemed to be in or near oak woodland in the southern Jordan Highlands near the Dead Sea Rift. Therefore, it is of great advantage to have many species adapted to the local environment and growing in such a limited area of 90,000 km². Many of these species can be considered important national genetic resources in need of conservation so that they can be used in the future as raw materials for agriculture, for example. These resources are integral to the sustainability of production systems and hence are key to development.

Current Threats to the Jordanian Flora

Plant diversity in Jordan has declined dramatically and some species have become totally extinct from the wild since the early part of the last century, due to habitat encroachment by urban and agricultural development, deforestation, deterioration of rangelands by over-grazing and soil erosion, illegal collection, and depletion of major water resources. The status of some species of the macro flora of Jordan is presented in Table 51.1.

Table 51.1 Some selected endemic, rare, endangered, extinct flora of Jordan. Based on the country study on biological diversity, 1998 (UNEP and GE, 1998).

Endemic	Rare	Endangered	Extinct
<i>Crocus moabiticus</i>	<i>Opopanax hispidum</i>	<i>Epipactis veratrifolia</i>	<i>Anacamptis pyramidalis</i>
<i>Iris petrana</i>	<i>Smyrniium connatum</i>	<i>Ophrys sphegodes</i>	<i>Orchis laxiflora</i>
<i>Iris nigricans</i>	<i>Scandix palaestina</i>	<i>Ophrys transhyrcanica</i>	<i>Ophrys vernixia</i>
<i>Iris edomensis</i>	<i>Seetzenia lanata</i>	<i>Ophrys apifera</i>	<i>Abutilon indicum</i>
<i>Iris postii</i>	<i>Atraphaxis spinosa</i>	<i>Ophrys oestrifera</i>	<i>Avicennia marina</i>
<i>Iris vartani</i>	<i>Ducrosia flabellifolia</i>	<i>Orchis simia</i>	<i>Hyphaena thebaica</i>
<i>Colchicum tunicatum</i>	<i>Zoegea purpurea</i>	<i>Orchis sancta</i>	
<i>Diplotaxis villosa</i>	<i>Lappula barbata</i>	<i>Capparis decidua</i>	
<i>Cousinia austrojordanica</i>	<i>Cytinus hypocistis</i>		
<i>Kickxia azaqensis</i>	<i>Anisosciadium lanatum</i>		
<i>Alyssum subspinosum</i>	<i>Daucus jordanicus</i>		
<i>Haplophyllum poorei</i>	<i>Biarum eximium</i>		
<i>Verbascum transjordanicum</i>	<i>Scandix turgida</i>		

Plant Genetic Resources Unit of NCARTT

As in most developing countries, the population of Jordan increases continuously, thus requiring big increases in the production of food and other agricultural commodities. Genetic diversity in general, and plant genetic resources in particular, are important in meeting this increased demand, and they need to be strengthened. By conserving genetic resources where they occur naturally (*in situ*), we can facilitate the natural process of evolution and adaptation, thus mitigating the effects of environmental and non-environmental problems. By conserving genetic resources in gene banks (*ex situ*), we can insure the continuing availability of a broad range of genes for crop improvement or for reintroduction in case of loss. Using this diversity, farmers and professional breeders can create crop varieties that are better able to adapt to changing environmental conditions, pests, and diseases, and thus ensure that we are able to meet the future food needs of Jordan and its rapidly growing population. Jordan has realized the high importance of conserving its national biodiversity and ratified the Convention on Biological Diversity (CBD) in 1992. The Convention highlighted three objectives: (1) conservation of biological diversity; (2) sustainable use of its components; and (3) equitable sharing of

benefits arising from the use of genetic resources. As a result, many international treaties have been signed aiming at conservation of biodiversity. In this context, Jordanian national programmes and/or centres realize that the functioning of a Plant Genetic Resources Unit is of high importance in order to handle, manage and follow-up the activities related to plant genetic resources. The Plant Genetic Resources Unit (PGRU) was established in 1993 at the National Center for Agricultural Research and Technology Transfer (NCARTT). The overall aim of the Unit is to study biodiversity and conserve (*ex situ* and *in situ*) plant genetic resources from deterioration and to make them available to users. This can be achieved through the following activities:

- (1) collection of plant genetic resources from their natural habitat and traditional users;
- (2) characterization and documentation of plant genetic resources in accordance with international rules;
- (3) biodiversity studies of the populations using morphological characters and molecular techniques (through separate research);
- (4) conservation of genetic resources by (a) storage of genetic material (germplasm material) for the short and long term, (b) conservation by means of herbarium specimens, and (c) *in situ* conservation; and
- (5) co-ordination with local, regional and international institutions through the exchange of information and plant materials (Table 51.2).

Table 51.2 Examples of joint activities between the Plant Genetic Resources Unit and International Institutes and internal programmes

Year	Activity	Institute
1989–1993	Collection	GRU – ICARDA
1991	Characterization	GRU – ICARDA
1995	Collection	GRU – IPGRI
1996	Conservation	GRU – UOJ (University of Jordan)
1996	Characterization	GRU – GTZ
1997	Collection	GRU – Rainfed program
1999	Exchange plant material	GRU – Yarmouk University & JUST
2000	Multiplication	GRU – Irrigated crops program
2001 →	Collection	GRU – Royal Botanic Gardens, Kew

GTZ – Gemeinschaft für Technische Zusammenarbeit

ICARDA – International Center for Agricultural Research in the Dry Areas

IPGRI – International Plant Genetic Resources Institute

JUST – Jordan University of Science and Technology

1. Gene Bank

1.1. Collection and conservation

Collecting activities in Jordan go back to 1952. Between 1952 and 1977 old cultivars of durum wheat were collected and deposited at the United States Department of Agriculture, USA and the Bari, Italy gene banks (Khairallah and Abu Laila, 1999). Following the establishment of ICARDA in 1978, intensive joint collection missions have been conducted by its staff with support or collaboration of Jordanian institutions, like NCARTT. The collected material concentrates on the groups of cereals, food legumes, forage legumes and their wild relatives. Because of a lack of *ex situ* conservation facilities (particularly cold stores) initially, the Jordanian plant material was held at the ICARDA seed bank. This equalled 3,966 accessions collected in the period 1989–1992. However, since the establishment of an operational gene bank at the PGRU at NCARTT in 1996, all of the previously collected plant material has been conserved by the PGRU in their country of origin. As a result, the number of accessions conserved has increased dramatically and numerous associated activities have been carried out (Table 51.3).

Table 51.3 Gene bank activities (1994–2001)

Year	Activity	Number of accessions
1993	Establishment of GRU	–
1994	Collection	16
1995	Preliminary conservation (training)	50
1996	Gene bank functioning – conservation & documentation	857
1997	Conservation at GRU of collections 1989–1996	1,031
1998	Collection, conservation and documentation (research output)	1,179
1999	Collection, conservation and documentation	1,214
2000	Collection, conservation and documentation	1,259
2001	Collection, conservation and documentation	2,243

In 2001, the NCARTT Gene Bank hosted 2,243 accessions representing 40 plant families, 122 genera and more than 204 species. This represents 8.2% of Jordanian species and around 0.08% of plant species in the world. The PGRU national Gene Bank is providing an *ex situ* conservation service for most of the national institutes. Various plant species and groups have been conserved, providing vital and documented material in sufficient quantities for users, like researchers, breeders and farmers (Tables 51.4 and 51.5).

The Genebank at NCARTT has the following facilities: (1) seed cleaning and processing laboratory; (2) two cold storage rooms, operating at 0 to 10°C and -10 to -20°C. Currently, the cold stores are able to hold 20,000 accessions and can be enlarged according to future needs.

Table 51.4 Plant groups conserved in the NCARTT Gene Bank and in the ICARDA Gene Bank

Accession group	Number of accessions (2001)
Forage legumes	347
Forage shrubs	146
Vegetables	399
Cereals	183
Fruit trees	177
Oil, medicinal, other use	25
ICARDA accessions – cereals, fodder, forage legumes (collected between 1989 and 1992)	3,966
Total	5,243

Table 51.5 Plant accessions borrowed from the NCARTT Gene Bank (1997–2001)

Year	Accession type	No. of accessions	Institute	Reason
1997	Eggplant	17	NCARTT	MSc. Research
1997	Okra	17	NCARTT	MSc. Research
1999	<i>Hordeum</i>	5	NCARTT	Research project
1999	Forage legumes	3	NCARTT	Research project
1999	Tomato	3	JUST	MSc. Research
2000	<i>Aegilops</i>	8	NCARTT	PhD. Research
2000	<i>Triticum</i>	19	NCARTT	PhD. Research
2001	Okra and eggplant	8	UOM	Teaching purposes
2001	Tomato	4	JUST	MSc. Research (tissue culture)
2001	Wild pear	1	JUST	MSc. Research
2001	<i>Hordeum</i> and <i>Triticum</i>	10	NCARTT	PhD research
2001	Tomato	48	NCARTT	Evaluation
2001	Eggplant	28	NCARTT	Evaluation
2001	Pepper	10	NCARTT	Multiplication

Total 181

UOM – University of Mu'ta

JUST – Jordan University of Science and Technology

1.2. Documentation

All accessions are documented on the computers and also written in books. The documentation software is still under modification since new database software was installed in the Unit with the help of the ICARDA Documentation Unit. This software will increase the ability to deal with data in a faster and more accurate way. It is also used in many gene banks in the ICARDA region, which facilitates transfer of data between different countries. The database uses visual FoxPro software, giving fast access to all passport data for all the accessions conserved, such as information on the accession, collection site, taxon, collectors, and current stock information. Since the gene bank started working only in 1996, the number of accessions in the gene bank is still small. However, considering that there are many new projects in the field of biodiversity and genetic resources evaluation and conservation, a significant increase in this number is foreseen.

1.3. Molecular biology laboratory

This laboratory was established and started functioning in 1997. The main objectives are the study and estimation of genetic variation and diversity of target plants and the application of DNA finger-printing techniques to the accessions conserved at the NCARTT Gene Bank.

1.4. Herbarium

The national herbarium holds >4,000 specimens, among which is a lot of material from Post and Dinsmore from the period of the late 19th Century up to 1940. The herbarium staff have produced many identification cards of the specimens in addition to some brochures of wild plants in Jordan, such as on *Salvia*, thyme and orchids.

2. The PGRU Work Plan

The PGRU has short-, medium- and long-term plans, which have been drawn up in relation to the strategic aims and priorities of the Unit. These are summarised in a series of text boxes (Boxes 51.2–51.05) for ease of reference.

Box 51.2 Short-term plan for PGRU, Jordan

1. Classification and documentation of the minimum required data for accessions: collection site; collection year; variety; name of collector; and the collection organization.
2. Propagating the accessions for use in hybridization and breeding programs.
3. Testing the viability of stored seeds and using advanced techniques for measuring the germination percentage.
4. Establishing a new system for arranging the stored seeds inside the cold stores according to international standards.
5. Providing extra cold stores for emergency and failures.
6. Giving the priority for conservation of plant species that are in threat of extinction in collaboration with other programs and research institutions.
7. Establishing a database for the herbarium to ease the dealing with its contents.

Box 51.3 Mid-term plan for PGRU, Jordan

1. Monitoring seed viability.
2. Increasing the quantity of conserved accessions and making them available for use to national scientific research and facilitation of the exchange of material with international institutes.
3. Managing work in the *in situ* genetic resource reserves/protected areas to ensure their safe maintenance.
4. Improving plant genetic resources conservation techniques, for example in relation to *in vitro* conservation of clonal material.
5. Carrying out diversity studies, such as on the allelic differences between the collected and conserved species using the biotechnology laboratory
6. Improving the herbarium as a national herbarium and developing a movable locker system for conserving plant specimens.
7. Improving the capability of the Gene Bank staff by providing MSc. and Ph.D. scholarships.

Box 51.4 Long-term plan for PGRU, Jordan

1. Developing the Gene Bank of NCARTT to be the authentic bank for conserving plant genetic material on a national scale.
2. Continue to follow-up and use recent developments in gene bank techniques.
3. Documenting and supervising *in situ* and *ex situ* plant genetic resources conservation sites such as:
 - plant genetic complexes
 - natural reserves
 - botanical gardens.
4. Co-operation with national and international institutes to exchange data and experiences on the best ways of using plant genetic resources to contribute in agricultural development.
5. Performing conservation techniques research.

Box 51.5 Strategy and priorities of the PGRU, Jordan

1. Systematic development of collections and repatriation of indigenous germplasm from foreign gene banks, if a duplicate does not exist in Jordan.
2. Transfer of germplasm from breeders and researchers to the national Gene Bank.
3. *In situ* conservation of plant resources in their natural habitats.
4. Assessing the socio-economic basis for the farmers' decisions regarding their choices of planting material.
5. Studies of genetic diversity among and within population of wild species and crop landraces.
6. Development of a natural genetic resources database.
7. Development of new plant genetic resources programmes.
8. Introduction of new plant genetic resources and safeguarding them.

References

- Al-Eisawi, D.M.(1983). Studies of the flora in Jordan. 10. Nine new species to the flora of Jordan. *Candollea* **38**: 359–364.
- Al-Eisawi, D.M.(1985). Vegetation of Jordan, pp. 45–57. In: *Studies in the history and archaeology of Jordan*.11. Ministry of Archaeology, Amman, Jordan.
- Al-Eisawi, D.M. (1988). *Resedaceae* in Jordan. *Botanische Jahrbuecher fuer Systematik Pflanzengeschichte und Pflanzengeographie* **110**: 17–39.
- Beskok, T. E. (1917). *Report to the Government of Jordan on forestry development*. UNDP/FAO.TA 3039, Rome, Italy.
- Boissier, P.E.(1867–1888). *Flora Orientalis. Five volumes and supplement*. H. Georg, Geneva and Basel, Switzerland; Lyon, France.
- Boulos, L. and Al-Eisawi, D.M. (1977a). Studies on the flora of Jordan. 6. On the flora of Ras En-Naqab. *Candollea* **32**:111–119.
- Boulos, L. and Al-Eisawi, D.M. (1977b). Studies on the flora of Jordan. 8. New and noteworthy plants. *Candollea*, **32**: 269–276.
- El-Oqlah, A.A. (1976). *A taxonomic study on the micro and macro morphological characters of indigenous Pistacia L. taxa in Jordan*. Ph.D., Istanbul University, Istanbul, Turkey.
- Harlan, J. R. (1970). Evolution of cultivated plants. In: O.H. Frankel and E. Bennett (eds). *Genetic resources in plants – their exploration and conservation*. Blackwell Scientific Publications, Oxford and Edinburgh, UK.
- UNEP and GE (1998). *Jordan country study on biological diversity, 1998*. The General Corporation for the Environment Protection (GCEP), Amman, Jordan.
- Kasapligil, B. (1956). *Report to the Government of the Hashemite Kingdom of Jordan on an ecological survey of the vegetation in relation of forestry and grazing*. UNESCO/FAO, Rome, Italy.
- Khairallah, K. and Abu Laila kh. (1999). *Biodiversity of Jordan*. Information paper submitted to the International Workshop on Strategies and Technologies for Conservation and Sustainable Use of Biodiversity in WANA. Egypt.
- Long, G. (1957). *The bioclimatology and vegetation of east Jordan*. UNESCO/FAO, Rome, Italy.
- Madany, M.H. (1978). *An ecological framework for a nature preserve system in Jordan*. BSc., Urbana, Illinois, USA.
- Poore, M.E.D. and Robertson, J.C. (1964). *An approach to the rapid description and mapping of biological habitats*. Sub-commission on Conservation of Terrestrial Biological Communities of the International Biological Programme, [London, UK].
- Post, G.E. (1932–1933). *Flora of Syria, Palestine and Sinai*. American University of Beirut, Beirut, Lebanon.
- Grunfleh, M.M., Arafah, M.M.S. and Zohary, M.(1962). *Plant life of Palestine*. Roland Press Co, New York, USA. 262 pp.
- Zohary, M. (1966–1972). *Flora Palaestina .Volumes I and II*. The Israel Academy of Sciences and Humanities, Jerusalem, Israel.

