Ecotoxicology and Climate
Edited by P. Bourdeau, J. A. Haines, W. Klein and C. R. Krishna Murti
© 1989 SCOPE. Published by John Wiley & Sons Ltd

4.2 *Effects in Arid Regions*

A. S. AND R. Y. PERRY

4.2.1 INTRODUCTION

An agro-ecosystem is a complex entity comprising a number of elements which interact with one another to form and stabilize the system.

An arid ecosystem differs in many respects from one of tropical or temperate zones. Unlike temperate zones, an arid zone is characterized as an area of low precipitation, high temperature, and high rate of evaporation. Frequency of rainfall does not describe accurately the type of the arid zone nor does the amount of precipitation govern the type of vegetation. Nevertheless, precipitation serves as a criterion for the subdividing of arid zones. In the broad sense, 57–300 mm mean annual rainfall is typical of an arid zone, while 300–550 mm is that of a semi-arid zone (Thornthwaite, 1948; *see* Figure 4.2.1).

The dry climate of the world occurs in five great geographical areas lying between 15° and 35° latitude. The largest of the five, known as the African-Eurasian Dry Zone, includes the Sahara desert from the Atlantic coast, extending eastward to the Arabian Peninsula, Pakistan and India; northward, it includes Iran and southern Russia, and still farther north, it includes Chinese Turkestan and Mongolia. The southern margin includes the semi-arid zone, the so-called 'Sahel' (Meigs, 1953). This vast region includes also the Middle Eastern arid zone and that of Israel.

Typically, the arid zone of Israel is characterized as a desert with a very low rainfall, low relative humidity, high solar radiation, and high potential for evaporation (Evanari *et al.*, 1971). In considering the complexity of the arid ecosystem of the land, one must take into consideration physical, chemical, and biological parameters such as air, water, soil, biota, and vegetation.

4.2.2 THE ARID ECOSYSTEM OF ISRAEL

The arid zone comprises mainly the Negev and the Arava regions extending north to the Jordan Valley and leading to the southern edge of Lake Kinneret (The Sea of Galilee).

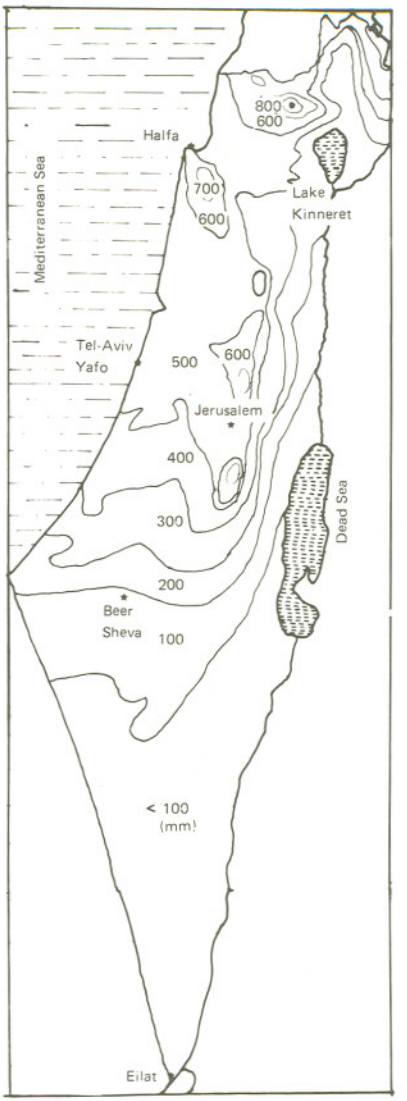

Figure 4.2.1 Climatic regions of Israel. Mean annual rainfall (mm). From Atlas of Israel. Reprinted with permission from Survey of Israel

The Negev comprises a total area of 1 186 000 ha, the Arava a total area of 193 400 ha, or 56.4% and 9.22%, respectively, of the total area of Israel.

4.2.2.1 The Climate

The desert of Israel extending south of Be'er Sheva to the city of Eilat consists

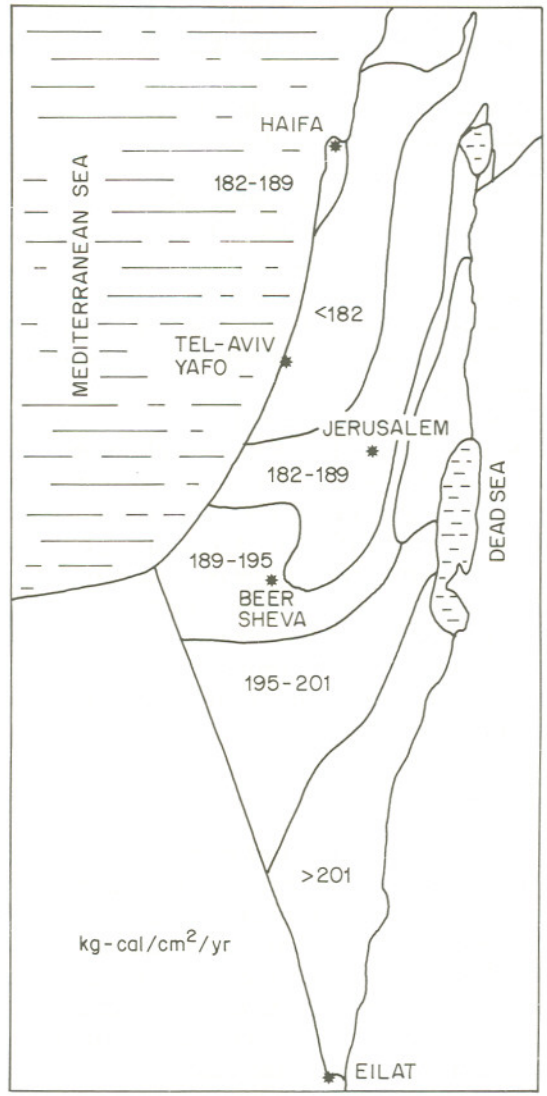

Figure 4.2.2 Solar radiation incident on horizontal surface. Annual mean (kg-calories/cm^2/year). From Atlas of Israel (1970). Reprinted with permission from Survey of Israel

of two distinct climatic ecosystems, i.e. the Negev and the Arava. These areas are characterized by high temperatures exceeding 30°C for a good part of the year, e.g. at Eilat 206 days of the year register maximum daily temperatures exceeding 30°C. This is defined as 206 tropical days (Atlas of Israel, 1970).

Relative humidities average 50% in January (the coldest month) to 28% in July (the hottest month). The average yearly rainfall in the central Negev ranges

between 28 and 168 mm, with an average of 86 mm (Atlas of Israel, 1970: Evenari *et al.*, 1968). Further south in the Arava desert, the yearly rainfall rarely exceeds 100 mm.

The desert of Israel is one of the sunniest areas of the world, having 200 or more cloudless days during the year. Consequently, solar radiation is received in an even manner and is quite intense (*see* Figure 4.2.2).

Strong north winds abound in the southern Negev during the summer months. Primarily in spring but also in autumn, easterly winds from the Sahara Desert move toward the most part of Israel but are felt more strongly in the desert area. These winds, called 'sharav' or 'hamsin', are hot dry desert winds carrying sand and dust particles and can raise the temperature up to 42°C. The Meteorological Service classifies light sharav as a day on which mean relative humidity is lower than 45% irrespective of temperature. A heavy sharav is defined as a day on which mean relative humidity is lower than 20% and mean daytime temperature is above its long-term monthly mean (Lomas and Shashoua, 1974). The number of sharav days in a year varies from a few days to 34 days in the wheat-growing region of the northern Negev. These winds have been reported to have a damaging effect on agricultural production in this region.

Concerning vapour pressure, the lowest values occur in the mountains, decreasing to a minimum of 10–12 mb on an annual average. In the central and southern parts of the Negev, the values are 13.6 and 12.8 mb, respectively. The annual run of vapour pressure forms a simple wave more or less parallel to that of temperature, i.e., high values in July–August, low values in January–February (Atlas of Israel, 1970).

4.2.2.2 Soil and Water

The soil in the arid zone is characterized by neutral or high pH (7.0–8.7), high calcium carbonate content, and low organic matter. Several soil types occur in the desert region, some of which can be utilized for agriculture. One of the obstacles to utilization of such soils is the high salt content (generally 0.15–2.0% or greater), mainly in the form of NaCl but also $CaSO_4$. To obviate such an obstacle, the need for irrigation water becomes paramount. Hence, the development of agricultural enterprises in the arid zone is primarily a function of the availability of water for irrigation. A portion of the water supplied by the National Water Carrier is relatively high in chloride content (about 250 mg/litre). This, coupled with low rainfall and the lack of leaching due to water shortage all contribute to the accumulation of salts in the soil profile (Bielorai and Levy, 1971). Detailed information on soil types and other parameters is given in the Atlas of Israel (1970).

4.2.2.3 Biota

Very few vertebrate species are found throughout the entire country. The species which occur under desert and semi-desert conditions include jirds and gerbils, the

Levant vole (*Microtus guntheri*), Tristram's jird (*Meriones tristrami*), and the ancestor of the house mouse, *Mus musculus praeraxtus*. These rodents periodically undergo explosive population outbreaks and could become agricultural pests. Indeed, the house mouse (*Mus musculus*) has recently become a major pest of green peppers in the desert region (Zook-Rimon, 1985).

Other mammalian, reptilian, and avian species include Baluchistan's gerbil, Cairo spiny mouse, fat jird, Negev jird, Ethiopian hedgehog, Egyptian dabb-lizard, Turkish gecko, Sinai agama, tropical cat-snake, crown-necked raven, Sinai rock partridge, and Desert partridge. Of seven species of poisonous snakes in Israel, six inhabit the desert and semi-desert areas. *Aspis vipera* occurs in the Arava (Atlas of Israel, 1970).

4.2.2.4 Vegetation

In the desert areas where mean annual rainfall is 150–300 mm, there exists almost no arboreal climax community. The vegetational landscape is characterized by poor but more or less continuous grey dwarf-shrub formations. In the areas where mean annual rainfall scarcely reaches 150 mm, vegetation is rare and patchy, mainly being limited to seasonal stream beds.

Trees occur only near permanent water bodies or in otherwise favourable habitats. Native desert vegetation includes principally the genera *Tamarix*, *Iris*, *Acacia*, and *Pistacia*. The genus *Tamarix* is represented in Israel by 11 indigenous species. All species require large amounts of moisture, which they obtain through their exceedingly long roots. Tamarisks are very useful in dune fixation and afforestation of deserts and salt pans, and as windbreaks and sea spray inter-ceptors. The genus *Acacia* includes four species, of which three are found in the desert areas. In the Arava valley, the most impressive feature of the landscape is the acacia pseudosavannah, comprising mainly *Acacia raddiana* and *A. tortilis*. One of the largest tropical oases of the northeastern corner of the Arava displays no less than 40 tropical species of plants. Halophilous shrubs dominate the vicinity of the Dead Sea and the Eilat-Timna segment, where extensive salt flats occur (Atlas of Israel, 1970). A complete and beautifully illustrated book on the flora of the Negev and Sinai desert, including edible native vegetation, has been published by Danin (1983).

4.2.3 AGRO-ECOSYSTEM

Agricultural development in arid zones must take into consideration, in addition to everything else, the shortage of natural resources. One of the typical features of the arid or semi-arid zones is the lack of geographical proximity between agriculture's two main natural factors of production—land and water. In Israel, most of the arid land and all of the water resources are state-owned. This facilitates water development from an economic viewpoint. The National Water

Carrier, whose source is Lake Kinneret (The Sea of Galilee), is responsible for supplying water to the farmers in the arid zone at relatively low cost. In addition to the supply of natural water, waste water can be used as a source of irrigation water in arid areas. Sewage water contains a considerable quantity of nutrient elements for plant growth, including a high nitrogen content, in addition to large quantities of organic matter and of trace elements. These waters represent a valuable nutrient source and can improve the structural and physical properties of soils in the arid region (Yaron *et al.*, 1983). Agricultural production for irrigated areas in the arid zone can attain full self-sufficiency in fruits and vegetables and other agricultural commodities. Obviously, this would entail substantial capital investment.

4.2.3.1 Effect of Irrigation

Introduction of water into an arid land inevitably will convert that area into an agro-ecosystem typical of the particular crop to be grown. Concurrently, changes will occur in the diversity of insect fauna as well as in the ecology of the insect dwellers of the arid zone. A typical example is the creation of an environment favourable for *Schistocerca gregaria*, where irrigation satisfies the moisture requirements for oviposition while vegetation becomes more abundant for supporting larger nymphal populations (Shulov, 1952; Popov, 1958; Stower *et al.*, 1958). Another example occurs during the period of the dry desert winds in springtime, when a mass migration of *Thrips tabaci* (Lindeman) takes place from the withering uncultivated vegetation to the irrigated fields of peanuts and cotton. Later in the summer the insects disappear from these crops (Rivnay, 1964). Bishara (1932) in Egypt pointed out that heavier outbreaks of *Agrotis ypsilon* (Rottenburg) took place in irrigated rather than non-irrigated fields. Likewise, greater infestations in irrigated fields by *Prodenia litura* (Fabricus) and by *Spodoptera exigua* (Hubner) in alfalfa, cotton, and peanut fields in Israel have been reported (Rivnay, 1964). Other insects, such as *Psallus seriatus* (Reuter), *Adelphocoris rapidus* (Say), *Lygus lineolaris* (Palisot de Beauvois), and *Tetranychus telarius* (Linnaeus), as well as leafhoppers on alfalfa caused more damage in irrigated than in non-irrigated plants (Adkisson, 1957). *Hylemia cilicrura* (Rondani) ordinarily oviposits in humid ploughed earth. The eggs and larvae are not capable of living in an arid soil and this is the reason why the fly does not exist in its larval stage in summer in Israel (Yathom, 1961). However, as a result of irrigation, several crops, such as peanuts, cotton, and water melon, may become infested.

Irrigation may also interfere with the normal life history of subterranean insects. In Israel, moisture causes the termination of diapause of scarabaeid larvae of the genera *Phyllopertha* and *Anisoplia*. In regions where rainfall is below 300 mm diapause is usually terminated toward the end of December and early January. The recent practice of early irrigation of winter crops in this region

in November has caused an earlier diapause termination of the larvae with a consequence of serious economic damage (Rivnay, 1964).

The type of irrigation may also create different ecological conditions for certain insects. For example, the eggs of *Raphidopalpa foveicollis* (Lucas) are laid in the ground around the stem of the plant and they need contact with moisture for successful development. Ditch irrigation does not provide such favourable conditions for the eggs as overhead irrigation does. Thus, in the latter type the beetles become more numerous. However, in this case, the excessive moisture around the plant is not conducive to healthy larval development, which normally takes place in the soil. Hence, the larvae migrate to the top surface where they attack the fruit with devastating results (Rivnay, 1964). In Israel, drip irrigation is now being practised for many irrigated crops. This new type of irrigation consists of partial wetting of the soil aiming particularly at the root zone only. Systemic pesticides can also be applied with this system, thus minimizing the amount of pesticide used and the extent of leaching. Irrigation water for the Negev comes from the north, but the western region and the Arava contain an abundance of underground water which is saline. Using such water for irrigation, although causing no damage to the plant itself, can be a potential pollutant to the arid zone. This is due primarily to the high Na/Ca ratio which has an adverse effect on soil properties (Yaron *et al.*, 1985). Under desert conditions such irrigation, although favourable from the standpoint of water conservation, may accentuate a change in the ecological conditions of insect life, resulting in adverse effects on crop production and necessitating perhaps more extensive applications of chemicals for pest control.

4.2.3.2 Effect of Other Agricultural Practices

As new virgin land is being exploited for agriculture it is anticipated that many changes will take place in the fauna and flora of that ecosystem. With the introduction of new crops not indigenous to the area, various insect pests may migrate to such territories and cause considerable damage. The abundance and continuity of food brought about by the application of agrotechnical methods inevitably will create favourable ecological conditions for insect development, resulting in outbreaks of pests. Many such examples are known (Rivnay, 1964). Soil temperature has a definite influence on the microclimatic conditions affecting the development of soil-dwelling insects. In semi-arid or more temperate zones the tobacco white fly, *Bemisia tabaci* (Gennadius), is a severe pest of tomato seedlings, cotton, and many other crops in the summer months. The adult insects can withstand temperatures of up to 45°C, but if the soil temperature reaches above 46°C, they will succumb to the intense radiation.

Mulching the soil may have the same effect on insect survival. An excellent example of this agrotechnical practice is thermal sterilization of the soil against soil insects and weed germination. This is accomplished by watering the soil

and then covering the area with transparent polyethylene sheets. After several days this raises the soil temperature to 70°C or higher, thus burning the seeds that had germinated and killing soil pests, such as fungi (Katan *et al.*, 1976b). This type of treatment obviates the use of methyl bromide, which is used extensively for soil sterilization in the north, in the temperate zones as well as in semi-arid and arid agro-ecosystems.

The thermal sterilization of the soil as outlined above has some severe limitations with regard to incorporation in most crop rotations due to the long period of solarization needed to obtain effective control, thus delaying the growth period of the crop itself. However, a more important reason is the cost of treatment. Solarization of the soil for control of soil-borne pests costs approximately $1500 per hectare. Treatment with metham-sodium, which provides good control of the soil-borne pathogens, costs only $210–420 per hectare, and methyl bromide treatments, such as those used extensively by most growers, cost only $350 per hectare (Krikun *et al.*, 1982).

4.2.3.3 Environmental Effects on Plant Growth

In general, plant growth in arid zones is subjected to damage more from natural sources than from introduced contaminants due to man's activities.

(a) Injury due to natural sources

In planning agricultural enterprises in the desert region, one must select plants that can withstand certain natural environmental conditions, such as sandstorms. Many plants are susceptible to injury by sandstorms, especially leafy vegetables such as curcurbits. The injury is mainly due to strong winds and sand particles which cause abrasion of the leafy surfaces of plants. Lack of vegetation in the desert is one of the primary causes of sandstorms: this lack results in the destabilization of the soil surface, which then becomes windblown. In the northern Negev, the amount of suspended particles in the air can reach three to four times the normal amount in the air. Most of these particles are larger than 100 μm. The problem becomes more acute further south (Lerman, 1985).

(b) Injury due to introduced industrial contaminants

Introduced contaminants may arise from the establishment or relocation of chemical industries from highly populated areas to desert regions. Pollution emanating from fossil fuel, photo-oxidants in the atmosphere, by-products from pesticide industries, flying ash from power plants, waste-water effluents from industrial plants, etc., may cause significant injury to plant growth. In the arid zone, acid rain is not a serious problem due to the alkalinity of the soil. However, flying ash with a high sulphur content (4% sulphur) produced by an electrical

plant in the desert area has caused corky tissue of citrus fruit. Flying ash can also have a detrimental effect on cotton fibre (Lerman, 1985). Moreover, flying ash can contain as much as 12% of coal as residue as well as 12% of heavy metals such as molybdenum and selenium. With a high pH in an arid environment, movement of heavy metals is deterred, thus the metals remain more or less confined to the soil surface. The significance of heavy metals in flying ash may become more acute in agricultural areas when residues which normally remain on the soil surface are ploughed in and become available to plant roots (Yaron *et al.*, 1985).

The concentration of heavy metals in domestic effluent is fairly low and is usually within a pH range of 7.0–7.5. It is anticipated, therefore, that under such conditions no detrimental effects would result. However, in light and coarse soils, which are characteristic of arid land, the metals in the effluent might move more freely and penetrate into deeper layers of the soil, thus becoming more available to the plant (Yaron *et al.*, 1985).

Excessive build-up of bromine occurs in native vegetation as a result of emission from a nearby pesticide industry. Theoretically, desert plants, such as *Tamarix* spp. and *Eucalyptus* spp., seem to be more tolerant to air pollution. However, a potential danger exists in the unwariness of the chemical industries spewing man-made pollutants into the desert atmosphere.

Suffice it to say that man-made pollution is not characteristic of desert regions but is typical of man's intervention in other ecosystem types.

4.2.3.4 Pesticides in the Desert Agro-ecosystem of Israel

The limited availability of agricultural land and the need for irrigation necessitate the use of intensive agricultural practices for crop production in Israel. Such practices are conducive to creating favourable conditions for soil-borne pathogens, which can cause great damage to crops if left uncontrolled. Pathogenic fungi, such as *Verticilium dahliae* and *Macrophomina phaseolina*, and the root-cortex-invader nematode, *Pratylenchus thornei*, are especially injurious to many crops (Krikun *et al.*, 1982).

Of particular interest is the influence of *Pratylenchus thornei* on wheat growing in the Negev desert region. Winter-sown wheat is grown in this area to utilize the sparse rainfall (200–250 mm) during the winter months. In cases where soil treatments were made with vaporized methyl bromide or with sprinkler irrigation-applied metham-sodium, which effectively controlled the nematode, the plants had higher leaf water potentials, increased water use efficiency, increased nitrogen uptake, and highly increased yields (Amir *et al.*, 1982). This led to the conclusion that under nematode attack the roots were unable to take up the scantily available water as efficiently as the non-parasitized roots, leading to a significant decrease in yield. In non-treated soils the pathogen builds up rapidly due to the low organic matter and relatively dry soil conditions which,

Table 4.2.1 Effect of metham-sodium application on crop yield and on pathogen eradication. From Krikun *et al.* (1982). Reproduced with permission of the Agriculturist Research Organization

Crop	Pathogen	Concentration of metham-sodium (ppb) μg/l a.i.	% Pathogen eradication	% Increase in yield	Absolute increase in yield (tonne/hectare)
Wheat	*Pratylenchus thornei*	160	100	48	1.76
Onion	*Pratylenchus thornei*	320	100	23	12.17
Potato	*Pratylenchus thornei*	160	85	25–29	7.7–12.2
Onion	*Pratylenchus terrestris*	320	84	>3.5 cm diam/45	5.5
				<3.5 cm diam/328	34.8
Peanut	*Pratylenchus myriotylum*	320	–	69	2.46

in turn, lead to low microbial activity and reduced antagonism. Another important factor is the poor mycorrhizal development in the affected plants, which leads to root cortical necrosis (Krikun *et al.*, 1982). Control of the nematode has made it possible to extend the wheat growing area further south to regions of lower soil moisture content. The effect of metham-sodium application on crop yield and on pathogen eradication is shown in Table 4.2.1.

4.2.3.5 Fate of Pesticides in the Environment

The disappearance of chemicals from the environment is due directly or indirectly to chemical, photochemical, physical, microbiological, and to higher plant and animal metabolic degradations. Chemical degradation of pesticides in soils is governed by a variety of factors, such as pH, presence of water, and the presence of various catalysts and reagents capable of attacking reactive compounds.

(a) Photochemical decomposition of pesticides

It is well known that light in the ultraviolet (UV) region of the spectrum contains energy capable of inducing chemical transformation in a variety of compounds able to absorb energy. Many insecticides, such as chlorinated hydrocarbons, organophosphorus esters, carbamates, pyrethroids, rotenone, and others have been shown to undergo photoreactions to form products that are either more toxic or less toxic than the parent compounds (Rosen *et al.*, 1966; Rosen, 1972; Robinson *et al.*, 1966; Chen and Casida, 1969; Crosby, 1972a, 1972b;

Khan *et al.*, 1974). Ordinarily, photolysis takes place only on the surface and is more pronounced on water surfaces. In the deepest layers of soil, photolysis is not a major process. However, the high surface temperatures of arid soils may cause a higher rate of volatilization of pesticides. Most of these photolytic reactions have been studied in the laboratory under simulated conditions. Hence, extrapolation of these data to actual field conditions should be done with reservation.

Under conditions of an arid environment where summer temperatures reach 35°C and higher it is anticipated that photoreactions will take place with greater intensity in comparison with temperate regions. In the arid regions of Israel more than 200 days per year are quite cloudless (15–26% cloudness) and are of high-intensity radiation. It is likely that photodecomposition of pesticides will take place more rapidly under these conditions but such data have not been documented by field experimentation. The toxicity of certain compounds may be enhanced by solar radiation. A recent example is the solar radiation-induced toxicity of anthracene to *Daphne pulex* (Allred and Giesey, 1985). Several classes of herbicides, too, undergo photodecomposition (Crosby and Li, 1969; Yaron *et al.*, 1984). Loss of herbicidal activity of organoborates under arid conditions has also been linked to sunlight (Rake, 1961). The difficulty in demonstrating clearly that many herbicides as well as insecticides undergo photodecomposition in the field is due to the fact that many of the products formed are identical with those produced by metabolic processes of plants and microorganisms. However, there is little doubt that photodecomposition of pesticides takes place in the field and that this phenomenon could play an important role in the disappearance of such chemicals from the environment (Kilgore, 1975). In this respect pesticide residues might be of less consequence in arid environments than in temperate regions.

(b) Physical factors

Volatilization is not necessarily a factor directly responsible for the disappearance of pesticides from the environment, but it is a means of transporting a pesticide from a region of inactivity to an environment more conducive to degradation (Kilgore, 1975).

Moisture lowers the persistence of pesticides in the soil, either by aiding their evaporation, by hydrolysis, by catalyzing photolytic reactions, by participating in the reduction of pesticides, or by enhancing their decomposition by microorganisms (Bowman *et al.*, 1965; Harris and Lichtenstein, 1961; Lichtenstein and Schulz, 1960, 1964; Crosby, 1972a, 1972b; Matsumura and Benezet, 1978; Cripps and Roberts, 1978; Woodcock, 1978). In submerged soils decomposition of pesticides proceeds at a faster rate (Sethunathan, 1980).

The soil of the Negev desert, though poor in organic matter shows a high level of microbiological activity, at least during the rainy season in winter, in

spite of a decrease in the average air temperature, which falls to 10–12°C. Beginning March-April there is a drastic fall in microbiological activity which lasts throughout the summer months. This fall in activity occurs over the entire soil profile excluding the lowest part where microbial activity is minimal throughout the year (Buyanovsky *et al.*, 1982). Disregarding other factors, decomposition of pesticides in arid soils with low moisture content will take place at a slower rate. On the other hand, high soil temperatures increase the tendency of pesticides to vaporize or decompose. The interplay between these two parameters, i.e. soil temperature and soil moisture, most likely will determine the rate at which pesticides will disappear from arid soils or will decompose to less bioactive compounds.

4.2.3.6 Arid Zone as an Effective Storage Environment for Cereal Grains

The high temperature and low humidity of the desert climate provide an excellent environment for the airtight storage of grains. Utilizing the principle of airtight or hermetic storage of grain (Hyde *et al.*, 1973), experiments were carried out in the northern Negev to determine the feasibility of storing grain in bulk under conditions of high temperature and low humidity. Wheat of 11.4% moisture was stored in airtight PVC-covered bunkers formed by a polyethylene liner at its base and a UV-resistant PVC sheet over the surface of the grain. Within three months the O_2 concentration fell to 6% and the CO_2 concentration rose to 9%. Under these conditions insects were controlled before they could cause significant economic damage to the grain. Wheat damage attributed to insects was estimated at 0.15% and that to moulds at 0.06% (Navarro *et al.*, 1984). It appears that the desert with its long hot dry summers, mild winters, and low rainfall, is an excellent environment for the temporary and long-term storage of grain.

4.2.3.7 A Typical Example of a Desert Crop—The Date Palm

(a) Insect pests of date palm trees and their control

The green leafhopper is known as one of the main pests of date palms in the Near East and North Africa. The insect causes damage to the tree by sucking the sap and by exuding large amounts of honeydew. The leafhopper identified as *Ommatissus binotatus* (Fieb.) var. *lybicus* (De Berg) of the family Tropiduchidae was first detected in Israel in 1981 and by 1983 it had spread throughout the entire region of the Arava desert. There was no sooty mould development on the honeydew and there is no evidence to date of direct damage to the tree, except for the accumulation of large quantities of sugars emanating from the trees in response to the insect's attack.

Control experiments with systemic insecticides, such as Temik (Aldicarb), butocarboxime, Rogor (dimethoate), and deltamethrin, applied to the soil

following drip irrigation showed that the leafhopper can be effectively controlled for a period of six months or more with a single spring application of the first three compounds. Deltamethrin was ineffective. Control plots showed the presence of large populations of the leafhopper except in May when there was a drastic fall in population density due to extensive damage to the insects caused by sandstorms (Aharonson *et al.*, 1984). Chemical analyses showed that Aldicarb and butocarboxime are effectively absorbed by the roots and are translocated in substantial quantities to the leaf blades and fruit where they persist for relatively long periods of time (Tables 4.2.2. and 4.2.3). Only after 150 days from the start of treatment was a noticeable reduction in residues obtained, approximating to 1–3 ppm. By analogy with the persistence of Aldicarb and butocarboxime in cotton, citrus, peaches, etc., the rate of disappearance of these compounds from date palm is slow. Dimethoate might be less persistent but this has to be ascertained (Aharonson *et al.*, 1984). Butocarboxime has an advantage over Aldicarb in that its toxicity to warm-blooded animals is much lower (200 mg/kg vs. <1.0 mg/kg, respectively). Consequently, its allowable residue in the fruit could be higher.

Table 4.2.2 Persistence and disappearance of the systemic insecticides Aldicarb and butocarboxime in the leaf blades of the date palm following their application to the soil close to the drip irrigation. Data from Aharonson *et al.* (1984). Reproduced with permission

Days after application	Aldicarb (ppm)		Days after application	Butocarboxime (ppm)
	30 g a.i./tree	60 g a.i./tree		100 g a.i./tree
24	9.8 ± 4.8	8.1 ± 2.1	32	30.1 ± 12.0
54	6.3 ± 0.5	5.7 ± 1.8	63	40.0 ± 14.0
85	2.0 ± 0.1	3.4 ± 1.0	123	23.3 ± 13.0
145	1.5 ± 0.2	2.6 ± 0.2	150	2.1 ± 1.2
172	0.5 ± 0.1	0.8 ± 0.1		

Table 4.2.3 Persistence and disappearance of Aldicarb and butocarboxime in the fruit of the date palm following their application to the soil close to the drip irrigation. Data from Aharonson *et al.*. (1984). Reproduced with permission

	Aldicarb (ppm)			Butocarboxime (ppm)	
Days after application	30 g a.i./ tree	60 g a.i./ tree	Days after application	100 g a.i./tree (experim. plot)	100 g a.i./tree (commerc. plot)
145	1.0 ± 0.1	–	42	–	3.0 ± 0.1
172	1.1 ± 0.1	1.9 ± 0.6	57	–	4.9 ± 0.2
			123	2.7 ± 0.5	–
			150	1.9 ± 0.3	–

One of the most serious scale insect pests of date palms is the Parlatoria date scale, *Parlatoria blanchardi* (Targ.). Damage is reflected in leaf withering, tree stunting, and infestation and disfigurement of the fruit, which greatly reduces its quality. Severe population explosions of this insect occurred following extensive spraying of the arid zone with chemicals for control of locusts and other pests, thus upsetting the biological equilibrium. Chemical control with 0.5% Rogor WP alone or in combination with 2% oil emulsion has given satisfactory results when used as an adjunct to a pest management programme (Kehat *et al.*, 1974). The main approach is biological control with two parasite species which keep the scale populations under control.

Other scale insects of lesser importance include *Asterolecanium phoenicis* (Green), *Saissetia privigna* (De Lotto), and *Aonidiella orientalis* (Newstead).

The pineapple mealybug, *Dysmicoccus brevipes* (Cockerell), a serious pest of pineapple, has recently been found on date palm trees in the Arava Valley. Populations of this insect occur throughout the year on the adventitious roots at the base of the trunk but causing no apparent damage. Occasionally, in late summer the mealybugs migrate upward to the ripening bunches, infesting the dates and causing great damage (Ben-Dov, 1985).

The raisin moth, *Cadra figulilella* (Gregs.), is one of the most important pests of dates in Israel. It inflicts considerable damage to the fruit from the beginning of ripening to picking time. Damage also occurs in storage if fruit is not fumigated. The insect is successfully controlled by several insecticides with the exception of cryolite (Table 4.2.4). Mechanical prevention of insect attack by covering the bunches with wire netting gives excellent protection against infestation. DDVP-treated strips (25% a.i.) were most effective and gave better protection than lindane, naphthalene, DBCP, and EDB (Kehat *et al.*, 1969).

The date stone beetle, *Coccotrypes dactyliperda*, and the sap beetle, *Carpophilus* spp., are considered to be economic pests of dates in the arid Jordan Valley but not in the arid Arava (Kehat *et al.*, 1974). Despite the establishment

Table 4.2.4 Percentage of infested date fruits following spray treatments with various insecticides

Treatment	Variety and site	
	Zahidi, Eilat	Deglet Noor, Yotvata
None (Control)	63.6	49.2
Cotnion 20 E.C. (azinphosmethyl) 0.5%	3.0	2.1
diazinon 25 E.C. 0.5%	11.0	0.8
malathion 50 E.C. 0.2%	19.0	1.6
Matacil 75 W.P. (aminocarb) 0.2%	–	3.7
Lebaycid 50 E.C. (fenthion) 0.15%	–	5.6
Dipterex 80 S.P. (trichlorfon) 0.3%	14.4	8.0
Rogor 40 E.C. (dimethoate) 0.3%	15.0	–
cryolite (44%) 1%	53.5	37.0

of an integrated pest management programme control of these insects requires four to five insecticide treatments during the season, a practice which interferes with biological control of other pests (Blumberg and Kehat, 1982).

(b) Mesurol residues in dates

Mesurol (Methiocarb) is licensed in Israel for use as a bird repellent in flowers, vegetables, beets, etc., and for the control of molluscs in flowers, ornamentals, citrus fruits, subtropical fruits, etc.

Palm trees received an application of 1% Mesurol WP at a rate of 5 gallons/tree for bird repellency six weeks prior to harvest. Chemical analysis by HPLC of six samples of fruit at harvest time showed concentrations of 1.85–7.3 ppm of the parent compound. These concentrations at harvest time were considered too high; therefore, the applications were discontinued (Adato, 1984).

The persistence of Mesurol under these conditions might be due to its high rate of absorption, its low rate of volatilization, and its high resistance to photolytic decomposition.

4.2.3.8 Insects Attacking Mango Trees

The mango thrips, *Scirtothrips mangiferae* (Priesner), has become established in Israel since 1975 and is considered the most damaging pest of mangoes in the arid Arava Valley. The thrips damage the new shoots of the trees causing the young leaves to curl along the midrib, thus distorting their shape and leading to their premature drop. No damage to fruit has yet been reported. Good control for a period of two to three months was achieved using 0.2% tartar emetic fortified with 0.3% sugar as a full-coverage bait spray. Equally good control has been achieved with cypermethrin. Control of the thrips with thionex (endosulfan), phosphamidon, and fenthion gave less satisfactory results owing to their short duration of action and the apparent development of resistance to these compounds after several treatments (Venezian and Ben-Dov, 1982; Ben-David *et al.*, 1985).

Additional host plants for the pest, including pomelos and grapevines, have recently been observed in the Arava Valley.

Other insects attacking mango trees but causing little damage include the Oriental red scale, *Aonidiella orientalis* (Newstead), a cosmopolitan and polyphagous diaspidid common in mango orchards along the Arava Valley, generally controlled biologically by *Habrolepsis aspidiotti* (Compere and Annecke), *Saissetia privigna* (De Lotto), and *Asterolecanium phoenicis* (Green) (Ben-Dov, 1985). Chemical control of these insects is being avoided for fear of potentially serious consequences to their natural enemies. The latter have, so far, maintained a good biological balance and have kept the scale populations under control.

4.2.3.9 Polychlorinated Biphenyls (PCBs)

Considerable amounts of PCBs are carried to the Mediterranean by aeolian transport (Elder *et al.*, 1976). PCBs are highly stable chemically, being resistant to thermal degradation and hydrolysis but are susceptible to photolysis (Herring *et al.*, 1972; Hutzinger *et al.*, 1972).

In areas of high water temperatures or high winds, surface evaporation will increase resulting in lower levels of PCBs in sea water (Elder and Villeneuve, 1977). However, wind-borne PCBs may be carried to desert areas and contaminate the fauna and flora of these regions.

4.2.3.10 Pesticide Usage in the Arava Region

Mention has been made of the fact that the introduction of new agricultural crops in the desert agro-ecosystem inevitably will require the use of large quantities of pesticide chemicals. Many such crops, e.g. watermelon, several varieties of melon, corn, cauliflower, tomato, eggplant, seed onion, onion, and green pepper, have been introduced in the past few years. The total acreage of the above crops is given in Table 4.2.5.

Obviously, the success of growing these crops, as in other climates, depends on using large amounts of pesticides and fertilizers. A wide variety of herbicides, insecticides, and fungicides are being used on these crops. A list of pesticides in use is presented in Table 4.2.6.

In some instances several fungicides are used together in cocktail form. For example, tomatoes are sprayed 5–6 times during the season with a cocktail consisting of triadimefon, chinomethionat, triforine, and fenarimol. Another example is an insecticide mixture consisting of cypermethrin, methamidophos, and chlorpyrifos which is used on green pepper and eggplant.

Table 4.2.5 Types and total acreage of crops grown in the Arava region. Dayan (1987). Reproduced with permission

Crop	Number of hectares	
	Spring cultivation	Full cultivation
Watermelon	201	–
Melons	280	327
Corn	22	–
Cauliflower	12	–
Tomato	27	218
Onion	11	220
Pepper	–	257
Eggplant	–	56
Others*	12	35
Total hectares	565	1113
Grand total (ha)	1678	

*Cucumber, squash, garlic, sweet potato, asparagus, seed onion

Table 4.2.6 Types of herbicides, fungicides and insecticides used on various crops in the Arava region. (Adler (1987). Reproduced with permission

Herbicides	Fungicides	Insecticides
Metribuzin	Maneb	Cypermethrin
Isopropalin	Mancozeb	Methamidophos
Oxadiazon	Triadimefon	Chlorpyrifos
Ethalfuralin	Chinomethionat	Propargite
Diphenamid	Triforine	Cyhexatin
Nitrofen	Fenarimol	Dicofol
Chlorthal dimethyl	Iprodione	Fenpropathrin
Pendimethalin	Vinchlozolin	Endosulfan
Alachlor	Dimethrimol	Chlorobenzilate
	Imazalil	DDVP
	Pyrazophos	Methomyl
	Tridemorph	Phosphamidon
	Benomyl	Ethiofencarb

As yet no major environmental problems have arisen in the desert from the usage of such large quantities of pesticides. However, there is no way of predicting future adverse effect on the environmental quality of the desert as more and more crops are introduced and larger quantities of chemicals are used.

A problem of major importance in the Arava is the existence of large numbers of the rodent, *Mus musculus*, as mentioned earlier the ancestor of the house mouse. This causes extensive damage to green pepper. At present, the rodent is successfully controlled with 5–6% coumatetralyl placed in plastic pipes at the rate of 10 kg a.i./hectare. This rodenticide also eliminated the problem of secondary poisoning of wild animals and birds of prey, which was prevalent with the use of other rodenticides (Zook-Rimon, 1985). Changes that occurred in distribution and density of wildlife in the desert resulted mainly from changes in agrotechnical practices in arid lands.

4.2.4 GLOBAL ASPECTS OF AGRO-ECOSYSTEMS IN ARID LANDS

There is no general agreement as to what constitutes a desert. Many parameters are involved, such as rainfall, temperature, types of vegetation and fauna, soil type, salinity, geomorphological characteristics, and others. Hence, the desert as a boundary marker may sometimes be defined in different terms by various authors. The definition by Meigs (1953) seems to be the most accepted. According to Meigs the essential trait and the one upon which all others depend, is the lack of precipitation, and some sort of ratio involving precipitation and temperature.

Thirteen major desert areas of the world are recognized: Kalahari-Namib, Sahara, Somali-Chalbi, Arabian, Iranian, Thar, Turkestan, Takla-Makan,

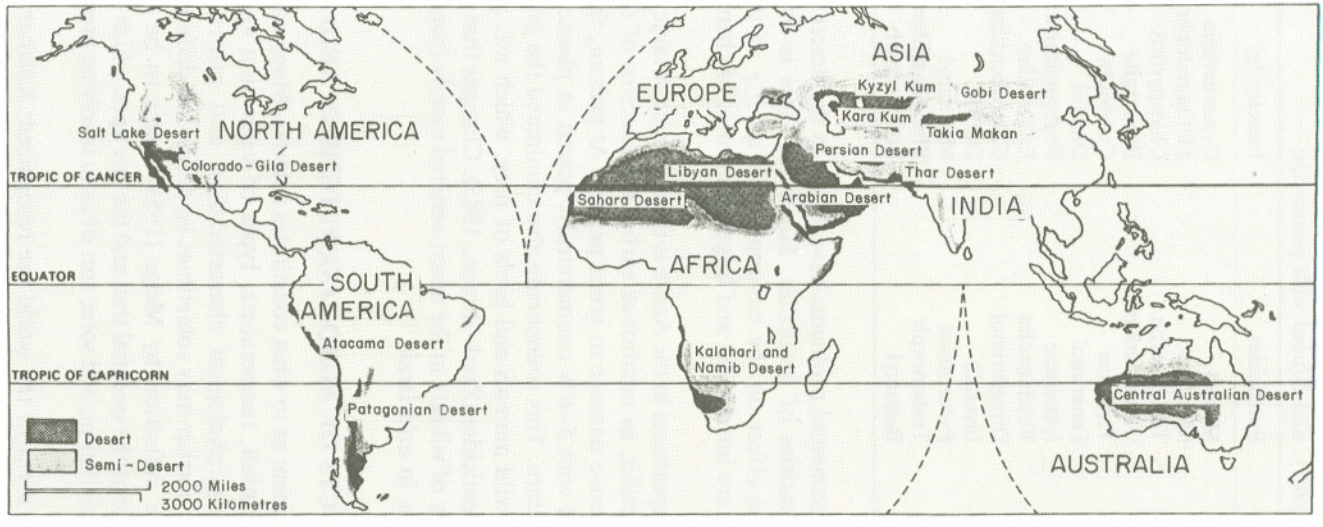

Figure 4.2.3 The deserts of the world. From Simons, 1968. Reproduced with permission from Oxford University Press

Gobi, Australian, Monte-Patagonian, Atacama-Peruvian, and North American (Figure 4.2.3).

More than a third of all the land in the world is desert or semidesert, empty and barren. During the day a fierce sun in a cloudless sky sends temperatures soaring, yet bitter winds may blow, whipping up grit and sand, while the night can be freezingly cold (Simons, 1967).

Every continent except Europe has deserts and many experts claim that most of the desert land will remain useless forever. However, as the population of the world increases more and more rapidly and the total fertile land becomes exceedingly overcrowded, it is realized that great efforts have to be made to conquer the deserts. The salinity of deserts is one of the most important and most difficult problems facing anyone who hopes to make use of such areas (Simons, 1967).

4.2.4.1 Desert Vegetation

There are two main types of desert plants. First, the *ephemerals*, which have seeds or fruits that can survive drought even though the mature plant itself cannot. Examples of such plants are the grasses *Boorhaavia rapens* and *Aristida funiculata*. These have short but widespread root systems capable of obtaining water from the shallow layers of the soil after rain.

Second, the *perennials*, which are established plants remaining in the same place for long periods. Examples, of this type are the various succulent species of cacti, the tamarisk, and acacia bushes. The last two are deep-rooted so that they can tap the water well below the surface. Because such water is somewhat saline, these plants have to tolerate a certain amount of salt. The date palm, for instance, has a high salt tolerance and thus can provide food where most other fruit trees or crops will not grow.

4.2.4.2 Desert Fauna

Animals living in the desert must also overcome the shortage of water and intense heat. Animals such as camels, goats, sheep, and small rodents have adapted well to a desert environment. Reptiles, snakes, and tortoises are also common due to their adaptation to a variable blood temperature.

Insects and arachnids are undoubtedly the best adapted to desert conditions. They require little water, can tolerate high temperatures, and are able to minimize water loss due to evaporation.

Man is not well adapted to desert life. In the past, human dwellers of the desert have been nomadic, moving about with their sheep and goats searching for pasture. Due to overgrazing, many areas which once supported good pasture became valueless scrub.

4.2.4.3 Agro-ecosystems with Irrigation

(a) Sources of water

Water for irrigation of arid lands comes from various sources. Many desert oases are fed by deep underlying water of 'fossil water'. Others are fed by shallow groundwater tables under the sand dunes. The scanty rains (50–100 mm per year) falling on the dunes seep quickly into the sand and the water accumulates on the impermeable underlying rock layers forming a shallow groundwater table which can be tapped by digging shallow wells. Fossil water has been trapped below ground for long periods of geological time. During its long stay below ground it has dissolved large quantities of salt and other minerals from the surrounding rocks. This type of water may form large aquifers, such as those found in the Sinai-Negev desert between Egypt and Israel (Issar, 1985) and the large aquifer existing under the Sahara desert (Ambroggi, 1966). Hydrogeologists now calculate that the Nubian sandstone aquifer under the Sinai-Negev desert, called Marah (*mar* meaning 'bitter' in Hebrew) or Ayun Musa (springs of Moses in Arabic), holds 200 billion m^3 of water.

By a recently developed method of isotope analysis measuring the amount of heavy hydrogen (deuterium) and heavy oxygen (oxygen-18) in water, Issar and colleagues (1985) determined the age of this palaeowater from Ayun Musa to be 30 000 years old. These brackish waters have a high content of $CaSO_4$ and $MgSO_4$ (epsomite) and are known for their bitter taste from biblical times. Agricultural settlements in the Negev utilize some of this water for irrigation. Apparently, the water is low enough in salt content to be usable for irrigation. It is anticipated that in future years more and more of this water will be tapped and will be used to irrigate new agricultural crops.

Drip irrigation has been practised in Israel for many years. Under traditional irrigation technologies large amounts of water are applied in a short period of time. On land with a low water-holding capacity, such as sandy soil or an uneven slope, a significant amount of this water is lost because of percolation beyond the root zone and runoff. Low-volume irrigation, especially drip irrigation, applies smaller amounts of water per unit time. This reduces percolation and runoff and increases the portion of applied water available to the crop (Caswell *et al.*, 1984). The relative advantage of drip irrigation over traditional methods is greater for arid and semi-arid lands and for lower quality soils. Drip irrigation was introduced into California in 1969. Other sources of water, such as saline water and blowdown water, will be dealt with under the heading 'Salinization'.

(b) India

Construction of the Rajasthan canal will service an arid area of over 2 million hectares of which 1.3 million hectares will be cultivable (Roy and Shetty, 1978). Conversion of arid land into cultivable fields and the tremendous increase in

population will have a great impact on the natural vegetation in this part of the desert. The Ganganagar district, which is a part of the Great Indian Desert, was a typical desert prior to the construction of the Gang canal. At present, parts of this district are irrigated by three major canal systems. This has resulted in the transformation of a vast inhospitable stretch of arid land into a fertile land famed for its agricultural produce. On the other hand, the natural vegetation (especially xerophytic plants) has been considerably destroyed by irrigation practices.

The non-irrigated soils, consisting of sandy plains and sand dunes, are poor in organic carbon, are neither saline nor alkaline but are able to support a wide variety of desert species of vegetation.

The Chaggar alluvial plain has slightly higher soil organic carbon but also greater problems of salinity and alkalinity. Natural vegetation is sparse but includes many species of shrubs and grasses. The Chaggar river bed is used for rice cultivation during the rainy season, while wheat, barley, and gram are grown as winter crops. Accordingly, weeds of cultivation are abundant in this region.

The extensive irrigation facilities provided by these three major canals have transformed the area into a fertile agro-ecosystem. The soil is slightly alkaline, the pH ranging from 8.0 to 8.5. This district supports 50% of the cotton and 35% of the food grain produced in Rajasthan. Other crops are also being grown, such as cereals and millets, rice, barley, maize, bajra (*Pennisetum typhoides*), and jowar (*Sorghum vulgare*); pulses, such as moth (*Phaseolus aconitifolius*), urd (*P. mungo*), mung (*P. aureus*), and arhar (*Cajanus cajan*); cotton, sugar-cane, tobacco, chillies, rapeseed, mustard, brown sarson, til (*Sesamum indicum*), groundnut (*Arachis hypogaeae*), linseed (*Linum usitatissimum*); fodder crops, such as guar (*Cyamopsis tetragonoloba*), different types of vegetables, etc. Fruit trees, such as citrus, guava, and pomegranates, are also grown. As in other irrigated lands many species of weeds invade the fields and orchards of this region.

Field trials on the response of mung bean (*Vigna radiata*) to irrigation and anti-transpirants in the Rajasthan district (Singh *et al.*, 1981) indicated that three irrigations applied at 0.75 bar until flowering time and at 5 bar thereafter till maturity, resulted in significant improvement in plant growth, yield attributes, and seed yield over no post-planting irrigation. Anti-transpirants had no effect on yield but straw mulch increased pod production.

The changes that have taken place in Ganganagar due to increased irrigation facilities are bound to expand to other districts along the Rajasthan canal where extensive cultivation will take place and a tremendous increase in weed flora will be evident concomitant with the destruction of natural vegetation.

There is only scant information available on the impact of pest control measures on the expanding agricultural practices in this desert region. The red hairy caterpillar, *Amsacta moorei* (Butler), is a serious pest of kharif (pearl millet) crops in the arid and semi-arid zones of Rajasthan. The most effective

control chemicals were methyl parathion, carbaryl, quinalphos, and the antifeedant compound triphenyltin acetate (TPTA). BHC, malathion, and triphenyltin hydroxide (TPTH) were not effective (Verma, 1981). Most likely, many problems will arise as more pesticides are introduced into the irrigated arid zone. The judicious use of such chemicals and a thorough understanding of pesticide ecology will undoubtedly obviate much chemical pollution and environmental hazard. In this respect, the practice of integrated pest management should be encouraged and there is reason to believe that it would be successful in a desert environment.

4.2.4.4 Agro-ecosystems without Irrigation

The problems of crop production in the Indian arid zone stem from an acute ecological imbalance of the components of productivity. Harsh and unfavourable climatic conditions, wind erosion, and poor soils with low moisture retention capacity all contribute to poor crop yields.

The importance of dry farming research in the arid zone becomes prominent when it is realized that 90% of the cultivated area of this region will continue to be rainfed for many years to come (Singh, 1978). Hence, ecological and economic considerations make dry farming research more of a necessity than a choice.

Lack of moisture is further aggravated by depletion of natural vegetation due to uncontrolled grazing, and cutting of trees and shrubs for fuel, leading to large-scale loss of soil and nutrients caused by wind erosion. Pressure due to the population explosion also leads to extended use of marginal and sub-marginal lands for cultivation. Where the annual rainfall does not exceed 300 mm, large-scale afforestation with suitable species of trees and a grass cover with adapted species of grasses supporting animal husbandry should be the mainstay to stabilization of these areas. Certain types of arid-adapted vegetation with economic potential, such as jojoba bushes (*Simmondsia chinensis*), buffalo gourd (*Curcurbita foetidissima*), and others should be evaluated for cropping in non-irrigated arid regions.

Until recently, land in the Sahelian arid zone in Africa has been left fallow for many years before recropping. Thus, the land was not over-exploited. With the introduction of cash crops, such as cotton and groundnut, marginal areas were brought into cultivation to provide subsistence for the increasing population. The strain of the intensive agriculture resulted in a decline of soil fertility and in lower productivity (Cloudsley-Thompson, 1977, 1978). These adverse effects can be remedied by selecting crops whose requirements of water are compatible with the normal precipitation in the particular area.

Needless to say the introduction of cash crops in dryland farming will bring with it pest and pesticide problems, albeit of a different nature from those encountered in temperate zones.

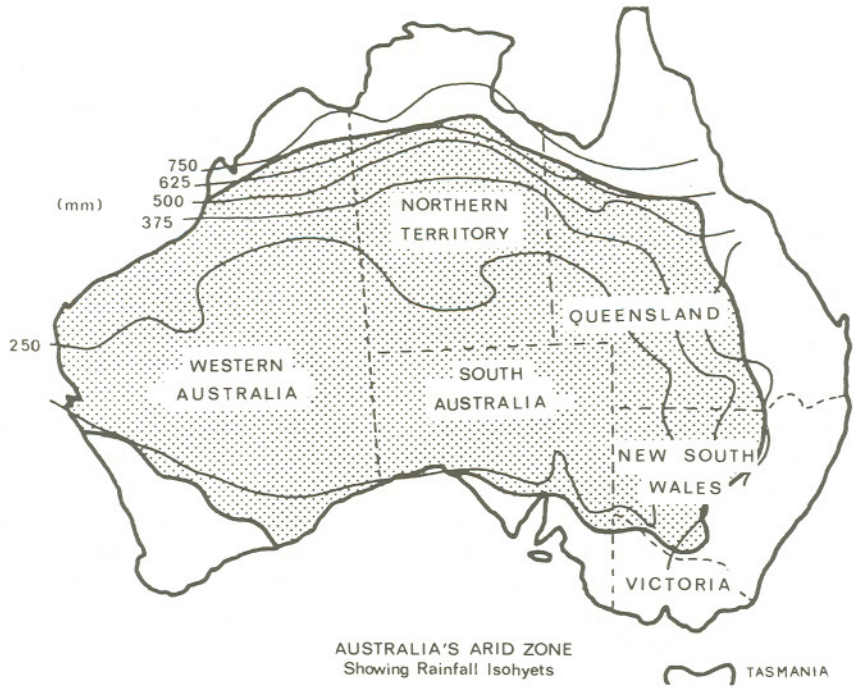

Figure 4.2.4 Australia's arid zone. From Arid Zone Newsletter, 1981, CSIRO. Reproduced with permission

4.2.4.5 Rangelands

Australia

In Australia, the arid zone is defined as that area which receives insufficient rainfall to allow pasture improvement or cropping without irrigation.

The arid zone of Australia (Figure 4.2.4) is bound to the north by the 250 mm rainfall isohyet, to the east by the 500 mm rainfall isohyet, and to the south by the 750 mm isohyet. Approximately 70% of Australia is either arid or semi-arid, and 26% of this area is unoccupied. Another 9% comprises aboriginal reserves and national parks. The remaining 65% is grazed by sheep or cattle.

Rangeland extension workers place more emphasis on the condition of vegetation than on livestock condition. It is believed that by the time a decline in livestock condition is observed considerable damage to pastures would already have been done. This condition, undoubtedly, arising from overgrazing. Progressive degrees of protection from overgrazing have been imposed by the Australian government.

The perennial grasses *Aristida leptopoda* (white spear grass) and *Astrebla lappacea* (curly Mitchell grass) are the main species of the grasslands of semi-arid Queensland in Australia. Long-term studies by Williams and Roe (1975) have clearly shown that severe mortality of seedlings of these and other grasses is due mainly to climatic factors. Drought survival of perennial range-grass seedlings is greatly influenced by soil moisture (Oppenheimer, 1960; Mueller and Weaver, 1942). However, soil temperature and nutrient supplies are also important factors (Christie, 1979). At a temperature of 30°C, and low soil-water potential, curly Mitchell grass has greater capacity to produce nodal axes quickly, higher relative growth rate, and greater root extension than other grasses. Drought endurance appears to be due mainly to differences in root system characteristics and to shoot/root ratio (Christie, 1979). It appears that surface root extension and deep root penetration are adaptations of arid and semi-arid plant species to drought endurance and survival, unlike many plant species in the temperate and humid zones which derive their moisture from upper layers of the soil; hence, their limited root system and shallow penetration.

Williams and Roe (1975) demonstrated that severe mortality of *Astrebla* seedlings as well as other native perennial grasses growing in semi-arid Australia can be directly attributed to climatic factors. The influence of soil water supply on drought survival of perennial range-grass seedlings has been well documented (Mueller and Weaver, 1942). Drought survival is closely related to species differences in the development of nodal axes and in rate of extension and depth of penetration of the root system.

Control of weeds and other undesirable plants is an ongoing process. *Parkinsonia aculeata*—a tall thorny shrub which forms dense thickets around bores, dams, or creeks—has created problems in Australia. This shrub is effectively controlled by spraying with 10% Picloram and with 40% 2,4,5-T diluted in diesel oil (Christmas *et al.*, 1980).

The sheep blow fly, *Lucilia cuprina*, has been a stumbling block in the wool industry in Australia. A wide variety of insecticides have been used to control the fly but many have failed because of the fly's ability to develop resistance to these chemicals. Resistance to dieldrin in 1957, to diazinon in 1965, and to carbaryl in 1967 has been reported (Harrison, 1969; Shanahan and Roxburgh, 1974a,b,c,d). Recently, experiments have been conducted with sheep showing resistance to the fly's attack, and with the use of $ZnSO_4$ given orally or in the drinking water (Perkins, 1980).

The most important problem for livestock in Australia has been that associated with ticks. The cattle tick, *Boophilus microplus*, a vector of piroplasmosis, had developed resistance to most insecticides used for its control, including arsenic dips (Brown and Pal, 1971; Drummond, 1977). Control measures with various acaricides as well as novel types of compounds are still being practised, so it seems inevitable that some degree of pesticide pollution will occur in rangeland areas.

California

More than 40 million of California's 100 million acres are rangeland. The forest, grassland, and rangeland environments occupy approximately two-thirds of the land area of the State, of which 50 million acres are grazed. The desert saltbush (*Atriplex* spp.), an abundant shrubby inhabitant of some of California's driest, saltiest rangelands, is one of many salt-tolerant plant species that have become adapted to growing in arid and saline lands. These salt-tolerant plants (halophytes) provide forage for livestock and wildlife throughout the West. Moreover, they are adaptable to genetic manipulation by selection and breeding (Kelley, 1984). Workers at the University of California at Davis and Riverside and at other universities have been able to improve the palatability and yield of saltbush and sagebrush. Bermuda grass and wheatgrass have been used in gene-transfer experiments to improve their salt tolerance. Native saltbush species are salt-, drought-, and heat-tolerant, as well as insect-, disease-, and fire-resistant, are easily cultivated, highly productive, nutritious, and palatable. *Atriplex* species have been found to contain up to 25% dry weight of crude protein, and one particular species produced 9 tons of forage per acre. Revegetation of marginal soils with these halophytes proved very successful.

Care must be taken in the use of halophytes for forage. Some palatable saltbush species can be toxic to livestock if consumed in excess, due to the accumulation of a toxic concentration of oxalates. *Halogeton* is a well-known toxic halophyte. The potential benefits of halophytes are still being explored. They represent important resources of rangelands, areas that provide grazing lands for livestock, habitats for wildlife, and repositories for genetic material.

4.2.4.6 Salinization—California as an Example

All waters and soils contain salt. Even the non-saline irrigation waters of the Sacramento-San Joaquin Delta in California contain enough salt to create hazard to crops if drainage is insufficient. With adequate sub-surface drainage and an average annual rainfall of 350–400 mm neither salinity nor a shallow water table becomes a problem (Oster *et al.*, 1984).

Saline and sodic soils occur naturally in arid and semi-arid regions, and as water development brings more land into irrigation the salinity problem expands. The condition is aggravated by poor soil drainage, improper irrigation methods, insufficient water supply for adequate leaching, and poor-quality water containing more than 300–800 mg/l total dissolved salts (Backlund and Hoppes, 1984).

Salts are usually leached below the root zone whenever the amount of infiltrated water exceeds that evapotranspired. Where rainfall is adequate salts will not normally accumulate. If rainfall is insufficient or the irrigation water is saline provisions for adequate leaching must be made.

Individual salt constituents as well as total salinity of irrigation water affect the stability of soil structure, and hence, water penetration. The major effects

of salinity on soil properties are swelling of soil clays, dispersion of fine soil particles, crust formation, and decrease in water penetration (Rolston *et al.* 1984).

Salinity and drainage problems have plagued Californian agriculture since the inception of irrigation in the second half of the nineteenth century. Of the 10.1 million acres under irrigation in California, 2.9 million acres are affected by salinity levels of approximately 2500 mg/l or more.

The arid Imperial Valley, situated in what was once the desolate Colorado desert, has had problems of salinization for several decades, yet it has become one of the most productive farming regions of California and of the world. This success was made possible by providing adequate subsurface drainage which removed more salt than was brought in by irrigation water from the salty Colorado River. The salty waste water thus removed was drained by gravity into the Salton Sea (Kelley and Nye, 1984). However, the increasing salinity of the Colorado River is creating new problems and if salinity levels reach 1140–1290 mg/l as projected by various agencies for the year 2000, serious economic losses due to lower yields of crops would result for Imperial Valley farmers.

Strategies for increasing crop yields in saline soils

One strategy available to farmers with saline soils is to select salt-tolerant plants. Crop tolerance to salinity ranges widely from the very salt-sensitive bean and corn plants to the highly tolerant cotton and barley. Salt-tolerant varieties of barley can fare well with seawater if grown on coastal sandy areas. The importance of a *sandy* environment for salt water irrigation was promulgated by Boyko and Boyko (1964). On sand, salt-tolerant barley can grow with seawater because sand is relatively inert and has small electrical effects on salt ions. Unlike soil, sand has sufficient aeration even with heavy water application because water percolates fast through the root zone and the roots are not damaged. Experimental results suggested that the more frequently the barley in sand was irrigated with salt water the higher was the grain yield (Kirkham, 1978).

Molecular techniques, such as recombinant DNA technology, may ultimately have a significant effect on agriculture in the isolation and transfer of genes governing agriculturally important characteristics, such as salinity and drought resistance (Valentine, 1984). The genetic potential to improve crops already exists, but there are limitations, such as limited sources of genes for salinity tolerance and lack of rapid and precise evaluation methods, which until now have prevented the development of salt-tolerant varieties among sensitive crops, such as beans and corn.

Salt-tolerant species, however, cannot substitute for good management practices that prevent salt accumulation in the soil. They can be useful where

good quality water is not available, and for cropping saline soils that are undergoing gradual reclamation (Shannon and Qualset, 1984).

In recent years it has been found that exposure of plants to environmental stress can signficicantly increase the occurrence or severity of *Phytophthora* root rots. Some of these stresses result from cycles of drought, heat, oxygen deficiency, and salinity. Experiments have shown that although salt itself caused no significant damage to the root system of chrysanthemum plants, it lowered the plant's resistance to disease (MacDonald *et al.*, 1984).

Similar results were obtained with tomato and citrus plants in both greenhouse and field experiments. In particular, an isolate of *P. parasitica* recovered from citrus soils showed the greatest salt tolerance. It survived and reproduced at salinity levels equal to or greater than those of seawater. Thus, it is expected that many *Phytophthora* species remain active in saline soils for long periods of time and can cause severe stress of crop plants (MacDonald *et al.*, 1984). Thus, apart from the propagation of salt-tolerant plants, a vital question is can fungi and other parasitic organisms acquire similar salt tolerance and would they become more resistance to chemical control? This area is worth investigating.

4.2.4.7 Desertification

According to the definition used in the assessment adopted by PACD, UNCOD (United Nations Conference on Desertification, 1977) desertification is the diminution or destruction of the biological potential of the land which can lead ultimately to desert-like conditions. It is an aspect of the widespread deterioration of ecosystems resulting in impoverishment and reduction in vegetative cover, exposing the soil surface to accelerated water and wind erosion, leading to loss of soil organic matter and nutrient content, deterioration of soil structure and hydraulic properties, crusting, compaction, salinization or alkalinization, and the accumulation of other substances toxic to plants and animals.

Desertification threatens 35% of the earth's land surface (95×10^6 km^2) and almost 20% of its population (approximately 850 million people). A good portion of the world's drylands is already affected and continues to be irretrievably lost to the desert at a rate of 60 000 km^2 per year, and land rendered economically unproductive is showing an increase at a rate of 210 000 km^2 per year (Karrar and Stiles, 1984). The areas affected by desertification include: rangelands (31 million km^2); rainfed croplands (3.35 million km^2); and irrigated lands (400 000 km^2).

It has long been suspected that regions immediately surrounding a desert area are vulnerable to encroachment by the desert. For example, much of what is now the arid eastern Sahara was once a productive savannah that catered to the herds of nomadic cattlemen until about 2700 BC. In our times, desertification

is a threat to a vast number of people in North and East Africa, northern Asia, and the tropical Americas.

Within a span of 17 years (1958–1975) the Sudanese Sahara has reportedly advanced northward almost 200 km through deterioration of marginal areas. Land at the southern border of the Sahara is turning into desert at an estimated rate of 100 000 hectares per year (Anonymous, 1977).

It is well known that overgrazing is one of the major causes of desertification. Overgrazing depletes the already scant vegetation in arid lands and it favours an increase in the populations of grasshoppers (Merton, 1959; Roffey, 1970). The density of the grasshopper population was shown to be significantly higher in overgrazed areas of the Rajasthan desert in India (Parihar, 1981). This may have been due to the preference for oviposition of the egg pods and their subsequent hatching in open sandy patches rather than in dense grasslands where the anastomosing fibrous roots of the grasses hinder these processes. Similarly, Grewal and Atwal (1968) reported that *Chrotogonus trachypterus* were least abundant in fields under tall vegetation. The effect of overgrazing on an increase in the density of grasshopper populations has also been reported by Dibble (1940) in the USA and by Uvarov (1962) in South America.

Iran

The Lut desert is situated in the southeastern part of Iran and extends over 80 000 km^2. It is extremely poor in vegetation and this is aggravated by the extremely low annual rainfall of no more than 60 mm. The only river flowing through the region is the saline Birjand River. The advancement of the Lut desert can be particularly traced to: (1) destruction of native vegetation; (2) severe land erosion; (3) blowing of sands; and (4) extension of the sand dunes causing the destruction of the Ganat irrigation system as well as damage to farms and inhabited areas.

Desertification of this region, other than by natural causes, was aggravated by human intervention, such as: (a) destruction of vegetation caused by eradicating bushes, trees, and shrubs for use as firewood, as construction material, or as forage for cattle: (b) making charcoal out of logs and trunks of trees; (c) continuous and excessive grazing of native grasses by cattle; and (d) salinization due to irrigation with saline water (Kardavani, 1978).

Amelioration of the situation can come about, in part, if steps are taken to reduce the number of animals grazing on the sparse vegetation, to prevent the disproportionate and imbalanced utilization of plants for firewood, and to prevent salinization of the marginal land of the Lut desert.

Chile

The semi-arid region of Chile is characterized by low precipitation with high

fluctuations from year to year. Agricultural activities are concentrated around the main river valleys and, to a lesser extent, along the coastal marine terraces. The intervalley areas are used mostly for subsistence grazing by goats, although some dry-farming is also found. The total intervalley area is one to two orders of magnitude larger than that of the relatively narrow river valleys. Because of overgrazing and excessive wood cutting this area is highly subject to desertification.

USSR

In recent years there has occurred in a number of arid regions a disturbance of the ecological balance in the environment resulting from an increase of man's influence upon nature and a rapid growth of the exploitation of natural resources, both in agriculture and in industry (Petrov, 1978).

Desertification is a combination of geographical and anthropogenous processes resulting in the destruction of arid and semi-arid ecosystems, and the degradation of their natural resources. The principal forms and degree of anthropogenous change of natural ecosystems in the USSR are: (a) degradation of range vegetation due to overgrazing; (b) deflation of light sandy soils utilized for non-irrigated agriculture, leading to destruction of the fertile soil layer; and (c) breaking up of compact sands by removal of shrubs for fuel, earthwork, road construction, industrial enterprises, settlement, etc.

Thus, in the course of time the old basic landscape, with its relatively stable vegetation cover that keeps surface sands and soils under control, changes into a landscape of shifting barkhan sands. It is anticipated that the influence of man on the nature of the arid regions of the USSR will grow rapidly. The 10th five-year plan for the development of the economy of the republics of Middle Asia and Kazakhstan indicate so. One of the important tasks that face scientists is the optimization of the landscape—meaning, the influence of man which can result in maximum productivity of the land. An important phase of this task will be improved methods of irrigation in agriculture. Secondly, salinization of soils will be prevented by supplying good drainage. These measures will result in the appearance of new agricultural oases in the deserts and semi-deserts of Middle Asia and Western Kazakhstan but only to the extent of 10% of the total area of the arid zone (Petrov, 1978). Other desert areas will be used for animal husbandry and for mining, giving impetus to accelerated urbanization, in turn increasing recreational facilities and tourism. If these measures necessary for the protection of the arid environment are not carried out there will be progressive desertification.

4.2.4.8 Effect of chemicals

Mention has been made of the high $CaSO_4$, $CaCO_3$, and $MgSO_4$ levels characteristic of arid lands; other chemicals might be found in abnormal

concentrations. One of these chemicals is boron. Although boron is an essential plant nutrient, it becomes toxic to growing plants if excessive amounts are present in the root zone. Soils containing high native concentrations of boron occur primarily in arid and semi-arid environments where drainage and/or leaching are inadequate. This situation can be aggravated by use of groundwater or irrigation water containing high levels of boron (Peryea and Bingham, 1984).

Before high-boron soil can be used for farming its boron content must be reduced to non-toxic levels by leaching with low-boron water. Reclamation of such soils, however, is not absolute. Soluble boron appears to increase even after the soil has been reclaimed and phytotoxic conditions may recur. Boron concentrations of 4 ppm or higher in the saturation zone are considered potentially injurious to cotton and sorghum crops (Peryea and Bingham, 1984). Regeneration of phytotoxic boron concentrations can be prevented by the use of good quality irrigation water that produces good drainage and leaching after crop planting.

Pesticides in soils

Whether pesticides are applied as ground or aerial sprays, as dusts to foliage, or directly to soil, it is inevitable that large amounts of them will ultimately reach the soil, which acts as a reservoir for these persistent chemicals. Eventually, many of these chemicals find their way into the tissues of invertebrates, they move into the atmosphere by volatilization, they concentrate in bodies of water by precipitation and leaching, and the residues of the active materials or their metabolites may reach the organisms at the end of the food chain in both aquatic and terrestrial ecosystems.

Factors that affect the persistence of insecticides in soils include volatility, solubility, concentration, formulation, and type of soil to which they are applied. Persistence is longer in heavier soils than in light soils and in those with much organic matter; however, residues in heavier soils are less toxic to insects because they are absorbed and inactivated. Pesticides are less likely to be adsorbed in the light sandy soils of the desert. Experiments by Edwards *et al.* (1957) showed that 34 times as much lindane and 16 times as much aldrin was needed in a muck soil as in a sandy soil to kill the test insects (*Drosophila melanogaster*).

Environmental factors, such as soil moisture and soil temperature, also influence pesticide persistence. In dry soils insecticides are tightly adsorbed, whereas in wet soils they are released and are apt to be broken down or physically removed. Chemical degradation, bacterial decomposition, and volatilization are all influenced by temperature so that at lower temperatures these processes slow down and less insecticide is lost. Temperature also affects adsorption of insecticides in soils because sorption tends to be exothermic so that increased temperature decreases adsorption and releases insecticides. Solubility of pesticides also depends on temperature. More insecticide dissolves in soil

moisture as the temperature increases and amounts of insecticide leached from soil also increase. However, warm soils are usually dry ones, so they hold insecticides more firmly than wet ones.

Needless to say, a wealth of information and data are available on pesticide residues in soils and their effects on various agro-ecosystems, especially those in temperate and humid zones (Edwards, 1975; Brown, 1978). However, there is a noticeable dearth of such information concerning arid lands. Brown and Brown (1970) found mean residues of 0.09 ppm DDT and related compounds in tundra of Canada; Lahser and Applegate (1966) found a mean of 1.60 ppm DDT and 0.20 ppm BHC in US desert land, and Ware *et al.* (1971) reported a maximum of 2.92 ppm DDT and related compounds (mean 0.48 ppm) in the US desert of Arizona, two years after cessation of its use.

In the past 30 years Lichtenstein and colleagues have done a tremendous amount of laboratory experimental work on the dynamics and fate of insecticides in soils. A few works summarizing these activities are: Lichtenstein, 1959, 1965, 1966, 1979; Lichtenstein and Schulz, 1959; Harris and Lichtenstein, 1961; Katan *et al.*, 1976a; Lichtenstein *et al.*, 1978; Fuhremann *et al.*, 1978.

The sandy loam soil that extends over approximately two-thirds of the state of Rajasthan in the desert area of India is an excellent environment for soil insects, which affect the growth and development of the major crop in that area, i.e. the bajra (*Pennisetum typhoides* P.). Experiments with carbaryl indicated that the insecticide persisted in the soil for more than 90 days. Applications of 20, 40, and 60 kg a.i./ha yielded initially residues of 140, 245, and 355 ppm, respectively; residues of 65, 121, and 243 ppm, respectively, were found after 30 days; and residues of 2.6, 13.1, and 17.4 ppm, respectively, after 90 days. Residues of carbaryl in bajra plants, however, were below detectable levels (Gangwar *et al.*, 1978). Hence it is suggested that carbaryl can safely be applied to sandy loam soils with no risk of pesticide uptake by the bajra plants. On the other hand, maize plants grown in carbaryl-treated soil absorbed the insecticide through the root system and translocated it to the aerial parts of the plant (Dhall and Lal, 1974).

Gupta and Rawlins (1966) also reported complete loss of carbaryl in 100 days from sand as against 75–85% from silt and muck soils. BHC also proved effective in the control of white grub populations attacking chilli crops. Soil residues of 2.41 ppm and 1.87 ppm were detected after 60 and 90 days, respectively (initial residue was 10.3 ppm), and 0.35 ppm was detected in the fruit after 90 days. The latter amount, however, is below the accepted tolerance level of 3 ppm at all stages of sampling (Pal and Kushwuha, 1977).

Insect pests of dryland crops in India

Soil insects: Under the direct influence of an arid environment the soil provides a variety of microclimates and microhabitats for the desert fauna. A number

of insect species inflict heavy damage on the cultivated crops of the Rajasthan desert region.

(a) Termites: These are particularly injurious to chilli and wheat crops, to plantations, nursery plants, grasses, etc. Out of 27 species of termite, 14 have been observed to be pests of crops. The important species attacking guar (*Cyanopsis tetragonoloba*) are: *Microcerotermes baluchistanicus* (Ahmad), *Odontotermes guptai* (Roonwal and Bose); and *Microtermes obesi* (Holmgren). *Microcerotermes tenugnathus* (Holmgren) is a major pest of wheat, a crop widely distributed in the area. *Microtermes mycophagus* (Desneux) is a pest of the castor crop. Seedlings of guar and wheat plants may be completely destroyed by the termites. Successful control of termites attacking wheat was achieved by using the organochlorine insecticides aldrin (5% dust), BHC (10% dust), and heptachlor (5% dust), all at a dosage of 10 kg a.i./ha. The most effective compound proved to be aldrin, which reduced the extent of damaged plants by 75% (Parihar, 1980).

(b) White grubs: *Holotrichia consanguinea* (Blanchard) and *H. serrata* (Fabr.). The former is particularly injurious to kharif, especially bajra crops in the arid and semi-arid zones. The foraging beetles have been successfully controlled by 0.2% carbaryl, 0.50% monocrotophos, and 0.025% quinalphos (Kushwaha *et al.*, 1980). Control of grubs was accomplished by soil application of phorate at 2–3 kg a.i./ha, thiodemeton and lindane at 0.75–1.0 kg a.i./ha, and mephosfolan at 2.5 kg a.i./ha.

(c) Grasshoppers: The major species injurious to dryland crops are *Hieroglyphus nigrorepletus* (Boliver); *Chrotogonus trachyptorus* (Blanchard); and *Oedaleus senegalensis* (Krauss). Control strategies include: (a) tillage of soil for destruction of eggs; (b) avoiding the use of chemicals during the intensive activity of natural enemies present in the area; (c) judicious use of insecticides such as 5% BHC, and lower dosages in peripheral areas of grazing lands.

(d) Hairy caterpillars: *Utetheisa pulchella* (L) is a common pest of pastures in the arid zone, and *Euproctis* spp. are serious pests of ber, castor, and bajra. Control measures include: (a) monitoring moth emergence with light traps; (b) collection of egg masses; (c) dusting with 4% endosulfan or 5% carbaryl at 1 kg a.i./ha, preferably in the early instar stage.

(e) Armyworm: *Mythimna separata* populations can be controlled by 5% BHC or carbaryl dust at 1.25 kg a.i./ha before the population peaks out.

(f) Weevils: *Myllocerus discolor* (Boheman), *M. pustulatus* (Faust), and *M. dentifer* (Fabr.) infest bajra, sorghum, sunflower, green gram, sesamum, moth and ber. Applications of 5% BHC or carbaryl dust provide effective control.

(g) Tissue borers: Shootfly (*Atherigona* spp.) infest bajra and sorghum. Early sowing following the first rain, seed dressing with 50% WP carbofuran (60–100 g/kg), or presowing soil application of phorate or thiodemeton granules gives good control.

(h) Sap suckers: sugar-cane leafhopper, *Pyrilla perpusilla* (Walker), infests jowar and bajra.

As can be seen from the above many insect species are serious pests of various crops in the arid zone, and with some exceptions, do not differ greatly from those encountered in temperate and humid regions. The use of persistent organochlorine insecticides is still in practice, although most of these have been banned in temperate zones of the Western countries some years ago. An assessment of the hazard to the arid environment due to the continuing use of these chemicals has not been made; certainly, there is need of such an investigation.

4.2.5 CONCLUDING REMARKS

The desert can be made to bloom. Evidence for that can be seen in the green fields of the northern Negev desert of Israel, the Imperial Valley of California, the Rajasthan district of India, the rangelands of Australia, and many others. The most important requirement is the availability of water for irrigation. A desert agro-ecosystem without irrigation can support only a few crops, such as dates, figs, a few species of grasses, and, in some instances, also cotton and some of the newer exotic plants, e.g. jojoba, guayule, etc. The introduction of irrigation can convert the desert land suitable for agriculture into large oases supporting major crops of fruits, vegetables, and fibres. However, there is no doubt that irrigation will bring with it pest and pesticide problems such as those encountered in temperate and other zones.

A desert environment is less susceptible to injury by pests because of the existing natural balance between predator and prey. In the oases there is a lack of natural balance due to the prevalence of different species, resulting in overpopulations which are not naturally regulated.

The nature of agriculture in the desert is known as 'islands of agriculture' because of the discontinuous character of crop production. Under such conditions, biological control, the use of pheromones, cultural methods, or a combination of these and other practices known as 'integrated pest management' should be very successful in an overall programme of pest control. The use of pesticides will undoubtedly be necessary; hence it is paramount that the dynamics of pesticide behaviour in soil and on crops should be thoroughly investigated. To date such data are wanting.

Although modelling of pesticide distribution, persistence, and fate can be of great help in predicting the behaviour of pesticides in different environments, there is no substitute for *in situ* determination of the dynamics of their behaviour and fate under different climatic conditions. Hence, extrapolation of data from laboratory experiments and from those simulating field conditions, especially as they apply to arid environments, must be made with reservation.

Once irrigation is introduced to the desert pest problems might become similar to those encountered in temperate regions. However, the dissimilarity in soil and climatic conditions will undoubtedly alter the behaviour of pests. Hence, a thorough knowledge of pest ecology will be required.

This section by no means encompasses all that is known about the desert. The surface has barely been scratched. It merely points to some of the major problems facing arid lands, their characteristics, their use and misuse, and the prospects for their rehabilitation. History teaches us that much of the desert area of the world was once teeming with life, and history can repeat itself. Pessimistic attitudes toward arid lands and the notion of the uselessness of the desert can be offset by vivid examples presented herein of the productivity of these lands and their essential role in combating famine.

The desert is not dead; it is only neglected.

ACKNOWLEDGEMENTS

The writers wish to express their sincere appreciation to Dr. I. Adato, Mr. I. Adler, Dr. N. Aharonson, Dr. Y. Ben-Dov, Mr. R. Dayan, Dr. M. Kehat, Dr. S. Lerman, Dr. U. Mingelgrin, Dr. S. Navarro, Dr. S. Saltzman, Dr. B. Yaron, and Mr. Z. Zook-Rimon for many helpful discussions and suggestions and for supplying us with unpublished data of their works.

4.2.6 REFERENCES

Adato, I. (1984). Mesurol residues in dates. Unpublished report to the Division of Plant Protection, Israel Ministry of Agriculture, Bet-Dagan.

Adkisson, P.L. (1957). Influence of irrigation and fertilizer on populations of three species of Mirids attacking cotton. *F.A.O. Pl. Prot. Bull.*, **6**(3), 33–36.

Adler, I. (1987). Types of herbicides, fungicides, and insecticides used on various crops in the Arava region. (Unpublished material) Arava Regional Council, Sapir Center.

Aharonson, N., Venezian, A., Klein, M., and Oko, O. (1984). Biology, phenology and control of the green leafhopper, *Omonatissus binotatus* var. *lybicus* (Berg), on dates in the Arava desert of Israel. Unpublished report to the Division of Plant Protection, Israel Ministry of Agriculture, Bet-Dagan.

Allred, P. M., and Giesey, J. P. (1985). Solar radiation-induced toxicity of anthracene to *Daphnia pulex*. *Environ. Toxicol. and Chem.*, **4**, 219–226.

Ambroggi, R. P. (1966). Water under the Sahara. *Scientific American*, May, 1966.

Amir, J., Vanunu, E., Krikun, J., Orion, D., Penuel, Y., Satki, Y., and Lerner, E. (1981). Long-term field experiments in the Negev. A monoculture of wheat under semi-arid conditions. *Hassadeh*, **62**, 198–204 (in Hebrew, with English summary).

Amir, J., Carmi, Z., Krikun, J., Orion, D., Penuel, Y., and Lerner, E. (1982). Effect of a continuous wheat rotation on yield in the Negev (1980–1981). *Gan, Sadeh veMesheki*, **5**, 15–19 (in Hebrew).

Anonymous (1977). The spectra of desertification: editorial. *Ann. Arid Zone*, **16** (3), Sept.

Atlas of Israel (1970). Amiram, D. H. K., Rosenan, N., Kadmon, N., Elster, J., Gilead, M., and Paran, U. (eds.). Ministry of Labour, Jerusalem, and Elsevier Publishing Co., Amsterdam.

Backlund, V. L., and Hoppes, R. R. (1984). Status of soil salinity in California. *Calif. Agric.*, **38**, 8–9.

Ben-David, T., Venezian, A., and Ben-Dov, Y. (1985). Observations on phenology, biology and control of the mango thrips, *Scirtothrips mangiferae* (Priesner), in the Arava Valley of Israel. *Hassadeh*, **65**, 1826–1830 (in Hebrew with English summary).

Ben-Dov, Y. (1985). Further observations on scale insects (Homoptera, Coccoidea) of the Middle East. *Phytoparasitica*, **13**, 185–192.

Bielorai, H., and Levy, J. (1971). Irrigation regimes in a semi-arid area and their effects on grapefruit yield, water use and soil salinity. *Israel J. agr. Res.*, **21** (1), 3–12.

Bishara, I. (1932). The greasy cutworm, *Agrotis ypsilon* (Rott.), in Egypt. *Egypt. Min. Agr. Tech. Bull.*, **114**, 1–55.

Blumberg, D., and Kehat, M. (1982). Biological studies of the date stone beetle, *Coccotrypes dactyliperda*. *Phytoparasitica*, **10** (2), 73–78.

Bowman, M. C., Schechter, M. S., and Carter, R. L. (1965). Behaviour of chlorinated insecticides in a broad spectrum of soil types. *J. Agric. Fd. Chem.*, **13**, 360–365.

Boyko, H., and Boyko, E. (1964). Principles and experiments regarding direct irrigation with highly saline and sea water without desalinization. *Trans. N.Y. Acad. Sci.*, Ser. II, **26** (suppl. to No. 8), 1087–1102.

Brown, A. W. A. (1978). *Ecology of Pesticides*. Wiley Interscience, New York.

Brown, A. W. A., and Pal, R. (1971). *Insecticide Resistance in Arthropods*, 2nd edn. World Health Organization, Geneva.

Brown, N. J., and Brown, A. W. A. (1970). Biological fate of DDT in a subarctic environment. *J. Wildl. Mgmt.*, **34**, 929.

Buyanovsky, G., Dicke, M., and Berwick, P. (1982). Soil environment and activity of soil microflora in the Negev Desert. *J. Arid. Envir.*, **5**, 13–28.

Caswell, M., Zilberman, D., and Goldman, G. E. (1984). Economic implications of drip irrigation. *Calif. Agric.*, July–August.

Chen, Y. L., and Casida, J. E. (1969). Photodecomposition of pyrethrin I, allethrin, phthalthrin and dimethrin. Modifications in the acid moiety. *J. Agric. Fd. Chem.*, **17**, 208–215.

Christie, E. K. (1979). Eco-physiological studies of the semi-arid grasses *Aristida leptopoda* and *Astrebla lappacea*. *Aust. J. Ecol.*, **4**, 223–228.

Christmas, R., Shaw, K., and MacEllister, F. V. (1980). *Arid Zone Newsletter*, p. 49.

Cloudsley-Thompson, J. L. (1977). Reclamation of the Sahara. *Envir. Conserv.*, **4**, 115–119.

Cloudsley-Thompson, J. L. (1978). The future of arid environments. In: Mann, H. S. (ed.), *Proc. Int. Symp. on Arid Zone Res. and Devel.*, pp. 469–474. Scientific Publishers, Jodhpur.

Cripps, R. E., and Roberts, T. R. (1978). Microbial degradation of herbicides. In: Hill, I. R., and Wright, S. J. L. (eds), *Pesticide Microbiology*, pp. 669–720. Academic Press, New York.

Crosby, D. G. (1972a). The photodecomposition of pesticides in water. *Adv. Chem.*, Ser. III, 173–188.

Crosby, D. G. (1972b). Environmental photooxidation of pesticides. In: *Degradation of Synthetic Organic Molecules in the Biosphere*, pp. 260–278. National Academy of Sciences. Washington D.C.

Crosby, D. G., and Li, M. (1969). Herbicide photodecomposition. In: Kearney, P. C., and Kaufman, D. D. (eds), *Degradation of Herbicides*, pp. 321–363. Marcell Dekker, New York.

Danin, A. (1983). *Desert Vegetation of Israel and Sinai*, p. 148. Cana Ltd., Jerusalem, P.O.B. 1199.

Dayan, R. (1987). Types and total acreage of crops grown in the Arava region. (Unpublished material). Arava Regional Council, Sapir Center.

Dhall, P., and Lal, R. (1971). Colorimetric determination of carbaryl residues in field-treated corn. *J. Ass. Off. Anal. Chem.*, 1095–1099.

Dibble, C. B. (1940). Grasshoppers, a factor in soil erosion in Michigan. *J. Econ. Ent.*, **33**, 496–499.

Drummond, R. O. (1977). Resistance in ticks and insects of veterinary importance. In: Watson, D. L., and Brown, A. W. A. (eds), *Pesticide Management and Insecticide Resistance*, pp. 303–319. Academic Press, New York.

Edwards, C. A. (1975). *Persistent Pesticides in the Environment*, 2nd edn. CRC Press, Cleveland, Ohio.

Edwards, C. A., Beck, S. D., and Lichtenstein, E. P. (1957). Bioassay of aldrin and lindane in soil. *J. Econ. Ent.*, **50**, 622–626.

Elder, D. L., and Villeneuve, J. P. (1977). Polychlorinated biphenyls in the Mediterranean Sea. *Mar. Poll. Bull*, **8**, 19–22.

Elder, D. L., Villeneuve, G. P., Parsi, P., and Harvey, G. R. (1976). *Polychlorinated Biphenyls in Sea Water, Sediments and Over-Ocean Air of the Mediterranean*. Activities of the Int. Lab. of Marine Radioactivity, Monaco. International Atomic Energy Agency, Vienna.

Evenari, M., Shanan, L., and Tadmor, N. H. (1968). "Runoff farming" in the desert: I. Experiment Layout. *Agron. J.*, **60**, 29–32.

Evenari, M., Shanan, L., and Tadmor, N. H. (1971). *The Negev*. Harvard University Press, Cambridge, Massachusetts.

Fuhremann, T. W., Lichtenstein, E. P., and Katan, J. (1978). Binding and release of insecticide residues in soils. *ACS Symposium Series*, **73**, 131–140.

Gangwar, S. K., Kavadia, V. S., Gupta, H. C. L., and Srivastava, B. P. (1978). Persistence of carbaryl in sandy-loam soil and its uptake in bajra (*Pennisetum typhoides* P.). *Ann. Arid Zone*, **17**, 357–362.

Grewal, G. S., and Atwal, A. S. (1968). Development of *Chrotogonus trachypterus* in relation to different levels of temperature and humidity. *Indian J. Ent.*, **30**, 1–7.

Gupta, D. S., and Rawlins, W. A. (1966). Persistence of two systemic carbamate insecticides in three types of soil. *Indian J. Ent.*, **28**, 482–493.

Harris, C. R., and Lichtenstein, E. P. (1961). Factors affecting volatilization of insecticides from soil. *J. Econ. Ent.*, **54**, 1038–1045.

Harrison, I. R. (1969). Development of organophosphorus resistance in the Australian sheep blow fly, *Lucilia cuprina* (Wied.). *Soc. Chem. Ind. Monogr.*, **33**, 215–223.

Herring, J. L., Hannan, E. J., and Bills, D. D. (1972). Ultraviolet irradiation of Aroclor 1254. *Bull. Envir. Contam. Toxicol*, **8**, 153–157.

Hutzinger, O., Safe, S., and Zitko, V. (1972). Photochemical degradation of chloro biphenyls (PCBs). *Envir. Hlth. Perspect.*, **1**, 15–20.

Hyde, M. B., Baker, A. A., and Ross, A. C. (1973). Airtight grain storage. *F.A.O. Agr. Serv. Bull.*, **17**. FAO, Rome.

Issar, A. (1985). Fossil water under the Sinai-Negev peninsula. *Scient. Am.* **253**, July, 82–88.

Kardavani, P. (1978). Role of biotic and environmental factors in the extension of the Lut Desert in Iran. *Ann. Arid Zone*, **17**, 92–98.

Karrar, G., and Stiles, D. (1984). The global status and trend of desertification (Review). *J. Arid Envir.*, **7**, 309–312.

Katan, J., Fuhremann, T. W., and Lichtenstein, E. P. (1976a). Finding of ^{14}C-Parathion in soil: a reassessment of pesticide persistence. *Science*, **193** (4256), 891–894.

Katan, J., Greenberger, A., Alon, H., and Grinstein, A. (1976b). Solar heating by polyethylene mulching for the control of diseases caused by soil borne pathogens. *Phytopathology*, **76**, 683–688.

Kehat, M., Blumberg, D., and Greenberg, S. (1969). Experiments on the control of the raisin moth, *Cadra figulilella* Gregs (phycitidae, Pyralidae), on dates in Israel. *Isr. J. Agr. Res.*, **19**, 121–128.

Kehat, M., Swirski, E., Blumberg, D., and Greenberg, S. (1974). Integrated control of date palm pests in Israel. *Phytoparasitica*, **2**, 141–149.

Kelley, D. B. (1984). Halophytes as a rangeland source. *Calif. Agric.*, **38**, 26.

Kelley, R. L., and Nye, R. L. (1984). Historical perspective on salinity and drainage problems in California. *Calif. Agric.*, **38**, 4–6.

Khan, M. A. Q., Khan, H. M., and Sutherland, D. J. (1974). Ecological and health effects of the photolysis of insecticides. In: Khan, M. A. Q., and Bederka, J. P. Jr. (eds), *Survival in Toxic Environments*, pp. 333–356. Academic Press, New York.

Kilgore, W.W. (1975). Mechanisms responsible for the disappearance of pesticides from the environment. In: *FAO/UNEP Consultation on Impact Monitoring of Residues due to Uses of Agricultural Pesticides in Developing Countries*. Food and Agriculture Organization of the U.N., Rome.

Kirkham, M. B. (1978). Salt water irrigation frequency for barley. *Ann. Arid Zone*, **17**, 12–18.

Krikun, J., Orion, D., Nachmias, A., and Reuveni, R. (1982). The role of soil borne pathogens under conditions of intensive agriculture. *Phytoparasitica*, **10** (4), 245–258.

Kushwuha, K. S., Noor, A., and Rathore, R. R. S. (1980). Insect pest management in arid agriculture. *Ann. Arid Zone*, **19**, 503–509.

Lahser, C., and Applegate, H. G. (1966) Pesticides at Presidio. III. Soil and water. *Texas J. Sci*, **18**, 21.

Lerman, S. (1985). Personal communication. Institute for Applied Research, Ben-Gurion University of the Negev.

Lichtenstein, E. P. (1959). Factors affecting insecticide persistence in various soils. *Pest Control*, Aug, p. 40.

Lichtenstein, E. P. (1965). Problems associated with insecticidal residues in soils. In: *Research in Pesticides*, pp. 199–205. Academic Press, New York.

Lichtenstein, E. P. (1966). Persistence and degradation of pesticides in the environment. In: *Scientific Aspects of Pest Control*, pp. 221–229. Nat. Acad. Sci. Publ. No. 1402.

Lichtenstein, E. P. (1979). Fate of pesticides in a soil-plant microcosm. In: *Terrestrial Microcosms and Environmental Chemistry*. National Science Foundation Publication, April.

Lichtenstein, E. P., and Schulz, K. R. (1959). Persistence of some chlorinated hydrocarbon insecticides as influenced by soil types, rate of application and temperature. *J. Econ. Ent.*, **52**, 124–131.

Lichtenstein, E. P., and Schulz, K. R. (1960). Epoxidation of aldrin and heptachlor in soils as influenced by autoclaving, moisture and soil types. *J. Econ. Ent.*, **53**, 192–197.

Lichtenstein, E. P., and Schulz, K. R. (1964). The effect of moisture and microorganisms on the persistence and metabolism of some organophosphorus insecticides in soils, with special emphasis on parathion. *J. Econ. Ent.*, **57**, 618–627.

Lichtenstein, E. P., Liang, T. T., and Fuhremann, T. W. (1978). A compartmentalized microcosm for studying the fate of chemicals in the environment. *J. Agr. Fd.Chem.*, **26**, 948–953.

Lomas, J., and Shashoua, Y. (1974). The dependence of wheat yields and grain weight in a semi-arid region on rainfall and on the numbers of hot, dry days. *Israel J. of Agric. Res.*, **23** (3–4), 113–121.

MacDonald, J. D., Swiecki, T. J., Blaker, N. S., and Shapiro, J. D. (1984). Effect of salinity stress on the development of *Phytophthora* root rots. *Calif. Agric.*, **38**, 23–24.

Matsumura, F., and Benezet, H.J. (1978). Microbial degradation of insecticides. In: Hill, I. R., and Wright, S. J. L. (eds), *Pesticide Microbiology*, pp. 623–659. Academic Press, New York.

Meigs, P. (1953). World distribution of arid and semi-arid homoclimates. *Arid Zone Progrm.*, **1**, (Rev. of Research on Arid Zone Hydrology), pp. 203–209.
Merton, L. F. H. (1959). Studies in ecology of the Moroccan locust (*Docoistaurus maroccanus* Thunberg) in Cyprus. *Anti-locust Bull.*, **34**, 123
Mueller, I. M., and Weaver, J. E. (1942). Relative drought resistance of dominant prairie grasses. *Ecology*, **23**, 387–398.
Navarro, S., Donahaye, E., Kashanchi, Y., Pisarev, V., and Bulbul, O. (1984). Airtight storage of wheat in a PVC covered bunker. In: Ripp, B.E. (ed.), *Controlled Atmosphere and Fumigation in Grain Storages*, pp. 601–614. Proc. Int. Symposium, Perth, Western Australia, April. Elsevier, North-Holland.
Oppenheimer, H.R. (1960). Adaptation to drought. Xerophytism. In: *Plant Water Relationships in Arid and Semi-Arid Conditions*, pp. 105–138. UNESCO, Paris.
Oster, I. D., Hoffman, G. J., and Robinson, F. E. (1984). Dealing with salinity. Management alternatives; crop, water and soil. *Calif. Agric.*, **38**, 29–32.
Pal, S. K., and Kushwuha, K. S. (1977). Persistence of BHC residues in soil and its translocation in chilli fruits. *Ann. Arid Zone*, **16**, 169–170.
Parihar, D. R. (1980). Termite problem in desert plantations. *Ann. Arid Zone*, **19**, 329–334.
Parihar, D. R. (1981). Effects of overgrazing on grasshopper population in the grasslands of Rajasthan desert. *Ann. Arid Zone*, **20**, 291–293.
Perkins, I. D. (1980). New methods for control of green sheep blowfly (*Lucilia cuprina*). *Arid Zone Newsltr*, **9**, 67.
Peryea, P. J., and Bingham, F. T. (1984). Reclamation and regeneration of boron in high-boron soils. *Calif. Agric.*, **38**, 35.
Petrov, M. P. (1978). Development and protection of natural resources of deserts and semi-deserts. In: Mann, H.S. (ed.), *Proc. Int. Symp. on Arid Zone Res. and Devel.*, pp. 491–496. Scientific Publishers, Jodhpur, India.
Popov, G. B. (1958). Ecological studies of oviposition by swarms of the desert locust, *Schistocerca gregaria*. Forskal in East Africa. *Anti-locust Bull.*, **31**, 1–70.
Rake, D. W. (1961). Some studies on photochemical and soil microorganism decomposition of granular organoborate herbicides. *Weed Soc. Am. Abstr.*, pp. 48–49.
Rivnay, E. (1964). The influence of man on insect ecology in arid zone. *Annu. Rev. Entomol.*, **9**, 41–62.
Robinson, J., Richardson, A., Bush, B., and Elgar, K. E. (1966). A photo-isomerization product of dieldrin. *Bull. Envir. Contam. Toxicol.*, **1**, 27.
Roffey, J. (1970). The effect of changing land use on locusts and grasshoppers. In: *Proc. Int. Study Conf. on Current and Future problems of Acridology*, London, pp. 199–204.
Rolston, D. E., Nielsen, D. R., and Beggar, J. W. (1984). Effect of salt on soils. *Calif. Agric.*, **38**, 11–12.
Rosen, J. D. (1972). The photochemistry of several pesticides. In: Matsumura, F., Bouch, G. M., and Misato, T. (eds), *Environmental Toxicology of Pesticides*, pp. 435–447. Academic Press, New York.
Rosen, J. D., Sutherland, D. J., and Lipton, G. R. (1966). The photochemical isomerization of dieldrin and endrin and effects on toxicity. *Bull. Envir. Contam. Toxicol.*, **1**, 133.
Roy, G.P., and Shetty, B.V. (1978). The impact of canal irrigation on the flora of the Rajasthan desert. In: Mann, H. S. (ed.), *Arid Zone Research and Development*, Proc. Int. Symp. on Arid Zone Res. and Devel., pp. 183–189. Scientific Publishers, Jodhpur.
Sethunathan, N. (1980). Effects of combined pesticides application on their persistence in flooded rice soils. *Agrochemical Residue-Biota Interactions in Soil and Aquatic Ecosystems*, pp. 259–281. IAEA, Vienna.
Shanahan, G. J., and Roxburgh, N. A. (1974a). Insecticide resistance in Australian sheep blowfly. *Agr. Gaz. N.S.W.*, **85**, 4–7.

Shanahan, G. J., and Roxburgh, N. A. (1974b). A significant increase in larval resistance of *Lucilia cuprina* (Wied.) to diazinon. *Vet. Rec.*, **94**, 382.
Shanahan, G. J., and Roxburgh, N. A. (1974c). The sequential development of insecticide resistance problems in *Lucilia cuprina* (Wied.) in Australia. *PANS*, **20**, 190–202.
Shanahan, G. J., and Roxburgh, N. A. (1974d). Insecticide resistance in Australian sheep blowfly *Lucilia cuprina* (Wied.). *J. Aust. Inst. Agric. Sci.*, **40**, 249–253.
Shannon, M.C., and Qualset, C.O. (1984). Benefits and limitations in breeding salt-tolerant crops. *Calif. Agric.*, **38**, 33–34.
Shulov, A. (1952). The development of eggs of *Schistocerca gregaria* in relation to water. *Bull. Ent. Res.*, **43**, 469–476.
Simons, M. (1967). *Deserts—the Problem of Water in Arid Lands*. Oxford University Press, Oxford.
Singh, A., Ahlawat, I. P. S., and Saraf, C. S. (1981). Response of spring mung bean (*Vigna radiata*) to irrigation and anti-transpirants with and without mulching. *Ann. Arid Zone*, **20**, 28–34.
Singh, R. P. (1978). Dry farming research—its relevance and prospects for arid zone agriculture. In: Mann, H. S. (ed.), *Proc. Int. Symp. on Arid Zone Res. and Devel.*, pp. 475–481. Scientific Publications, Jodhpur.
Stower, W. J., Popov, G. B., and Greathed, D. J. (1958). Oviposition behaviour and egg mortality of the desert locust, *Schistocerca gregaria*. *Anti-locust Bull.*, **30**, 1–33.
Thornthwaite, C. W. (1948). An approach toward a rational classification of climate. *Geogrl. Rev.*, **38**, 55–94.
United Nations Conference on Desertification (1977). *Report A/Conf. 74/36*, Nairobi, 29 Aug.–9 Sept.
Uvarov, B. P. (1962). Development of arid lands and its ecological effects on their insect fauna. *Arid Zone Res.*, **28**, 235–248.
Valentine, R. C. (1984). Genetic engineering of salinity-tolerant plants. *Calif. Agric.*, **38**, 36–37.
Venezian, A., and Ben-Dov, Y. (1982). The mango thrips *Scirthothrips mangiferae* Priesner, a new pest of mango in Israel. *Hassadeh*, **62**, 1116–1117 (in Hebrew with English summary).
Verma, S. K. (1981). Field efficiency of insecticides and antifeedants against advanced stage larvae of *Amsacta moorei* Butler. *Ann. Arid Zone*, **20**, 253–257.
Ware, G. W., Estesen, B. J., and Cahill, W. P. (1971). DDT moratorium in Arizona. Agricultural residues after 2 years. *Pest. Mon. J.*, **5**, 276.
Williams, O. B., and Roe, R. (1975). Management of arid grasslands for sheep: Plant demography of six grasses in relation to climate and grazing. *Proc. Ecol. Soc. Aust.*, **9**, 142–156.
Woodcock, D. (1978). Microbial degradation of fungicides, fumigants and nematocides. In: Hill, I. R., and Wright, S. J. L. (eds), *Pesticide Microbiology*, pp. 731–799. Academic Press, New York.
Yaron, B., Vinien, A. J., Fine, P., Metzger, L., and Mingelgrin, U. (1983). The effect of solid organic components of sewage on some properties of the unsaturated zones. *Ecol. Studies*, **47**, 162–181.
Yaron, B., Gerstl, Z., and Spencer, W. F. (1984). Behaviour of herbicides in irrigated soils. *Adv. Soil Sci.*, **2**, 1–143.
Yaron, B., Mingelgrin, U., and Saltzman, S. (1985). Personal communications.
Yathom, S. (1961). Studies on the bionomics of *Hylemia cilicrura* Rond. in Israel. *Ktavim*, II, 51–55.
Zook-Rimon, Z. (1985). *Mus musculus* as a pest of green peppers in the Arava desert region of Israel. Personal communication.
Zook-Rimon, Z. (1985). Personal communication.