SOILS OF ICARDA'S AGRICULTURAL EXPERIMENT STATIONS AND SITES

CLIMATE, CLASSIFICATION, PHYSICAL AND CHEMICAL PROPERTIES, AND LAND USE

John Ryan
with
Samir Masri, Sonia Garabet,
Jurgen Diekmann
and Hasan Habib

International Center for
Agricultural Research
in the Dry Areas

About ICARDA

Established in 1977, the International Center for Agricultural Research in the Dry Areas (ICARDA) is governed by an independent Board of Trustees. Based at Aleppo, Syria, it is one of 16 centers supported by the Consultative Group on International Agricultural Research (CGIAR), which is an international group of representatives of donor agencies, eminent agricultural scientists, and institutional administrators from developed and developing countries who guide and support its work.

The mission of the CGIAR is to contribute, through its research, to promoting sustainable agriculture for food security to alleviate poverty and hunger in developing countries. The CGIAR conducts strategic and applied research, with its products being international public goods, and focuses its research agenda on problem-solving through interdisciplinary programs implemented by one or more of its international centers, in collaboration with a full range of partners. Such programs concentrate on increasing productivity, protecting the environment, saving biodiversity, improving policies, and contributing to strengthening agricultural research in developing countries.

In the context of the challenges posed by the physical, social and economic environments, ICARDA's mission is to improve the welfare of people in the dry areas of the developing world by increasing the production and nutritional quality of food while preserving and enhancing the resource base. ICARDA meets this challenge through research, training, and dissemination of information in partnership with the national agricultural research and development systems.

ICARDA serves the entire developing world for the improvement of lentil, barley and faba bean; all dry-area developing countries for the improvement of on-farm water-use efficiency, rangeland and small-ruminant production; and the West Asia and North Africa region for production enhancement of bread and durum wheats, chickpea, and farming systems. ICARDA's research provides global benefits of poverty alleviation through productivity improvements integrated with sustainable natural-resource management practices.

Much of ICARDA's research is carried out on a 948-hectare farm at its headquarters at Tel Hadya, about 35 km southwest of Aleppo. ICARDA also manages other sites where it tests material under a variety of agroecological conditions in Syria and Lebanon. However, the full scope of ICARDA's activities can be appreciated only when account is taken of the cooperative research carried out with many countries in West Asia and North Africa and elsewhere in the world.

The results of research are transferred through ICARDA's cooperation with national and regional research institutions, with universities and ministries of agriculture, and through the technical assistance and training that the Center provides. A range of training programs is offered extending from residential courses for groups to advanced research opportunities for individuals. These efforts are supported by seminars, publications, and specialized information services.

SOILS OF ICARDA'S AGRICULTURAL EXPERIMENTAL STATIONS AND SITES:

CLIMATE, CLASSIFICATION, PHYSICAL AND CHEMICAL PROPERTIES, AND LAND USE

by

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Correct citation: Ryan, J., S. Masri, S. Garabet, J. Diekmann and H. Habib. 1997. Soils of ICARDA's Agricultural Experimental Stations and Sites: Climate, Classification, Physical and Chemical Properties, and Land Use. International Center for Agricultural Research in the Dry Areas, Aleppo, Syria. vi + 107 pp.

ISBN: 92-9127-050-4

Printed at ICARDA.

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Foreword

The value of an agricultural experimental station lies in its ability to conduct applied research that is potentially transferrable to, and beneficial for, the farming community. Thus, virtually all research and educational institutes involved with the agricultural sciences have experimental sites of one kind or another. These sites represent the intermediate step between the laboratory and the farmer's field. Indeed, it is difficult to imagine any international research center without extensive facilities for field experimentation.

The value of any experimental station is limited by the extent to which the site is representative of the agro-ecological conditions of the surrounding environment. Given the importance of weather (rainfall and temperature) and soil types for cropping systems, it is vital that stations broadly represent such conditions prevailing in the region. Research results can only be validly transferred to broadly similar environmental situations.

ICARDA was placed in Syria so as to represent rainfed conditions of the Mediterranean area. Its headquarters in Tel Hadya is representative of the cereal (mainly wheat)/legume system with moderate rainfall (300-350 mm yr^{-1}). Its soil type (Calcixerollic Xerochrept) is widespread in the area. To further expand its "laboratory," ICARDA established stations or sites in different areas to represent the range in rainfall zones in northwest Syria, e.g., Jindiress in the wettest area, and Breda and Boueidar at the drier end of the cultivated zone. Maragha, in the steppe, represents an exclusively grazing area. In addition, two stations in Lebanon (Terbol and Kfardane) represent colder conditions.

While weather conditions at these stations are the most obvious characteristic, knowledge of the soil and its many chemical and physical properties that impinge on plant growth has only gradually unfolded as our research activities have progressed since the inception of ICARDA. The data on soil properties is to be found in diverse sources. With time, the need to have proper classification of the soil at the various stations became obvious. Such data facilitate the interpretation of field trials, and are essential for publication of results in the broader scientific community. The authors of this timely manual are to be congratulated for bringing together all the available soil information in a manner that can be easily interpreted by the non-soil scientist. The manual will be invaluable to ICARDA scientists and will reduce the demands for analysis from experiments as most information is contained in the manual.

Prof. Dr Adel El-Beltagy
Director General
ICARDA

Experimental Stations and Sites

Syria

1.	Tel Hadya	ICARDA Headquarters, 35 km S.W. of Aleppo. Principal research site.
2.	Breda	35 km S.E. of Aleppo. Main station in lower rainfall (<300 mm) zone.
3.	Jindiress	75 km N.W. of Aleppo. Main station in higher rainfall (>450 mm) zone.
4.	Ghrerife	47 km S. of Aleppo. Limited to barley/*Atriplex* trial.
5.	Boueidar	80 km S. of Aleppo. Site out of use, an adjacent field is now being used.
6.	Maragha	110 km S.E. of Aleppo. Station of Steppe Directorate used for *Atriplex* research.

Lebanon

7.	Terbol	Beka'a Valley, 10 km S.E. of Riyak.
8.	Kfardane	Beka'a Valley, 30 km N. of Riyak.

Note: Both stations are operated jointly with the Lebanese Agricultural Research Council

INTRODUCTION

Since its inception in 1977 at Tel Hadya, ICARDA has endeavored to reflect the range of agricultural conditions, or environments, in its research in northwestern Syria. While the bulk of the research activity was concentrated at the 947-ha headquarters farm, with an average annual rainfall of 327 mm/year, the lower and higher rainfall zones had to be represented as well.

As drought is ever-present in the region, seasonal rainfall is the dominant parameter and the one used to separate the area into three zones: Zone A (> 350 mm, largely devoted to wheat), Zone B (250-350 mm, mixed cereals, legumes, rotations with fallow) and Zone C (< 250 mm, almost exclusively barley and fallow).

Increasingly, it was realized that parallel with this rainfall gradient was variation in other climatic factors—and *soils*. While "environment" implies temperature or rainfall to many people, soil is an intrinsic part of any field-crop environment. However, little emphasis was given to soil differences since the soils at all three locations representing these zones, Breda, Tel Hadya, and Jindiress, are deep and have relatively large water-storage capacities. With increasing experimentation, differences in spatial distribution of soil properties became evident along with their implications for plot design.

The need to consider the soil aspect became all the more apparent as the ICARDA's sub-station system was expanded to include drier marginal areas, i.e., Ghrerife and Boueidar; and Maragha, in the grazing area of the steppe, through the cooperation of the Steppe Directorate of the Syrian Ministry of Agriculture and Agrarian Reform. This dimension was again stressed with the addition of colder higher-rainfall areas in Lebanon to the experimental-site network.

Awareness of the soil properties at any station is essential to the effective transferability of knowledge to the broader area or environment which that station represents. Indeed, technical and economic management of such stations is dependent on such knowledge as well. Accurate characterization of soil types upon which experiments were conducted is also a prerequisite for publication in international refereed journals.

While generalized soil maps are available for Syria (Ilaiwi 1985), there was unfortunately no detailed classification of the soils at Tel Hadya or the other stations. Nevertheless, efforts were made to describe some profiles at Tel Hadya and in some of the other stations, including Khanasser and Kafr Antoun, both of which are no longer in use (Harmsen 1981). However, some classifications were tentative and made in the absence of analytical data. In his assessment of soil information in Syria, Subramanian (1981) emphasized the importance of having site characteristics and profiles described in areas where experiments are carried out.

As new developments have since occurred in soil classification, it was essential to re-examine the soils at the stations/sites and apply the current criteria based on adequate supporting analytical data. A major objective of our study was to update existing classifications and to classify those stations where none was available.

While it would be ideal to have a detailed (1:5000) map of Tel Hadya or the other stations, unfortunately we do not. Mapping costs money and takes time. Site description is the next best thing, and is feasible with currently available resources.

However, classification is only part of the story. A considerable amount of miscellaneous information has been compiled on nutrient behavior in terms of distribution and variability as well as on soil depth, physical properties and soil moisture relationships. Additional information in the recent data set included total forms of phosphorus and potassium and micronutrient cations and boron. We therefore provided complete up-to-date analytical data to illustrate these parameters. While many of the trends presented here are familiar to the soil scientist, most are not readily known or appreciated by our colleagues without a soils orientation.

In essence, our attempt was to bring together in one accessible volume all the available information on soils and their properties at ICARDA's stations with special emphasis on those aspects that would remain valid in the years ahead. As soil formation and soil use, i.e., cropping pattern, is linked with temperature and rainfall, we have included these environmental parameters, which were extracted from the voluminous meteorological station reports. This bulletin is designed as a document for use by ICARDA's scientists and collaborating scientists in Syria and the West Asia-North Africa region in general.

The document is presented in an easily readable form for the non-specialist and is a summary of ICARDA's accomplishments in the area of soil research. For the interested reader, a list of all ICARDA's soil-related publications is presented, in order to illustrate how our knowledge base in northwestern Syria has grown; and to provide a basis for research efforts and technology transfer in the years ahead.

ICARDA's STATIONS

Location

The location of Tel Hadya and the other five experimental sites in northwestern Syria (Breda, Jindiress, Ghrerife, Boueidar, and Maragha) is depicted on the schematic rainfall map of Syria in Fig. 1. The two stations in neighboring Lebanon, Terbol and Kfardane, are also indicated. These stations provide a range of climatic conditions for crop experimentation.

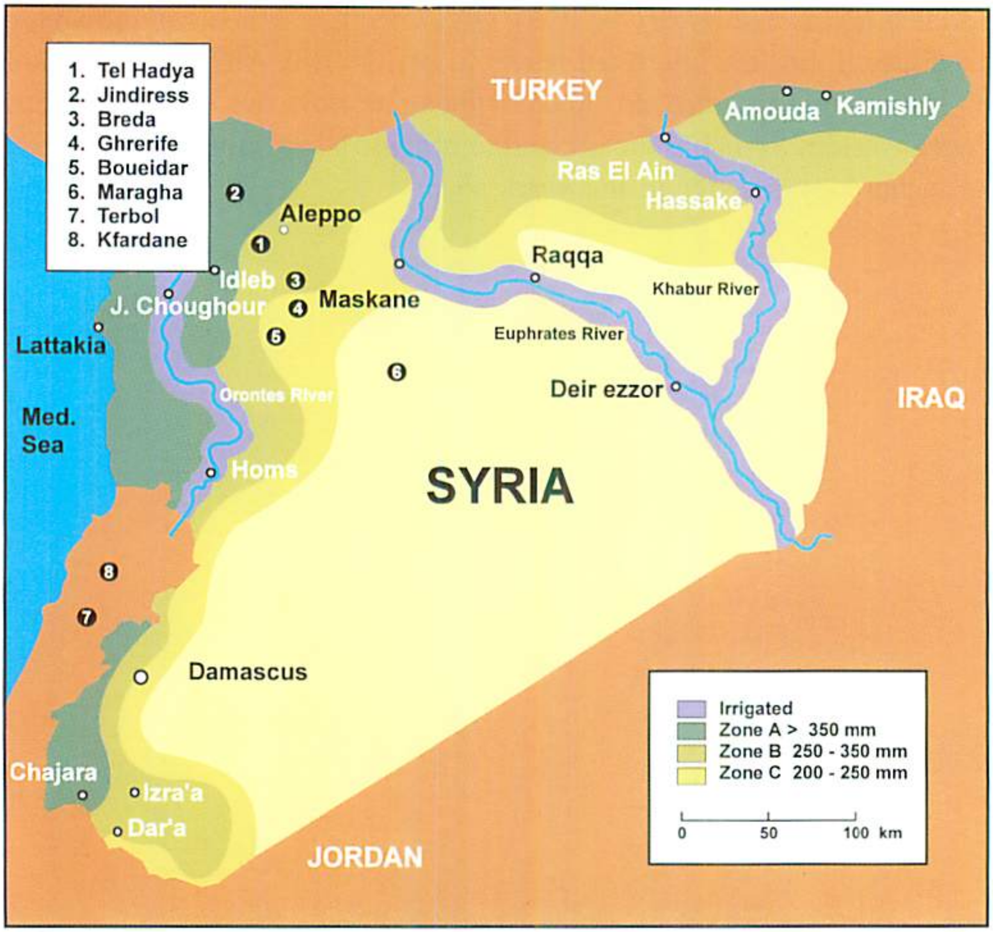


Fig. 1. Location of experimental stations in Syria and Lebanon and rainfall zones.

A brief word on the stations' general characteristics is appropriate. Details of location in terms of latitude and longitude and elevation are shown in Table 1 along with area and date of establishment. Most are entirely rain-fed, with some supplemental irrigation available in Tel Hadya and Terbol. The Tel Hadya site is the largest and most intensively cultivated station. Maragha belongs to the Steppe Directorate of the Syrian Ministry of Agriculture and Agrarian Reform, who have cooperated with ICARDA to meet the latter's needs for research in dry areas. It is totally devoted to range development. The other Syrian stations involve rented land with minimum infrastructure. The two higher-elevation sites in Lebanon are operated jointly with the Lebanese Agricultural Research Council.

Rainfall and Climate

Rainfall, the principal climatic factor, is shown in Table 2 in terms of mean, maximum and minimum values. These range from lowest at Maragha to highest at Jindiress for Syria, with similarly higher rainfall in Lebanon. The seasonal rainfall pattern shows a maximum in January and virtually nothing in July to September (Table 3).

Air temperatures similarly vary with location (Table 4). Coldest weather is in January-February and hottest in July-August. In Syria, extremes of both hot and cold are found in Maragha. Soil temperatures generally follow a similar pattern (Table 5), being less than 10°C in January and well over 30°C in mid-summer.

Evaporation data (Class A pan) again shows a seasonal pattern (Table 6); at the onset of the cropping season in November, evaporative loss is about 4 mm/day, declining to a minimum of 1-2 mm/day in January, and then gradually increasing to about 15 mm/day at harvest time in June. The likelihood of frost occurring in any one year varies with location (Table 7), being higher in the more inland areas of Boueidar and Maragha, and in Lebanon.

Table 1. General characteristics of the experimental stations.

Character	Syria						Lebanon	
	Tel Hadya	Breda	Jindiress	Ghrerife	Boueidar	Maragha	Terbol	Kfardane
Latitude (N)	36°01'	35°56'	36°26'	35°50'	35°40'	35°33'	33°33'	34°01'
Longitude (E)	36°56'	37°10'	36°44'	37°15'	37°10'	37°40'	35°59'	36°03'
Elevation (m)	284	300	210	320	270	370	890	1075
Area (ha)	948	102	12.5	5	10	7000	38.8	49.9
Irrigated	Partly	No	No	No	No	No	Partly	No
Year[1]	1977	1979	1979	1985	1989	1989	1978	1978

[1] Indicates when ICARDA began operation at site; Maragha, Terbol and Kfardane were in operation previously.

Table 2. Rainfall (mm/year): mean, maximum and minimum.

	Syria						Lebanon	
	Tel Hadya	Breda	Jindiress	Ghrerife	Boucidar	Maragha	Terbol	Kfardane
Mean	328	263	446	245	223	196	494	452
Minimum	230	183	333	169	151	182	317	—
Maximum	504	415	715	442	386	210	709	—

Table 3. Mean monthly precipitation (mm).

Station	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Total
Tel Hadya	60.9	50.2	43.8	28.4	14.2	3.0	0.0	0.1	0.5	24.5	48.5	53.8	328
Breda	48.6	40.2	36.3	23.9	16.3	2.7	0.6	0.0	0.6	22.8	32.5	40.2	263
Jindiress	78.6	67.0	60.9	41.2	13.2	3.0	0.0	0.0	0.4	42.3	69.1	70.0	446
Ghrerife	44.0	34.8	33.4	14.6	12.2	0.6	0.0	0.0	0.0	38.5	23.9	38.5	245
Boueidar	44.2	32.3	30.7	14.5	7.7	1.2	0.0	0.0	0.1	28.0	24.8	39.4	223
Maragha	49.2	62.2	8.4	0.2	19.8	1.8	0.0	0.0	0.0	6.8	14.2	19.6	182
Terbol	91.2	103.3	95.6	26.2	13.4	0.6	0.4	0.0	0.0	28.9	56.1	77.9	494
Kfardane[1]	52.0	31.3	42.6	6.9	2.6	—	—	—	—	17.0	110.8	104.4	365

[1] 1994/95 season only.

Table 4. Monthly maximum and minimum air temperature (°C).

Station		Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Tel Hadya	Max	11.2	13.5	17.5	23.7	29.2	33.9	36.7	36.7	34.4	27.3	18.6	12.9
	Min	1.7	2.1	4.6	8.0	12.1	17.2	20.7	21.0	17.2	11.7	6.4	2.7
Breda	Max	10.4	12.7	17.2	23.9	29.3	34.3	37.0	37.1	33.9	26.6	17.9	12.2
	Min	1.4	1.7	4.4	8.0	12.1	16.6	19.7	19.6	15.4	10.4	5.4	1.9
Jindiress	Max	10.9	12.9	17.2	23.0	28.1	32.6	34.5	34.7	33.1	26.4	18.1	12.7
	Min	2.2	2.6	5.4	8.9	12.0	16.9	10.8	21.1	17.6	11.7	6.7	3.5
Ghrerife	Max	10.8	13.2	17.5	24.6	29.5	34.4	36.8	36.9	33.7	26.0	17.7	11.7
	Min	1.8	2.9	4.9	9.8	13.2	18.0	20.2	20.3	17.3	12.6	6.0	2.5
Boueidar	Max	10.0	13.5	17.2	25.2	29.6	35.1	38.3	37.6	34.7	27.0	17.6	11.9
	Min	0.3	1.8	3.7	7.9	10.4	15.0	17.6	16.6	14.7	10.8	4.1	1.4
Maragha	Max	12.5	15.6	25.8	32.7	39.8	39.0	41.6	43.4	40.2	34.6	24.8	17.3
	Min	-7.1	-4.6	-4.4	2.9	8.0	11.6	13.1	15.0	13.3	6.4	1.0	-5.4
Terbol	Max	10.8	11.7	15.7	22.0	26.4	30.4	33.0	33.0	31.6	25.6	18.7	13.2
	Min	-1.1	-0.5	1.2	4.6	6.8	9.0	11.2	11.8	9.9	6.8	2.8	-0.2
Kfardane[1]	Max	9.3	11.4	13.6	15.5	26.0	31.9	31.8	33.1	30.9	24.9	13.2	7.0
	Min	2.3	4.2	6.4	3.4	12.4	20.2	14.3	14.6	17.7	14.9	6.8	1.7

[1] 1994/95 season only.

Table 5. Mean soil temperatures (°C) at 5-cm depth.

Station	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Tel Hadya	8.4	9.1	13.6	18.7	23.3	30.9	32.7	33.3	32.0	25.7	16.3	11.0
Breda	8.8	10.2	15.7	21.4	27.1	34.7	36.7	35.9	30.7	25.2	16.6	11.6
Jindiress	7.0	7.6	12.7	21.8	25.9	31.1	33.4	32.5	29.9	25.0	16.5	10.8
Ghrerife	7.6	8.7	13.8	19.2	23.1	29.7	32.7	33.3	30.5	25.2	16.3	10.7
Boueidar	7.4	8.2	13.3	18.7	24.6	30.7	32.3	32.1	30.6	25.3	16.5	10.8
Maragha	3.4	5.2	10.2	19.7	26.2	33.7	35.1	35.2	28.7	23.2	14.8	6.9
Terbol[1]	8.0	9.7	13.2	15.6	25.8	30.4	30.8	—	30.5	24.3	13.3	6.3
Kfardane		not available										

[1] 1994/95 season only.

Table 6. Mean monthly evaporation (mm, Class A pan).

Station	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Tel Hadya	1.3	2.7	4.1	6.2	9.3	15.5	17.3	16.1	11.7	7.5	3.9	2.2
Breda	1.4	3.2	4.4	7.2	10.2	15.7	17.4	15.9	10.9	7.8	3.7	2.5
Jindiress	1.5	2.2	3.3	5.3	7.2	10.2	13.1	16.0	12.9	8.4	3.3	2.1
Ghrerifc	1.0	2.2	2.3	4.2	7.8	18.7	16.2	15.8	13.5	10.4	4.4	2.1
Boueidar	1.1	2.5	4.0	7.5	10.9	15.0	15.5	13.5	11.1	7.3	3.8	1.9
Maragha	not available											
Terbol	2.5	3.0	2.8	5.1	4.9	11.9	14.9	13.3	12.3	9.6	4.3	3.0
Kfardane	not available											

Table 7. Mean number of frost events per month.

Station	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May
Tel Hadya	0	2.6	7.8	9.9	8.7	4.2	0.3	0
Breda	0	3.8	10.6	11.3	9.4	4.3	0.6	0
Jindiress	0	1.9	7.6	9.5	7.5	2.8	0.3	0
Ghrerife	0	2.1	8	9.7	6.9	3.6	0.2	0
Boueidar	0.6	5.7	11.7	12.8	9.3	5.2	0.5	0
Maragha	0	0	16	22	14	11	0	0
Terbol	1	6.8	15.6	17.5	17.0	12.5	2.8	0.7
Kfardane[1]	0	0	3	10	3	3	3	0

[1] 1994/95 season only.

Layout and Land Use

Some detail on the organization of the stations with respect to plot plan is also pertinent. The Tel Hadya layout (Fig. 2) shows the sites for the four excavated profiles, the three blocks (A,B,C) used for cropping research, and the area with shallow hilly soil devoted to grazing research. Because of the small scale, it is not possible to show the current land use and experimentation. However, a general description for each block will indicate the range of crops and research.

In 1992/93, Block A had wheat and barley high-elevation trials, medic, chickpea and vetch plots, chickpea ascochyta nursery, and breeding trials as well as areas for physiology and pathology research; Block B had trials for long-term P fertilization, orobanche control, supplemental irrigation, and tillage comparisons; and Block C was dominated by the Farm Resource Management Program's (FRMP) two-course rotation (durum wheat vs. fallow, continuous wheat, summercrop, lentil, chickpea, vetch, medic), and the Pasture, Forage and Livestock Program's (PFLP) grazing rotation, durum breeding, and genetic resources.

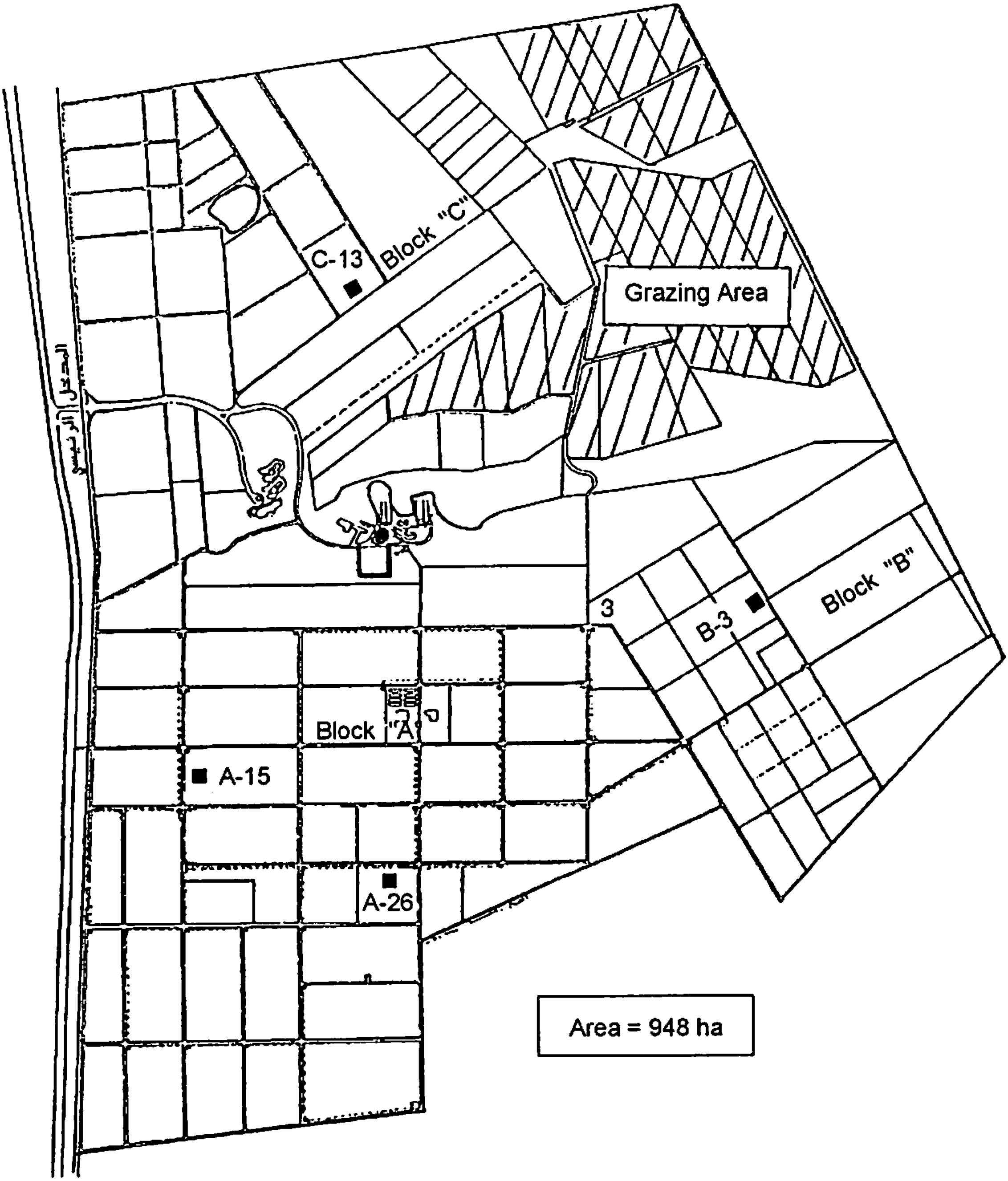


Fig. 2. Schematic diagram of Tel Hadya station.

A sketch of Breda (Fig. 3) indicates the cropping pattern in this drier station. Here barley is the main cereal, as it is more drought-tolerant than wheat, and vetch the main legume instead of chickpea and lentil. The relatively smaller rented site, Jindiress (Fig. 4), in the higher-rainfall zone, has a similar diversity of use, mainly oilseed crop, i.e., rape, sunflower, safflower, chickpea, lentil and watermelon, and a long-term P fertilization trial with durum wheat in rotation with lentil, essentially the same trial as in Tel Hadya and Breda. (Layouts for Lebanon stations are shown in Fig. 5 for Terbol and Fig. 6 for Kfardane.)

The research activity at the other stations, i.e., Ghrerife, Boueidar and Maragha, is minor. The tiny site at Ghrerife consists solely of an experiment with barley alternated with rows of *Atriplex* bushes. Boueidar is somewhat larger (20 ha) and mainly devoted to barley variety trials, with the other half as fallow or covercrop in alternate years. While Maragha in the steppe is large (7000 ha) and devoted to *Atriplex* research, a small section is devoted to PFLP grazing trials. Each of these ICARDA sites is poorly developed in terms of infrastructure with little other than a fence and a meteorological station.

The management practice at all stations where cropping occurs is to follow a system of rotations, i.e., cereals and legumes or fallow in alternate years. Research experiments are accommodated within this framework. Typical systems at Tel Hadya and Jindiress involve wheat in rotation with chickpea or lentil, and barley in rotation with fallow or vetch at the drier Breda site. The system is designed to eliminate residual soil effects of experiments. Thus, when the trial involves a legume, a uniform cereal is planted the following year as a "covercrop" to homogenize the site. Similarly, if cereals are involved in the trial, the alternate legume crop is used as a "covercrop."

Cropping Experiments

Where crops or different categories of research are indicated in the station layout, the intention is to broadly reflect the various activities that normally occur at these stations. The data presented are valid for the 1992/93 cropping season, but can be expected to change from year to year.

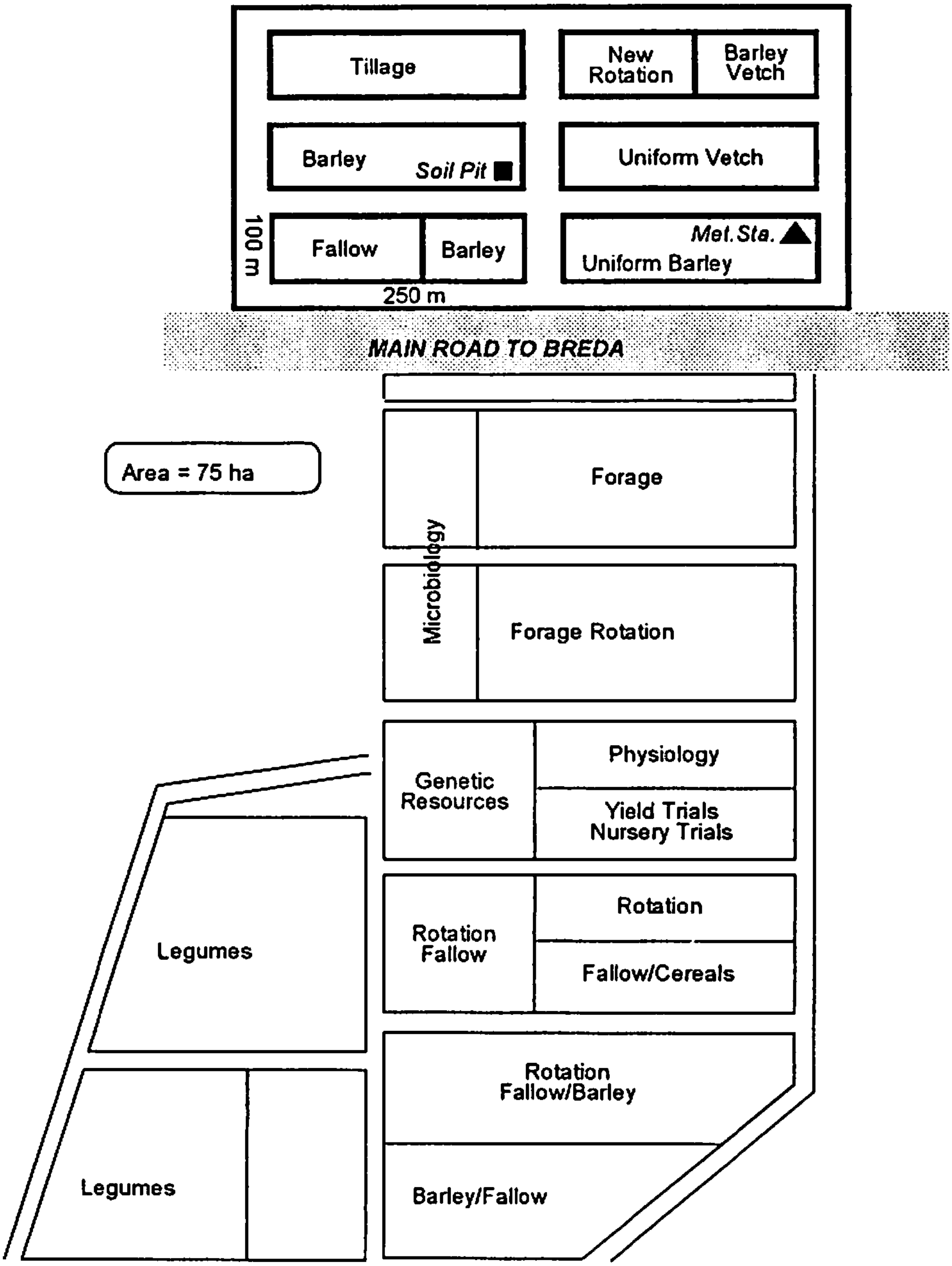


Fig. 3. Schematic diagram of Breda station.

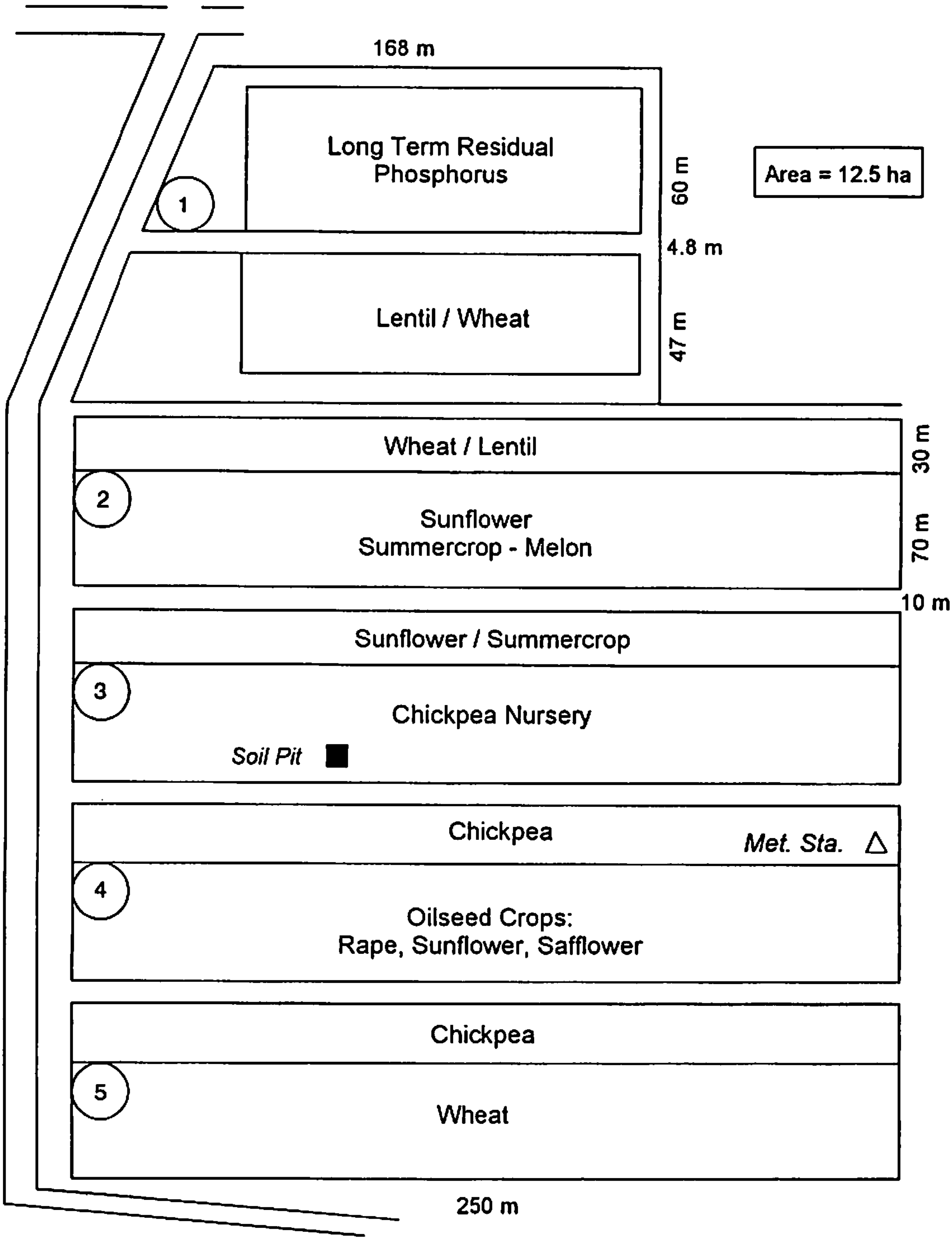


Fig. 4. Schematic diagram of Jindiress station.

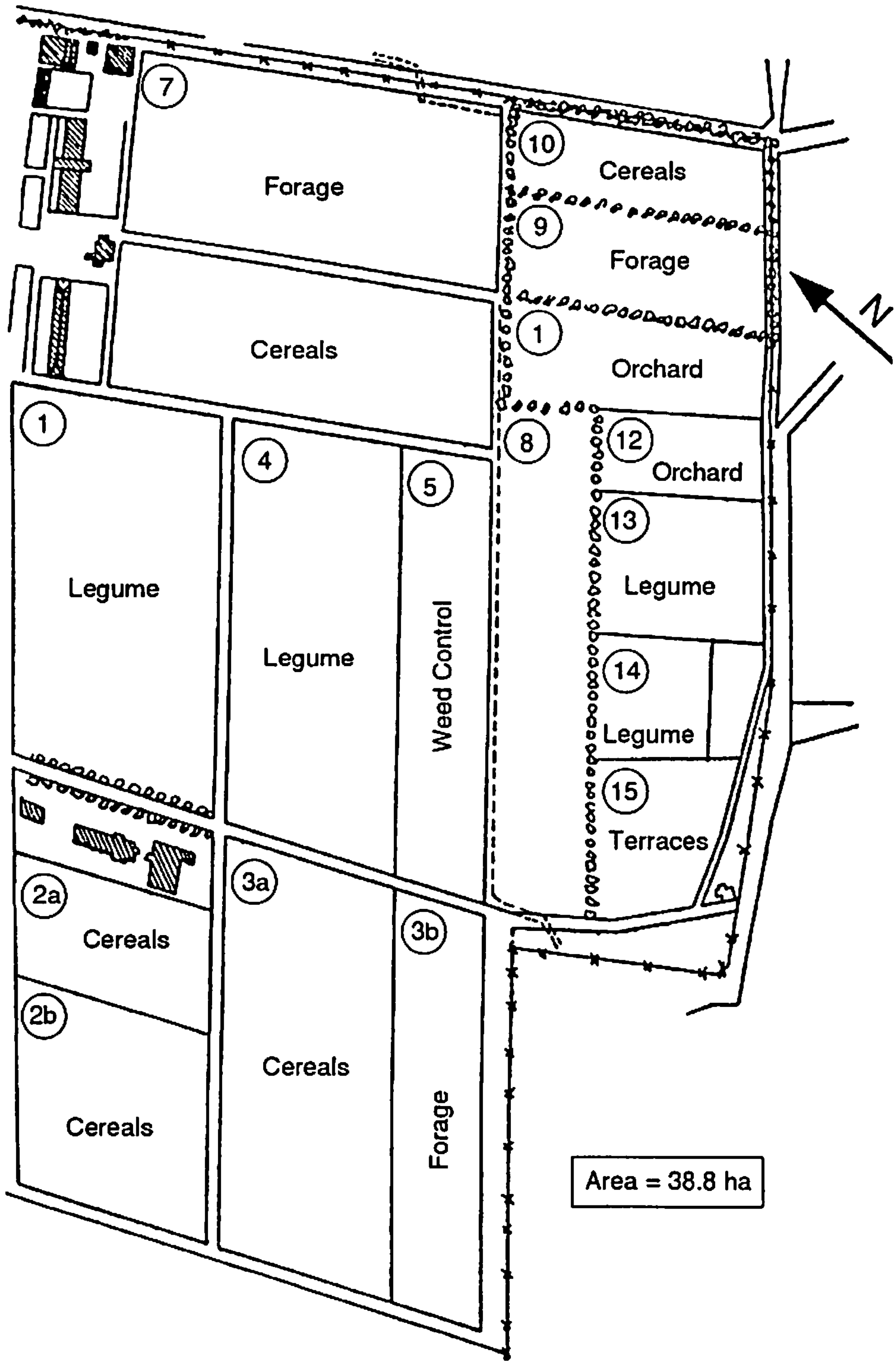


Fig. 5. Schematic diagram of Terbol station.

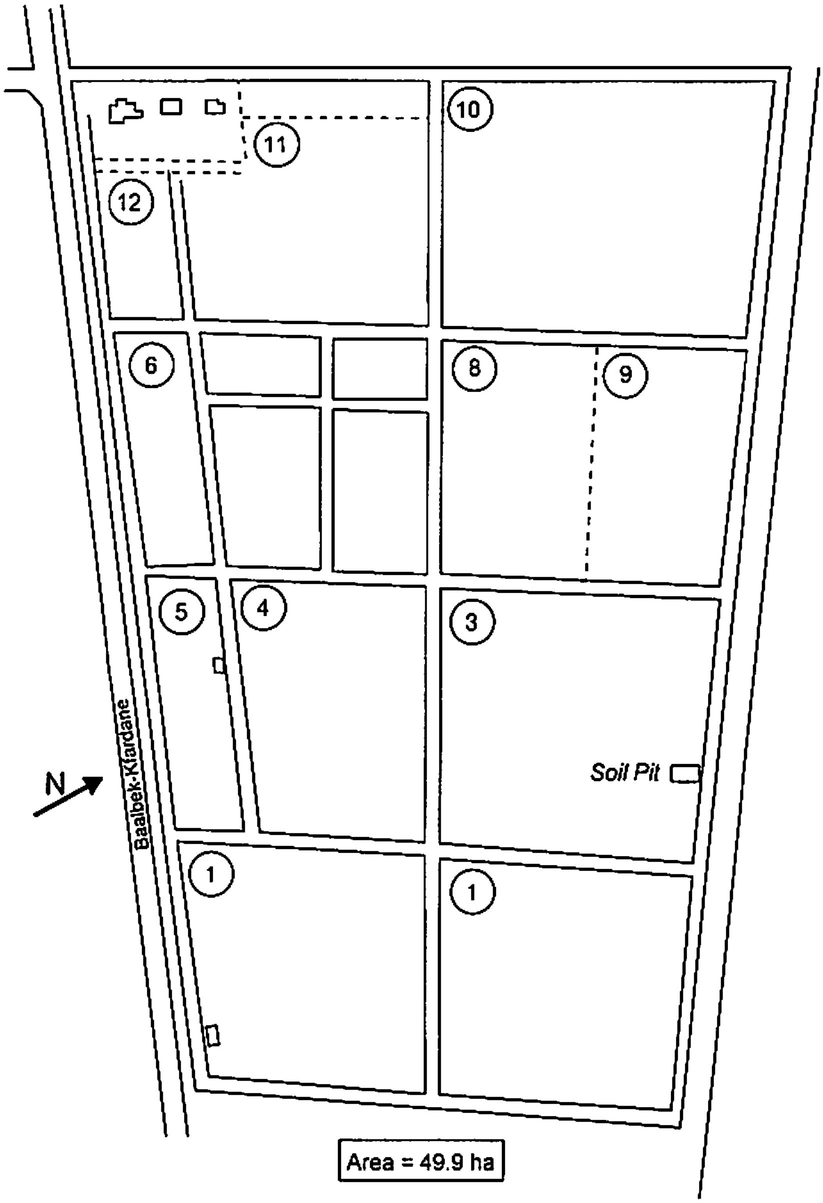


Fig. 6. Schematic diagram of Kfardan stations.

The plots least subject to change are the long-term trials. Some, such as the two-course rotation in C-16 at Tel Hadya, have both cropping phases each year, with plots in cereals in any one year being in the alternative crops the next year. Some long-term trials remain the same each year, e.g., at Gherife, which is continuously cropped to barley interspersed with rows of *Atriplex*.

Other trials are of determinate medium-term duration, i.e., the supplemental irrigation experiments (bread wheat, durum wheat, water levels, nitrogen) in A-2, which are scheduled to last 4 years. Several trials are conducted for only to 2 years, e.g., the 2-year trial with P, Zn, and inoculation of pasture and forage legumes in B-3.

The suite of trials at these stations at any one time reflects the evolution of ICARDA's research; as problems of research are solved, new challenges are there to be tackled. Trials at these stations can, in general, be expected to vary with available research personnel and with fluctuations in funding.

Tillage Systems

The soil conditions at the stations dictate to a large extent the kind of tillage practised and the timing of the operation. At Tel Hadya, the soil is clayey and, as a result, is fairly cloddy, especially after irrigation. Primary tillage or plowing is therefore often combined with the operation of a packer in order to break large clods before they dry out completely. This also improves germination from early rains. Seedbed preparation involves a spike-tooth harrow if the soil is soft and a rotary power harrow for sufficient effect if the soil is dry and hard. Accurate planting is possible if the soil is dry enough and clod-free.

Deep clay soils, such as at Tel Hadya, often pose a problem with summer weeds; this requires mechanical or chemical control after summer cultivation. *Sorghum halepense* can still be a problem if enough residual moisture remains in deeper layers, particularly after irrigation. If chemical weed control is not available, mechanical weeding is essential, either by hand, as inter-row cultivation, or with a weeding harrow.

At Jindiress, the soil is even heavier in clay; this poses some limitation on the timing of tillage. The soil should not be too dry or too wet for plowing or cultivation; both extremes produce too many clods. If primary tillage produces good soft soil conditions, the seedbed may be prepared by a spike-tooth harrow; a spring-time harrow should be used for a rougher surface. However, a spike-tooth harrow does not produce good lateral surface leveling. Again, soil conditions are critical for planting; this has to be done as quickly as possible after planting in fairly dry soil in order not to give weeds a chance to be established before the crop.

Because the soil at Breda is of lighter texture than that at either Tel Hadya or Jindiress, there is less of problem with clods. However, in order to avoid soil pulverization, excessive cultivation should be avoided. Frequently, the spike-tooth harrow is enough to prepare a seedbed. Indeed, because of low weed pressure, a one-passage combination of cultivation and planting is possible. This would not be feasible unless all surface residues were removed—because of demand for fodder—by stubble grazing with sheep.

As Breda is the driest of the cultivated sites, care has to be taken in preparing the ground for barley-planting to avoid excessive cultivation in order not to destroy the soil structure (this is reflected in the low organic matter content—only 0.5%, or about half that of Tel Hadya). Because of drought and surface dryness, care must be taken to ensure uniform planting depth. Weeds are not a serious problem at this dry site; they occur mainly after fallow, and are dominated by a leguminous weed, *Alhagi camelorum* or camelthorn.

CLASSIFICATION

A Brief Explanation

Like all branches of science, classification of soils helps us remember the many facts about soil, facilitates interpretation of the multitude of data that soil science has gathered, and helps us predict properties or behavior of soils. This science is as old as time; it began when man first noticed that the soil in one field was different from that in another.

Pedology, as soil classification was referred to in the early days, emerged independently as a separate science from geology in Russia and America in the last century. Thus, we have two main classification systems today, and many others that exist in other regions of the world but which have elements of the Russian or American models, or both. The FAO/UNESCO system is such a hybrid.

Classification of soils continues to change and evolve as our store of knowledge accumulates. This is particularly so for the US system of Soil Taxonomy (USDA 1975). Since its inception in 1938, the system has been subjected to continuous scrutiny by field scientists and several revisions have been published, culminating in the 7th Approximation and Soil Taxonomy in the 1970s. Indeed, the latest update (USDA 1992) shows considerable changes in the criteria for horizon and soil classification. No doubt more changes can be expected in the future.

General Soil Map of Syria and Lebanon

The soils of ICARDA's stations must be seen in the context of the major soil types in Syria and Lebanon. Fortunately, these are mapped on a 1:1,000,000 scale (Ilaiwi 1985). The dominant soil orders in this map (Plate 1) are: **Inceptisols** (Calcixerollic, Lithic, Typic, Petrocalcic, Vertic), which dominate the cereal-growing area; **Aridisols** (Gypsiorthid, Calciorthid), which dominate the arid steppe and desert area; **Entisols** (Torrifluvents in

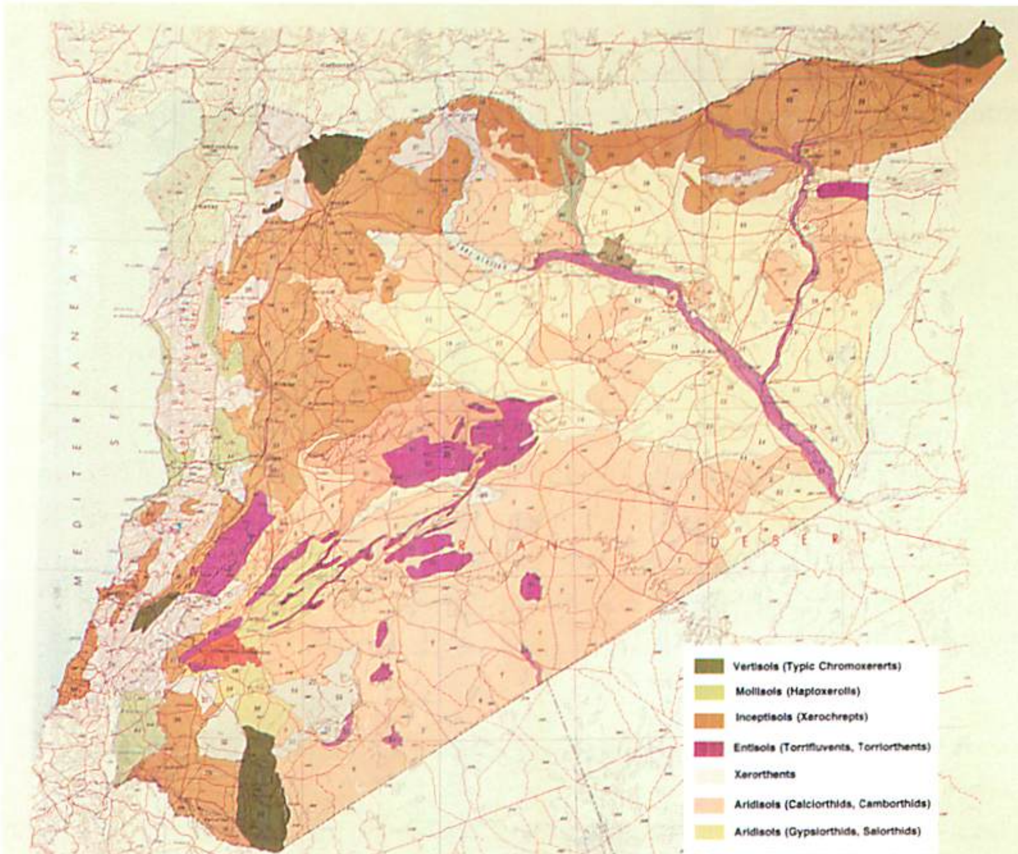


Plate 1. Soil map of Syria and Lebanon. Iliawi, M. 1985.
The Arab Center for the Studies of Arid Zones and Dry Lands (ACSAD), Damascus, Syria.

irrigated river valleys, i.e., Euphrates valley, and **Torriorthents** or shallow stony soils in the desert zone); and small areas of **Vertisols** (near Jindiress area in the N.W., the N.E. corner near Iraq, and around Suwayda near the Jordan border), and a small area of **Mollisols** in the Golan Heights. Lebanon's Beka'a valley is dominated by **Vertic Inceptisols.**

Profile Description and Interpretation

Against this very general background, we present a profile closeup and general area view for each station, including the three exposures at Tel Hadya (Plates 2-13). This series of pictures illustrates the concept of a soil profile to the non-specialist, the relationship between a profile and landscape, and the vertical variation that exists beneath the soil surface.

This is followed by standard morphological descriptions of each horizon or layer with depth, according to *Soil Taxonomy* (1975) using the latest (5th) edition of *Keys to Soil Taxonomy* (1992). The pits were dug and the profiles exposed in October 1992 prior to the onset of the season's rain. This includes general landscape observations and aspects such as structure, depth, color, roots, concretions, and other features.

A few general remarks are pertinent for the reader. What constitutes a "soil" depends on one's perspective. For the farmer, it is the medium for growing crops and one that anchors plants and allows roots to permeate through its mass to obtain nutrients and water. The pedologist considers how the soil developed, i.e., its genesis. While some soils are derived from the rocks beneath them (*in situ*), most are derived from transported materials. Thus, one can observe different layers or horizons as we examine a vertical section of soil, i.e., profile. Some layers have been changed with time due to processes of soil development, while others are depositional and have not been affected by pedogenic processes.

The horizons identified by the pedologist are designated by letters and numbers. The "A" horizon is fairly synonymous with the topsoil and often coincides with the depth of plowing, i.e. Ap. Such surface layers usually have higher amounts of organic matter due to root decomposition and are better aggregated—that is to say, more porous.

Where the sub-surface layer is noticeably different from the surface and there is evidence of genetic development such as deposition of fine clay and carbonates and changes in color or structure, the layer is designated B. In essence, the soil is made up of both A and B horizons. At greater depths, one may find loose unconsolidated material that has not been affected by pedogenic processes, and such layers are designated C horizons. Beneath that again, one finds solid rock or the R layer. Where the soil is uniform with depth, the entire layer is designated A, but may be arbitrarily divided into sub-layers for analysis, e.g., in the case of the Vertisol at Jindiress.

Bearing these descriptions in mind, one sees a similarity in several of the soils described here as they have evolved in a similar climate. Thus, the formative element "xer" is used in the classification, i.e., under a xeric moisture regime characterized by a wet season (winter) and a dry season (summer) typical of the Mediterranean region.

As one examines the Tel Hadya profiles visually, it is easy to see that: (a) they are deep—in most cases the bottom of the pit does not reach bedrock, (b) the top 70 cm or so is dark reddish, and (c) the lower layers have whitish specks that indicate the presence of calcium carbonate. The depth of this carbonate layer is related to rainfall. One also finds carbonate concretions in the Breda soils. However, at the higher-rainfall sites (Jindiress, Terbol, Kfardane), there is no evidence of calcium carbonate concretions. The soils of the drier areas reflect the type of parent material and have variable amounts of gypsum, especially at Maragha.

Any soil is the outcome of many factors that have operated for perhaps million of years, for example different parent rock, topography or land shapes, climate, vegetation—and all under the influence of man's activity over time. But the classification of any site is also strongly influenced by climate. Thus we find sites with moderate rainfall classified as Inceptisols or moderately- developed soils, Vertisols or well-developed deep soils in higher rainfall areas, and Aridisols or soils of dry regions which are poorly developed and have many features of the original deposits.

Sampling and Analysis

Subsequently samples were taken in duplicate to the laboratory for a range of chemical analyses (<2 mm) according to Page et al. (1982), i.e., total N and ammonium (NH_4^+) and nitrate forms (NO_3^-), available $NaHCO_3$, extractable P and total P, extractable and total K, $CaCO_3$, organic matter, micronutrient cations (Fe, Mn, Zn, Cu) and boron (B), electrical conductivity (EC), pH, cation exchange capacity (CEC), and gypsum. One reference sample from Tel Hadya was analyzed for clay minerals and iron oxides at the National Laboratory in Lincoln, Nebraska. Some representative samples were tested for total and available moisture capacity as well as for bulk density.

Depth Considerations

Normally soil analyses are performed on "surface" samples, i.e., the top 10 to 20 cm layer. This layer is not always indicative of what lies beneath, but it is easier to sample and represents the zone of most biological activity. Depth has particular significance for soils of dryland areas. Shallow soils hold little water, while deep ones, 50 to 100 cm or more, hold correspondingly more water for plant uptake. Thus, in such areas, crop yields are proportional to depth—assuming there is adequate rainfall and soil moisture to exploit that depth. Even in deeper soils, the surface layer is frequently dry and roots depend on deeper layers for moisture.

Sub-surface layers frequently differ from the surface layer in terms of nutrient availability. While available P and organic matter is generally lower with depth, in some cases elements such as boron and NO_3-N increase with depth, and therefore have an influence on plant growth which is undetected by surface sampling and analysis.

From the practical standpoint, the distribution of nutrients and water with soil depth is of considerable importance. However, the distribution of soil chemical and physical properties are of concern to the soil morphologist, who seeks to identify the various soil horizons, classify pedons, and extend the information gathered from exposed profiles to soil units in the landscape. Therefore, in this document, we have presented a visual profile display and its associated landscape, and morphological descriptions, as well as nutrient and moisture profiles.

Soil Taxonomy: What Is It?

Soil Taxonomy is a comprehensive multi-category system based on hierarchical differentiating criteria. Thus, at the broadest level, we have the soil order, based on key or diagnostic soil horizons; there are now 11 soil orders recognized throughout the world.

The various orders and their main characteristics are: Entisols (mainly alluvial and very shallow soils); Vertisols (heavy clay soils); Inceptisols (moderately deep weathered soils); Aridisols (soil of arid regions); Mollisols (dark soils with high levels of organic matter, mainly in temperate grasslands); Spodosols (highly leached soils developed on acidic rocks in high- rainfall temperate areas); Alfisols (deep, moderately weathered, high-base ($CaCO_3$) soils); Ultisols (highly weathered low-base soils in subtropics); Oxisols (weathered soils of tropics, high rainfall); and Andisols (soils developed from volcanic ash).

The next category is the sub-order, based on properties associated with wetness and soil moisture regime. The third category of great group is centered around other properties such as base status, temperature, and diagnostic layers. The sub-group is based on the central concept taxa for the great groups. The family is based on properties such as texture and mineralogy. The sixth category, series, is based on arrangement of horizons, color, structure, etc. With increasing differentiating characteristics as one goes from the order level to series, the numbers increase almost exponentially. Thus, as of 1973, over 10,000 distinct soil series were identified in the USA alone. A seventh category, the phase, is of relevance to erosion and is based on slope and stoniness.

In many countries where soil-survey organizations are well established and funded, soils are classified and mapped at the detailed series level, and thus at a scale that one can identify soil differences at the farm level. However, in many developing countries, soils are not classified or mapped at all or, at best, at the generalized level—the soil order or sub-order. In Syria, a generalized map exists (Ilaiwi 1985) which depicts soil types at the great group level.

What The Soil Name Tells Us

Unlike other soil-classification systems, which are based on assumed genesis, Soil Taxonomy is based on physical measurement of actual soil properties. Similarly, other systems have had nomenclature which offered little enlightenment as to the properties of the soils in question ("Chernozems", "Podzols", "Brown Earths"), while Soil Taxonomy is a classification system can be deciphered using some key formative elements. For example, a listing of the major soils at ICARDA's stations can serve as an illustration.

Jindiress: Chromic Calcixerert

- This is a *Vertisol*, as indicated by the formative element "*ert*". Vertisols are soils with high clay content (more than 30%), are deep (at least 1 m), and have deep wide cracks during the dry season (several months in any year).
- It is a *Xer*ert because it is dry (xeric) for a long period of the year and therefore typical of the Mediterranean zone, with wet winters and dry summers.
- It is a *Calci*xerert because it has a horizon rich in $CaCO_3$.
- It is a *Chromic* Calcixerert because of its reddish color.

Tel Hadya: Calcixerollic Xerochrept

- This soil is an *Inceptisol* meaning soils of the humid and sub-humid regions that are moderately weathered (have altered horizons that have lost bases but retain some weatherable minerals). Hence, the "*ept.*"
- It is an "*ochr*ept" because of its light reddish-brown color and is free-draining.
- It is a *Xer*ochrept because it is characteristic of a Mediterranean-type climate.
- It is a *Calci*xer*oll*ic Xerochrept because it also has a calcareous or $CaCO_3$-rich layer in the sub-soil as well as having some organic matter enrichment in the surface horizon, but not enough to classify it as a *Moll*isol.

Maragha: Typic Gypsiorthid

- This soil is on *Aridisol*, i.e., from very dry or arid (<200 mm/year rainfall) areas.
- It is an "*Orth*id" because it does have some horizons, but no layer rich in clay or sodium.
- It is a "*Gypsi*orthid" because it has a gypsic horizon, i.e., it has a layer (at least 15 cm) rich in gypsum or calcium sulfate (at least 5%), and which is not cemented.
- It is a *Typic* Gypsiorthid because it has the normal features associated with this great group or soil type.

A Guide To Field Description Of Soils

In the following section, we present morphological description of the soil profiles: four sites at Tel Hadya and one profile at each of the other stations, except Breda, for which there are two.

Each of the standardized descriptions involves: identification of the soil type and observation on the physiography or topography of the site; the extent of erosion, if any; the degree of drainage and soil moisture status; parent material or the geological sub-stratum upon which the soil has formed; natural vegetation and land use; and any relevant remarks.

Then follows identification of the perceived soil horizons or layers. Within each layer, measurements are made of soil color (wet and dry), the type of soil structure, the presence of $CaCO_3$ and its form, the extent of roots and biological activity, and the nature of the boundary between the particular horizon and the one beneath.

To the non-pedologist, most soil profiles look the same in depth at first glance. However, distinct horizons can be identified through closer examination by trained personnel. And most people can see from the average profile that there is usually a darker layer of variable thickness at the top of the pit or cutting. Below that, one can notice color changes and differences in structure; often the subsoil is blocky because of high clay content and little organic matter.

The "real" soil is these two layers (topsoil and subsoil) where one can identify plant roots. Below the subsoil one can observe a layer that is "parent material," upon which the soil itself developed; it could be loose unconsolidated deposits (sand, carbonate gravel), clay deposited geologically, or solid rock (in our sites, the excavation did not reach the bedrock). The general differences with depth are more readily appreciated by looking at the color plates of these profiles.

Morphological Description of the Stations' Soil Profiles

In the pages that follow in this section, we have described the horizonation and morphology of each profile, along with its associated landscape features. Because of its diversity and size, four profiles are presented to represent the soils of Tel Hadya, two from Block A and one each from Blocks B and C. One profile has been chosen from each of the other stations, except Breda, where two were taken. In addition, a closeup of some soil features unique to Vertisols is also presented for Jindiress. Accompanying each profile is the associated landscape perspective, indicating the pit location where possible.

Tel Hadya (Block A, Field 15)

Classification:	fine clay montmorillonitic, thermic, Calcixerollic Xerochrept
Physiography:	plain bordered by small hills from north
Topography:	flat
Erosion:	none
Drainage:	well drained
Moisture status:	dry
Vegetation:	winter grass
Parent materials:	deposited material on limestone
Land use:	cereal crops
Remarks:	few narrow (3 mm) and short cracks (20-40 cm)

Ap: 0-30 cm
Red (2.5 YR 4/6) dry, and dark red (2.5 YR 3/6) moist, clay, moderate fine to medium granular, with locally weak fine to medium subangular blocky, hard dry, friable moist, sticky, plastic, calcareous, very few subangular gravels of calcareous nature (2-7 mm in diameter), many fine roots, common biological activity, abrupt smooth boundary.

Bk1: 30-65 cm
Dark red (2.5 YR 3/6) dry and moist, clay, moderate medium subangular blocky, very hard dry, firm moist, very sticky, very plastic, calcareous, gravels as in Ap, few concretions of $CaCO_3$ soft to slightly hard of about 3 mm in diameter (occupies about 10% of the horizon by volume), very few fine roots, merging boundary.

Bk2: 65-85 cm
Structure is less compact, $CaCO_3$ concretions constitute about 25% of the horizon by volume and larger in size.

C: 85+ cm
Layer of slightly weathered limestone.

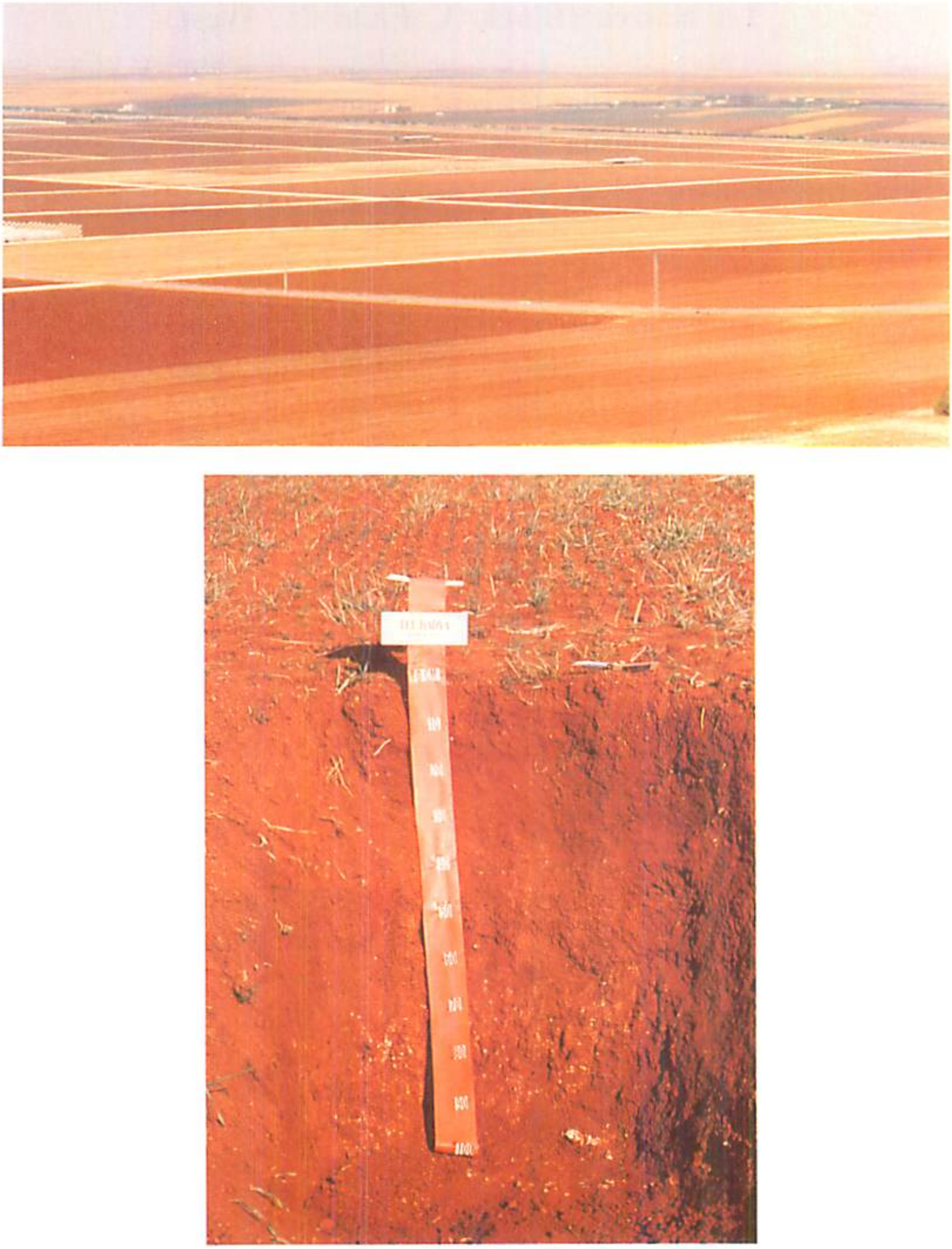


Plate 2. Location and profile of Tel Hadya, Block A-15. (View southwest, profile exposed at top right quarter of picture.)

Tel Hadya (Block A, Field 26, West)

Classification:	very fine (clayey), montmorillonitic, thermic, Chromic Calcixerert
Physiography:	plain
Topography:	flat
Erosion:	none
Drainage:	well drained
Moisture status:	dry
Vegetation:	winter grass
Parent materials:	deposited material on limestone
Land use:	rain-fed agriculture (cereal crops)

Ap: 0-40 cm
Red (2.5 YR 4/6) dry, and dark red (2.5 YR 3/6) moist, clay, moderate fine to medium angular with weak medium subangular blocky, which prevails at a depth of 20-40 cm (the horizon has been disturbed by deep plowing), hard dry, firm moist, sticky, plastic, calcareous, very few fine roots, few gravels up to 5 mm in diameter of lime origin, moderate biological activity, abrupt smooth boundary.

Ak1: 40-110 cm
Dark red (2.5 YR 3/6) dry and moist, clay, massive compact, separated by cracks (> 50 cm deep and > 1 cm wide) to very coarse prisms, some moderate medium subangular blocky is observed in the upper 10 cm of the horizon, very hard dry, firm moist, very sticky, very plastic, calcareous, few soft to slightly hard concretions of $CaCO_3$, 4-10 cm in diameter, few fine roots, little biological activity, common pressure faces, merging boundary.

Ak2: 110-180 cm
As above, except cracks are narrower and shorter (3 mm x 30 cm), massive and compact, intersecting slickensides (at 120 cm deep).

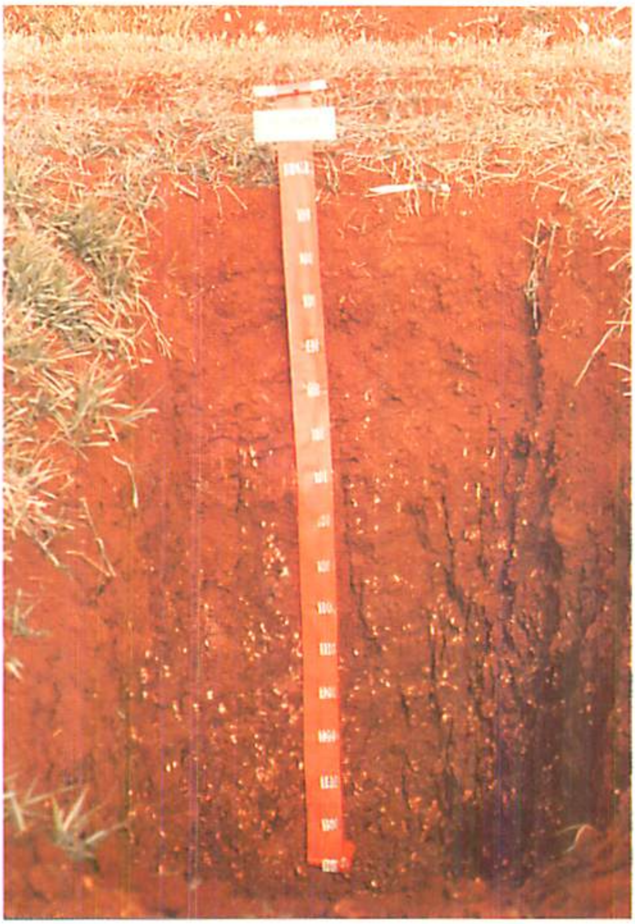


Plate 3. Location and profile of Tel Hadya, Block A-26. (View south, profile exposed behind buildings in center of picture.)

Tel Hadya (Block B, Field 3)

Classification:	very fine (clayey), montmorillonitic, thermic, Chromic Calcixerert
Physiography:	very gentle slope (towards south)
Topography:	almost flat
Erosion:	none
Drainage:	well drained
Moisture status:	rather moist from 40 cm downwards
Vegetation:	winter grass
Parent materials:	deposited material on limestone
Land use:	cereal crops
Remarks:	cracks up to 1 cm wide and about 30 cm deep

Ap: 0-12 cm
Dark red (2.5 YR 3/6) dry and moist, clay, moderate fine to medium granular with weakly developed subangular blocky in places, hard dry, friable moist, sticky, plastic, calcareous, high biological activity, few fine limestone gravels (1-3 mm in diameter), abrupt smooth boundary.

Bk1: 12-40 cm
Dark red (2.5 YR 3/6) dry and moist, the mass of the horizon is separated into large blocks (prisms) with locally developed moderate medium subangular blocky, hard dry, friable moist, very few fine roots, few gravels of calcareous origin (3-10 mm in diameter), very few soft $CaCO_3$ concretions, merging boundary.

Bk2: 40-150 cm
Color and texture as above, moderate medium prismatic, hard dry firm moist, calcareous, soft to slightly hard concretions of $CaCO_3$, up to 10 mm in diameter constitute about 20% of the horizon by volume.

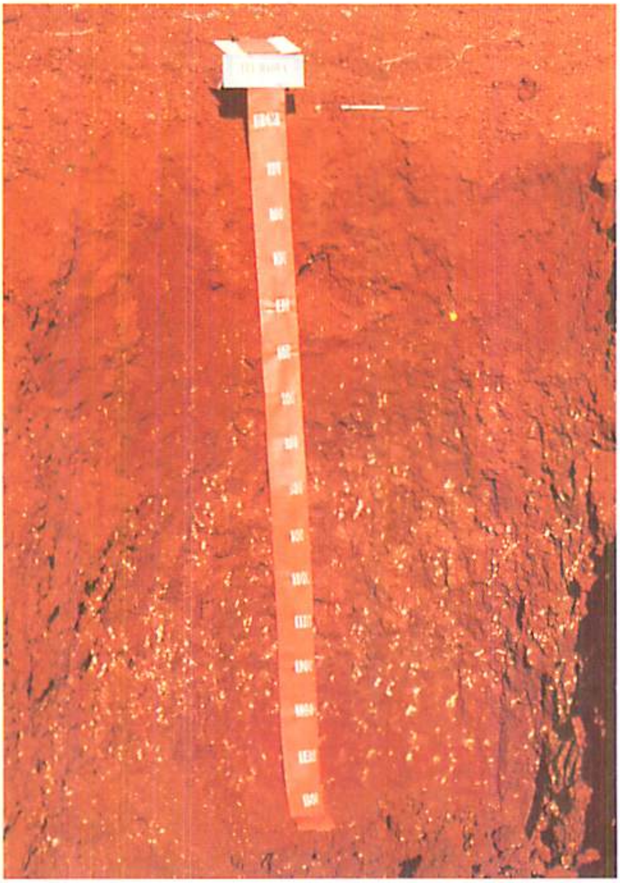


Plate 4. Location and profile of Tel Hadya, Block B-3. (View south, profile exposed at left-center of scene.)

Tel Hadya (Block C, Field 13)

Classification:	very fine (clayey), montmorillonitic, thermic, Chromic Calcixerert
Physiography:	very gentle slope north
Topography:	almost flat
Erosion:	none
Drainage:	well drained
Moisture status:	dry
Vegetation:	winter grass
Parent materials:	deposited material on limestone
Land use:	rain-fed agriculture (cereal crops)
Remarks:	The bulk mass of the C1 horizon is separated by cracks (5 mm wide and about 40 cm deep), into large prisms or blocks

Ap: 0-18 cm
Red (2.5 YR 4/6) dry and dark red (2.5 YR 3/6) moist, clay, moderate, fine to medium granular, hard dry, friable moist, sticky, plastic, calcareous, very few gravels up to 2 cm in diameter of calcareous nature, few fine to medium roots, common pores, moderate biological activity, abrupt smooth boundary.

Bk: 18-45 cm
Dark red (2.5 YR 4/6) dry and moist, clay, weak medium subangular blocky, hard dry, friable moist, sticky, plastic, calcareous, few angular gravels of calcareous origin up to 1 cm in diameter fine common roots, cracks of about 5 mm wide and 30 cm deep, clear smooth boundary.

Ck1: 45-85 cm
Dark red (2.5 YR 3/6) dry and moist, clay, massive, separated into large blocks by cracks. hard dry, firm moist, very sticky, very plastic, calcareous, gravels as above, few soft to slightly hard $CaCO_3$ concretions, many fine roots, merging boundary.

Ck2: 85-130 cm
Dark red (2.5 YR 3/6) dry and moist, clay, massive, cracks are narrower, $CaCO_3$ concretions constitute about 20% of the horizon by volume, very few fine roots.

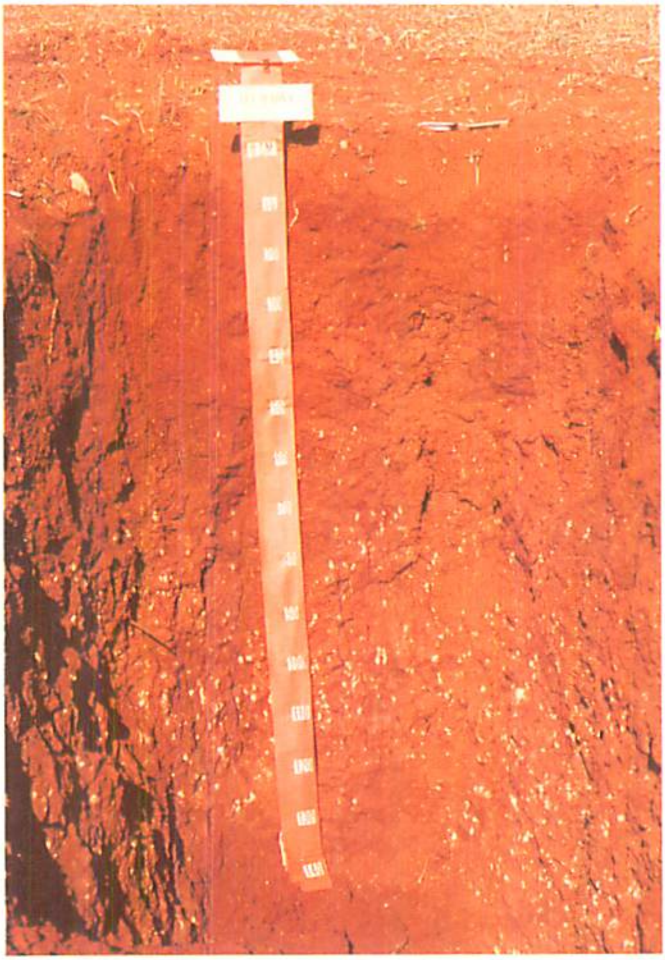


Plate 5. Location and profile of Tel Hadya, Block C-13. (View north, profile exposed in right side of picture in plowed field.)

Jindiress

Classification:	very fine (clayey), montmorillonitic, thermic, Chromic Calcixerert
Physiography:	plateau, surrounded by small mountains
Topography:	almost flat
Erosion:	none
Drainage:	well drained
Moisture status:	dry
Vegetation:	winter grass
Parent materials:	deposited material on limestone
Land use:	cereal crops
Remarks:	cracks starting from the lower boundary of the Ap horizon at depth of about 70 cm, slickensides were observed at between 80 and 100 cm depth

Ap: 0-18 cm

Red (2.5 YR 4/6) dry and moist, clay, moderate fine to medium granular, very hard dry, firm moist, plastic, sticky, calcareous, few medium roots, very few angular calcareous gravels up to 1 cm in diameter, moderate biological activity, abrupt smooth boundary.

Ak1: 18-45 cm

Red (2.5 YR 4/6) dry and moist, clay, moderate medium subangular blocky, very hard dry, very firm moist, very sticky, very plastic, calcareous, very few angular gravels (2-5 mm in diameter) of $CaCO_3$ origin, very few concretions of $CaCO_3$, few fine to medium roots, moderate biological activity, merging boundary.

Ak2: 45-90 cm

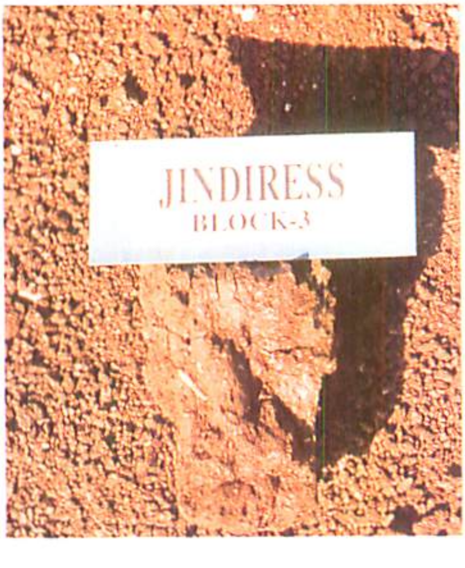
Red (2.5 YR 4/6) dry and moist, clay, very coarse prismatic, very hard dry, very firm moist, very sticky, very plastic, calcareous, very few angular gravels (2-5 mm in diameter), of calcareous origin, very few concretions of $CaCO_3$, very few fine to medium roots, little biological activity, merging boundary.

Ak3: 90-130 cm

Red (2.5 YR 4/6) dry and moist, clay, massive, extremely hard, extremely firm, very sticky, very plastic, calcareous, slightly hard $CaCO_3$ concretions (about 5% of the horizon by volume), gravels as above, very few fine roots, merging boundary.

Plate 6. Location and profile at Jindiress. (View westward, profile exposed near hut on right.)

Plate 7. Features of soil at Jindiress: close-up of cracks (above) and shiny surfaces (below), i.e. slickensides, which are characteristic of Vertisols.



Breda (Block C)

Classification: clayey, montmorillonitic, thermic, Calcixerollic Xerochrept
Physiography: plain
Topography: flat
Erosion: none
Drainage: well drained
Moisture status: dry
Vegetation: winter grass
Parent materials: deposited material on limestone
Land use: rain-fed agriculture (cereal crops)

Ap: 0-20 cm
Yellowish red (5 YR 5/6) dry and yellowish red (5 YR 4/6) moist, clay loam, moderate fine to medium granular, slightly hard dry, very friable moist, slightly sticky, slightly plastic, calcareous, few fine roots, medium common pores, moderate biological activity, abrupt smooth boundary.

Bk1: 20-58 cm
Dark reddish brown (5 YR 3/4) dry and moist, clay, moderate medium subangular blocky, hard dry, friable moist, sticky, plastic, calcareous, soft to slightly hard concretions of $CaCO_3$ of 1-4 mm (form about 5% of the horizon by volume), few grains (2-5 mm in diameter) of calcareous origin, very few fine roots, fine to medium tubular common pores, merging boundary.

Bk2: 58-120 cm
Yellowish red (5 YR 4/6) dry and moist, clay, massive with local development of structure, hard dry, friable moist, sticky, plastic, calcareous; soft to slightly hard concretions of $CaCO_3$ up to 10 mm in diameter form about 10% of the horizon by volume; very few fine roots, little biological activity, clean smooth boundary.

C1: 120-140 cm
Reddish brown (5 YR 4/4) dry and moist, clay, massive, slightly hard dry, friable moist, slightly sticky, slightly plastic, calcareous, very few soft concretions of $CaCO_3$, merging boundary.

C2: 140-200 cm
Yellowish red (5 YR 6/5) dry and moist, loamy, massive, other as above. This horizon overlies materials rich in gypsum, which were probably deposited and/or accumulated earlier.

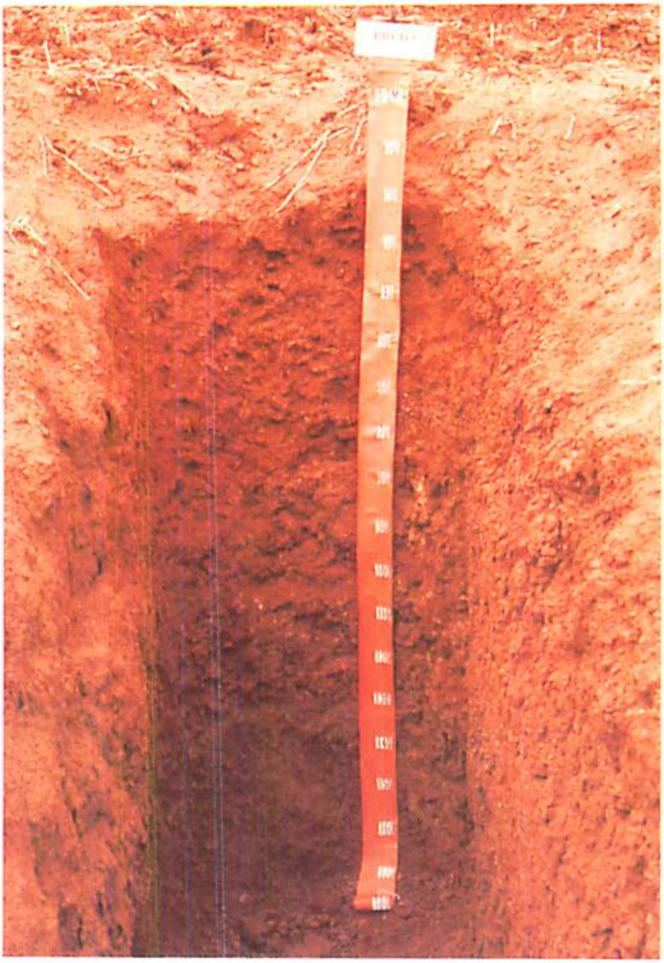


Plate 8. Location and profile of Breda. (View northwards, pit exposed near hut.)

Boueidar

Classification:	clayey, mixed, thermic, Calcic Gypsiorthid
Physiography:	plain
Topography:	flat
Erosion:	none
Drainage:	well drained
Moisture status:	dry
Vegetation:	winter grass
Parent materials:	deposited material on gypsum and limestone
Land use:	rain-fed agriculture (barley)

Ap: 0-15 cm
Brown (7.5 YR 5/4) dry, and reddish brown (7.5 YR 4/4) moist, clay loam, moderate fine to medium granular, locally developed weak medium subangular blocky, hard dry, very friable moist, slightly sticky, slightly plastic, calcareous, very few fine to medium roots, common tubular pores, moderate biological activity, clear smooth boundary.

Bk: 15-55 cm
Yellowish red (5 YR 4/6) dry, and reddish brown (5 YR 4/4) moist, clay, moderate medium subangular blocky, hard dry, friable moist, slightly sticky, slightly plastic, calcareous, very few soft to slightly hard concretions of $CaCO_3$ up to 3 mm in diameter, very few fine to coarse roots, medium tubular common pores, moderate biological activity, clear smooth boundary.

C1: 55-105 cm
Dark brown (7.5 YR 4/4) dry and moist, sandy clay, massive (very slightly compact), hard dry, friable moist, slightly plastic, slightly sticky, calcareous, slightly hard $CaCO_3$ concretions of about 1-3 mm in diameter and secondary gypsum as coarse crystallization and sand grains occupy about 35% of the horizon, while the carbonates occupy about 15% of the horizon by volume, the secondary materials decrease in size with depth, few fine and coarse roots, tubular common pores, clear smooth boundary.

C2: 105 cm
Compact layer composed of both $CaCO_3$ and gypsum (gypsum dominates over the carbonates).

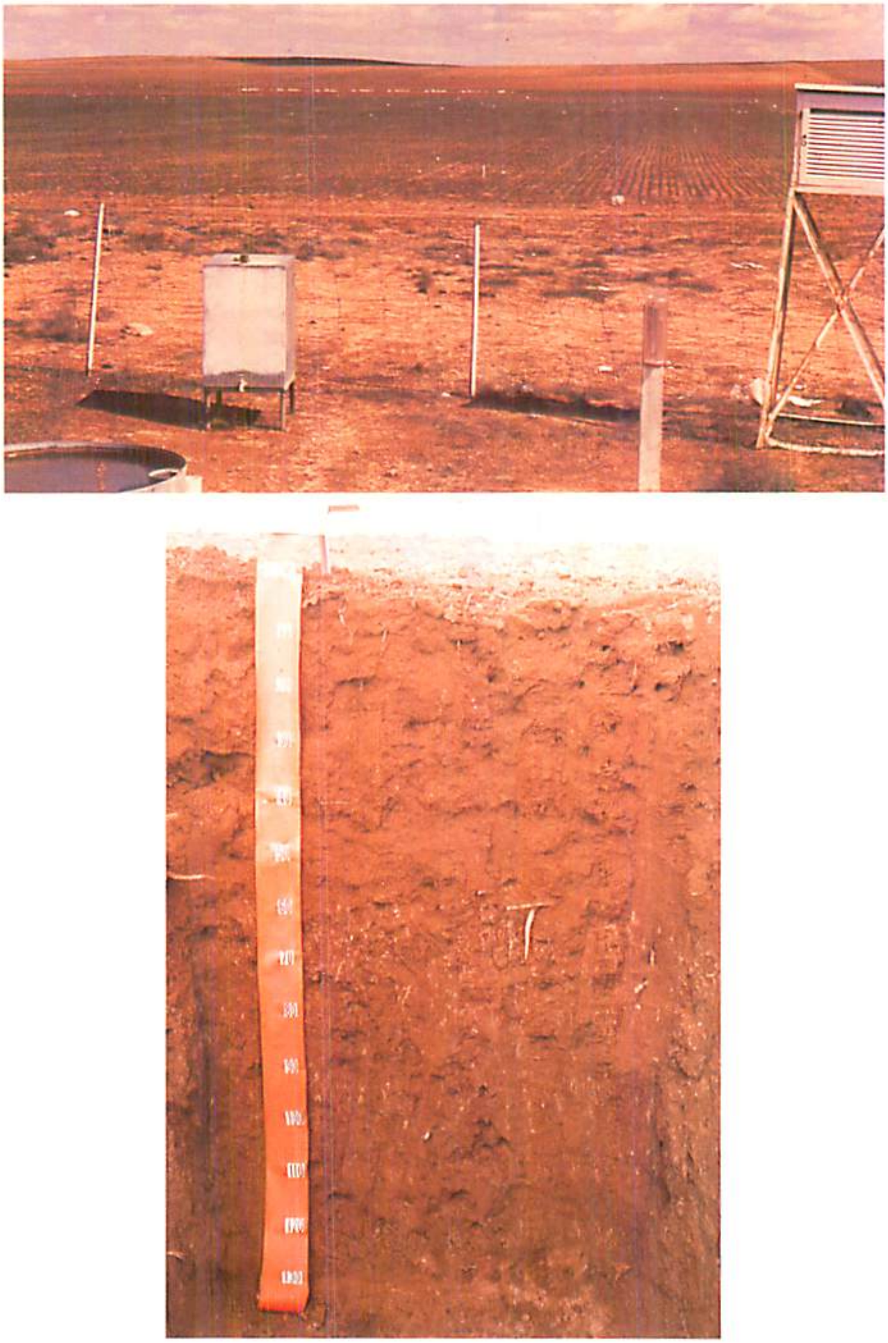


Plate 9. Location and profile of Boueidar. (View eastward, profile exposed in center of field.)

Ghrerife

Classification:	clayey, montmorillonitic, thermic, Calcixerollic Xerochrept
Physiography:	plain bordered by small hills to northeast
Topography:	flat
Erosion:	none
Drainage:	well drained
Moisture status:	dry
Vegetation:	winter grass
Parent materials:	deposited material on limestone (and probably some basalt)
Land use:	rain-fed agriculture (cereal crops)

Ap: 0-10 cm

Yellowish red (5 YR 5/6) dry and reddish brown (5 YR 5/4) moist, clay loam, weak fine to medium granular, hard dry, friable moist, slightly sticky, slightly plastic, calcareous, very few fine to medium roots, common medium pores, much biological activity, clear smooth boundary.

Bk: 10-50 cm

Yellowish red (5 YR 4/6) dry, and reddish brown (5 YR 4/4) moist, clay, massive (separated by vertical and horizontal cracks about 2 mm), beginning of structural development is observed in places, hard dry, friable moist, sticky, plastic, calcareous; soft to slightly hard $CaCO_3$ concretions up to 3 mm in diameter constitute about 5% of the horizon by volume; very few fine roots, little biological activity, merging boundary.

C1: 50-85 cm

Yellowish red (5 YR 4/6) dry moist, clay, structureless (massive), hard dry, friable moist, sticky, plastic, calcareous, very few fine roots.

C2: 85-130 cm

As above, separated only for sampling.

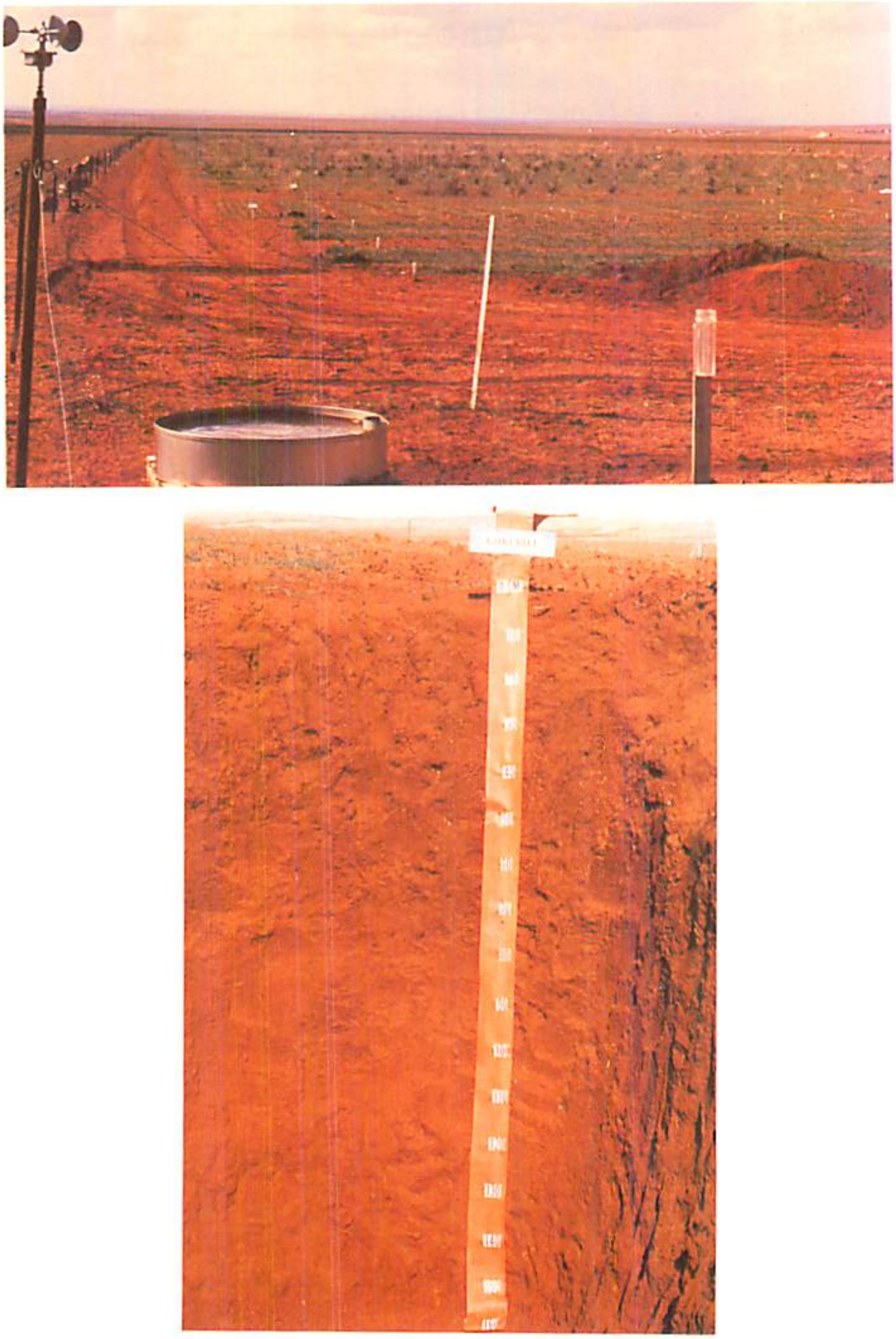


Plate 10. Location and profile at Ghrerife. (View northwest with meteorological station and soil pit in foreground.)

Maragha

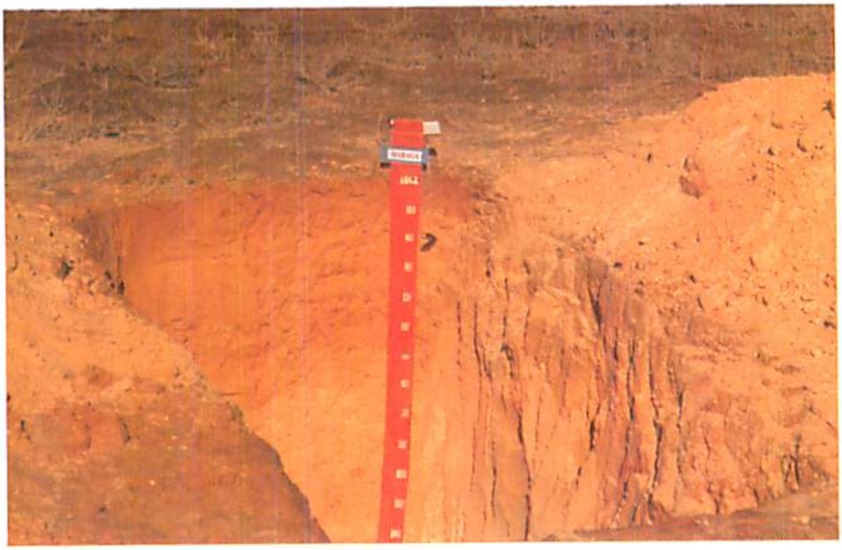
Classification:	Typic Gypsiorthid
Physiography:	slightly undulating
Topography:	almost flat
Drainage:	well drained
Moisture status:	slightly moist (up to 70 cm deep)
Vegetation:	winter grasses
Parent materials:	deposited gypsum materials
Land use:	pastures
Remarks:	a thin surface layer of about 2 mm thick of dark color (probably an accumulation of plant remains)

C1: 0-18 cm
Reddish yellow (7.5 YR 6/6) dry and moist, loamy sand, structureless (loose), very soft dry, very friable moist, non-sticky, non-plastic, calcareous, common pores, clear smooth boundary.

C2: 18-65 cm
Reddish yellow (7.5 YR 7/6) dry and moist, loamy sand, structureless (loose), soft dry, friable moist, non-sticky, non-plastic, calcareous, very few fine roots, common pores, pockets of indurated gypsum occupy about 10% of the horizon by volume (up to 15 cm in diameter), few hard to slightly hard individual nodules of gypsum up to 5 mm in diameter, merging boundary.

C3: 65+ cm
Reddish yellow (7.5 YR 8/6) dry and moist, the mass of the soil material is mainly composed of fine sand-sized gypsum crystals.

Note: A unique feature of the Maragha soil is the thin (1-2 cm) dark surface crust which is richer in organic matter, available N, total P, and micronutrients.



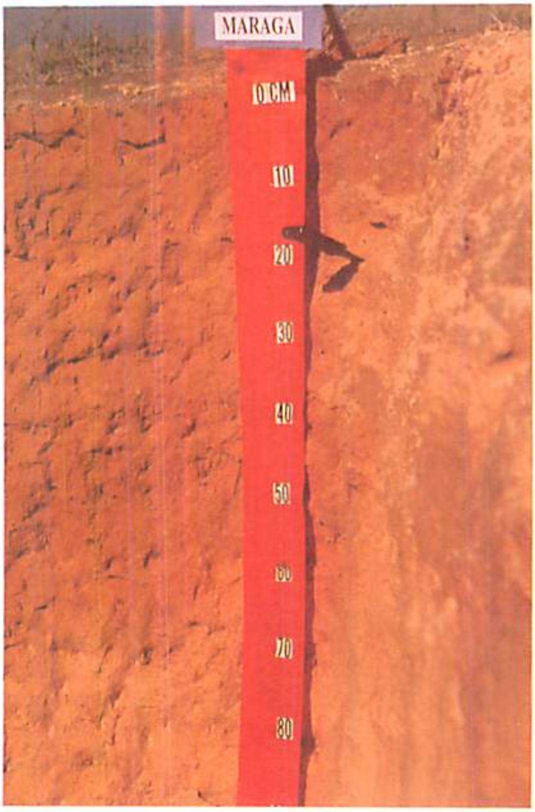


Plate 11. Location and profile at Maragha. (Note sparse vegetative cover and dark surface crust.)

Kfardane

Classification:	very fine (clayey), montmorillonitic, thermic, Chromic Haploxerert
Physiography:	plateau, bordered by small mountains to the northwest
Topography:	almost flat
Erosion:	none
Drainage:	well drained
Moisture status:	dry
Vegetation:	winter grass
Land use:	cereals crops

Ap: 0-20 cm
Dark red (2.5 YR 3/6) dry and dark reddish brown (2.5 YR 3/4) moist, clay, moderate fine to medium granular, hard dry, firm moist, sticky, plastic, non-calcareous, few fine roots, common tubular pores, cracks about 2 cm wide and more than 50 cm deep, very few subangular gravels up to 2 cm in diameter, moderate biological activity, abrupt smooth boundary.

A1: 20-80 cm
Dark red (2.5 YR 3/6) dry and dark reddish brown (2.5 YR 3/4) moist, clay, moderate medium subangular blocky, very hard dry, firm moist, very sticky, very plastic, non-calcareous, very few fine roots, common fine pores, gravels as above, little biological activity, merging boundary.

A2: 80-150 cm
Red (2.5 YR 4/6) dry and reddish brown (2.5 YR 4/4) moist, clay, strong coarse subangular blocky, very hard dry, firm moist, very sticky, very plastic, non-calcareous, few fine pores, less and smaller gravels than above, intersecting slickensides.

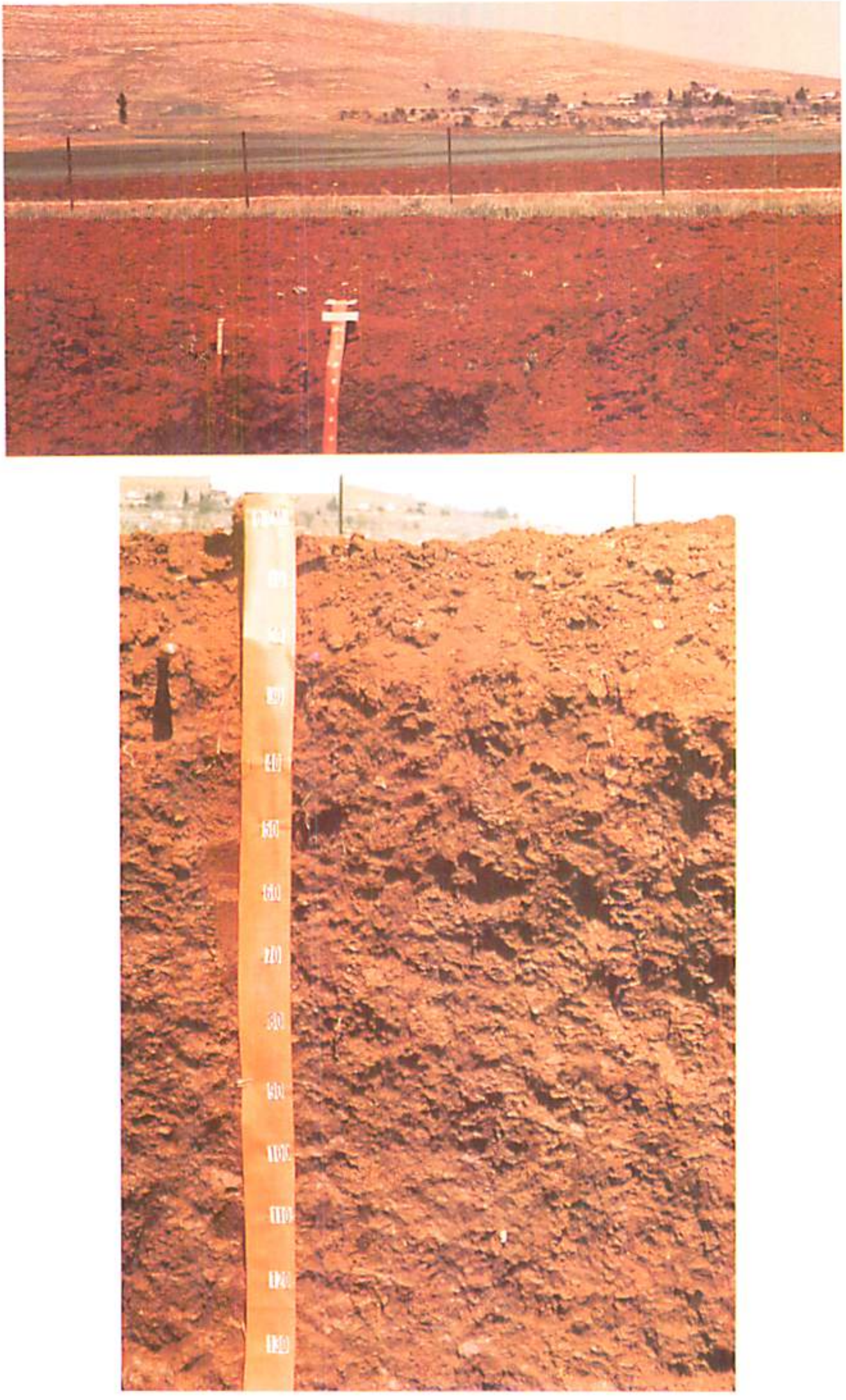


Plate 12. Location and profile at Kfardane. (View northwards, Field No. 3.)

Terbol

Classification:	fine clay, montmorillonitic, thermic, Chromic Haploxerert
Physiography:	plateau, bounded by small mountains to the northwest and southeast
Topography:	almost flat
Erosion:	none
Drainage:	well drained
Moisture status:	slightly moist
Vegetation:	winter grass
Parent materials:	deposited material on limestone
Land use:	cereal crops
Remarks:	cracks more than 50 cm deep and about 2 cm wide

Ap: 0-30 cm
Dark reddish brown (5 YR 3/3) dry and moist, clay, moderate fine to medium granular grading to moderate medium subangular blocky in the lower part of the horizon, hard dry, firm moist, very sticky, very plastic, non-calcareous, common fine pores, moderate biological activity, clear smooth boundary.

A1: 30-150 cm
Dark reddish brown (5 YR 3/4) dry and moist, clay, strong coarse subangular blocky (grading to strong coarse prismatic in the low part of the horizon), very hard dry, very firm moist, very sticky, very plastic, non-calcareous, few fine pores, intersecting slickensides (particularly at a depth of 60-120 cm), little biological activity, clear smooth boundary. This horizon was separated to 30-60 cm, 60-120 cm and 120-150 cm for sampling.

C1: 150-200 cm
Yellowish red (5 YR 4/6) dry and moist, clay, structureless, hard dry, firm moist, sticky, plastic, calcareous, few concretions of $CaCO_3$.

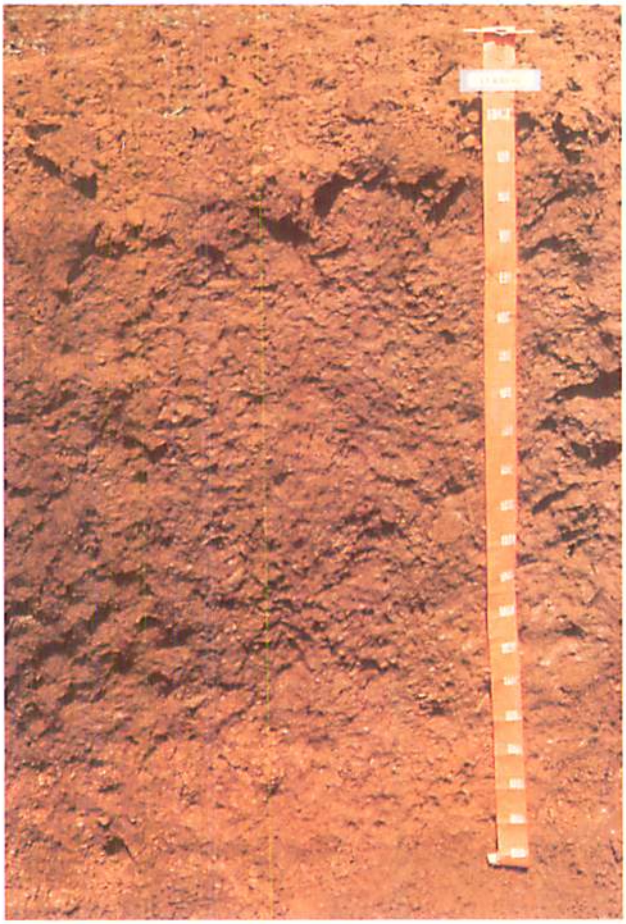


Plate 13. Location and profile at Terbol. (View northwards, Field No. 1.)

Soil Name Changes

The soils in the Aleppo region (where most stations are concentrated) are characterised by a **xeric** soil moisture regime, and a **thermic** (< 22°C mean annual temperature) soil temperature regime, typical for a Mediterranean climate, which is transitional to a temperate-continental climate. Parent material of most soils is clay or heavy clay, mainly of colluvial origin, with montmorillonite as the main clay mineral.

All soils are calcareous, often with accumulation of lime at shallow depth. The soils mainly have a subangular blocky structure in the surface layer due to self-mulching. In the experimental fields, most soils are at least 80 to 120 cm thick, overlying a substratum consisting of limestone, gypsum or heavily cemented sand. Outside the experimental fields, shallow soils occur. Not surprisingly, these common features are reflected in the classification, with three stations having similar classification at the great group level. Rainfall differences dominate, while soil differences are subordinate to the influence of rainfall.

Previous reports list a variety of names for the soils at ICARDA's stations, These were based on different classification systems; in some cases where Soil Taxonomy was used, a tentative classification was employed in the absence of detailed laboratory measurements. Since the early 1980s, the criteria for Soil Taxonomy have also changed. Therefore, while "a rose is a rose by any other name," it is important to use the latest classification to reconcile the past (Anon. 1981) with the present. Let us examine what changes in naming have occurred for each station.

Tel Hadya

The 1981 report listed, according to the FAO system, the soil as a Vertic (calcic) Luvisol (B-4) and a Chromic Luvisol (C-17) in the USDA system. This is equivalent to a Chromoxerertic Rhodoxeralf and a Calcic Rhodoxeralf, respectively. In older classification systems, these soils would be considered Terra Rossa (USA), Red Mediterranean Soils (France), or Red-Yellow Earth soils (USSR). The assumption was that this soil had an argillic horizon as indicated by clay accumulation in the subsoil due to movement or elluviation from the topsoil.

However, subsequent analyses showed that there were no clay skins, or slickensides, which would indicate such movement, nor was there evidence of a layer of clay enrichment. Furthermore, the presence of substantial levels of $CaCO_3$ would make such movement unlikely. Therefore, *based on Soil Taxonomy and supported by morphological and laboratory analyses, the soils at Tel Hadya are now considered either a Calcixerollic Xerochrept* or *a Chromic Calcixerert* (the latter largely because the depth criteria for Vertisols have changed).

Breda

This soil was previously considered a Calcic Xerosol (FAO) or a Typic Calciorthid (USDA) or a Carboxysol vertique sur carbonates (France). Under the older systems, it may have been considered Reddish Brown Soils (USA), Brown Steppe Soils or Sierozems (France), and Semi-Desert Brown Soils or gray Cinnomonic Brown Soils (USSR).

However, the soil does not meet the criteria of an aridic moisture regime nor the requirements of growing a successful crop. It is therefore *not* an Aridisol and is now considered a clayey (high clay content), montmorillonitic (the dominant clay mineral), thermic (mean annual temperature at 5 cm of 15 to 22°C), *Calcixerollic Xerochrept.*

Jindiress

This soil was previously classified as a Chromic Vertisol (FAO), Palexerollic Chromoxerert (USDA), or Smecti-Bisialsols, Vertique (France). In the older systems, it would have been a Grumosol (USA), Vertisol (France), or a cinnomonic-Brown Earth or Takyr (USSR). This soil still meets the Vertisol criteria and is now classified as very fine, montmorillonitic. thermic *Chromic Calixerert.*

CHEMICAL PROPERTIES

Nitrogen

The forms of N available to plants are mainly nitrate (NO_3^-) and ammonium (NH_4^+); the sum of these constitute the pool of plant-available N. These N forms are relatively small compared to Kjeldahl-N, which reflects the bulk of soil N that occurs in the organic fraction. Ammonium-N is held on clay surfaces, but is readily transformed by bacteria to the mobile NO_3^- form, i.e. nitrification. The organic-N fraction can be slowly mineralized depending on environmental conditions. Thus, the distribution of mineral-N, especially NO_3^-, varies with soil depth and throughout the season, since NO_3^- is stable but highly mobile.

These general trends were evident for profiles at Tel Hadya (Fig. 7), Breda and Jindiress (Fig. 8) and the other stations in Syria (Fig. 9), as well as in Lebanon (Fig. 10). Thus, Kjeldahl-N, essentially the bulk of soil N, decreased with soil depth. Ammonium-N was generally the smallest N fraction, and varied widely, i.e., from field to field at Tel Hadya, and decreased with depth in some soils (Fig. 7, B-3), but increased in others (Fig. 9).

Organic Matter

The amount of organic matter is normally highest in the surface horizon, reflecting higher root densities and increased biological activity. While the organic matter content and climate are interrelated, i.e., increasing aridity is associated with decreasing organic matter levels, a pattern of depthwise decrease is usually exhibited.

Indeed, those trends were much in evidence in this survey. While OM contents of surface samples varied (0.9 to 1.5%) at Tel Hadya (Fig. 11) and in other Syrian sites (0.5 to 1.2%; Fig. 12), all values consistently decreased with depth. Both patterns in Lebanon (Fig. 13) were similar.

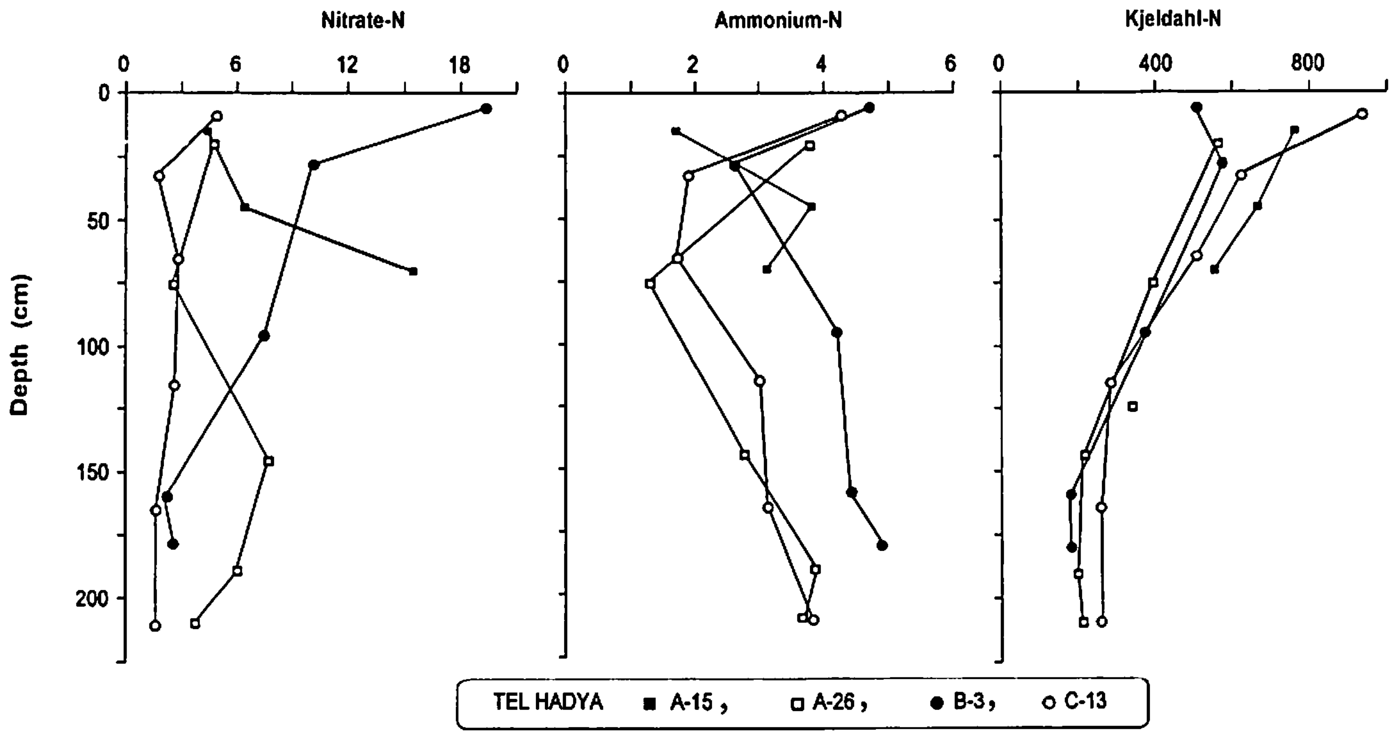


Fig. 7. Distribution of nitrate, ammonium, and Kjeldahl nitrogen (ppm) with depth in Tel Hadya

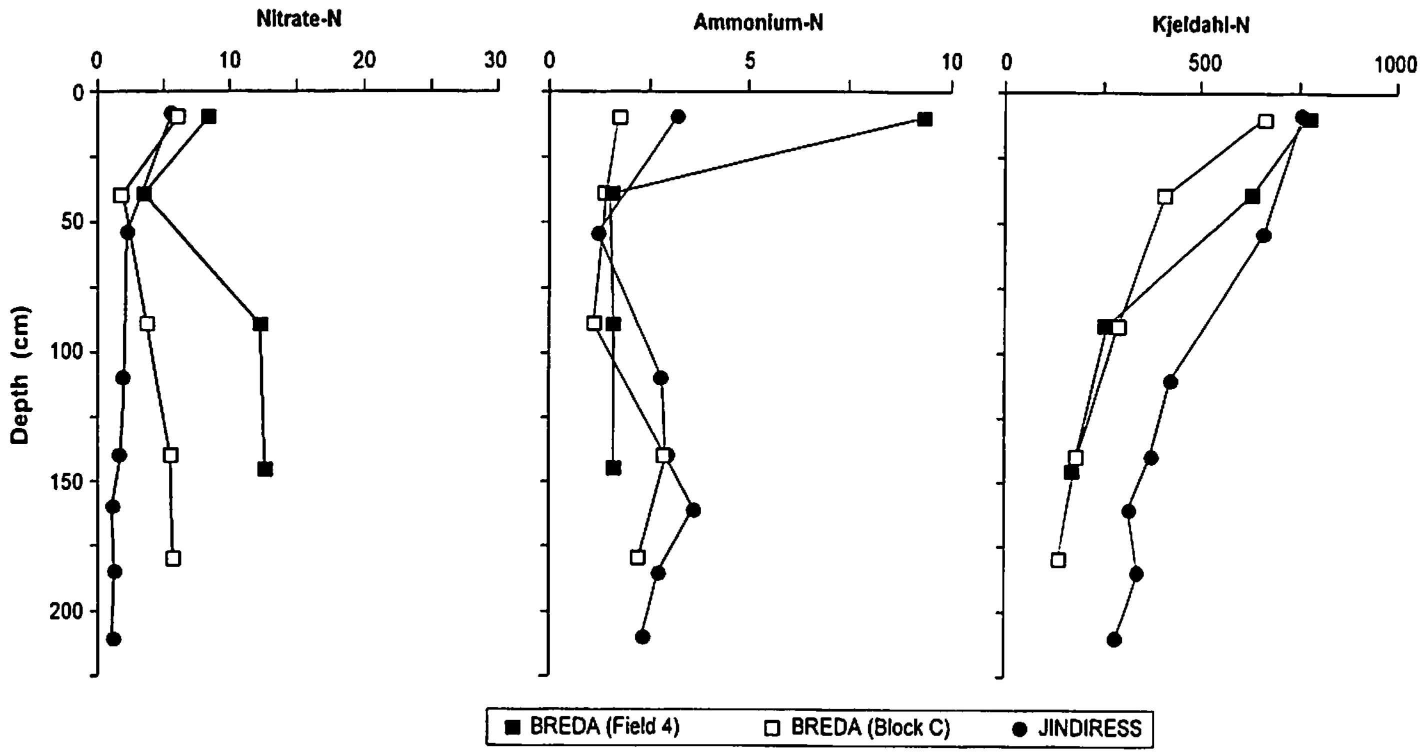


Fig. 8. Distribution of nitrate, ammonium, and Kjeldahl nitrogen (ppm) with soil depth at Breda and Jindiress.

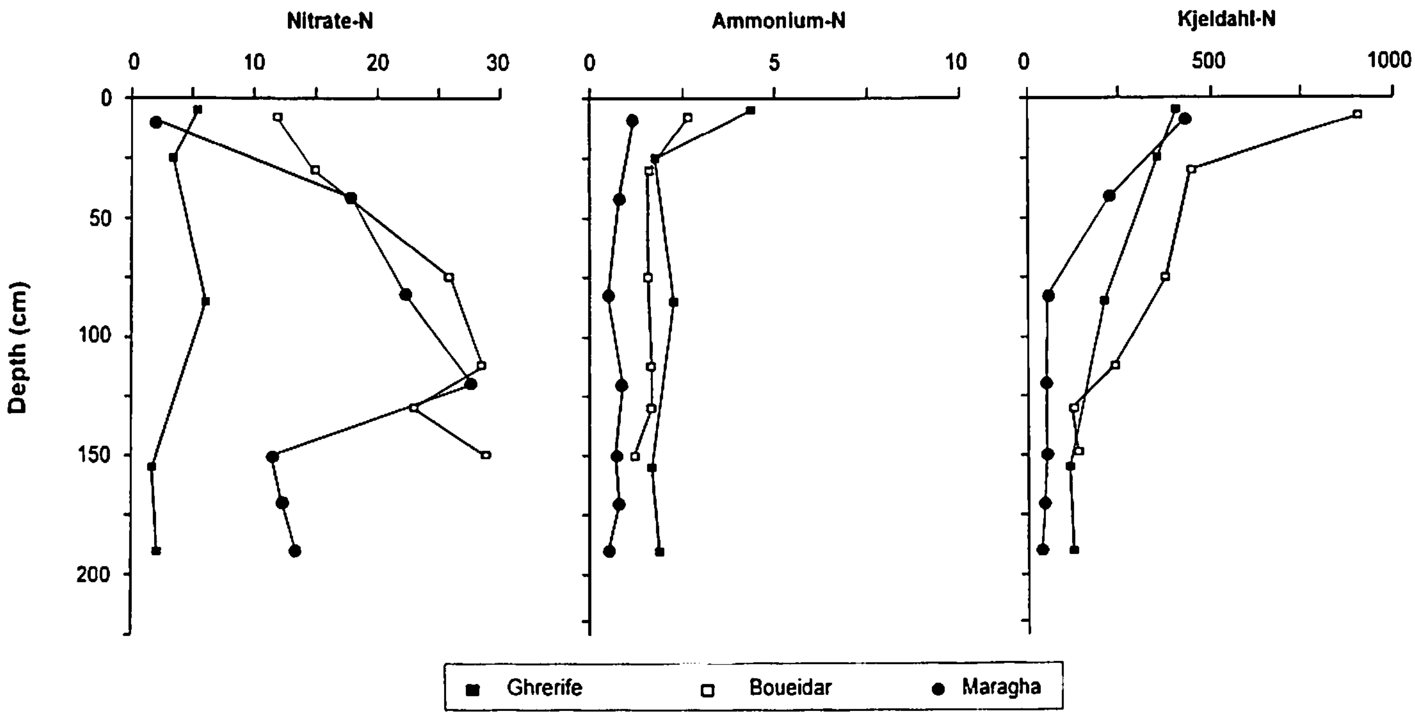


Fig. 9. Distribution of nitrate, ammonium, and Kjeldahl nitrogen (ppm) with depth at Ghrerife, Boueidar, and Maragha.

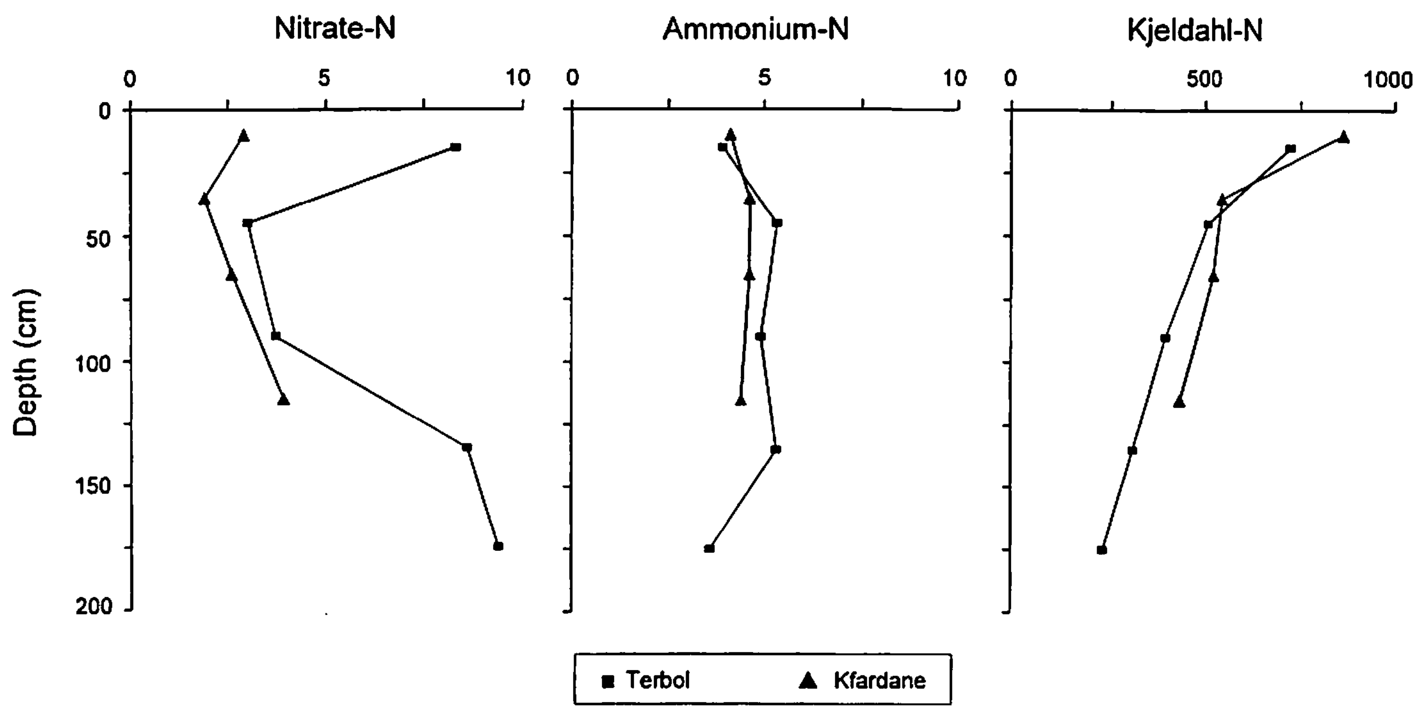


Fig. 10. Distribution of nitrate, ammonium, and Kjeldahl nitrogen (ppm) with soil depth at Lebanese stations.

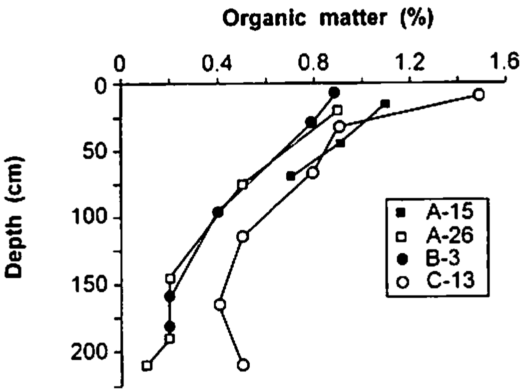


Fig. 11. Distribution of organic matter with depth at Tel Hadya.

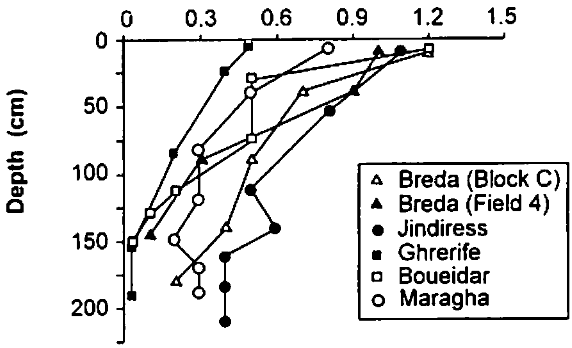


Fig. 12. Distribution of organic matter in other Syrian stations.

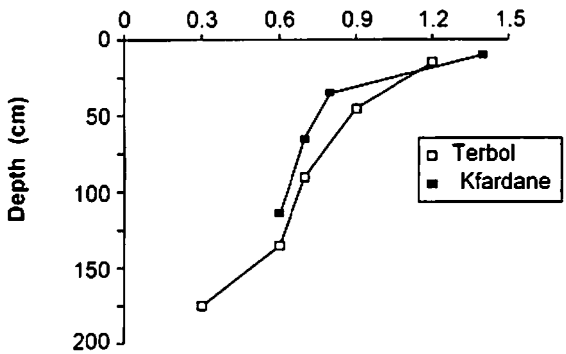


Fig. 13. Distribution of organic matter in Lebanese stations.

Available Phosphorus

While soils in their natural state are usually deficient in plant-available P, some sites are often have high levels due to fertilization. However, unlike N, P is attracted to soil particles and thus does not move down the profile with soil water. Fertilization is always reflected in the surface layer. Thus, without exception, all measurements of available P (Fig. 14, 15, 16), measured by the Olsen test, showed decreases with depth. Surface samples varied depending on soil type and/or cropping history. Some were extremely and naturally low, as in Maragha, and others were very high, as in Lebanon, presumably due to fertilization. For the ICARDA rain-fed region, Olsen-P values (available P extracted by the conventional $NaHCO_3$ extractant which is commonly used in calcareous soils) of less than about 6 ppm are likely to be deficient; values above 10 ppm can be cropped for some years without P fertilization.

Total Phosphorus

As only a small fraction of soil P is biologically available to plants at any one time, little consideration is given to the soil's content of total P, most of which is in insoluble mineral forms. Determination of this usually involves digestion of the sample with strong acids, and is rarely done on a routine basis. However, it does reflect mineralogical differences between soil types, and where total P is very low, the soil's capacity to supply P is usually low also. Distribution of P in soil profiles can reflect horizon development.

The higher total P values at Tel Hadya (Fig. 17) probably reflect varying degrees of P fertilization among the four sites. Block B3, for example, is managed to maintain a low-fertility site for experimental purposes. While marked differences occurred with the other Syrian stations (Fig. 22), the Maragha site again was unusually low. Fertilization probably accounted for the high surface-layer values in Lebanon (Fig. 19).

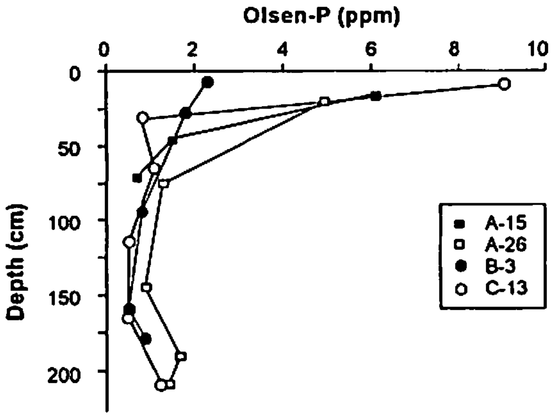


Fig. 14. Distribution of available phosphorus with depth at Tel Hadya.

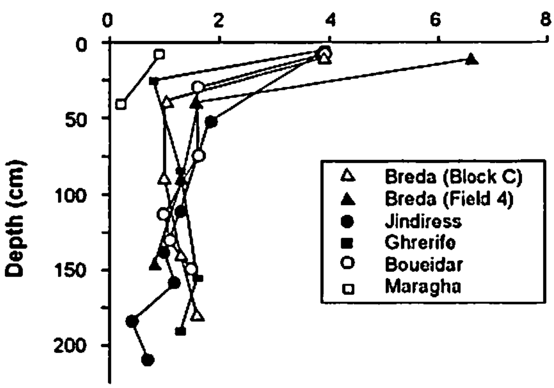


Fig. 15. Distribution of available phosphorus with depth in other Syrian stations.

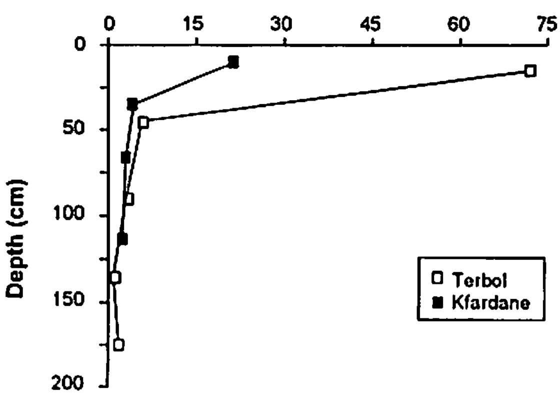


Fig. 16. Distribution of available phosphorus with depth at Lebanese stations.

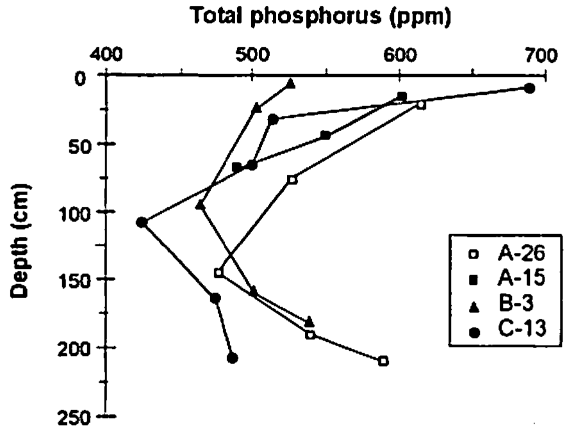


Fig. 17. Distribution of total phosphorus with depth at Tel Hadya.

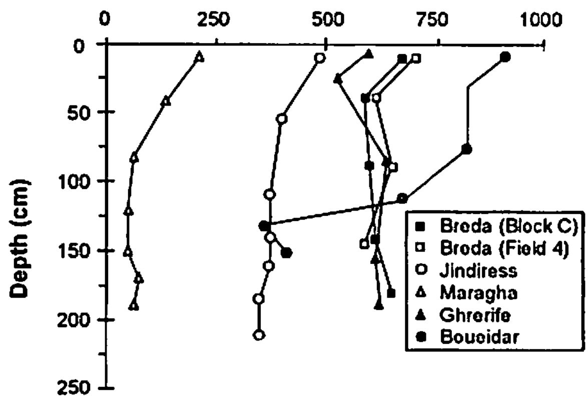


Fig. 18. Distribution of total phosphorus with depth in other Syrian stations.

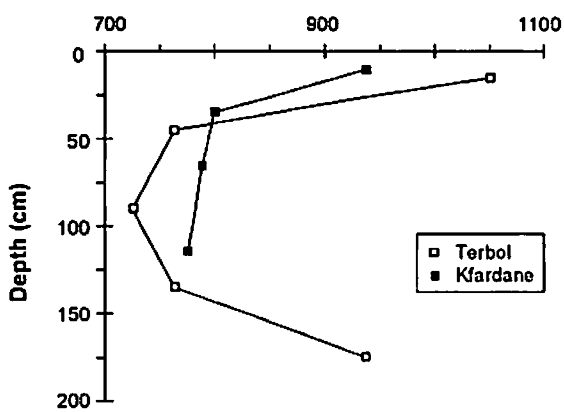


Fig. 19. Distribution of total phosphorus with depth in Lebanese stations.

Extractable Potassium

Shaking a soil sample with a solution of NH_4OAc enables us to determine a fraction of total soil K that is available to plants, i.e., water-soluble and exchangeable. Where extraction values are less than about 150 ppm or 0.3 meq/100 g, a deficiency might be expected. In general, soils of the Middle East region are well supplied with K.

While there were some differences between soils at Tel Hadya (Fig. 20) with rest of Syria (Fig. 21) and in Lebanon (Fig. 22), all were well supplied with K, which tended to decrease with depth. The Maragha site in the Syrian steppe was again an exception, being low in clay and high in gypsum.

Micronutrients

Though needed in very small amounts, micronutrients are nevertheless essential for crop growth. Because their chemical behavior in response to soil pH is similar, iron (Fe), zinc (Zn), manganese (Mn) and copper (Cu) are usually considered together. Additionally, all four elements can be simultaneously extracted by one reagent—DTPA (diethylene-triaminepentaacetic acid). According to the test (Lindsay and Norvell 1978) criteria, neither Mn or Cu are likely to be deficient at Tel Hadya (Fig. 23). However, Zn values were low, as was Fe to a lesser extent, and deficiency may occur with sensitive plants. The pattern was similar for the other Syrian stations (Fig. 24). No deficiency is likely in Lebanon's stations (Fig. 25); indeed, levels of Fe and Mn are considerably higher than in Syria.

Boron

Of concern in drier regions of the world is boron (B). There one can find deficient levels of B in the soil and, in other areas, toxic levels. The range between deficiency and toxicity is low, i.e., less than 0.5 to 5 ppm, where damage can occur with sensitive plants.

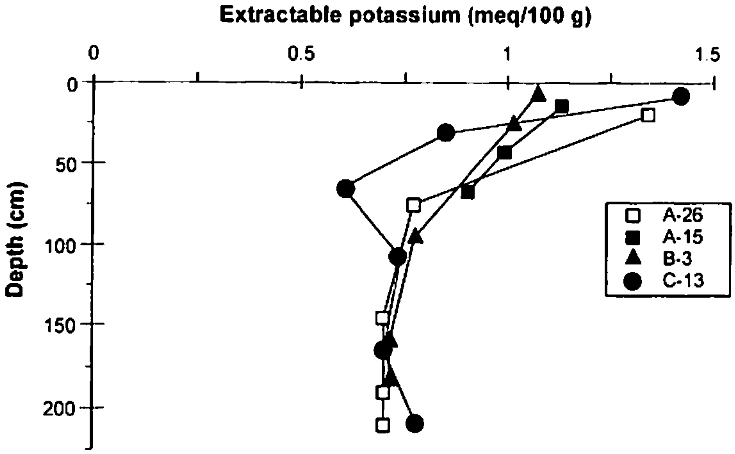


Fig. 20. Extractable potassium with depth at Tel Hadya.

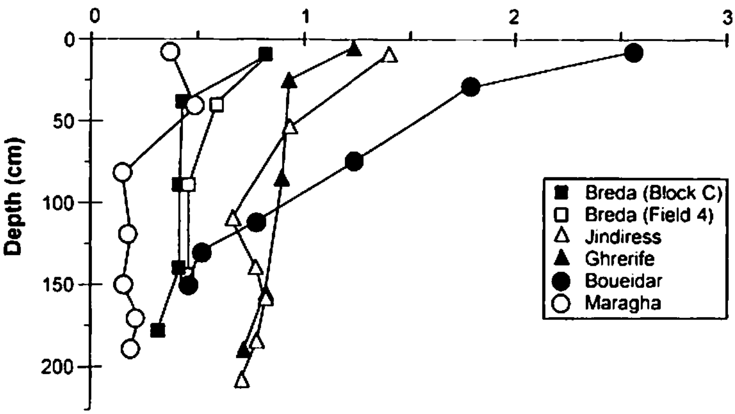


Fig. 21. Extractable potassium with depth in other Syrian stations.

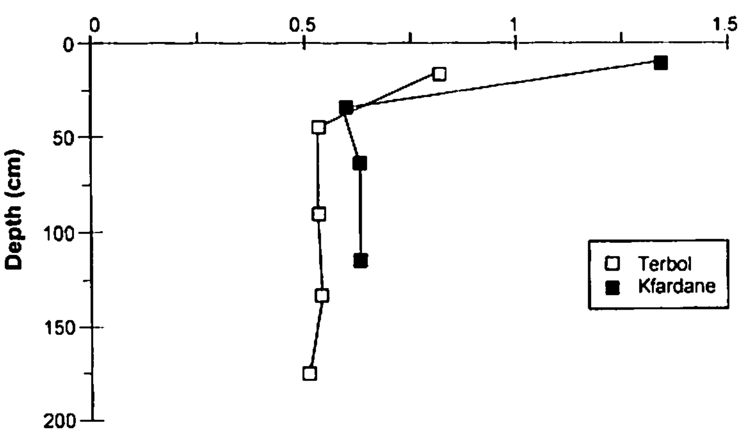


Fig. 22. Extractable potassium with depth in Lebanese stations.

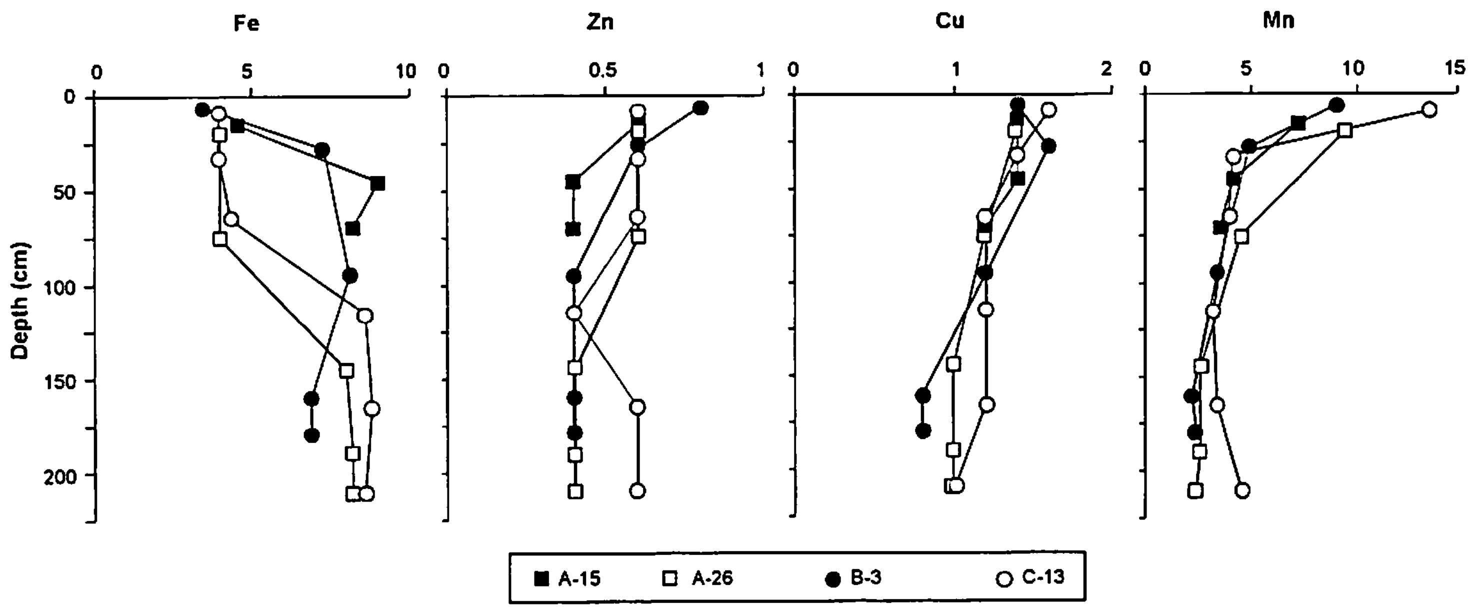


Fig. 23. Distribution of extractable micronutrient cations (ppm) with depth at Tel Hadya.

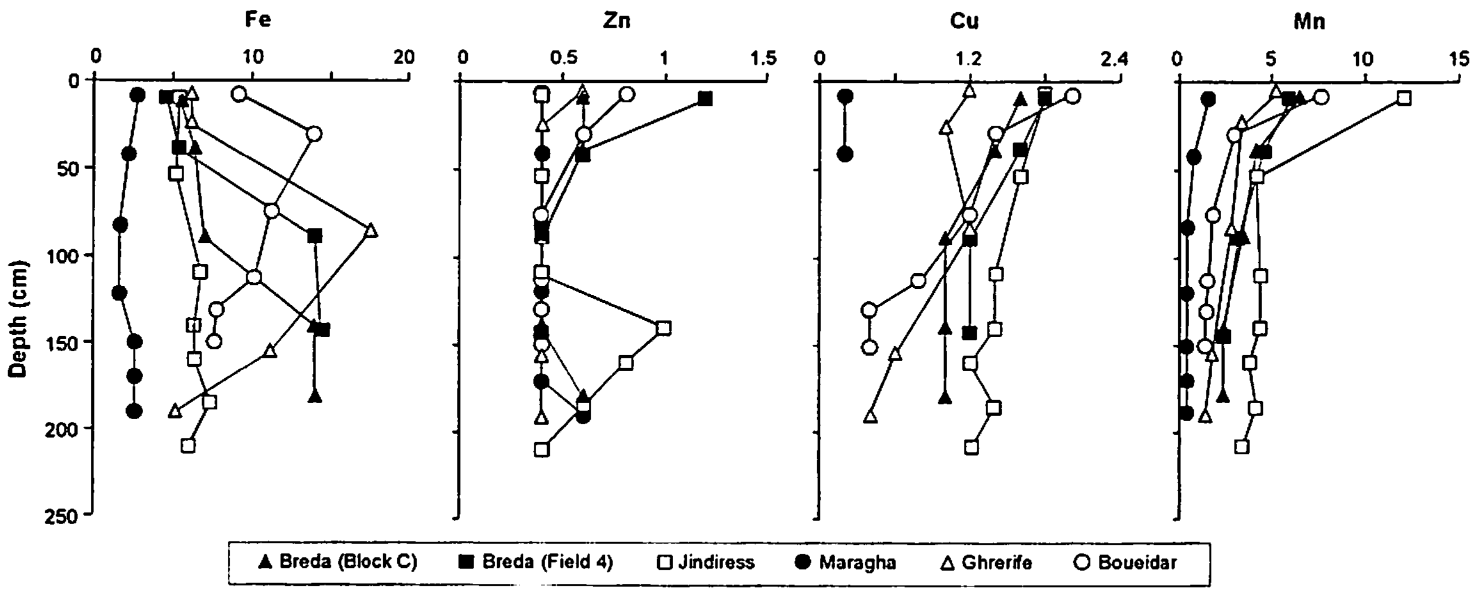


Fig. 24. Distribution of extractable micronutrient cations (ppm) with depth in Syrian stations.

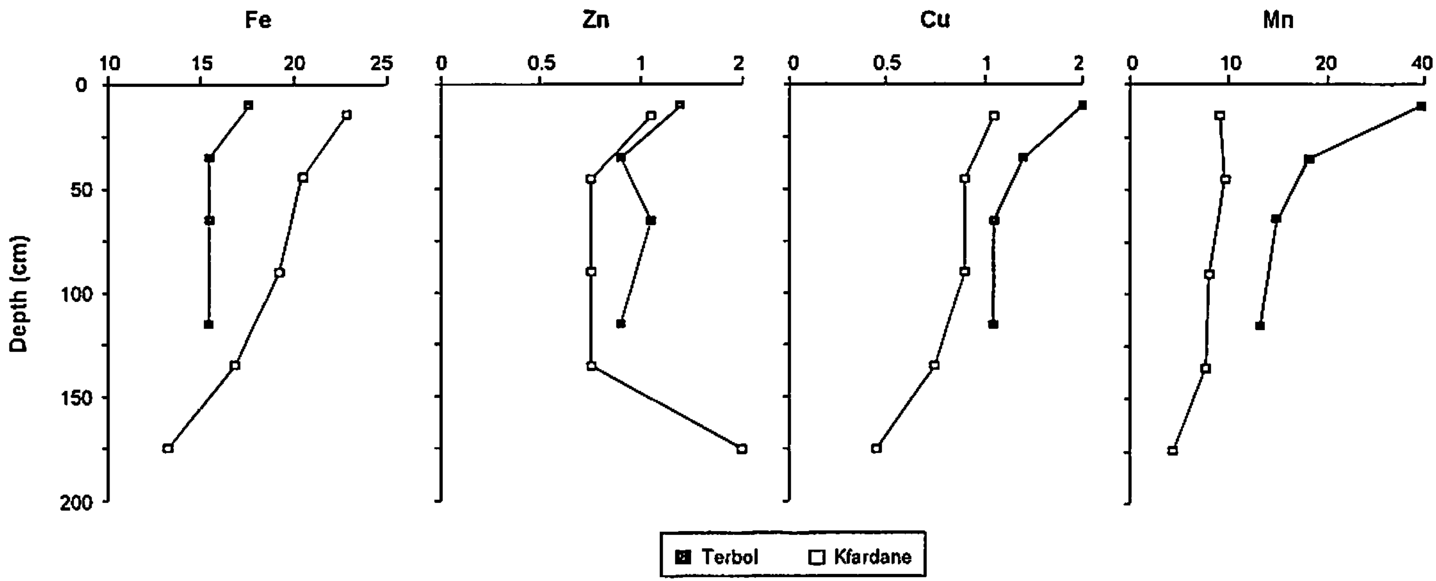


Fig. 25. Distribution of extractable micronutrient cations with depth in Lebanese stations.

As anticipated in this survey, there was considerable variability. The Tel Hadya sites (Fig. 26) had low but adequate in B and had generally higher levels in the sub-surface, while other stations—notably Boueidar and, to a lesser extent, Ghrerife and Breda—showed much higher B values (Fig. 27). Values for Lebanon, especially Terbol (Fig. 28), were on the low side.

Calcium Carbonate

As a general rule, soils of arid and semi-arid regions are well supplied with $CaCO_3$, mainly due to inheritance from parent materials and the lack of leaching and weathering. In itself, $CaCO_3$ is not important, but it does control soil pH, usually around 8.0 to 8.3, and this in time influences nutrient and biological reactions. Calcium carbonate ranged from 20 to 25% at Tel Hadya (Fig. 29) and from 20 to 30% in the other Syrian stations (Fig. 30), except Maragha. Values increased with depth, reflecting a modest degree of leaching during soil development. The sites in Lebanon (Fig. 31) were almost devoid of $CaCO_3$ throughout the profile.

pH, Electrical Conductivity, Cation Exchange Capacity

As all soils had some free $CaCO_3$, the pH values were clustered between 7.9 and 8.2 (Fig. 31, 32), except for the Lebanese sites which ranged from 7.0 to 8.0, reflecting the lower $CaCO_3$ status of these soils (Fig. 33)

The figures for these groups of soils also showed low electrical conductivity (EC) values; all were less than the level which would cause salinity damage to crops, that is 4 mS/cm.

Likewise, cation exchange capacity (CEC) values were all relatively high (Fig. 34), reflecting the clay content as well as the type of dominant clay mineral, i.e., smectite or 2:1 type.

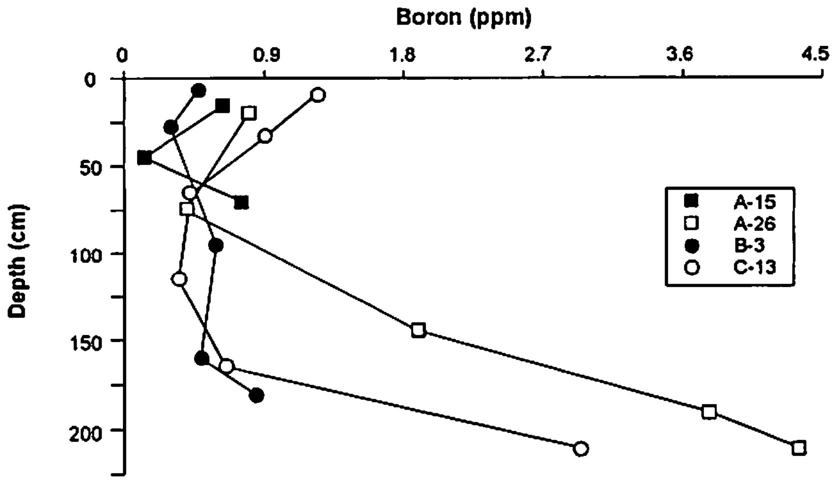


Fig. 26. Extractable boron with depth at Tel Hadya.

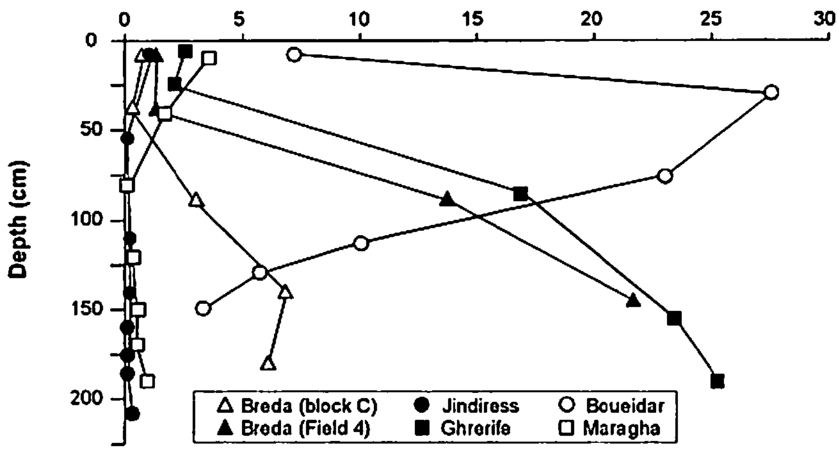


Fig. 27. Extractable boron with depth in other Syrian stations.

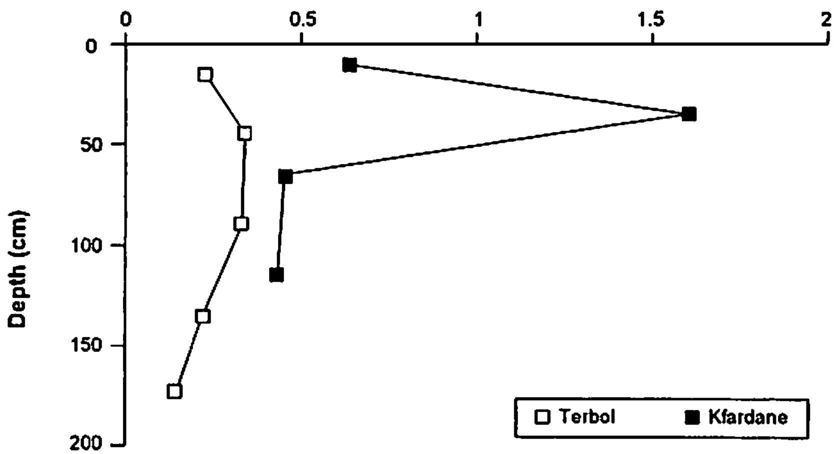


Fig. 28. Extractable boron with depth in Lebanese stations.

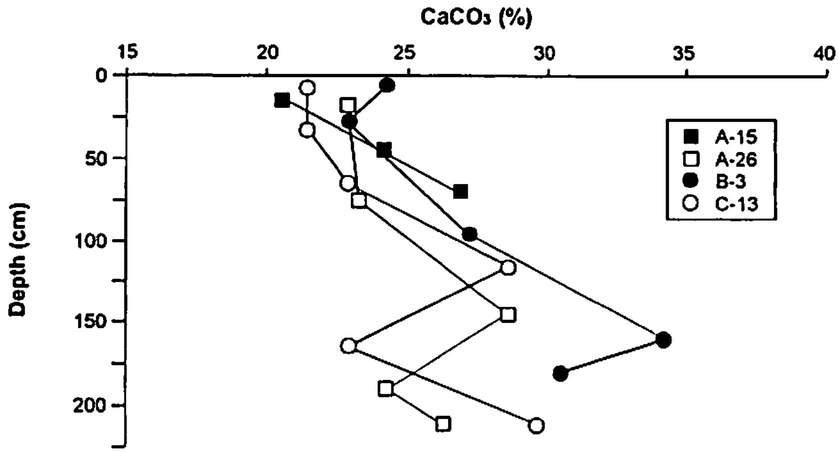


Fig. 29. Distribution of calcium carbonate with depth at Tel Hadya.

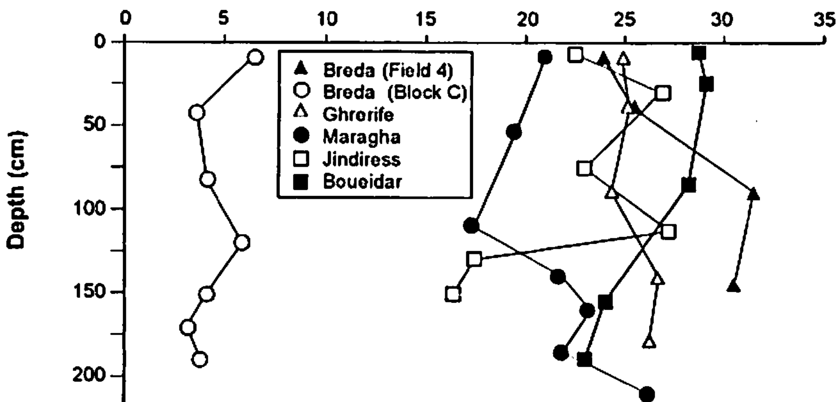


Fig. 30. Distribution of calcium carbonate with depth at other Syrian stations.

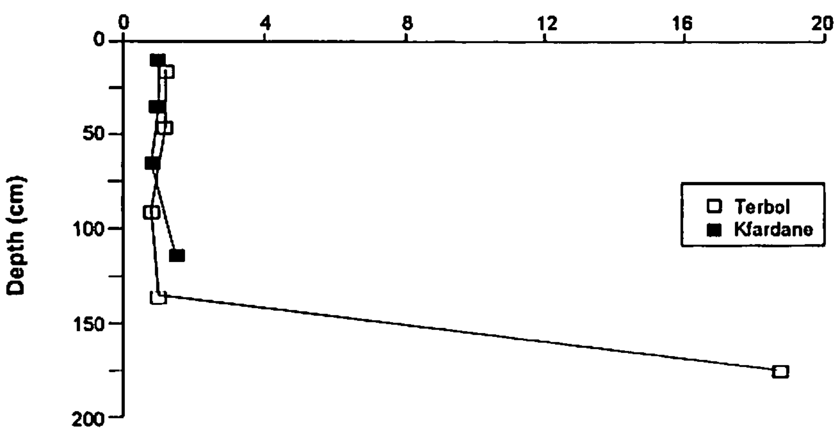


Fig. 31. Distribution of calcium carbonate with depth at Lebanese stations.

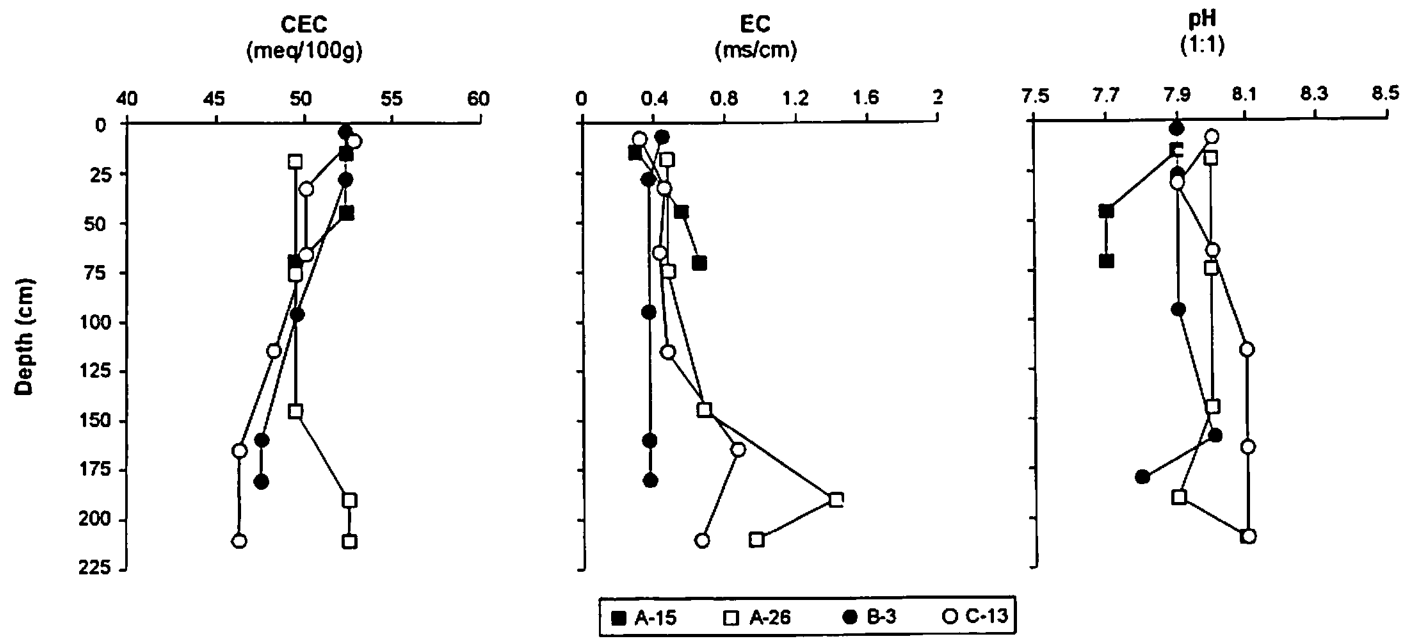


Fig. 32. Distribution of cation exchange capacity, electrical conductivity, and pH with depth at Tel Hadya.

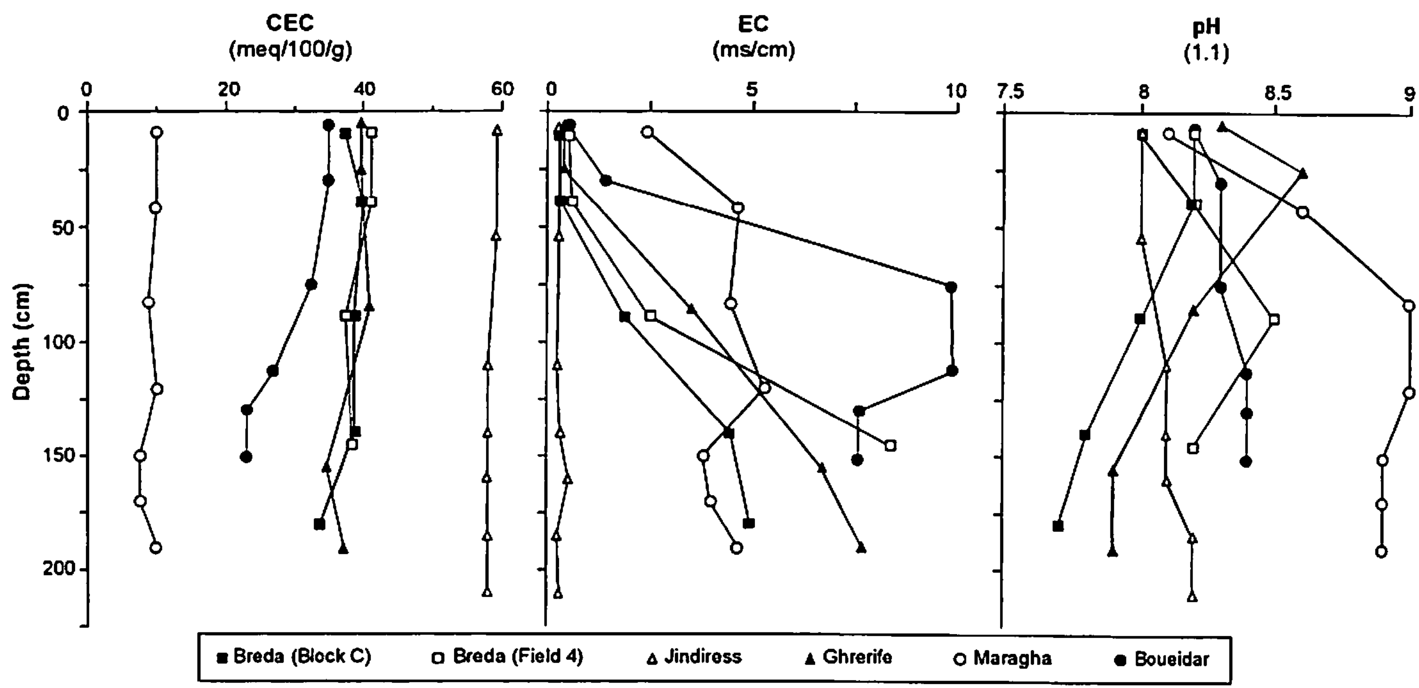


Fig. 33. Distribution of cation exchange capacity, electrical conductivity, and pH with depth at other Syrian stations.

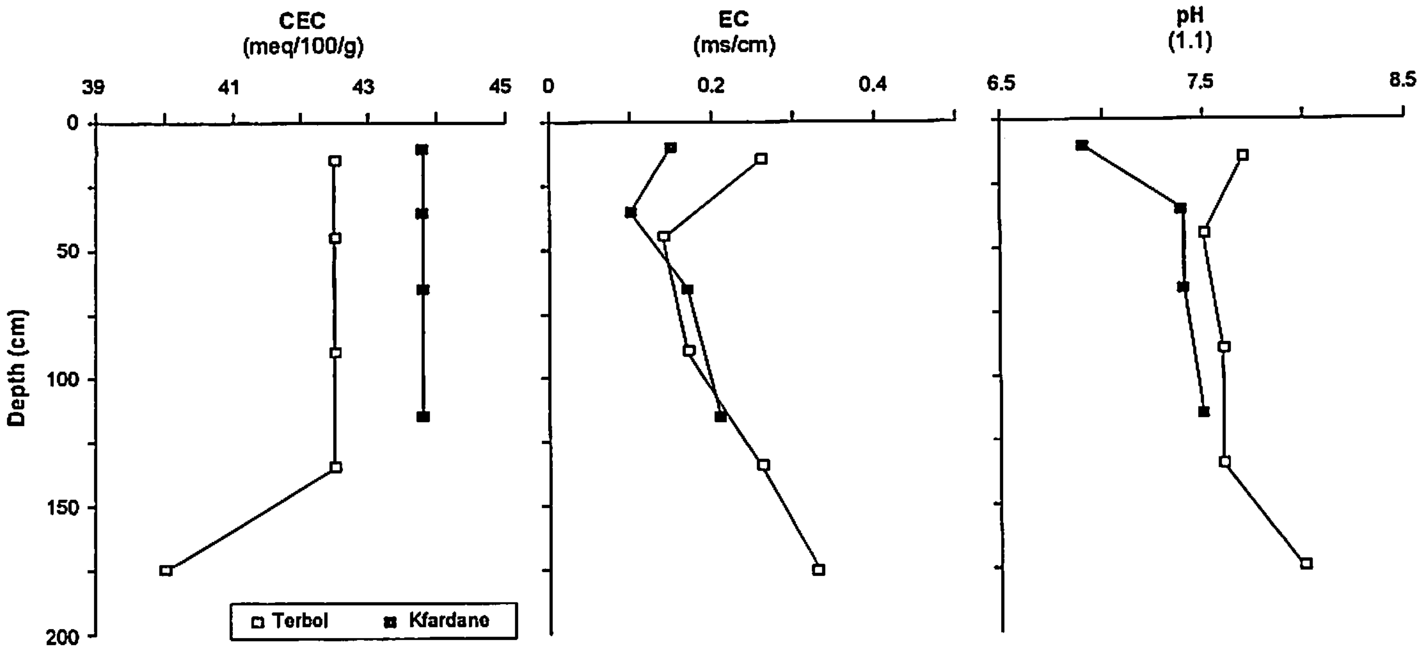


Fig. 34. Distribution of cation exchange capacity, electrical conductivity, and pH with depth at Lebanese stations.

Gypsum

For most soils of the world, gypsum is of no concern. However, in drier regions, it occurs in soils in amounts ranging from traces to several percent. It is derived from sedimentary rock and/or precipitation of calcium and sulfate during salinization. As gypsum is relatively soluble (1.7 g/L), it is subject to leaching and is therefore usually found at variable depths within the profile. Indeed the presence of substantial amounts of gypsum is the basis for some arid-region soils to be classified as "Gypsiorthids."

Gypsum is of minimal importance in rain-fed areas; a large amount of gypsum simply means that the soil has proportionally lower contents of clay and other components which influence the soil as a medium for plant growth. For irrigation, the presence of gypsum can be good and bad. Where the soil has some gypsum, relatively poor-quality irrigation can be used without doing any harm, since the soluble Ca^+ counteracts the negative effects of Na^+. However, where levels of gypsum are high, concrete irrigation canals are likely to collapse due to massive soil funneling caused by solubilization.

Gypsum was detected in only three locations in any real quantity, ranging from the least at Ghrerife to being the main soil constituent in Maragha, the latter being classified as a Gypsiorthid. At Ghrerife, gypsum was less than 0.5% of the soil weight between 130 and 200 cm. A similar pattern was observed at Boueidar, with only traces of gypsum down to 45 cm; but it then increased consistently from 8.3% in the 45-105 cm layer to 38% at 140-160 cm. At Maragha the surface layer (0-20 cm) contained about 54% gypsum, with 70-80% gypsum throughout the profile to 2 m.

PHYSICAL PROPERTIES

Texture

The proportions of sand, silt and clay (< 2 mm) determine texture. This property governs the suitability of a soil to hold water, transmit air, serve as a nutrient store—in general, be a good medium for growing plants. Soils derived from alluvial or water-lain deposits are generally clayey. Thus, soils of the cultivated area of north Syria are heavy-textured, as are those in Lebanon's Beka'a Valley.

Therefore, it was not surprising to find that all sites at Tel Hadya (Fig. 35) were clays. Similarly, those at the other Syrian stations were heavy-textured (Fig. 36), except Maragha, which has very little clay. However, because of the high content of gypsum and its influence on dispersion, the proportions of sand, silt and clay could not be estimated. The two soils from Lebanon were high in clay (Fig. 37), especially Terbol with over 65% clay throughout the profile.

Bulk Density

The extent to which a soil is compacted is reflected in bulk density measurement. This involves a measure of weight and volume of a given soil sample. However, measurement is difficult in clay soils that exhibit shrink/swell characteristics. Where soil has densities of greater than 1.4 g/cm^3 for clays and 1.6 g/cm^3 for sands, deleterious effects on plant growth are probable. The limited data presented here (Table 8) does not indicate a problem with compaction. The increases with depth reflect an increase in clay and a decrease in organic matter, which favorably influences soil structure.

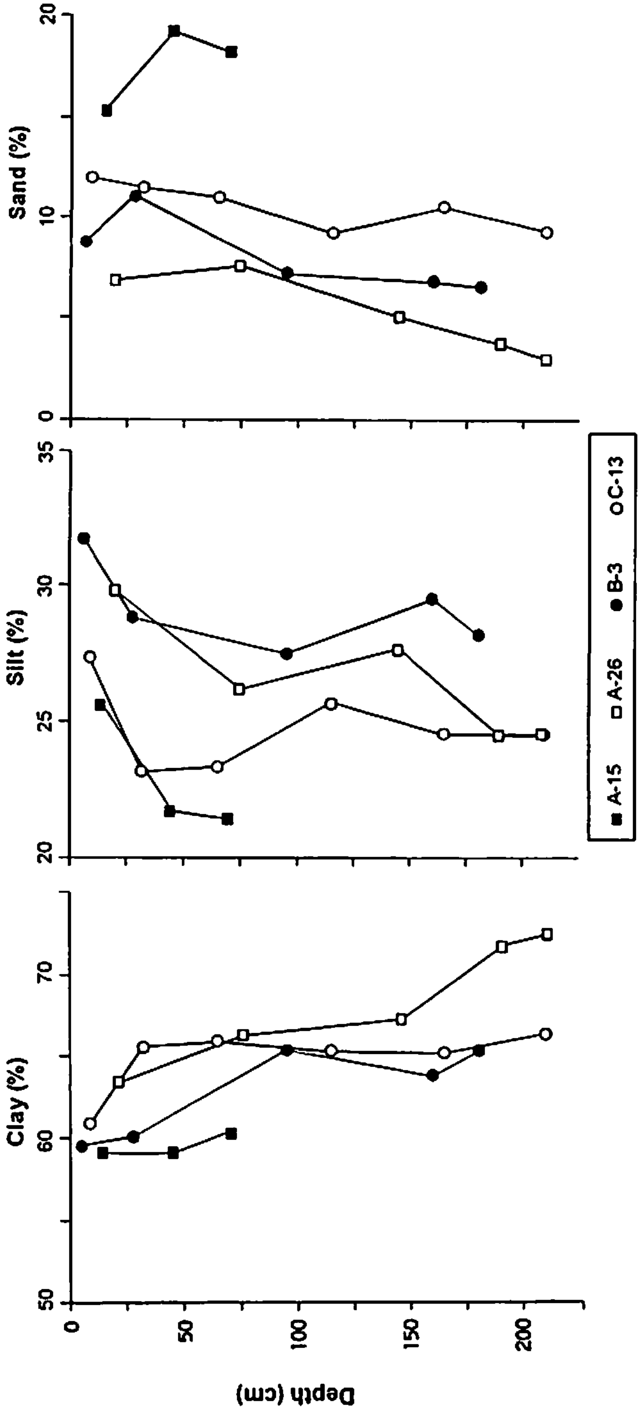


Fig. 35. Distribution of clay, silt, and sand with soil depth at Tel Hadya.

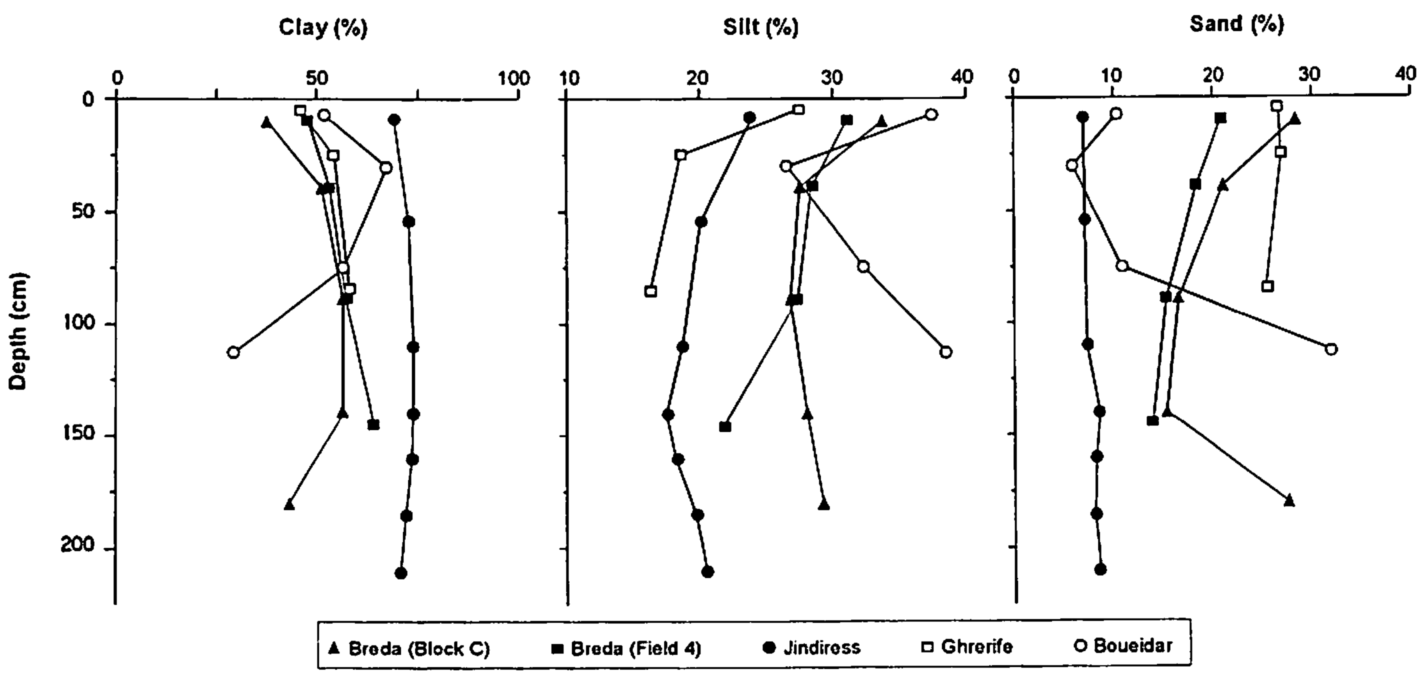


Fig. 36. Distribution of clay, silt, and sand with depth at other Syrian stations.

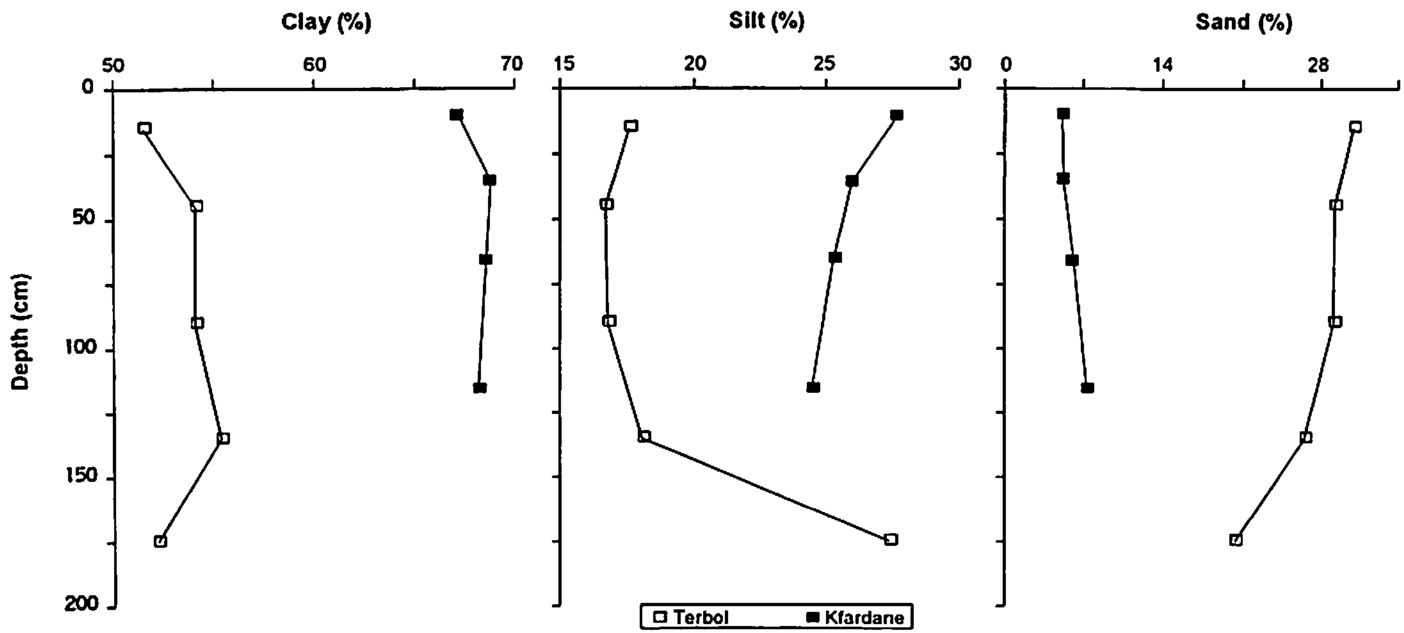


Fig. 37. Distribution of clay, silt, and sand with depth at other Lebanese stations.

Table 8. Bulk density (g/cm^3) of the surface soil layer, and with depth in some profiles.

Depth (cm)	Tel Hadya	Breda	Jindiress	Ghrerife	Boueidar	Maragha	Terbol	Kfardane
0-15	1.01	1.04	1.01	1.12	1.0	1.26	1.35	1.19
15-30	1.06	1.05	1.01	—	—	—	—	—
30-45	1.18	1.09	1.09	—	—	—	—	—
45.60	1.25	1.20	1.11	—	—	—	—	—
66-75	1.25	1.34	1.17	—	—	—	—	—

Moisture Characteristics

The available moisture for plant use is that fraction of total soil moisture which is held between permanent wilting point and field capacity. Excess soil water beyond field capacity drains out of the root zone, while at permanent wilting point the soil water is held with such tension that plants cannot remove it. These characteristics are influenced by soil texture, in particular the clay fraction. Thus, not surprisingly, the Tel Hadya samples (Table 9) were all similar at about 13 to 17%. Though field capacity and permanent wilting point varied with the other stations (Fig. 38), the range in available water was narrow.

An important aspect of soil moisture in the Mediterranean climate is the pattern of soil wetting (recharge) during the "rainy" season and drying (discharge) toward the end of the wet season and during early summer. A pattern for a season with high rainfall at Tel Hadya is illustrated in Fig. 39. The profile is wetted during the late fall and early winter when soil water is surplus to crop needs; with increasing growth in early spring and decreased rainfall the soil is gradually dried out. By the end of crop growth, there is little or no available moisture in the rooting zone. The upper part of the profile (≅ 60 cm) dries further during the arid summer and has to be re-wetted to above the permanent wilting point before germination of crops can occur in the next season. Not only does this fluctuating soil moisture regime directly affect crop growth, it also has a controlling influence on biological processes such as N mineralization. The extent to which the profile is wetted varies with the amount of seasonal rainfall—as illustrated in Fig. 40, which shows seasonal maxima in relation to the "dry" profile at the beginning of the season.

Table 9. Moisture characteristics (% by weight) of surface layer.

Station	Field Capacity	Permanent Wilting Point	Available Moisture
Tel Hadya			
A-15	39.3	24.7	14.6
A-26	38.3	24.8	13.5
B-3	38.0	23.6	14.4
C-13	40.8	23.7	17.1
Breda			
Block C	31.9	19.6	12.3
Field 4	36.1	21.0	15.1
Jindiress	45.3	30.6	14.7
Ghrerife	33.0	21.3	11.7
Boueidar	36.6	22.9	13.7
Maragha	42.4	23.7	18.7
Terbol	30.2	19.0	11.2
Kfardane	30.2	21.0	9.2

Another aspect of this phenomenon of variable soil water is illustrated in Fig. 40 for differences in seasonal rainfall. This shows that the soil profile (>1 mm) only approaches field capacity in years of exceptional rainfall, i.e., 1987/88. In dry years, i.e., the profile is not wetted beyond 60 cm. Thus, in dryland areas, the effective depth of the soil is controlled by the depth of soil moisture penetration.

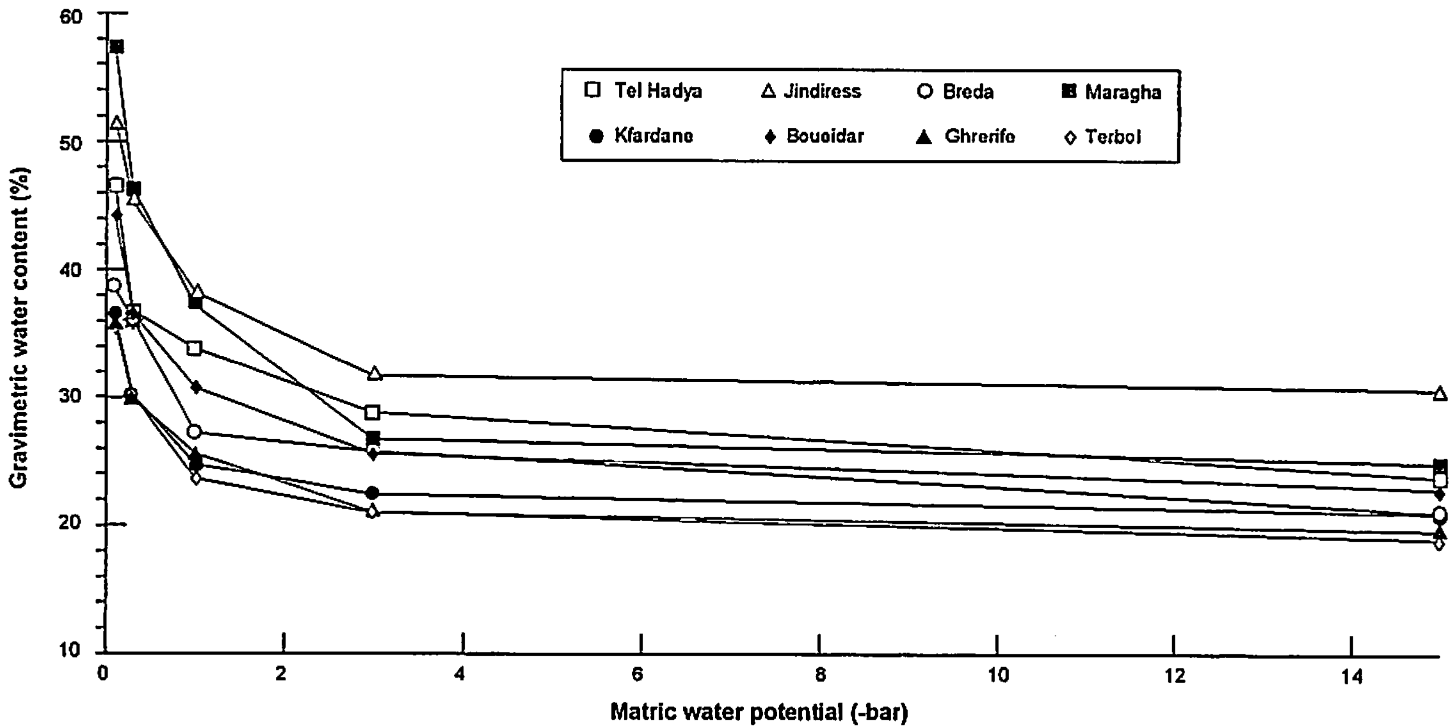


Fig. 38. Moisture characteristic curves for the stations.

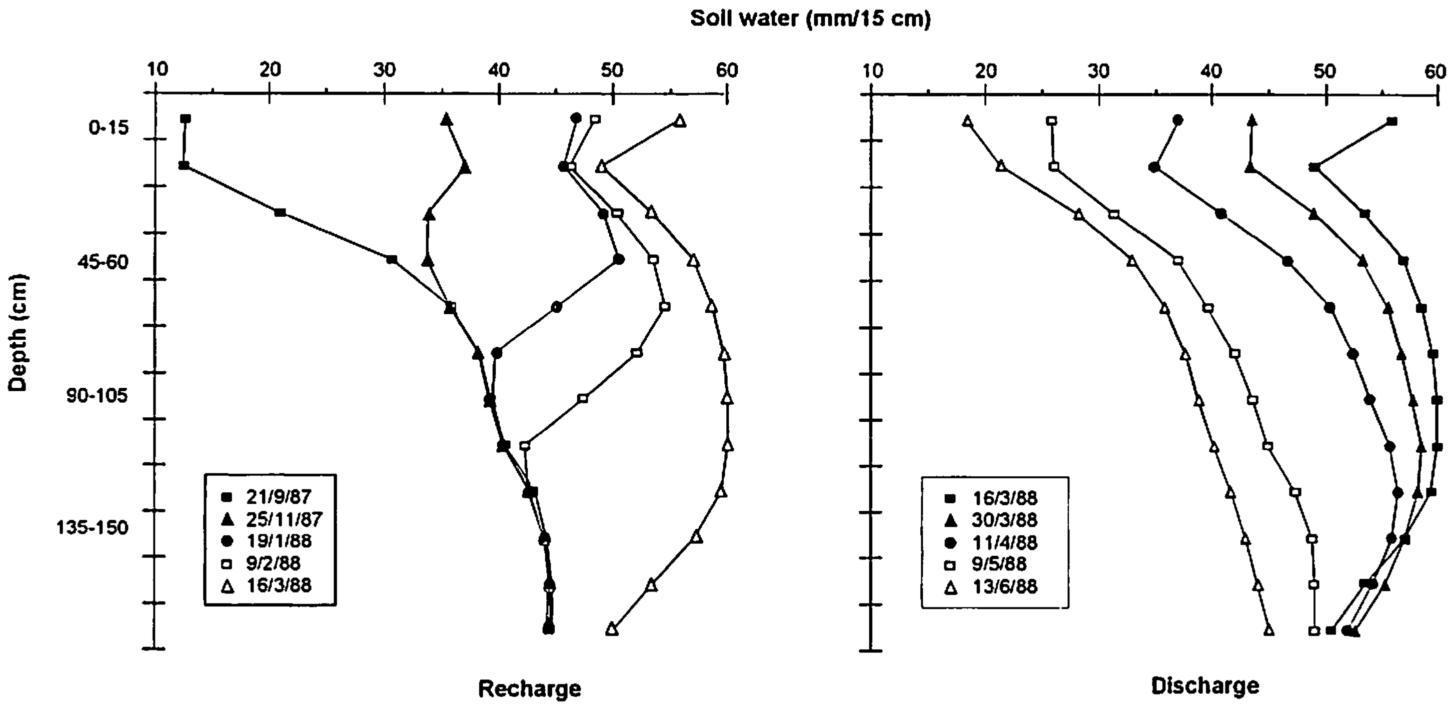


Fig. 39. Representative moisture recharge-discharge pattern from Tel Hadya. (Courtesy Dr Hazel Harris.)

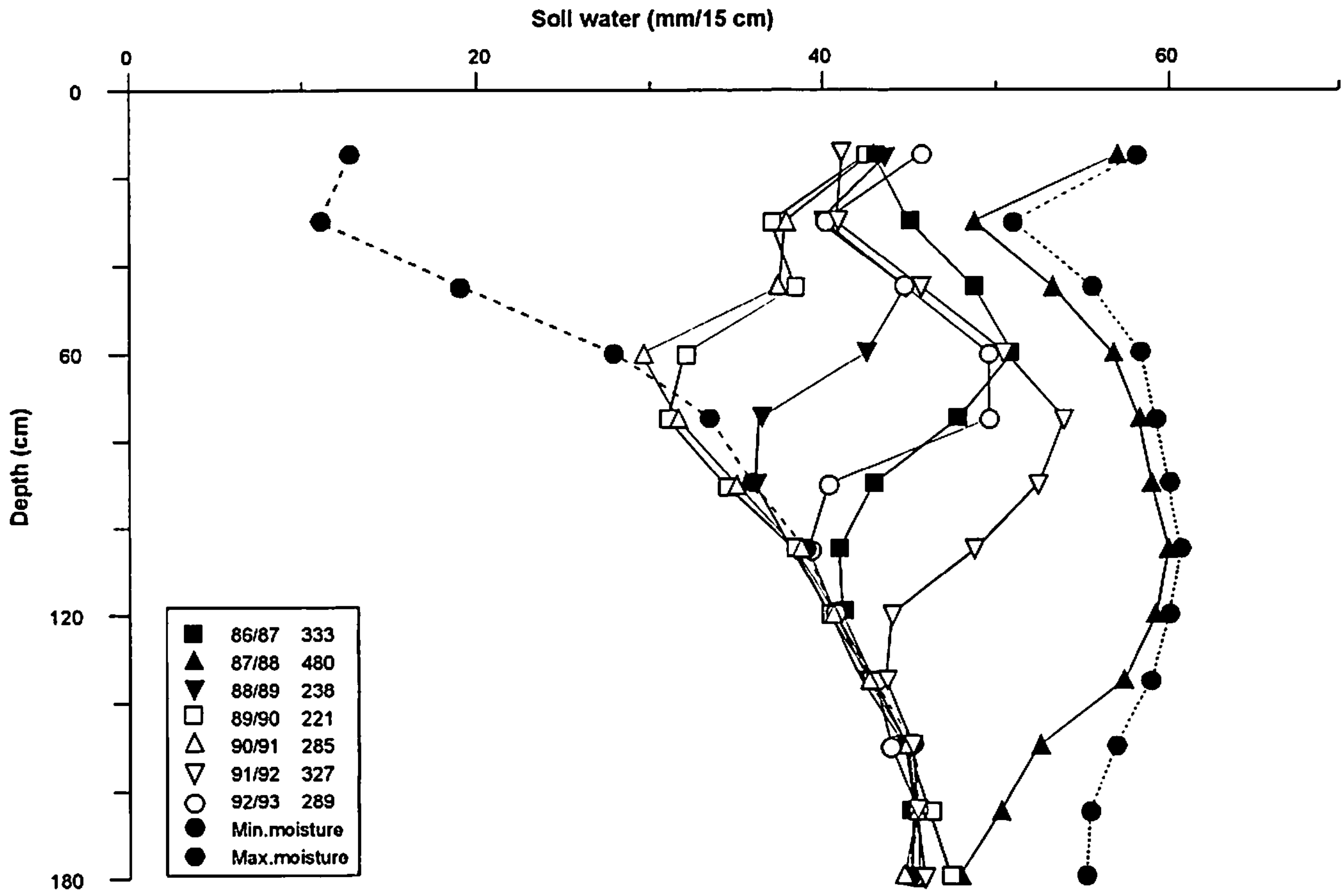


Fig. 40. Depth of soil moisture recharge over several seasons. (Courtesy Dr Hazel Harris.)

VARIABILITY

Soil is a variable medium, both in space and time. Soil properties vary from area to area, from field to field and even between locations in the same field. Similarly, soils that appear uniform on the surface may have varying sub-surface topography. Soils may exhibit changes in properties from season to season. A few brief observations from this work will suffice.

Depth

Measurements of soil depth have been made (Harmsen 1981b) for a few areas at Tel Hadya, i.e, Block A and Fields 17 and 20 in Block C. Depth observations have been made at individual locations elsewhere on the Farm and at the other stations in question. Soil depth usually implies the distance between the surface and the non-soil parent material—which, in the case of Tel Hadya, is either soft limestone which can be penetrated by moisture, roots and the sampling augur, or imperious hard limestone rock.

The sketch of depth in Fig. 41 for Block A, though incomplete, nevertheless shows "islands" of shallow soil in a flat area where the soil is otherwise homogeneous. It illustrates that any area of seemingly uniform land may have varying sub-surface topography—i.e., vary in depth from place to place in any one field. While this variation is not apparent, one should be aware that it does exist.

Temporal

Nutrient availability changes with the *season* and *over time*. The most obvious seasonal change is with mineralization of soil N from organic matter. Flushes of nitrate are common in early fall, when the first rains come and when temperatures are still high enough for microbial activity. Another change—that of P availability with time—has been documented at

ICARDA's stations (Fig. 42). Thus P, whether applied as a band or broadcast, decreases in solubility with time as a result of slow chemical reactions; the pattern was fairly similar at all sites.

Given the fact that available soil P changes with time following fertilization in a predictable pattern, an equation was developed to predict the levels of P in any field at Tel Hadya in any given year. This equation involved base-line test data from the year of the initial Tel Hadya survey (1988), the amount of P added in the intervening years, and the amount added in the last year. Predicted values agreed closely with measured values, thus reducing the need for yearly soil P testing as a basis for annual P fertilizer application.

Spatial

A glance at a crop growing in a field will reveal differences in plant height and vigor. This can reflect nutrient or soil physical differences within that field. An example is shown of variability in the natural distribution of boron at one of the stations, Boueidar (Fig. 43). This was of consequence because of the potentially damaging effects of B on cereals. Boron levels (hot-water extraction) in excess of 3-4 ppm may reduce growth of barley, the dominant crop in the area.

Thus, the figure illustrates the range in B values over a rectangular area of 250 x 170 meters, with observations every 10 m. A random pattern was apparent. Where nutrients such as N and P are added to the soil, total variability might be much greater. Spatial variability over such short distances has implications for soil sampling and for plot layout.

The problem of spatial surface variability of B was also compounded by depthwise variability (Fig. 44). Indeed, three distinct patterns of distribution were evident, i.e., increases with depth, decreases, and maximum accumulation at variable depths.

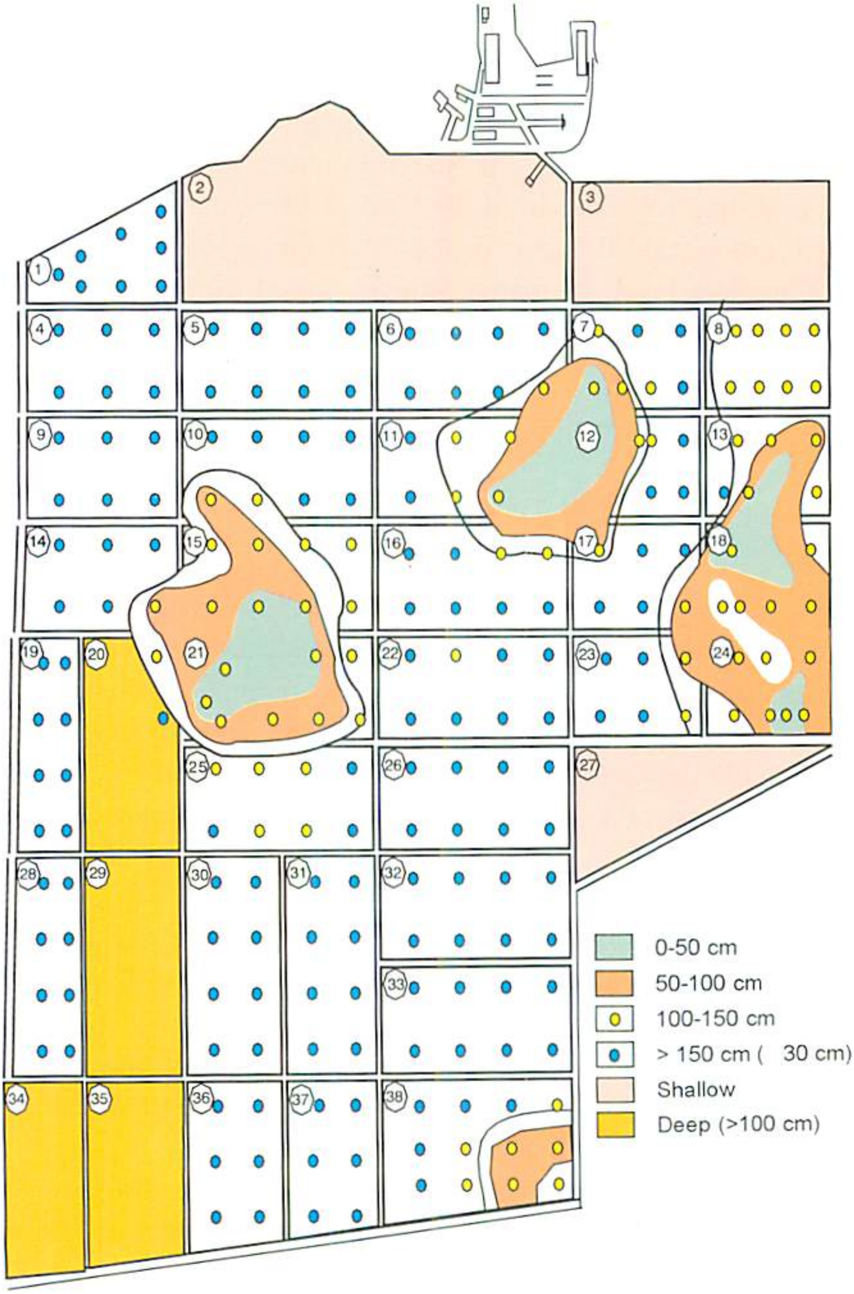


Fig. 41. Soil variation with depth in block A, Tel Hadya.

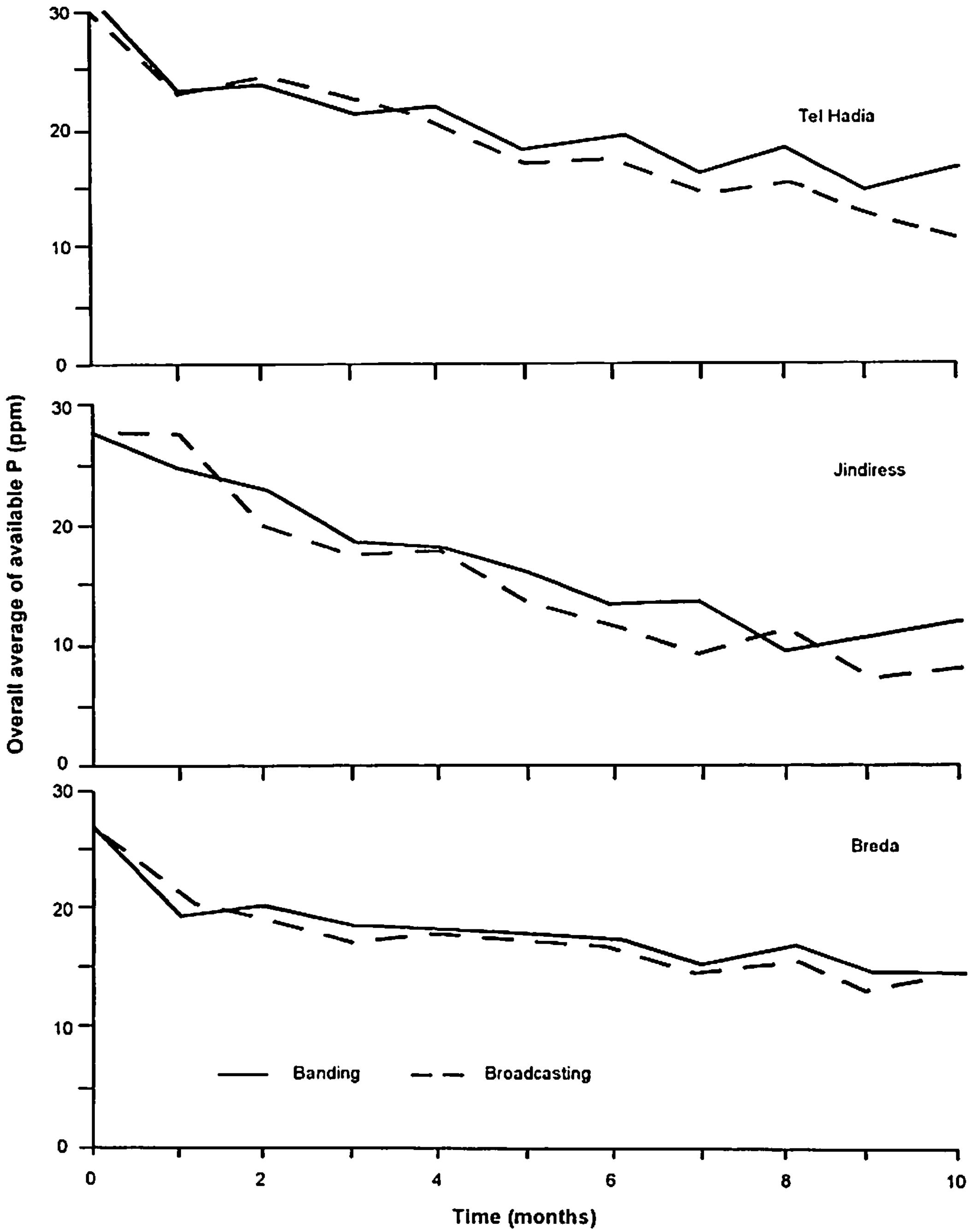


Fig. 42. Net changes in availability of applied phosphorus with time after banded and broadcast P application (time zero).

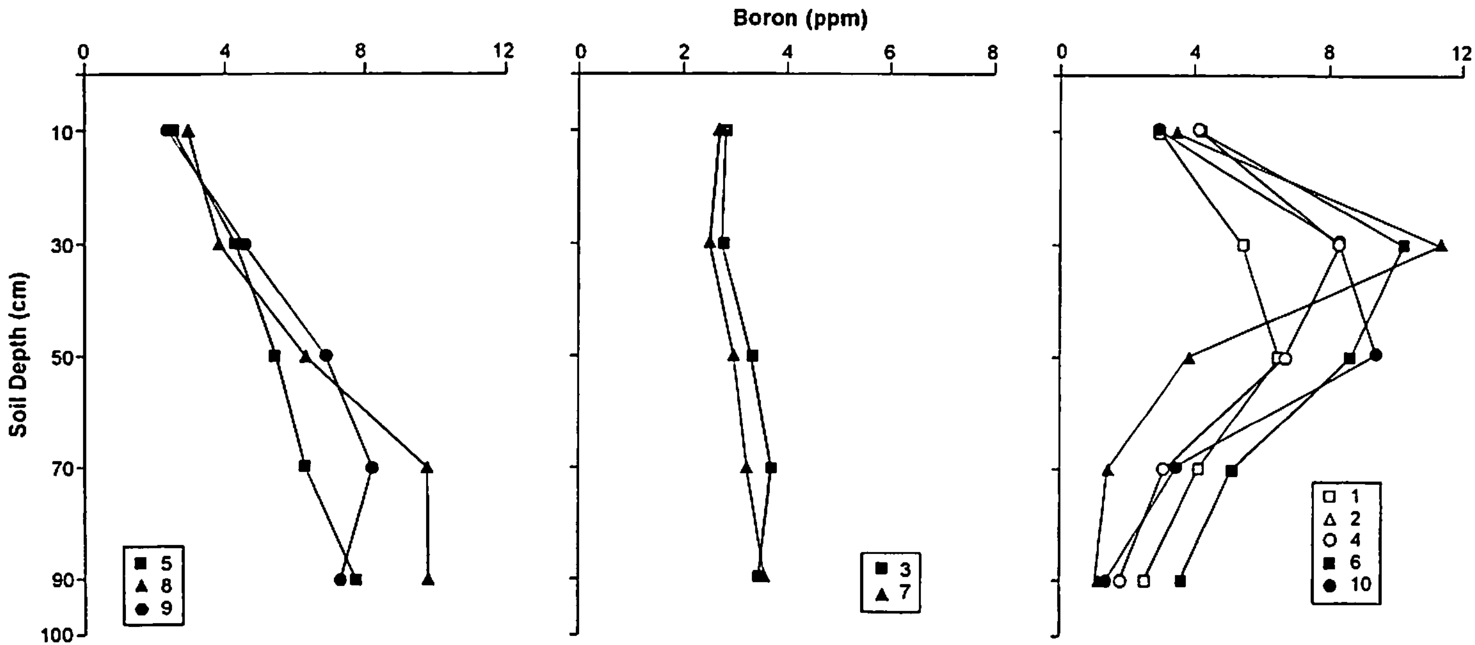


Fig. 43. Patterns of depthwise distribution of water-soluble boron in various profiles at Boueidar.
Numbers = Profiles.

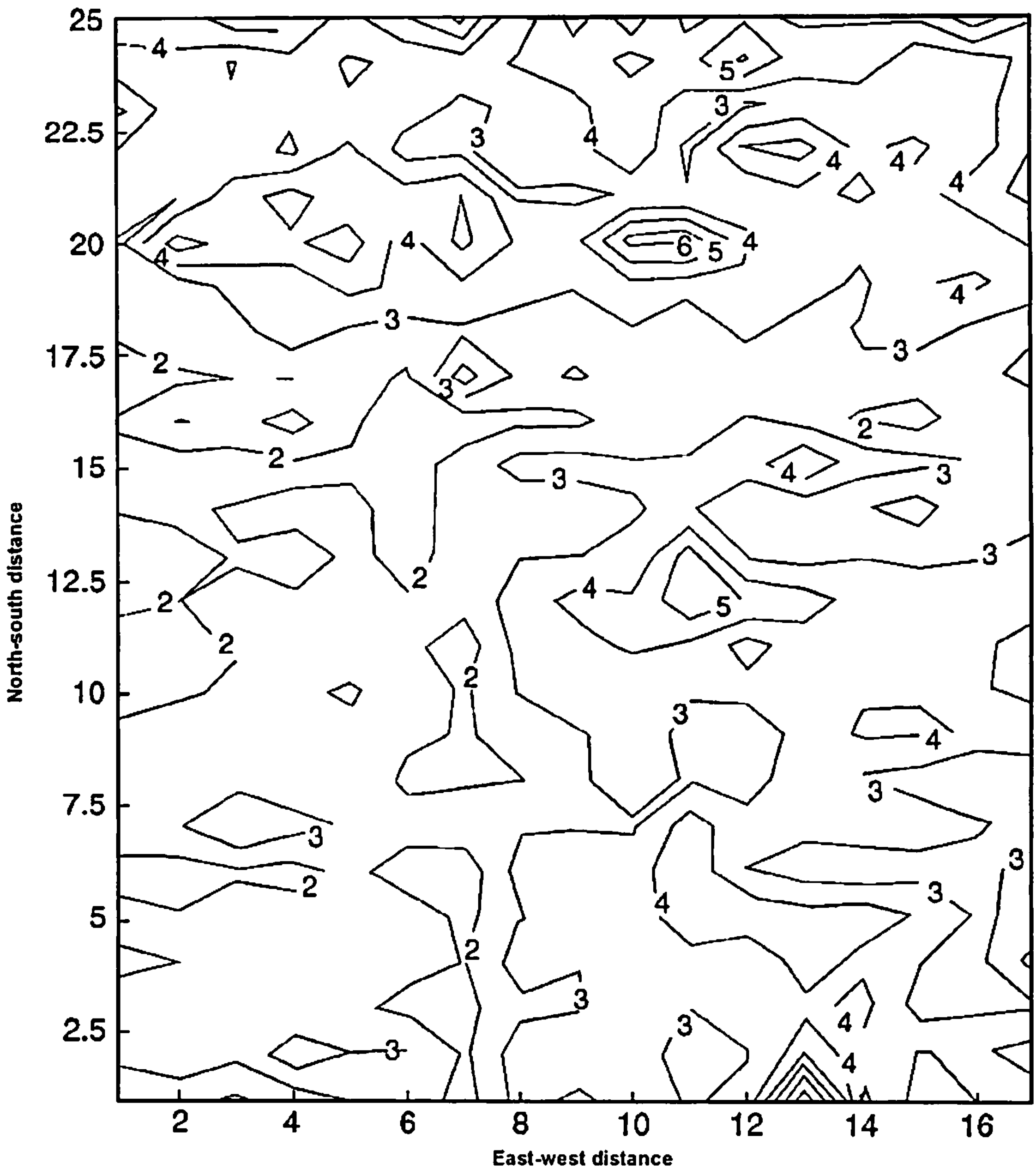


Fig. 44. Variability of water-soluble B values by centering.

CONCLUSIONS AND MANAGEMENT IMPLICATIONS

While this bulletin focused on the soil information we have regarding ICARDA's stations, an incidental benefit was the compiling of key climatic data that enables one to clearly see the range of differences between these stations. Thus, cropping decisions can be easily made, i.e., those that involve a consideration of drought tolerance, planting date and germination, and frost damage. The information on station layout and cropping system sequences helps with logistical decisions on the use of these stations.

Classification of the soil at each site using the Soil Taxonomy system helps make the research emanating from these stations more interpretable to the international scientific community; for most journals, accurate pedological description of research sites is essential. Agricultural experiment stations are invariably established at favorable sites with deep—that is "good"—soils. Thus, depth was not a variable factor in our survey. Most were deep clay Inceptisols or Vertisols. The drier sites, Maragha and Boueidar, were judged to be Aridisols as climate is an intrinsic factor in soil formation and is considered in its classification.

The bulk density measurements suggested that poor physical structure was not an adverse factor to be considered. While field measurements of infiltration were relatively low (11 mm/h) due to the clay content (Dr T. Oweis), in reality, the soil's capacity to absorb water is rarely exceeded because of soil cracks combined with infrequent sharers. Similarly, most soils had a good potential water-holding capacity. The problem is—and in most cases always will be—inadequate supply of water, i.e., insufficient rainfall. At least in periods of adequate rainfall, the excess moisture is stored in the soil and is not lost by leaching. Indeed the name of the soil type, using Soil Taxonomy, can tell the reader a lot about climatic factors in addition to soil properties.

While the information on soil depth was limited, it does illustrate the importance of this third dimension of soil which we cannot always see and most often ignore. When establishing field trials, one should establish by augur probings that the area is of uniform depth.

The nutrient data underline the importance of the surface layer in relation to plant growth; most of the nutrients and roots are concentrated there. A glance at the data also shows how important organic matter is as a store of such nutrients and indeed for preserving soil structure. Research on long-term trials at ICARDA is beginning to show that the adoption of suitable legumes in a rotation can lead to a substantial improvement in soil organic matter and soil structure.

While the amounts of available N—NO_3-N and NH_4-N—were low, necessitating N fertilization in most cases, all sites were well supplied with potassium and therefore do not need fertilization with potassium. Though the Tel Hadya sites and the other Syrian stations were in the deficient zone for available P, both stations in Lebanon had adequate levels of available soil P. Fertilization in such circumstances is a waste of money and reduces the farmers' overall profit.

In terms of nutrient distribution, most elements decreased with depth—except for NO_3-N, which, being mobile, could accumulate at any depth depending on soil moisture movement. The variable distribution of total P reflected variability in pedogenic processes and parent material stratification. It was clear from the data available to us, and from what is known in the literature, that the content of water-soluble B in the subsoil is an important consideration in relation to B toxicity.

Micronutrient cation values, while varying with location, suggested that in some cases Zn deficiency may be a problem, since all values were in the marginal range of 0.5 to 1.0 ppm. Even some Fe values were close to the deficient range, for example A-26 and C-13 at Tel Hadya and at Maragha. While soil research at ICARDA has always focused on N and P, this was the first set of micronutrient analyses reported for ICARDA's stations. The possible local significance of these elements in the region's cropping systems is currently being investigated, especially for Zn (Materon and Ryan 1995) and B (Yau et al. 1994).

The issue of B has already attracted attention in view of its potentially damaging effects when occurring in concentrations of over 5 ppm. As this is a phenomenon of drier areas, higher concentrations were found at Breda, Ghrerife and Boueidar. Barley is believed to be sensitive to higher B concentrations. This aspect is being investigated. In contrast, the data from Lebanon, especially Kfardane, indicate that B may even be deficient, as values were less than 0.5 ppm.

The data on B distribution illustrates how a naturally-occurring element may vary over a small area of land. The variation may be much greater where an element is added in fertilizer form or is changed by management practice. Soil sampling procedures must take this variability into account if they are to meaningfully represent the fertility status of any area of land. The data on P changes with time illustrate the dynamic nature of nutrients with time—*the effect of fertilizer is not permanent.*

An encouraging finding was the absence of any salinity problems at the various stations; however, subsoil salinity values showed a predictable increase in the drier stations—Ghrerife, Boueidar, and Maragha. Caution should be exercised in generalizing this statement to areas adjacent to these stations. With increasing use of on-farm irrigation, often with poor-quality well water, salinity will be an inevitable problem.

The main emphasis in this survey was on soil factors which affect crop growth and which can be manipulated, such as nutrients. Other measurements, like $CaCO_3$ and pH, are only indirectly related to cropping and are interrelated. Soils of drier regions invariably have solid-phase $CaCO_3$ which, in turn, controls pH at around 8.0. These factors are of consequence in that they generally reduce the chemical availability of P and micronutrients. Calcium carbonate assumes greater significance in soil-genesis studies. Cation-exchange capacity measurements reflect the soils' potential to hold nutrients. One can infer from these values that the dominant clay minerals were of the 2:1 type, i.e., montmorillonite. Indeed this was confirmed by the limited data performed on one Tel Hadya sample by the US National Soils Laboratory; this showed that the relative order of the clay minerals was montmorillonite (medium), kaolinite (small) and mica (very small). Related analyses for the sample were iron, 5.6%, and aluminum, 1.9%.

In conclusion, this study has brought together all available and fragmentary information on the soils of ICARDA's stations—i.e., classification, nutrient profiles, and relevant physical properties. It is not the last word on these soils—we cannot wait until we have a complete understanding of their properties before we can say *something* about the usefulness of the information we already have. The research accomplished in the area of soils—primarily related to fertility—can be deduced from the attached list of publications. It provides a rational basis for using such stations and may help in the interpretation of the ensuing experimental findings.

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Selected Soil-related ICARDA Publications

A wide range of publications are produced by ICARDA: reports—annual, program, regional, outreach and meteorological; specialized publications such as *FABIS Newsletter*, *LENS Newsletter*, *Rachis*; training and policy-procedure manuals; and reference books, workshop proceedings and special research reports. A file is kept of all journal articles by ICARDA staff and related to the region it serves. As these are readily available in libraries worldwide, we wish to present those publications that are directly related to soils and those involving cropping systems, fertilization and soil moisture regimes. The list is selective but serves to document what is known about soils of the ICARDA region. A few soil-related internal reports are also cited and are available upon request.

Our primary emphasis is on what has been accomplished in soils research and not in attempting to discuss in detail all ICARDA publications. One has to bear in mind that the same findings are frequently reported initially in annual reports or special internal bulletins, and—depending on the quality and originality of the work—in refereed journals. Therefore, it is relevant to this publication to briefly highlight what has been achieved in relation to ICARDA station soils and their use.

Overview

Initial descriptions of soil profiles at Tel Hadya and other research sites are only found in bulletin or report form and date back to the early 1980s (Harmsen 1981a, 1981b; Subramanian 1981; Anon. 1981a) and have limited circulation, within ICARDA. Two additional internal reports (Matar 1985; Matar et al. 1987) are related to soil tests for available P and to particle size distribution. General descriptions of the climate of northwestern Syria in relation to cropping patterns is contained in several journal articles, e.g. Dennett et al. (1986a, b), with emphasis on water-use efficiency (Cooper et al. 1983, 1987; Gregory et al. 1984; Cooper and Gregory 1987) and root growth (Gregory et al. 1984).

As N is the next major limiting factor after moisture in Mediterranean areas (Harmsen 1984), various aspects of N research have been addressed at ICARDA, i.e., varietal differences in response to N (Anderson 1985a, b), and to the split application of N (Anderson 1985c). Other research dealt with the role of nitrate as a guide to N fertilization (Matar et al. 1990), N mineralization potential (Matar et al. 1991), and N fixation (Beck et al. 1991; Beck 1992). One study (Abdel Monem 1986) was concerned with N volatilization from urea. Several publications on barley fertilization emanated from the thesis research of Shepherd (1985). A recent study (Garabet 1995) used ^{15}N to assess N-use efficiency under supplemental irrigation of wheat.

Much effort was also concentrated on P, another widespread limiting factor for crop growth. Studies addressed issues of root growth and development (Brown et al. 1987; Gregory et al. 1984), rate and method of P placement (Matar and Brown 1989a, b), and forage quality (Osman et al. 1983). Other aspects, such as calibration of field response data in relation to soil test, have been reported in the various workshop proceedings (Soltanpour 1987; Matar et al. 1988; Ryan and Matar 1990, 1992; Ryan and Pala 1996) and in a general review of P in dryland areas (Matar et al. 1992). Greenhouse-based research showed that the Olsen ($NaHCO_3$) test was most appropriate for measuring available P (Matar et al. 1988). Other work was exclusively laboratory-oriented, i.e., adsorption isotherms (Bakeit and Dakermanji 1993) and on P reactions in relation to soil properties (Afif et al. 1992). Though not directly related to soils of ICARDA's stations, the seasonal changes in organic and inorganic soil P (Habib et al. 1994) in a Mediterranean environment (wet and dry seasons) are pertinent. Several theses have dealt with various aspects of P (Afif 1992; George 1993; Wadih 1992) and arbuscular mycorrhizae (Weber 1992).

In the context of farming systems of the Mediterranean region, long-term trials were evaluated in different environments (Keatinge et al. 1986) and for the specific influence of legumes on N fixation (Keatinge et al. 1988) and improving soil organic matter and N (Harris et al. 1993). Overviews of ICARDA's long-term trials (Harris 1993) and water-use efficiency of rotations (Harris 1994) have recently been presented. Work at ICARDA demonstrated the need for nodulation for adaptation of legumes in soils where suitable *Rhizobia* did not exist (Materon 1991). A preliminary assessment of the 9-year P trial at Tel Hadya, Jindiress and Breda was made recently (Ryan et al. 1994).

Factors of a third category are beginning to be investigated as constraints to cropping: micronutrients. While iron was shown to be frequently deficient for chickpeas (Saxena et al. 1990), the recent focus is on zinc deficiency in pasture legumes (Materon and Ryan 1995) and on the potentially harmful effects of boron toxicity on cereal growth (Yau et al. 1995; Mahalakishmi et al. 1995). The implications of the spatial variability of B were also dealt with (Ryan et al. 1995). One thesis (Ajouri 1993) dealt with the interaction of P and micronutrients in chickpea.

While most of the studies mentioned here were conducted at Tel Hadya and/or its satellite stations, other work conducted on farms in the region is relevant and worthy of mention. The major series of on-farm trials with barley (Anon. 1992a) and wheat (Anon. 1992b) represent a major effort between ICARDA and the Soils Directorate on N and P fertilization. These trials were assessed economically (Mazid and Bailey 1992), and in terms of models (Jones and Wahbi 1992) and residual response (Wahbi et al. 1993). A recent report (Wahbi et al. 1994) dealt with fertilization of on-farm and researcher-managed trials in the area encompassed by the ICARDA stations.

Soil research at ICARDA has been oriented towards crops and cropping systems. However, as cropping in semi-arid regions has implications for soil loss by wind or water erosion, the potential dangers have been highlighted by Jones (1991). Similarly, the network approach to collaborative soil fertility research with the region's national programs was described by Matar (1992) and Ryan et al. (1995), while Ryan and Garabet (1994) pointed to the need for standardization of soil and plant testing procedures. A manual dealing with appropriate soil and plant tests has just been completed (Ryan et al. 1996).

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Acknowledgements

We wish to thank the following people for their assistance in the background effort and production of this technical bulletin.

Ahmed Hamwieh, Hayel El Shaker, Ahmed Khudr, and Mohamad Kassem of FRMP field staff for digging the pits and sample preparation.

The Soils Laboratory staff, George Estephan, Elianor Nasseh, Shireen Baddour, Rania Abd and Nezha Merjaneh, for the many soil chemical analyses.

The staff at Terbol and Kfardane who arranged for pit preparation, especially Mr Mounir Sughayar.

Miss Tamar Maksoudian and Miss Ramzia Wafaii for typing the manuscript.

Drs Hazel Harris, Peter Smith, and Mike Jones for reading the manuscript and making helpful comments.

Jouhyna Issa, Mike Robbins and Guy Manners for editorial input.

Mrs Sossi Ayanian for typesetting the manuscript.

Finally, Mr Hassan Khairallah for the artwork and design, and the final production of the document.


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