# NILE VALLEY REGIONAL PROGRAM
# PHASE II

## Resource Management Series

### Volume 2

## INVENTORY STUDIES

### Old Irrigated Lands of Egypt
### Soil Fertility and Management

Editors
Mohamed Abdel Monem, Rashad Abo Elenein, Mahmoud B. Solh
and Abdel Wahed Abdel Shafi

Volume 2

# Resource Management in the Old Irrigated Lands of Egypt: Soil Fertility and Management

## Technical Input


**Team Coordinator:** **Dr Mohamed Abdel Monem**
*International Center for Agricultural Research in the Dry Areas*

**Team Members:** **Dr Mohamed Saleh Khedr**
*Soil, Water and Environment Research Institute, ARC*

**Dr Abdel Wahed Negm**
*Soil, Water and Environment Research Institute, ARC*

**Dr Mohamed Abdel Halim**
*Soil, Water and Environment Research Institute, ARC*

**Dr El Zanati Abou El Nour**
*National Research Center*

**Language Editors:** **Dr Hala Hafez**
**Ellen Larson**

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# Foreword

Limited soil and water resources and threatened sustainability of agricultural production call for an effective resource management strategy and farming systems approach in agricultural research. Implementing a long-term research program where more emphasis would be on systems-oriented rather than commodity-oriented agricultural research would represent such a strategy. Therefore, the Resource Management Component of the Nile Valley Regional Program (NVRP) of the International Center for Agricultural Research in the Dry Areas (ICARDA) was developed. The Component, which started in 1994 in one of the Nile Valley countries, Egypt, and is expected to be extended to the others, aims at achieving sustainable production at a high level, based upon the need to protect the resource base (land and water) through good management. This would be achieved through basic intensive technical research (long-term on-station trials) and on-farm extensive monitoring of resources in farmers' fields and farmers' decision making logic.

Preparatory studies were carried out prior to conducting the trials and monitoring activities. The objectives of these studies were to define and characterize the major farming systems of the main agroecological environments; to identify and prioritize—with respect to the natural resources—the constraints to optimum utilization and the threats to sustainable production; and to provide an outline for the strategy, design and implementation of the long-term research activities.

The preparatory studies involved three procedures for information collection: **Inventory Studies**, in which existing information and details of the ongoing research and development, related to soil and water management, agronomy and cropping systems, and socioeconomics were collected; **Rapid Rural Appraisals**, which included qualitative sampling of farmers and extension views concerning current limitations, constraints, dangers, and opportunities in the utilization of soil, water, and inputs; and **Multidisciplinary Surveys**, which employed short-focused questionnaires to fill some important information gaps. In general, information collected in the preparatory studies dealt with resource description, resource utilization and management, productivity, and threats to sustainability. This knowledge was used in planning the long-term research activities at selected locations by identifying high-priority researchable resource management problems, in the context of realistic cropping sequences and farm level economics.

The outcome of these studies is hence presented in what is called the **Resource Management Series**. The series includes a total of 18 volumes on Inventory Studies, Rapid Rural Appraisals, and Multidisciplinary Surveys in the Old Irrigated Lands, New Lands, and Rainfed Areas. In the Inventory Studies, five volumes on the research and development activities and findings in each of the Old and New Lands were compiled. These volumes were on Agronomy, Soil Fertility and Management, Water Management, Socioeconomic Studies, and a Synthesis of all the latter. The Inventory Studies of the Rainfed Areas included two volumes, one on the Northwest Coast and the other on North Sinai.

These studies were conducted in Egypt with the involvement of the Agricultural Research Center (ARC), Desert Research Center (DRC), National Water Research Center (NWRC), National Research Center (NRC), Ain Shams University and ICARDA within the NVRP with financial support from the European Commission. Appreciation is expressed to all those who contributed to these important reviews and studies.

**Rashad Abo Elenein**
**National Program Coordinator, NVRP**
**Agricultural Research Center, Egypt**

**Mahmoud B. Solh**
**Director of International Cooperation and**
**Former Regional Coordinator NVRP/ICARDA**

## Weights and Measures

1 feddan (fed) = 0.42 hectare = 1.037 acres

1 hectare (ha) = 2.38 feddans

## Acronyms

ARC = Agricultural Research Center

CEC = Cation Exchange Capacity

EPA = Environmental Protection Agency

EU = European Union

FAO = Food and Agriculture Organization

GTZ = Gesellschaft für technische Zusammenarbeit (German Agency for Technical Cooperation)

ICARDA = International Center for Agricultural Research in the Dry Areas

NRC = National Research Center

NVP = Nile Valley Project

NVRP = Nile Valley Regional Program

SWERI = Soil and Water Research Institute

UNESCO = United Nations Educational, Scientific and Cultural Organization

USDA = United States Department of Agriculture

WHO = World Health Organization

## Introduction

The Nile Valley and Delta comprise 35,000 $km^2$, equivalent to 3.5% of the area of Egypt, extending from the Sudanese border in the south to the Mediterranean coast in the north. The approximate area of the Valley is 12,000 $km^2$, while the Delta is 23,000 $km^2$. The vast majority of the land cultivated in Egypt today is located in the Valley and Delta. The soils of these cultivated areas are described as alluvial soils.

The suspended matter that is carried by the river—clay, organic matter and soluble salts—was substantially decreased by the construction of the Aswan High Dam in 1964. Most of the soils of the Valley and Delta are now generally poor in organic matter and nitrogen, moderate in available phosphorus, and rich in available potassium. Due to extensive agricultural production in the Valley and Delta, the use of chemical and organic fertilizers has become an essential component of the technology package recommended for cereal and legume crops.

Wheat production in 1991 increased 160% over that in 1980, due to increased yield per hectare and increased cultivated area. Several studies have been carried out to establish the rate, time, method, and form of fertilizer application for wheat production. Although little research has been conducted on barley fertilization, the recommended technology package has been tested in the barley area. Mineral fertilization and microbial inoculation studies have been carried out to establish the requirements for faba bean production in Egypt. Foliar application of micronutrients has proved to be important in increasing faba bean yield. The response of lentil and chickpea to P and micronutrients was found to be significant in several studies. Response to seed inoculation with *Rhizobium* and mineral fertilization has been studied in soybean, a newly introduced food legume crop. Berseem production (the main forage crop in Egypt) can be significantly increased if fertilized with K and P. Sorghum showed a response to nitrogen as well as to micronutrients.

As the recommended rate of fertilization has increased significantly over the last two decades, the consumption of chemical N, P, and K fertilizers has also increased. Significant amounts of fertilizers are lost due to poor management, which contributes to the environmental pollution problem.

# Soil Classification and Geomorphology

The soils of the Nile Valley and Delta originated from alluvial Holocene deposits, consisting mainly of dark grayish-brown suspended matter. The dark color of these sediments can be attributed to the presence of micaceous minerals (biotite) and hydrated magnetite. These deposits have accumulated to a considerable thickness as a consequence of the annual overflow over thousands of years. The thickness of the deposit varies according to locality, as well as to the regularity of the surface (because the river had changed its path from time to time). However, the mean thickness of the suspended matter in the Nile varies from 6 to 7 meters in Aswan and Qena in the south to 11.2 meters in the north part of the Delta. The average thickness in the Delta is approximately 9.8 meters, and in the Nile Valley between Aswan and Cairo approximately 8.3 meters. The map compiled by the Soil Survey Division of the Soil, Water and Environment Research Institute (SWERI), ARC, shows the soil association units according to the world soil classification system adopted by FAO and UNESCO (El Tobgy, 1976). The soil association units for Egyptian soils are fluvisols, solonshaks, vertisols, regosols, and lithosols.

The Egyptian Academy of Scientific Research and Technology carried out a project to prepare a soil map of Egypt. The colored map was finished in 1986, and covers arable land, the fringes between the alluvial soils in the Delta and Valley and the desert, as well as the pilot areas in both the Eastern and Western Desert. Cadastral maps, aerial photographs, and, for the desert, a false-colored Landsat map (ERTS) were used. It was the first attempt in Egypt to prepare a soil map with a uniform legend using a modern classification system.

Results of a detailed soil survey are available in the EMCIP (1983) report for the main research and extension centers in the Valley and Delta, according to the USDA soil taxonomy system.

## Research and Extension Centers

### *Gemmeiza*

The study area includes 1,287 fed (540 ha), located 7 km north of Tanta in Gharbia governorate in the Delta. The soils of Gemmeiza are classified, according to the USDA system, as:

**Order:** Vertisols.

**Subgroup:** Typic torrests.

**Family:** Clayey, montmorillinitic, thermic, slightly calcareous, deep, and level.

Clay content ranges between 40 and 68%, CEC between 32 and 39 meq/100 g, and calcium carbonate between 2 and 4%. Organic matter in the topsoil is approximately 2%.

### *Sakha*

The study area is approximately 11,000 fed (4,620 ha) in Kafr El Sheikh governorate. The soils of Sakha are classified as:

**Order:** Vertisols.

**Subgroup:** Typic torrests.

**Family:** Clayey, montomorillonitic, thermic, slightly calcareous, deep, and level.

Clay content ranges from 38 to 78%, CEC from 28 to 46 meq/100 g soil, calcium carbonate content from 2 to 3%, and organic matter from 0.7 to 2.64%.

#### *Sids*

Sids is in Beni Sueif governorate. The study area is 758 fed (318 ha), with the soil classified as:

**Order:** Entisols.

**Subgroup:** Vertic torrefluvents.

**Family:** Clayey, mixed, thermic, slightly calcareous, deep and level.

Clay content ranges from 39 to 62%, CEC from 27 to 37 meq/100 g, and organic matter from 0.7 to 2.48%.

#### *Shandaweel*

Shandaweel is located in Sohag governorate. The study area comprises 585 fed (245 ha), with soils classified as:

**Order:** Entisols.

**Subgroup:** Typic torrefluvents.

**Family:** Fine loam, mixed, hyper thermic, slightly calcareous, deep, and level.

The clay content ranges from 20 to 30%, CEC from 5 to 17 meq/100 g soil, organic matter from 0.78 to 2.33%, and $CaCO_3$ from 0.28 to 3.41%.

### The Valley and Delta Soils

The soil classification for the Nile Valley and Delta, according to the USDA soil taxonomy system, is described by the Soil Survey Division (ARC) as follows:

#### *Delta*

##### *West Delta*

The soils of the West Delta are classified as vertisols, subgroup typic torrests, with entisols present in some areas.

- Typic torrifluvents: Present in a narrow strip along the western side of the Rosetta Branch, and in a large area from southwest of Edko Lake to south of Maryut Lake.
- Vertic torrifluvents: Medium to large areas south east of Edko Lake.
- Typic torripsamments: Present in a large area around Nubaria Canal.
- Typic quartzipsamments: Present in a large area south of Nubaria Canal (from the Rosetta Branch to several kilometers west of the Alexandria–Cairo Desert Road), and small to medium areas southwest of Wadi El Natrun Depression.

- Typic torriorthents: Along with typic torripsamments and typic quartzipsamments, these soils are present in a large area around the Desert Road, and in another large area between the Rosetta Branch and the Desert Road (between km 65 and 115).
- Aridisols: Present in different areas as subgroups.
- Typic salorthids: Present in two medium areas west of Rosetta and southwest of Maryut Lake.
- Aquollic salorthids: Present in a narrow strip along the coast of Abu Qir Bay.
- Typic calciorthids: Present in large areas on both sides of the Desert Road (km 165–195 and km 65–120).
- Typic gypsiorthids: Large areas west of the Desert Road (km 65–120) and west of El Natrun Depression.

### *Middle Delta*

Most of the soil was classified as vertisols, subgroup typic torrests.

Entisols are present in the following subgroups:

- Typic torrifluvents: Small areas along the river branches and other scattered areas.
- Typic ustifluvents: Medium areas southeast of Moheit Drain No. 8 and north of the Zaini Drain.
- Vertic ustifluvents: Large areas to the northeast and scattered areas in the north and northwest.
- Typic quartzipsamments: Small to medium areas in the north of the Delta.

Aridisols are present as subgroup aquollic salorthids.

### *East Delta*

Most of the soils in the middle and west of the area are vertisols, subgroup, typic torrests.

Entisols are present as the following subgroups:

- Typic torrifluvents: Present in a small strip along the Damietta Branch and other small scattered areas.Typic torriorthents: Present in large areas south of the Ismailia Canal between Abu Hammad and Abu Sowier, and around the Cairo–Ismailia Desert Road.
- Typic torripsamments: Present in medium to large areas in the middle and east.
- Typic quartzipsamments: Present in small to large areas concentrated in the middle of the East Delta, and a very large area between the Ismailia Canal and the Cairo–Ismailia Desert Road.
- Vertic torrifluvents: Present in large areas in the middle of the region.

Aridisols are present as the following subgroups:

- Aquollic salorthids: Present in a narrow strip along the coast and a very large area west of the Suez Canal.

- Petrogypsic gypsiorthids: Present in a small area west of the Suez Canal between Qantara and Ismailia.
- Typic gypsiorthids: Present in a large area west of the Suez Canal between the Little Bitter Lake and Suez.
- Calcic gypsiorthids: Present in medium to large areas around the Cairo–Suez Desert Road and a medium-sized area west of the Little Bitter Lake.

### *Fayoum Depression*

Vertisols, subgroup typic torrests, are the dominant soils of the Fayoum Depression.

Entisols are present as the following subgroups:

- Typic torrifluvents: Present in a medium-sized area in the middle of the depression.
- Typic torripsamments: Present in an elongated strip in the southwest, and a small area in the east.

Aridisols are present as the following subgroups:

- Typic salorthids: Present in a strip south of Birket Qarun.
- Typic calciorthids: Present in two medium-sized areas in the eastern and western sides of the depression.
- Calcic gypsiorthids: Present in a medium-sized area in the northeast of the depression.

### *The Nile Valley*

The dominant soils of the Nile Valley are vertisols, subgroup typic torrests.

Entisols are present as the following subgroups:

- Typic torrifluvents: Present in a strip along the river bank and small scattered areas in the valley.
- Typic quartzipsamments: Present in strips in the traditional farming zone between the Nile Valley and the Western and Eastern Deserts.
- Typic torriorthents: The dominant soil in desert areas.

Aridisols are present as the following subgroups:

- Petrogypsic gypsiorthids: Present in medium to large areas northwest of El Wasta, west of Beni Sueif, and between El Idwa and Matai west of Bahr Youssef in the Western Desert.

# Soil Productivity

A soil survey was carried out by the Agricultural Research Center (ARC) in several governorates in the Nile Valley and Delta for soil productivity.

### Kafr El Sheikh governorate

The data provided by SWERI, ARC, characterize the soil texture as deep and heavy (clay to heavy clay), with no obstacles down to 150 cm below the surface. The northern soils are characterized by a salt crust. Lack of drainage in some areas causes soil salinity. Some of the soils are affected by medium to severe alkalinity.

### Sharkia governorate

The soils are clay with low permeability (0.1 mm/hour), which increases in the northern area due to soil salinity. Soils in the northwest of the governorate are of marine formation. The soils located around the Ismailia Canal are sandy plain soils with light or coarse texture. The soils of the south and middle of the governorate are non-saline. Saline and highly saline soils are found in the north, and scattered areas around the Ismailia Canal, and adjacent to Manzala Lake.

### Dakahlia governorate

The soils are clay with a heavy texture, except in the north, adjacent to the Mediterranean Sea, where the texture is coarse. Saline soils are found in scattered patches. Highly saline soils are found adjacent to Manzala Lake and the northeastern part of the governorate. Alkaline soils are found in some areas of El Senbillawin and Manzala.

### Beni Sueif governorate

Deserts border the governorate to the east and west, greatly affecting particle size distribution. Soils to the west and east are sandy with very light textures and high levels of $CaCO_3$. The soils along the Nile are loams or clay loams, depending on sedimentation factors. The flood plain soils, which represent most of the cultivated areas, are heavy textured (light clay). Saline, highly saline and very highly saline soils exist in separate locations of the governorate.

### Minya governorate

Most of the cultivated soils of the governorate are flood plain soils of heavy clay texture. Soils to the west, adjacent to the Western Desert, have a very light texture. The soils adjacent to the Eastern Desert have a very coarse texture (calcareous, sandy soils). Saline soils are found in scattered areas between the Ibrahimia and Bahr Youssef Canals.

Results of the physical and chemical analysis of the many soil samples collected from the experimental sites are presented in Table 1. They indicate a wide range in physical and chemical characteristics. The pH values are slightly alkaline. The soils vary in calcium carbonate content, but are poor in organic matter. Average values of total salts are low. The cation exchange capacity (CEC) is high.

A survey was conducted by the National Research Center (NRC), in which soil samples were collected from farmers' fields. There was a wide range of textures, a strong alkaline reaction (pH >8), poor N content, rich K content, and varied P and micronutrient content (Table 2).

**Table 1. Physical and chemical analysis of soil samples collected from different experimental sites in the Nile Valley and Delta.**

| Character | Range | Mean value |
|---|---|---|
| pH (1:2.5) | 7.3–8.3 | 7.9 |
| $CaCO_3$ (%) | 2.1–8.3 | 3.9 |
| Total soluble salts (%) | 0.09–0.33 | 0.17 |
| Organic matter (%) | 1.22–2.24 | 1.7 |
| CEC (meq/100 g soil) | 31–61 | 46 |
| Exchangeable Ca (meq/100 g soil) | 10–34 | 22 |
| Total nitrogen (%) | 0.07–0.113 | 0.087 |
| Available P-Olsen (ppm) | 1–29 | 12 |
| Exchangeable K (OAC) (ppm) | 288–663 | 464 |

Source: Hamissa *et al.* (1992).

**Table 2. Soil physio-chemical characters of irrigated farmers' fields in the Nile Valley and Delta.**

| Character | Depth 0–30 cm | |
|---|---|---|
| | Range | Mean |
| pH (1:2.5) | 8–9 | 8.3 |
| $CaCO_3$ (%) | 0.5–15 | 5.0 |
| Organic matter (%) | 0.2–2.0 | 1.3 |
| Total nitrogen (%) | 0.06–0.17 | 0.10 |
| P-Olsen (ppm) | 2–50 | 25 |
| Exchangeable K (OAC) (ppm) | 200–700 | 380 |
| DTPA-extractable (ppm): | | |
| Zn | 0.8–2.5 | 0.9 |
| Mn | 4.0–140 | 25 |
| Fe | 4.0–40 | 20 |
| Cu | 0.8–5 | 4 |

Source: Fawzi *et al.* (1987); Fawzi (1991a,b).

## Soil Fertility Status

Before the Aswan High Dam was built, Nile mud played an important role in the fertility of Egyptian soils. El Tobgy (1976) found that floodwater carried considerable sediment. Approximately 8.8 million tons were deposited on the irrigated basins of Upper Egypt, 2.7 million tons on the perennially irrigated lands, and 0.5 million tons in the Delta, annually. Thus, large amounts of macro- and micronutrients and organic matter were annually deposited on the cultivated land of Egypt before construction of the Aswan High Dam. A significant reduction in nutrient supply was reported after the building of the dam. Nabhan (1966) estimated the reduction of micronutrients in the suspended matter at 80.5% for Fe, 83.4% for Mn, 80.9% for Zn, 76.5% for Cu, and 78.7% for Mo. In conclusion, it is clear that because Nile mud is no longer distributed over Egyptian soils, replenishment of soil with macro- and micronutrients is needed to ensure crop production for the increasing population.

Numerous soil and plant nutrition studies have established the poverty of most Egyptian soils in terms of organic matter and nitrogen content. Although the total P in most soils is rather high, the level available to plants (P-Olsen) ranges between sufficient and marginal, and response to P fertilizers differs according to crop and soil. Potassium is fairly high, and there is no significant response to K fertilizers, except for some horticultural crops and on sandy and some calcareous soils. With regard to micronutrients, Fe deficiency is marked in some calcareous soils, while Mn deficiency is found in some alluvial soils. Zn deficiency is evident in some sandy and lowland soils. Copper accumulations are sometimes found, due to heavy use of Cu fungicides.

### Delta

Soil fertility studies have been carried out for various governorates. A summary of the findings, including macro- and micronutrient content, is presented below.

#### *Dakahlia governorate*

During the 1990 growing season, a soil fertility survey was carried out, with 1,445 soil samples collected from nine districts (SWRI, 1990). Chemical analysis of macro- and micronutrients showed that 68% of the tested sites were poor in N, while 17% were rich. Sixty-six percent of the sites were poor in P, while 3% were rich. Ninety-seven percent of the tested soils were rich in available K. Most soils were rich in Fe, Zn, and Mn. Another study, conducted by NRC (NRC-GTZ, 1991c), involved the collection of 653 soil samples and 363 plant samples, representing 7,160 fed (3,008 ha). Soil analysis showed that most soil samples were rich in P, K, Mn, Fe, and Cu, and 44% of the soil samples were poor in Zn. Mean values of tested sites revealed N deficit in 73%, P, Zn, and Cu deficits in 41–45%, and Mn deficit in 26% of the plant samples.

#### *Sharkia governorate*

Soil samples (665 samples) were collected, representing 14 districts (SWRI, 1990). Chemical analysis showed that 75% of the tested soils were poor in N content, with only 9% rich in N. Five percent of the tested sites were rich in P-Olsen, and 70% were poor.

Most of the soil samples had an adequate concentration of K. Most of the samples were rich in Zn, Fe, and Mn.

### *Gharbia governorate*

Soil samples (1,474 samples) were collected from eight districts (SWRI, 1990). Chemical analysis of the soil samples showed that 85% of the sites were poor in N, with 8% rich in N. Thirty-five percent were poor in available P and 40% were rich in P-Olsen. Most of the tested soils had adequate concentrations of K, Zn, Fe, and Mn.

### *Kafr El Sheikh governorate*

Soil samples (988 samples) were collected from nine districts (SWRI, 1990). It was found that 92% of the tested sites were poor in N content, while 69% were poor in available P. Adequate concentrations of K, Zn, Fe, and Mn were found.

### *Beheira governorate*

Soil samples (808 samples) and plant samples (808 samples) were collected from 14 districts (NRC-GTZ, 1991b). Soil analysis showed that 100% of the samples were poor in N content, with 25% poor in available P. Although soil analysis showed adequate concentrations of micronutrients, plant analysis for wheat showed that more than 90% of the samples were poor in Fe, Zn, Mn, and Cu.

## Nile Valley

### *Fayoum governorate*

Soil samples (779 samples) were collected from five districts (SWRI, 1990). Soil analysis showed that 82% of the tested sites were poor in N content, with 28% poor in available P. Most soils had adequate amounts of K, ranging from 300 to 1,333 ppm. In another study (NRC-GTZ 1991d), 320 soil and 220 plant samples were analyzed in five districts. The soil was low in Fe and Mn as well as marginal Zn. Ninety-two percent of the plant samples were deficient in Mn and Fe, and 42% were deficient in Zn.

### *Beni Sueif governorate*

Soil samples (377 samples) were collected from five districts (SWRI, 1990). Eighty-one percent of the tested sites were poor in N content, and 30% were poor in available P. Sufficient concentrations of K were found in all soil samples. In another study (NRC-GTZ, 1993), in which 260 samples were collected, P deficiency was found in 27 and 91% of faba bean and berseem plant samples, respectively. Mn deficiency was 33–73%, Zn was 52–89%, and Cu was 18–32%.

### *Minya governorate*

Two soil fertility surveys were conducted. In the first, 847 soil samples were collected from nine districts (SWRI, 1990). In the second, 1,271 soils samples were collected from nine districts (NRC-GTZ, 1991e). Average values for the two studies showed that 72% of the sites were poor in N content, 33% were poor in available P, while only 12% were poor in K. Plant samples were collected and analyzed for micronutrients. On average, 37% of the samples were poor in Fe, 21% were poor in Mn, and 89% were poor in Zn.

### *Assiut governorate*

Two fertility surveys were conducted. In the first, 1,152 soil samples were collected from 11 districts (SWRI, 1990). In the second, 1,376 soil samples and 1,056 plant samples were collected (NRC-GTZ, 1992). The SWRI (1990) survey showed that 54% of the tested sites were poor in N content, while only 3% were poor in available P. Adequate concentrations were reported for K, Fe, and Mn, while 31% of the samples were poor in Zn. The NRC-GTZ (1992) survey showed that 50% of the soil samples were poor in available P, with adequate concentrations of Fe, Mn, Zn, and Cu. Wheat samples showed adequate concentrations of micronutrients.

### *Sohag governorate*

Soil samples (663 samples) were collected from 11 districts and analyzed for macro- and micronutrients (SWRI, 1990). The results showed that 49% of the tested sites were poor in N content, while 27% were poor in available P, and 3% were poor in K. Available Fe and Mn were adequate, while 6% of the soil samples were poor in available Zn.

### *Menoufia governorate (Kafr El Khadra)*

Soil samples (908) and plant samples (676) were collected from the village of Kafr El Khadra for a soil fertility survey (NRC-GTZ, 1991a). Chemical analysis of the soil samples showed that 87% were poor in N content, while 25% were poor in available P. About 30% of the samples were poor in Fe and Zn, while adequate amounts were reported for K and Cu. Analysis of wheat samples showed that 25, 85, and 26% of the samples were poor in N, P, and K, while 30, 71, 73, and 0% were poor in Fe, Mn, Zn, and Cu, respectively.

El Fouly (1983) studied the DTPA-extracted micronutrient content (ppm) in alluvial soil at various locations of the Nile Valley and Delta (Table 3). Fawzi *et al.* (1987) state that micronutrient deficiencies in Egypt are as follows: Zn > Mn > Fe > Cu.

Fawzi (1991c) states that nutrient deficits in crop plants reflect the low availability of micronutrients (e.g., Zn) in soil, and/or the low capability of plants to use nutrients available in sufficient quantities (P, Mn, Fe, Cu) or abundantly applied (N).

**Table 3. DTPA-extracted Zn, Mn, Fe, and Cu in Egyptian soils (ppm).**

| | Dakahlia | Menoufia | Kalioubia | Minya | Assiut |
|---|---|---|---|---|---|
| Zn | 2.1† | 1.4†† | 1.3†† | 1.5†† | 1.9† |
| Mn | 31.0 | 14.0†† | 4.0†† | 28.0† | 136.0 |
| Fe | 34.0 | 24.0 | 10.0† | 21.0 | 42.0 |
| Cu | 4.4 | 3.6 | 4.5 | 4.7 | 4.9 |

† Low.

†† Deficient.

# Fertilizer Use in Egypt

## Criteria for Fertilizer Recommendation

The idea of using soil tests to judge fertilizer requirements in Egypt has been around for a long time. Different methods of chemical analysis have been evaluated to find the one with the highest correlation to crop yield response per nutrient. Although several experiments have been carried out, little attention has been given to the initial fertility status of the cultivated soil, or its relation to actual fertilizer needs. Hamissa *et al.* (1975) report a low response of corn to phosphorus. When a comparison of soil test results for different previous crops was made, accumulation of available phosphorus was found when legumes were rotated.

The recommended fertilizer packages in Egypt are either general (based on the results of field trials distributed throughout the crop belt covering different agro-climatic conditions), or specific (based on soil tests and/or plant tissue test values). Micronutrient recommendations are based on soil and plant-tissue tests for fruit trees, vegetable crops, and field crops (NRC-GTZ, 1991). However, application of N, P, and K is generally recommended without taking into account the fertilization of the previous crop, the nutrient concentration before planting, or soil type.

NRC is working on recommendations based on soil testing, leaf analysis, nutrient removal by crop, previous crop, and farming system. In most cases, soils receive more fertilizers than can be used by the crop, and the unused portion either accumulates in the soil (P and K), or is lost (nitrogen). Recently, approximately 6,000 soil samples were collected by SWERI from cotton areas in the Valley and Delta and analyzed for macro- and micronutrients. The SWRI (1990) report shows that this approach should be followed for other major field crops. The critical parameters used in these and other studies characterizing soil fertility were established as a result of field research. Ensuring plant intake of nutrients needed for the target yield and a balanced plant–nutrition relationship, are NRC's main concerns when making specific fertilizer recommendations (Fawzi, 1991b, c). Varietal differences, nutrient inputs, rotation, water, and organic manure are factors involved in correcting for nutrient losses and fertilizer efficiency in the NRC arithmetic model (El Bendary, 1991; Fawzi, 1991c).

## Response to Fertilizers

### *Wheat*

Wheat is the most important cereal crop in Egypt. Increasing wheat production to narrow the gap between production and consumption is a national goal. Increases of 67, 62, and 170% in cultivated area, yield, and total wheat production, respectively, between 1980/81 and 1990/91 were reported. These increases were due to the adaptation of technology packages by the farmer, including fertilization with plant nutrients.

### *Rate of fertilizer application*

Currently, fertilizer rates for wheat are based on the results of a long-term series of field trials conducted under different agro-climatic conditions, using different varieties and soils. The data were processed and response curves established to calculate the nitrogen response for newly released wheat varieties (Hamissa *et al.*, 1984a). Results from 40 factorial trials show that nitrogen is the major plant nutrient affecting the production of wheat. The following equation was developed:

$$y = 2.880 + 21.8581x - 0.0593x^2$$

where y = wheat yield in t/ha, and x = amount of applied N in kg/ha.

According to this equation, maximum yield was obtained at 180 kg N/ha. Hamissa *et al.* (1992) report that N fertilization of wheat increased from 106 kg N/ha in 1970/71 to 172 kg N/ha in 1989/90. The rate of P fertilization is 36 kg $P_2O_5$/ha. The Annual Report of the Ministry of Agriculture (MOA, 1967) and Hamissa (1971) found that wheat production is markedly increased when fertilized with 96 kg N/ha, although there is little response to P and K. Solh *et al.* (1987) reported a response of newly introduced varieties to N fertilization up to 80 kg N/fed. They also found a significant increase in grain yield resulting from the application of 30 kg $P_2O_5$ and 4 kg Zn/fed. Similar results were obtained by Hegazy *et al.* (1990) in their field study in Dakahlia, where 75 kg N and 30 kg $P_2O_5$/fed were found to be the most effective rates for wheat production.

Several studies have been conducted in the Nile Valley to establish fertilizer rates for wheat production. At Sids (Beni Sueif), 60 kg N/fed resulted in higher yields (Saleh *et al.*, 1982), with as much as 75 kg N/fed for semi-dwarf varieties (Sadek, 1985). Also at Sids, and at Shandaweel, Mosaad *et al.* (1990) used two newly released durum wheat cultivars (Sohag 2 and Beni Sueif 1). They found that increasing N level from 30 to 120 kg/fed resulted in higher grain yields at Shandaweel, with no significant effect at Sids. At Mallawy station (Minya governorate), the varieties Sakha 69 and Giza 164 were tested for their response to N fertilization in several field studies (Basilious and Mosaad, 1988; Basilious, 1992; Basilious *et al.*, 1992). They concluded that 80 kg N/fed is the most economic N rate given Middle Egypt's environmental conditions. However, 75 kg N/fed, along with 24 kg $K_2O$/fed resulted in significant increases in grain yield at Sids.

Abdel Shafi *et al.* (1991) recommend 90 kg N/fed to increase grain yield at Sohag and Qena in Upper Egypt. However, Mitkees *et al.* (1992) recommend (as a result of 12 field experiments) 60 kg N/fed at Sohag, 75 kg at Qena and Aswan, and 90 kg at Fayoum. The response of newly released wheat varieties to N, P, and K fertilizers was studied by Hamissa *et al.* (1984a) in 40 field trials over three growing seasons. They found that optimum yield is produced by adding 60 kg N and 15 kg $P_2O_5$/fed. In 18 factorial field trials, Khalil *et al.* (1986) examined the response of varieties to fertilizer application. As a result, they recommended 100 kg N/fed for the Delta, 60 kg N/fed for Middle Egypt and 80 kg N/fed for Upper Egypt. Gomaa *et al.* (1977) found that Giza 155 (a tall variety) responds up to 60 kg N/fed, while Chenap 70 (a semi-dwarf variety) needs 80 kg N/fed. Durum wheat and triticale respond to higher N rates (90 kg N/fed) than bread wheat (60 kg N/fed) (Ghanem *et al.*, 1988). Following a comprehensive study conducted in farmers' fields by Khadr *et al.* (1994) between 1987 and 1993 in Kafr El Sheikh, Sharkia, Menoufia, Damietta, Gharbia, Beheira, Minya, Assiut, and Sohag governorates, an application of 75 kg N/fed, combined with 24 kg $K_2O$/fed was recommended. They concluded that wheat responds to higher N rates (90 kg N/fed) and K application more in Upper Egypt than in the Nile Delta.

### *Method and time of application*

The method and time of fertilizer application are important factors in increasing fertilizer use efficiency. Working at Sids, Hamissa *et al.* (1978) showed that the application of N and P fertilizers banded together and placed approximately 2 cm below the seed, or applied together with the seed, results in similar yields. They showed that splitting the N fertilizer into three applications (1/3 at planting and 2/3 at stage II) is most effective.

### *Nutrient sources*

An evaluation of six N sources for wheat was carried out for different soils (Hamissa, 1971; Eid *et al.*, 1981). The fertilizers used were calcium nitrate, ammonium sulfate, urea and calcium cyanamide. For clay and loamy soils, results show that calcium cyanamide is the least efficient source compared with the other sources, while ammonium sulfate and calcium ammonium nitrate are the most effective sources for sandy soils. Urea is of intermediate effectiveness.

Complex fertilizers (NP) were tested and compared with single fertilizers under field conditions in the Delta and Middle Egypt (ARC 1991). The results showed that, in general the relative effectiveness of the nutrient elements in the compound fertilizers is almost the same as the effectiveness of those in the single fertilizers.

More than 600 fertilizer compounds have now been registered in Egypt. Most of them are carriers for more than one nutrient. They are used to fertilize trees, vegetables, cotton, faba bean and berseem. NRC has developed 10 micronutrient foliar compounds based on the results of soil tests and plant analysis (El Fouly 1983; Fawzi, 1991b). These compounds contain different ratios of Zn, Mn , and Fe, which are deficient in the major crops of Egypt (El Fouly 1991; El Fouly *et al.*, 1992).

Application of micronutrients (Fe, Zn, Mn and Cu) to wheat and their effect on yield were studied in a series of field trials conducted by Abd El Hadi *et al.* (1990b) in the Delta (Sakha and Gemmeiza), Middle Egypt (Sids and Mallawy), Upper Egypt (Shandaweel and Mataana), Sharkia, and Minya governorate. Results show that the response of wheat to micronutrient application is higher in Minya than in Sharkia. In the Delta and Upper Egypt, Zn spray is the superior foliar fertilizer. Abdel Latif *et al.* (1990) stated that the highest net return for wheat is obtained when seed is soaked in a micronutrient solution just before sowing. The results of 33 on-farm trials proved that grain yield responds positively to Zn:Mn:Fe combinations in Menoufia, Dakahlia, Beheira, Minya and Assiut (Firgany *et al.*, 1983; NRC-GTZ, 1991a,b,c,e; NRC-GTZ 1992, 1993). Fawzi (1991a,b) showed that grain yield increases range from 1.19 t/ha (40%) in small trials to 0.7–1.0 t/ha (19–22%) in large extension trials. According to the results of field trials and pot experiments, yield increments and increases in dry weight are related to plant nutrients and growth, including the uptake of macronutrients from the soil (Abdalla *et al.*, 1992; NRC-GTZ, 1993). NRC results also mention that compound formulation and the nature of the element-carrier can influence yield increase. Both chelation (EDTA) and N additives (urea) raise yield as a result of higher nutrient intake by leaves (Firgany, 1983; NRC-GTZ, 1993).

### *Organic and bio-fertilizer application*

Organic manures are common nitrogen sources. They are either non-proteid organics—such as farmyard and green manure—or proteid organics, such as oil cake, pigeon refuse and dried blood. The availability of nitrogen in organic manures depends on their C:N ratio. The narrower the ratio, the greater the availability. Concentrated organics release their nitrogen more rapidly than bulk organic manures.

Soliman and Abdel Monem (1994) report better corn yield and nutrient uptake when wheat straw is applied in combination with Azotobacter. Organic matter content, total nitrogen content and cation exchange capacity are increased by organic manuring.

Utilization of bio-fertilizers—such as nitrogen-fixing bacteria, phosphate-dissolving bacteria, VA mycorrhizal fungi, Azolla and blue green algae—has received great attention lately in Egypt as a possible partial substitute for chemical fertilizers, and for their potential role in sustaining production and soil fertility. Nitrogen fixation through legume/*Rhizobium* association has been well established by studies of winter and summer food legumes, and forage legumes. Inoculating cereal crops with asymbiotic nitrogen fixers such as Azotobacter and Azospirillum has proved effective in increasing wheat, barley and corn yield, as well as increasing nutrient levels in these crops. Eweda (1983), Ishac *et al.* (1982), and Fayez *et al.* (1988) show significant increases in wheat yield due to inoculation with Azotobacter and Azospirillum. *Azolla anabaena* symbiosis and blue green algae were found to be effective in rice fertilization (Alaa El Din *et al.*, 1984; Abdel Monem *et al.*, 1994). Azolla not only fixes $N_2$, but also reduces the losses of chemical fertilizers (Abdel Monem *et al.*, 1994).

### *Barley*

Compared with other cereal crops, little research has been conducted on barley fertilization in the Valley and Delta. Twelve field experiments were conducted in the Delta, and Middle and Upper Egypt over three growing seasons (Hamissa *et al.*, 1984b) to study the response of newly released barley varieties to N, P, and K fertilizers. Results show that barley yield increases as the rate of N increases, up to 60 kg N/fed. When evaluated economically, a rate of 40–50 kg N/fed is recommended. No significant response was obtained from P and K fertilization. Abou El Enein (1984) reviewed the agronomy research of the barley program and reported that 45 kg N/fed is the optimum N rate. EMCIP (1983) concluded that 30–45 kg N/fed should be recommended, and that there is no need for P and K fertilization for all tested varieties. Osman *et al.* (1991) evaluated the effect of different N sources on barley. They concluded that the highest yield is obtained by application of ammonium nitrate at a rate of 60 kg N/fed, with foliar application of 0.6% $ZnSO_4$ at tillering stage. Urea, applied at a rate of 45 kg N/fed without Zn, shows the lowest values. Osman *et al.* (1992) found that foliar application of magnesium sulfate (6%) at tillering increases the response of barley to N fertilizer. The highest barley grain and straw yields are obtained by application of ammonium nitrate at a rate of 60 kg N/fed, in combination with magnesium sulfate foliar spray at a rate of 6%.

A study on calcareous sandy loam soil shows that grain yield of NPK-fertilized barley increases by 0.88 t/ha (45%) in response to a combination of 105 g Zn + 70 g Mn + 35 g Fe/ha (NRC-GTZ, 1993).

## *Faba bean*

### *Mineral fertilization with macronutrients*

In two long-term field trials (1959–1963, 1966–1977), faba bean was fertilized with N, P and K (Hamissa *et al.*, 1975). Although there was no response to N and K, a 20% increase in seed yield was obtained due to application of $P_2O_5$ at a rate of 30 kg/fed. The response of faba bean (Giza 3) to N, P, and K was studied in five locations (Hamissa *et al.*, 1980). Significant increases in seed yield were found in three out of the five locations as a result of NP application at a rate of 15 kg N + 15 kg $P_2O_5$/fed. At three locations—Sakha (Kafr El Sheikh), Sids (Beni Sueif) and Mallawy (Minya)—faba bean response to various P sources and rates was tested over two growing seasons (Khadr *et al.*, 1987). Faba bean planted in Kafr El Sheikh responded to 15 kg $P_2O_5$/fed, and higher N, P, and Zn uptake was obtained as a result of P fertilization. In Middle Egypt (Sids and Mallawy) similar results were obtained. In NVP (1981) report, it was stated that application of N and P in combination results in higher yield increases than application of either nutrient alone. Application of foliar compounds increases yield when faba bean is planted in soils with low fertility. In field trials, El Fouly *et al.* (1989) found that adding 50 kg $K_2O$/fed resulted in a 9% yield increase. For three years (1979–1982), several field trials were conducted at various locations in Lower and Middle Egypt to establish fertilizer recommendations for faba bean farmers. The most important findings are:

- Recommended fertilizer levels are 15 kg N/fed and 30 kg $P_2O_5$/fed for newly developed varieties.
- There is no response to K application.
- In low-fertility soils, application of foliar compounds increases faba bean seed yield, while in highly fertile soils, no significant effect results from foliar application.
- Faba bean yield is similar whether planted after cotton or maize.

To study the effect of P and Zn on faba bean yield, Taha *et al.* (1990) carried out field tests at three experimental centers (Sakha, Sids and Mallawy). While application of P alone resulted in an average seed yield increase of 12% at the three locations, combined application of P and Zn resulted in an increase of 20%.

### *Mineral fertilization with micronutrients*

The effect of micronutrients (Fe, Zn and Mn) on faba bean was studied in field trials at Sakha, Sids and Mallawy (Hamissa, 1983). Significant yield increases due to micronutrient application were reported. The highest increases were obtained at Sakha, where foliar application resulted in higher increases in yield than soil application. At three locations in Gharbia governorate, field trials were conducted to study the effects of Fe and Zn on faba bean (Giza 2). Seed yield was increased in one location by 34% for Fe and 43% for Zn. The increases in the other two locations were not significant. The method of application was also tested. Osman *et al.* (1990) report higher yield and nutrient uptake when Fe, Zn and Mn is applied as EDTA by the coating method. Bazza *et al.* (1992a) report a positive response to Fe, Zn, and Mn when applied as a foliar spray to faba bean in Sakha. In Shandaweel (Sohag governorate), Bazza *et al.* (1992b) report an increase in faba bean yield when Fe, Zn, and Mn are applied as a foliar application. In general, the response of faba bean to micronutrients varies according to location. This was reported by Monged *et al.* (1992), as she studied the effect of Fe and Zn on faba bean yield in Beheira, Menoufia, Fayoum and Assiut. The same result was recently reported by NVRP (1993), where faba bean was planted in ten demonstration trials in Fayoum, Beni Sueif, Minya and Assiut governorates. The recommended production package includes 15 kg N + 30 kg $P_2O_5$/fed.

Results of 218 on-farm trials carried out by NRC in Menoufia, Dakahlia, Beheira, Fayoum, Beni Sueif, Minya and Assiut governorates prove that foliar application of Zn:Mn:Fe increases faba bean seed yield. The average seed yield increase was 0.83 t/ha (30%), ranging from 0.71 t/ha (22%) in large-scale extension trials to 1.19 t/ha (40%) in small trials (Fawzi *et al.*, 1983; Fawzi, 1991a,b; NRC-GTZ, 1991a,b,c,e; El Sayed *et al.*, 1992a; NRC-GTZ, 1993). NRC results show that the rate of yield increase reaches its maximum with micronutrients applied as EDTA-chelation and/or as nitrogenous carriers such as urea (Fawzi, *et al.*, 1983; NRC-GTZ 1991b,c; NRC-GTZ 1993). Results of NRC field trials and pot experiments led to the conclusion that the correction of micronutrient deficits in plants triggers improvement of physiological preferences leading to higher seed yield. Increases of plant dry weight and uptake of both macro- and micronutrients from soil are accompanied by higher mobilization of micronutrients from root and/or stem to leaves and pods (El Sayed *et al.*, 1992a,b).

### Chickpea and lentil

Little attention has been given to mineral fertilization of chickpea and lentil. Although Khattab *et al.* (1992) report that application of P fertilizer significantly increases chickpea seed yield. Most of the work was related to chickpea response to inoculation and N fertilizer at a rate of 15 kg N/fed. Khattab *et al.* (1993) report higher yields due to foliar fertilization with Zn. Significant lentil yield responses, resulting from the application of phosphorus, are reported by Rizk (1980). In several field trials conducted at two sites in the Delta and two sites in Upper Egypt (Rizk, 1984) higher seed yield response was obtained when P was applied at rates of 30 and 90 kg $P_2O_5$/fed. Nassib *et al.* (1984) recommend a package for lentil production including application of 10 kg N + 30 kg $P_2O_5$/fed. Taha *et al.* (1967) found a significant response to P fertilization in several field trials in Upper Egypt. They recommended an economic rate of super phosphate for lentil of 100 kg/fed. Fifteen kg N + 30 kg $P_2O_5$/fed is the recommended package, tested in 59 demonstration plots in the main lentil production area in the Delta and Upper Egypt (NVRP, 1993). In Kalioubia, Mohamed (1990) found that an application of Zn+Mn+Fe+Cu increased seed yield of NPK fertilized lentil by 4.45 t/ha (58%).

### Forage crops

#### Berseem

As berseem is the main forage crop of Egypt, its response to chemical fertilizers has been the main subject of several studies. Hussein *et al.* (1983) found that fresh and dry forage yield of berseem is significantly increased by applying P fertilizers up to 45 kg $P_2O_5$/fed. However, they report that the difference between 30 and 45 kg $P_2O_5$/fed is not significant. A series of field trials was conducted at Sakha, Gemmeiza, Sids and Shandaweel to study the effect of time, method and source of P fertilizers on berseem forage yield (Khadr *et al.*, 1984). The lower the soil test value for P-Olsen, the higher the response for P application was found to be. The increase in yield over the control for the best treatment reached 32%. Abd El Hadi *et al.* (1990a) carried out long-term field trials between 1981 and 1987 in the Delta and Middle Egypt to study the effect of K and P fertilizers on berseem forage yield. They found that application of K (50 kg $K_2O$/ha) generally increases forage yield by 0.80 t/fed/cut. However, in loamy soils, K fertilizer is more efficient, with an increase of 13% for forage yield, 15% for N uptake, 13% for K uptake and 6% for P uptake. Application of combined P and K fertilizers results in a higher increase in berseem forage yield. In NRC trials, berseem yield was increased by 4.8–7 t/ha fresh weight or 0.7 t/ha dry weight in the Delta and Valley, thanks to micronutrient application (Fawzi, 1991a,b; NRC-GTZ, 1991c,e; NRC-GTZ, 1992, 1993).

### *Forage sorghum*

Sorghum varieties were tested for their response to N fertilizers at four locations (Sakha, Gemmeiza, Sids and Shandaweel) by Rammah *et al.* (1984a). They reported that forage yield is steadily increased by the application of N fertilizer up to 135 kg N/fed. Similar findings were reported by Khadr *et al.* (1990) in their study on the response of sorghum to different rates of N fertilizers. They also reported significant increases in forage yield due to foliar spraying with micronutrients. Two field trials were carried out over two years to study the effect of N fertilizer and foliar application with Zn, Fe, Mn and Cu on the yield of a mixture of berseem and rye grass (Seif and Hakeem, 1987). Results show that 60 kg N/fed is the best treatment for green and dry forage yield. Micronutrient application significantly increases yield.

# Nitrogen Fixation by Legume Crops

Due to their ability to fix atmospheric nitrogen, food and forage legume crops have the advantage of a minimum requirement for nitrogen fertilizers. The amount of fixed N depends on several factors, such as crop variety, microbial strain, soil properties, and application of chemical fertilizers.

## Faba Bean

A field trial was carried out at Sids station, using N-15 to estimate N fixation by faba bean (Hamissa *et al.*, 1983). Findings show that lower nitrogen fixation results from application of N fertilizers. However, N fertilizers applied at seeding increases seed yield, while foliar spray with nutrient solutions (NPKS) enhances the absorption of fertilizers and soil nitrogen by roots, and considerably reduces the amount of fixed N (Hamissa *et al.* 1988). In a comparison between faba bean varieties for yield and ability to fix nitrogen, F 402 was superior to Aqua doce. Several researchers report that the amount of N fixed by faba bean is between 90 and 145 kg N/ha (38 and 60 kg N/fed). Inoculation with *Rhizobium* increases seed yield and N fixation significantly. However, high water table, salinity and alkalinity are unsuitable environments for faba bean production and nodulation.

## Chickpea and Lentil

Nitrogen fixed by chickpea is between 14 and 28 kg N/ha (6 and 12 kg N/fed) (Hamissa *et al.*, 1983), while lentil is between 53 and 83 kg N/ha (22 and 35 kg N/fed). Rizk *et al.* (1984) report an increase in lentil seed yield of 31% due to inoculation.

## Soybean

Inoculation of soybean resulted in an increase in seed yield of 160% (Rizk *et al.*, 1984). Fertilization with nitrogen at a rate of 144 kg N/ha (60 kg N/fed) resulted in lower yields and N uptake compared with inoculation. However, the highest soybean yield was recorded for inoculation and application of micronutrients (Hegazy *et al.*, 1990). In general, nitrogen fixation by inoculated soybean ranged from 157 to 200 kg N/ha (65 to 83 kg N/fed).

## Clover

Inoculation, soil type and number of cuts are the main factors affecting nitrogen fixation by berseem. N fixed by berseem *miskawi* (five cuts) was estimated at 236 kg N/ha (98 kg N/fed), and by berseem *fahl* (one cut), 68 kg N/ha (28 kg N/fed).

## Threats to Sustainability

### Fertilizer Abuse and Water Quality

Egypt is known to be a heavy user of chemical fertilizers, which have been used in agriculture since the turn of the century. According to an FAO report (1987), Egypt consumes about 8–10 times as many nutrients per hectare as the USA and world average. In addition to the increase in agricultural area in Egypt, a gradual increase in fertilizer rates for various crops contributes to the heavy consumption of chemical fertilizers. However, the efficiency of fertilizers is low. This is due to the high pH of Egyptian soils (7.3–8.3) and high calcium carbonate content, both of which are responsible for phosphate fixing and the low efficiency of phosphate fertilizers. Nitrogen recovery by plants is as low as 20–30% in sandy soils and rice fields. Ammonia volatilization, denitrification, and nitrate losses are the main mechanisms for nitrogen loss from the soil/plant system. Although different methods and timing of N fertilizer application have been recommended, losses from added N fertilizers can be as high as 50%. Along with increasing concern about environmental pollution, attention is being given to nitrate leaching into the groundwater, which causes water pollution. The concentrations of $NO_3$-N along the river are below the standard value given by the US EPA (45 mg/L). Abdel Dayem and Abdel Ghani (1992) report that nitrate concentration is as high as 1038 ppm in a well for drinking water in a village in Sharkia governorate. Applying fertilizers to different crops, without taking the crop rotation into consideration, is responsible for the heavy use of chemical fertilizers.

### Saline Soils

More than 2 million feddans (833,000 ha) of Egypt's agricultural land still require field drainage to control waterlogging and salinity. This includes half a million feddans (210.000 ha) of heavy soils located in the northern part of the country, south of lakes Burullos and Manzala, and to the east of Port Said. The soils in these areas are considered highly saline. The sodicity hazard is high, and soil permeability is very low. In a pilot study at Mashtul, soil salinity was as high as 10 mmhos/cm (Abdel Dayem, 1994). However, the average salinity of the area varies from one cropping season to another due to changes in crop water requirements and management. Also, it was found that groundwater salinity before drainage was 8.2 mmhos/cm on average. Groundwater is thus a serious source of salinization when it is brought upwards and evaporated, leaving its salt on the surface and within the root zone. A decrease in wheat yield of more than 50% was reported by (Abdel Dayem, 1994) due to the lack of drainage. Use of highly saline drainage water for irrigation is considered another threat to sustainable crop production. The total quantity of drainage water discharged into the irrigation system amounts to $2.878 \times 10^9$ $m^3$/year. The amount of drainage water planned for reuse before the year 2000 is $5.382 \times 10^9$ $m^3$/year. The salinity of the drainage water ranges from 500 to 7,000 ppm, therefore, soil irrigated with saline drainage water has the potential to be saline.

### Soil Pollution with Heavy Metals

Soils in the Nile Valley and Delta are subject to serious problems related to high heavy metal content, a problem of increasing interest due to its impact on environmental pollution and public health. The main source of pollution is irrigation water mixed with drainage water from domestic and industrial effluent. Industrial wastes from oil, soap, fertilizer, and textile factories pour into the Nile River and its branches. Analysis of soil irrigated with industrial and sewage waste, collected from sites near Giza, showed higher concentrations of heavy metals in the surface soil compared with non-irrigated soils.

The long-term impact of sewage effluent on sandy soils in Sharkia (El Gabal El Asfar farm) was evaluated by Aboulroos *et al.* (1991) (Table 4). Increasing the duration of sewage effluent irrigation significantly elevated the orange leaf content of heavy metals. Concentrations of Fe, Zn, Co, and Pb were increased 3.38, 1.7, 5.2, and 4.9 times, respectively. There were 19 and 8% increases in Mn and Ni, respectively, in barley irrigated with sewage wastewater mixed with fresh water (1:2), compared with barley irrigated with fresh water. In Gharbia governorate (Tanta city), various dilution rates of industrial waste from an oil and soap company, a super phosphate fertilizer factory, and city sewage effluent were evaluated to judge their impact on soil and plant. Oil and soap waste considerably deteriorates the yield of medicinal plants, which were used as indicators. The higher concentration of wastes inhibits plant growth. It is estimated that 6,545 ton/day of sewage sludge will be produced by cities in Egypt by the year 2010. This product could be of great value as a source of plant nutrients and soil conditioners. However, the existence of hazards such as toxic trace elements, toxic organics, and disease-causing organisms in these products could lead to phytotoxicity, crop damage and increased health risks. To minimize these side effects, guidelines and regulations must be followed to ensure proper management. The following should be taken into account:

- The quality of the product.
- Soil properties.
- Crop species, excluding vegetable crops.
- Irrigation practices.
- Effect on groundwater quality.
- Public health.

**Table 4. Heavy metal concentration (ppm) in sewage effluent irrigated soils.**

| Element | Years | | |
|---|---|---|---|
| | 8 | 28 | 60 |
| Fe | 5,166 | 8,566 | 11,500 |
| Mn | 133 | 190 | 377 |
| Cu | 33 | 87 | 138 |
| Zn | 290 | 451 | 740 |
| Pb | 100 | 310 | 393 |
| Ni | 45 | 109 | 125 |
| Cd | 1.8 | 3.9 | 4.5 |
| Co | 50 | 125 | 154 |

Source: Aboulroos *et al.* (1991).

## Conclusions and Recommendations

The alluvial soils of the Nile Valley and Delta owe their existence to the Nile River. The suspended materials carried by the river formed the Valley and Delta soils. Although vertisols are the dominant soil, entisols and aridisols are present in strips along the Nile branches, close to the coast, and in desert areas. Soil properties vary according to site; generally the texture ranges from sandy to heavy clay, pH is between 7.3 and 8.3, calcium carbonate content between 2.1 and 8.3%, and organic matter content between 1.22 and 2.44%.

Soil fertility surveys have definitely established the poverty of organic matter and nitrogen content in most Egyptian soils. Potassium is fairly high, while phosphorus is moderate. Fe deficiencies dominate in some calcareous soils, while Mn is deficient in alluvial soils, and Zn is deficient in lowland and sandy soils.

As the soils of Egypt are poor in nutrients, fertilization has become an important component of the technology package recommended to the farmer. For wheat, the recommended rate of N fertilizer has increased from 108 kg N/ha in 1970 to 180 kg N/ha in 1990 (45 to 75 kg N/fed). Splitting the amount of N fertilizer results in higher yield. As barley is not cultivated in the Valley and Delta, little attention has been given to barley fertilization. To maintain optimum yield in faba bean, fertilization with 36 kg N + 36 kg $P_2O_5$/ha is recommended. For chickpea, 36 kg N + 54 $P_2O_5$/ha is recommended as a mineral fertilization in combination with *Rhizobium* inoculation. As lentil is highly responsive to P application, 72 kg $P_2O_5$/ha is recommended along with 36 kg N/ha and inoculation with *Rhizobium*. Response of berseem to P is significant; however, 72 kg $P_2O_5$/ha was found to be the most economical application. Application of K (50 kg $K_2O$/ha) generally increases berseem forage yield if the soil is deficient. Forage yield of all tested varieties of sorghum are increased by N fertilizer up to 324 kg N/ha. For all legume and forage crops, significant increases in yield and nutrient content occur as a result of foliar application of micronutrients.

Food and forage legume crops play an important role in the Egyptian farming system, due to their ability to fix atmospheric nitrogen. The amount of fixed N depends on crop variety, soil properties, and inoculation with the suitable *Rhizobium* strain. Nitrogen fixed by faba bean is estimated to be between 90 and 145 kg N/ha. High water table and high application of N fertilizer depresses N fixation, while foliar application with nutrient solution (NPKS) enhances N uptake from soil and fertilizer, and reduces the amount of fixed N. N fixation by chickpea is estimated at 14–28 kg N/ha, while the range for lentil is 53–83 kg N/ha. Inoculation of soybean results in an increase in seed yield up to 160% over the control. Inoculation results in higher seed yield and N uptake than fertilization with 144 kg N/ha. Fixed N by inoculated soybean is between 157 and 200 kg N/ha.

Regarding Egypt's resources, the concern is to maintain the quantity and quality of soil and water. The main threat to soils of the Nile Valley and Delta is salinity due to the high water table and lack of drainage. Two million feddans (840,336 ha) of agricultural land still require field drainage to control waterlogging and salinity, including 500,000 fed (210,000 ha) of heavy soils located in the northern part of the country. Reuse of high-saline drainage water for irrigation is another threat to soil fertility, unless proper management practices are followed. Water salinity may be as high as 7,000 ppm, which causes several hazards to the soil and plant. In addition to salinity, soil pollution with heavy metals, due to the use of pesticides and application of sewage sludge as organic fertilizers, is of major concern. The adverse environmental impact of fertilizer abuse is another threat to drinking water quality. With the production area and rate of fertilization increasing, in addition to low recovery of N fertilizer, nitrate concentration in the groundwater is expected to increase. In fact, it was found to be as high as 1,038 ppm in a well for drinking water in Sharkia.

### Recommended Research Topics

For better management of soil and other resources of the Nile Valley and Delta, the following topics are suggested for further research:

- Modeling fertilizer recommendations, based on soil testing and plant tissue analysis, to re-assess the current fertilization package.
- Studying the possibility of using bio- and organic fertilizers as partial substitutes for chemical fertilizers.
- Long-term trials to assess the impact of different rotations and management practices on soil.
- Impact of heavy fertilization on water quality.
- Management of saline soils.
- Water-use efficiency as it relates to soil management and crop rotation.

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