ABSTRACT

THE POTENTIAL USE OF FERTILIZER FOR THE INTENSIFICATION AND DEVELOPMENT OF AGRICULTURE IN THE UNITED ARAB REPUBLIC

By

Bushra Migally Abdel-Sayed

The intensification of agriculture in Egypt through the increased use of fertilizer and closely associated inputs is the subject of this study. The central question: How much fertilizer can be technically and economically used in an expansion of Egyptian agriculture?

This research seeks to identify the present and future potential (1975) use of fertilizer through intensification of Egyptian agriculture.

Specifically, the objectives of this study are: (1) to identify the agronomic, economic and managerial factors that influence fertilizer use; (2) to compute the optimum level of fertilization at the present state of technological and fertilizer crop price ratios for the five major crops; (3) to estimate the present and future (1975) potential use of fertilizer as affected by the following factors: (a) fertilizer and crop price ratios, crop varieties, soil characteristics, cropping systems and fertilization, irrigation and other agronomic practices; (b) cropped and cultivated

area; and (c) quantities of deposited silt; and (4) to examine the possible structuring of price policies and institutions to attain fertilization potentials.

Three hypotheses are examined: (1) increased use of fertilizer is profitable and can be demonstrated by experimental data; (2) sufficient experimental data exist to calculate appropriate levels of fertilizer use for principal crops under present economic and cultural conditions; (3) evidence can be gathered in sufficient detail to estimate the optimal level of fertilization as farmers adopt a number of fertilization and cultural practices given assumptions relative to price and resource parameters.

To identify the present and future potentials, past and present fertilization practices were reviewed for the five major crops with respect to effects of: (a) agronomic, (b) economic, and (c) managerial factors affecting fertilizer use.

Estimates of optimum fertilizer use is based on economic and agronomic data and principles. Of the many factors upon which the calculations of the optimum level of fertilization depends, only the following three factors were employed in this study: crop response to fertilizer and crop and fertilizer prices.

Review and analysis confirmed the first hypothesis, that with present crops, area cultivated and cultural practices there was still substantial opportunity to use more fertilizer. Egyptian farmers could have profitably used

630,000 tons instead of the 316,000 tons of nitrogen and phosphorus that were used in 1965, and total cotton, wheat, rice, corn, and berseem production would have increased by 2.5 million kentars, 45,000, 57,000, 880,000 and 10,000,000 tons respectively.

It was found that the present potential after the change in crop varieties, soil characteristics, cropping systems and fertilization, irrigation and other agronomic practices, was 1.25 million tons of N, P_2O_5, K_2O which is twice the computed optimum (644,000 tons) before change, and four times as much as actual quantities (316,000 tons used in 1965).

Estimates of the potential quantities of fertilizer that could be utilized in 1975 on the present cultivated land and that scheduled to be added depend upon several assumptions. The assumptions and consequent estimate of fertilizer use follow: (1) Existing fertilizer use on present land continues, is extended to the additional 0.75 million acres converted to covered drainage, 1.5 million acres of reclaimed land, 0.97 million acres changed from basin to perennial irrigation and for the absence of 12 million tons of silt. Under this assumption, the estimated use is 390, 74, and 121 thousand tons of N, P_2O_5 and K_2O, respectively. (2) Egyptian farmers expand the use of fertilizer to the level of 1965 recommendations of the Ministry of Agriculture for present and new lands, and with adjustments for perennial irrigation and the absence of silt. The potential use in

1975 then becomes 538,173, and 135 thousand tons of N, P_2O_5 and K_2O,respectively. (3) No further technological change, but farmers operate on the basis of the calculated optimal level of fertilizer for 1965. Usage then becomes 606, 315 and 142 thousand tons of N, P_2O_5 and K_2O, respectively. (4) Technological changes (such as soil characteristics, crop varieties, cropping systems, etc.) occur, and farmers use the new calculated optimums and adjustments indicated above. The potential fertilizer use in 1975, on this basis, becomes 1242, 548 and 160 thousand tons of N, P_2O_5 and K_2O, respectively.

This study makes it evident that attaining these potentials requires development and refinement of a whole host of institutions and organizations which link Egyptian rural villages and the outside world in a vast network of service exchange. A change, also, in price policy to make product price fertilizer cost ratios more consistent with real costs, such as reflected in world prices, would promote a substantial economic stimulus to fertilizer use and expanded production.

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CHAPTER I

INTRODUCTION

"Give us this day our daily bread."

Matthew 6:11

Identification of the Problem

Two broad approaches characterize the discussion of expanding agricultural production in Egypt. "Vertical expansion" refers to the intensification of agriculture, including new technology and an increase in nonfarm produced inputs and in the crop index. "Horizontal expansion" refers to increasing the land area in farming, primarily by creating new irrigation facilities.

Agricultural production in Egypt depends upon the availability of irrigation water. The Aswan High Dam is expected to provide water for about 1.5 million acres of new land and change 930,000 acres from basin to perennial irrigation, yet the cultivated land per capita in 1975 after the completion of the dam will be no greater than in 1967 (0.2 acres) due to the continued increase in population (3 percent per year). At the same time the soil will be deprived of more than 12 million tons of the rich Nile silt retained by the dam.

For the long run, population control, new sources of irrigation water, industrial exports, tourism etc. to pay for food imports, and intensification of agriculture are theoretical alternatives. Realistically, population control and intensification must be given attention. Additional irrigation faces both cost and quantity limits--Nile water and suitable land are not available for major additional projects. Industry and other sources of export earnings eventually may be possible but such developments are likely to require much time and a substantial transformation of the economy. Thus, intensification, difficult though it may be, constitutes the major intermediate term policy alternative available within agriculture, concomitant with policies to control population growth.

The focus here is on the intensification of agriculture in Egypt through the increased use of fertilizer and closely associated inputs. The central question: How much fertilizer can be technically and economically used in an expansion of Egyptian agriculture?

This research seeks to identify the present and future potential (1975) use of fertilizer in the "vertical expansion," or intensification of Egyptian agriculture.

Objectives

Specifically, the objectives of this study are:

1. To examine the technical and economic information on Egyptian agriculture, specifically related to the intensification of agriculture.
2. To identify the agronomic, economic, and managerial factors that influence fertilizer use.
3. To compute the optimum level of fertilization at the present state of technological and fertilizer crop price ratios for the five major crops.
4. To estimate the present and future (1975) potential use of fertilizer as affected by the following factors: (a) fertilizer and crop price ratios, crop varieties, soil characteristics, cropping system and fertilization, irrigation and other agronomic practices; (b) cropped and cultivated area; and (c) quantities of deposited silt.
5. To examine the possible structuring of price policies and institutions to attain fertilization potentials.

Hypotheses to Be Tested

The central hypothesis, almost an assumption underlying this entire research effort, is that (1) the increasing use of fertilizer is both feasible and profitable and also can be demonstrated by experimental data.

Additional hypotheses include: (2) sufficient experimental data exist to calculate appropriate levels of fertilizer use for principal crops under present economic and cultural conditions, (3) evidence can be gathered in sufficient detail to estimate the optimal level of fertilization as farmers adopt a number of fertilization and cultural practices, and as national agricultural policy changes price and resource parameters.

One or more of these hypotheses could be negative; i.e., little or no data are available, but more likely a degree of validation is possible. If so, then projections of fertilizer use may be made with a wide range of error if the data are limited, projected with a narrower range of error if the data are good, or optimized if the data are excellent. Thus, one aspect of the conclusions will relate to the quality of the information on crop response to fertilization and associated changing practices.

Significance of Project

1. The results will contribute directly to an overall study of the agricultural development potentials of the Middle East, a research project of Resources For the Future (R.F.F.).

2. The size and importance of the U.A.R. in the Middle East, and of agriculture within the U.A.R. economy, means that agriculture must contribute substantially to the development of the area.

3. Egypt has to feed almost one million new born every year and in order to maintain the urban population, Egypt has to import foods instead of the industrial goods that its development plan calls for. Also Egyptian industrialization must be supported by an adequate food supply. Agricultural development and industrialization are not valid alternatives; effective development plans must embrace both goals.

Thus for both economic and nutritional reasons, a considerable expansion in food supplies is a necessary condition for economic development.

Achievement of this increase from domestic production depends upon the technology used in farm production and upon its organization and management. One of the most effective technical measures for raising production is the increased use of fertilizers. Promotion of programs for increased and efficient use of fertilizers in Egypt has therefore been one of the important features of planning in recent years. The importance of these programs lies not only in the fact of fertilizer being a useful input factor by itself but also of being a catalyst in the promotion of other improved agricultural practices which have to be introduced simultaneously to get the best results from the use of fertilizers.

Format

Chapter I deals with the identification of the problem, objectives, hypotheses to be tested and significance of the project.

Chapter II reviews the main features of the Egyptian economy.

Chapter III provides information regarding the past and present technical use of fertilizers in Egypt.

Chapter IV examines the crop characteristics and environmental factors that might affect the efficient use of fertilizers.

Chapter V is concerned with the economic and managerial factors affecting decisions on fertilizer use. It shows the method of analysis used in computing the optimum fertilizer level, and also discusses the risk and the uncertainties that might affect decisions.

Chapter VI focuses on crop response data and contrasts the computed optimum level with the present and the government recommended levels of fertilization.

In Chapter VII we estimate the present potential by changing crop varieties, soil characteristics, cropping system and fertilization, irrigation and other agronomic practices, that were assumed constant in the previous chapter. Then, the future potential is estimated on the basis of present conditions and practices, present trend, government recommendations, computed optimum before and after change.

Chapter VIII examines the possible structuring of price policies and credit, extension, research and product and factor market institutions to attain fertilization potentials.

Chapter IX provides a summary and conclusions.

The statistics and agro-economic studies that have been undertaken and reported are incomplete and not always reliable for the purposes of this study. Thus, the existing statistics must be reviewed carefully on the basis of collateral information, including both logic and personal experience of the author.

CHAPTER II

MAIN FEATURES OF THE EGYPTIAN ECONOMY

> "For the land, whither thou goest in to possess it, is not as the land of Egypt, from whence ye came out, where thou sowest thy seed and waterest it with thy foot, as a garden of herbs."
>
> Deuteronomy

Natural Environment

At the crossroads of Africa, Asia and Europe lies Egypt, one of the oldest countries that history has ever known. The total area of about 386,000 square miles is more than three times that of the British Isles or equal to the combined area of New Mexico and Texas (one million square kilometers). Approximately 97 percent of this area is classified as desert or mountains. A large part of this desert (and for that matter, most of the Middle East), once a flourishing region, has suffered a long and variable decline into a "man-made desert." The hills and mountains have been denuded of ancient forests, while the vegetation of the grasslands has been grazed into the ground by goats and camels.

The uniformity of the country's physical features makes it practical for agricultural purposes to divide the country into three basic zones: Lower, Middle and Upper Egypt.

a. Lower Egypt (3.9 million acres) consists of the delta proper, from Cairo northward to the Mediterranean.[1]

b. Middle Egypt includes the narrow cultivated strip along the Nile from Cairo to Assiut.

c. Upper Egypt includes the narrow cultivated strip along the Nile from Assiut southward to the Sudanese border. Little water is available for crops. Nevertheless, this region grows most of the country's onions, grain, sorghum and cane sugar.

Topography

With the exception of the Nile Valley, topography is not an important factor in Egyptian agriculture. The Nile Valley from the south to the Delta is 10 to 15 miles wide for most of its extent but in places narrows to less than 3 miles, and occasionally widens to as much as 25 miles. The Delta fans out below Cairo and reaches a width of nearly 150 miles at the Mediterranean.

Climate

The year breaks into two distinct seasons: a cool winter, from November to April, and a hot summer from May to

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[1] Approximately two-thirds of all the cultivated area.

October. Crops ripen not only in July and August but also in April and May. During the summer, the highest temperatures occur in the desert areas south of Cairo, often reaching 100° to 115° F. Originating in the vast desert, hot dry sandwinds called khamsin are frequent, particularly in spring, and cause much damage to crops.

Alexandria has an average rainfall of 190 mm, Cairo 30 mm, Assiut 5 mm, and Aswan practically no rain. This rain falls in the winter months.

The fact that Egypt's 7 million acres of cultivated land are strung out over eight degrees of latitude does provide a certain diversity. In the north, vines, apricots, and even apple trees can be seen, while sugar cane flourishes in the south. Corn, onions, wheat and cotton, the principal crops, are grown all over the country.

Water Resources

No description of Egypt, however brief, can fail to mention the Nile. A most remarkable river geographically and historically, the Nile has from time immemorial irrigated and fertilized Egypt's soil, served as its principal means of communication, and opened a gate into Central Africa. From the earliest times the main effort of the Egyptians has been directed towards the fullest possible utilization of the life-giving waters of their river. And even today the much-quoted saying of Herodotus that Egypt is the gift of the Nile has lost none of its truth.

The length of the Nile in Egypt is 1,530 km. The annual rise and fall of the Nile is about 4.5 meters. The maximum content of suspended matter as the Nile enters Egypt measures up to about 4,000 parts per million by weight, or 4 kilograms per cubic meter. The proportions average 30 percent fine sand, 40 percent silt and 30 percent clay.

In no country in the world does water play such a paramount role in every aspect of human life as in Egypt. The Nile Valley, in fact, is a typical desert oasis. Any improvement in the utilization of Egypt's water resources will undoubtedly have far-reaching effects on its agricultural economy and the pattern of population distribution.

The colossal High Dam project is viewed as a starting-point for a new era in Egypt. Important relocations of population may result from it. In addition to its use for water storage, the Dam will generate a large amount of cheap hydroelectric power estimated at 10 billion KW/hour per year (essential for the fertilizer industry), will provide water for about 1.5 million acres of new land, will shift 0.97 million feddan[1] from basin to perennial irrigation.[2] The reservoir will also guarantee water for the possible cultivation of about one million feddans of rice every year. But

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[1]Feddan equals 1.038 acres.

[2]With the completion of the High Dam, Egypt will have more water than it has good land on which to put it.

since the quiet waters of the reservoir will retain the silt, the stored water reaching Egypt proper down-stream will be devoid of suspended materials. This may increase the erosive power of the water in addition to depriving the land of rich alluvium, but at the same time the uniform level of the stream will eliminate the annual flooding.[1] The Nile fisheries down-stream of the reservoir will be reduced by the Dam, but the new lake behind the Dam (10 km. wide by 500 km. long) may replace much of the loss to down-stream fishing.

Soils

The Nile Delta and the narrow belt of land along the borders of the river have become the most productive soils in Egypt. The floor of the Nile Valley and the Delta is covered to an average depth of 9 meters with alluvial silt and clay derived largely from the disintegration of the igneous rocks of the Abyssinian plateau. The alluvial deposits overlay coarse sands and gravels. This surface layer of soil is low in organic matter (0.2 to 2 percent), low in nitrogen, generally well supplied with potash and phosphorus,[2] and has a tendency to be alkaline (Ph8-12).

The largest portion of the Delta is a heavy black soil with over 50 percent clay. This soil is very fertile and deep. It becomes stiff and quite hard to work when

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[1]The salt-flushing action of those floods will also cease.

[2]Available phosphorus is only 10 percent of total soil phosphorus.

overirrigated but produces high yields even with excess applications of water. These black clay soils are commonly called "cotton soils" and are, by far, the most productive in the U.A.R.

The second group of soils occurs in Upper Egypt and differs from the heavy clays of the Delta in that it is not as deep and has a lighter sandy subsoil.

A third group of lighter loam soils is found in the extreme northeastern part of the Delta. Because of its location, parts of this soil group have become salty and are in need of drainage.

The soils of the desert area, largely uncultivated, may be alluvial, sandy, salty, gypseous or gravelly. Over 90 percent of these soils consist of coarse and fine sand, with 0.1 to 4.0 percent silt, 0.1 to 8.0 percent clay, and 0.1 to 4.0 percent calcium carbonate. There are usually less than 0.5 percent water-soluble salts and the water-holding capacity is 20 to 25 percent.

Soils in Egypt are affected by many factors, the most important of which are the annual floods which deposit silt,[1] distance from the desert, depth of water table, drainage, composition of the silt, type of irrigation, and cultivation.

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[1]A layer approximately one mm. thick on the perennially irrigated soils, while on basin irrigated soils it is several milimeters.

The soils are well supplied with calcium and magnesium due to the presence of much calcium and magnesium carbonate in all size fractions of the soils. This excess of limestone in the soils serves not only as a diluent for the active soils components but also leads to a chlorotic condition in some crops--such as citrus, for example.

Since the beginning of the 20th century the basic fertility of Egyptian soil has been continuously reduced. The major reason given for this decline is the rising water table in the delta, which has been caused by mass infiltration of water from the barrage pond, seepage from high level canals, and over-irrigation.

Many other factors have contributed to this decline in fertility, such as over-cropping and the absence of scientific fertilization practices; these and many other factors will be discussed in later chapters.

A number of writers perceive a symbiotic relationship between the soil and the lives of the Egyptian peasant. Father Ayrout, for example, claims that the soil has shaped their lives, providing an astonishing stability and uniformity. He adds that between these two there has grown up a bond both firm and elastic, a balanced self-sufficient interdependence which neither crises nor governments can disturb, "that stern and immemorial wedlock of a people and a land which have made each other." "Traditional rites and customs in the Egyptian village" he says, "are a mysterious correlation of nature and man." The "soil" he says, explains the "changelessness" of peasant life.[1]

This view is contrary to the historical record that clearly shows that rapid change has characterized Egyptian agriculture in recent years and it appears certain that even more change is likely to occur.

Population Pressure and Internal Migration

Historically the Egyptians are old people, but biologically they are very young. Egypt is one of the many countries which, in the nineteenth century, entered a period of demographic transition, i.e., their populations were growing rapidly because the former balance between births and deaths has been upset. Egypt continues in the first stage, that of declining death-rates not accompanied by falling birth-rates.

During the 160 years, from 1800 to 1960, the population increased from some 2.5 million to 26.1 million persons, that is, over tenfold. In the period from 1947 to 1960, the average annual rate of natural increase was 2.4 percent. In the period 1960-1965 the growth of the country's population was even greater, as seen in Table 2-1.

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[1] H. C. Ayrout, The Egyptian Peasant (Cairo, 1952).

Table 2-1. Population increase in Egypt, 1960-1965

Year	Population (in thousands)	Population Growth (in thousands)	Percent
1960	25,832	...	.....
1961	26,557	725	2.807
1962	27,244	687	2.587
1963	27,968	724	2.657
1964	28,758	790	2.825
1965	29,620	862	2.997

Source: Marcin Rosciszewski, "Egypt, Population, Growth and Economic Development" (paper submitted at Symposium on the Geography of Population Pressures, Pennsylvania State University, September, 1967).

[a]The population had been increasing between 1882 and 1946 at a steady rate which fluctuated between 0.9% and 1.7% until it increased suddenly in 1947 to about 2.2% and had been growing rapidly at an increasing rate ever since.

C. Issawi indicates that the official extrapolations of a population of 31,883,000 to 34,762,000 in 1972 and 38,473,000 to 44,682,000 in 1982 are distinctly too low.[1]

The dilemma of present-day Egypt is first of all of a demographic nature. The scope of the dilemma is best shown by Table 2-2. Assuming that up to the year 2000 the average rate of annual growth is maintained at a level of 2.5 percent (it is almost 3 percent at present) it is to be expected that the relation of density of population to the area of agricultural land (taking into account the 40 percent

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[1]C. Issawi, Egypt in Revolution (London, New York: Oxford University Press, 1963).

Table 2-2. Relation between population and agricultural land in Egypt

	Year			
	1965	1980	1990	2000
Population density per 1 sq. km. of cultivated land	1,200	1,324	1,696	2,143
Hectares per capita	0.083	0.076	0.059	0.047

Source: Same as Table 1-2.

growth of cultivated area including the new land from the High Dam) will seriously deteriorate.[1]

In one of his speeches, President Nasser said that the population problem is not primarily a food problem but a general development problem, putting great burdens of adjustment on economical and social institutions and making social transformation more difficult. A high rate of population growth means a high dependency ratio and a lower ability to save. Resources are absorbed in child raising. Birthrates can be reduced by the desire and capacity of people to shape their lives and their institutions, and the country that accepts the powers of modern society to delay death should accept birth control.

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[1]M. Rosciszeweski, "Egypt, Population, Growth and Economic Development" (paper submitted at Symposium on the Geography of Population Pressures, Pennsylvania State University, September, 1967).

Two basic trends can be distinguished in the internal migration of the population. One is the movement of population living in the Nile Valley (Upper and Lower Egypt) towards the Delta of the Nile, while the other is the migration from the countryside to towns.

The reason for the trend to migrate northward from the Nile Valley (both seasonal and permanent migrations) is overpopulation in Upper Egypt and the resulting more difficult living conditions. Arable land per capita in the Valley is only 0.176 ha, as against 0.248 ha in the Delta.

All the bigger cities and the majority of existing industrial works have been concentrated in the area of the Delta and in the vicinity, this being an essential factor attracting people from the south. In the Valley, the gross income derived from agriculture amounted to 52 Egyptian pounds as against 75 Egyptian pounds in the Delta.

General Characteristics of the Economy

Before the 1952 revolution, the economy operated on a free enterprise basis; however, the distribution of assets and income was highly concentrated, and had little correlation with productivity. During the decade long revolution, economic organization has been profoundly transformed.

This transformation has several aspects and one of these concerned the distribution of income, as between rich and poor as well as between Egyptians and foreigners. This income redistribution is significant in a number of respects,

aside from its direct effects on the welfare of the populace. For one thing, it may have had some impact on the composition of consumer demand. Beyond this, the departure of foreigners, whether they be managers or skilled artisans, surely did have an impact on output and productivity. The capital outflow associated with their departure added to the balance-of-payments pressures of the country. Finally, and perhaps most significantly, the income redistribution which took place within the country was associated with a loss of political influence of the wealthy few who previously had dominated the economic policy of the government.

The leaders of the revolution are in a hurry. Faced with staggering problems of population pressure, large scale poverty, urban migration at rates outstripping industrialization, and with a concern, at least some of the time, for the welfare of the masses, the leaders are unwilling to await the adjustment to market forces, since they do not feel directly participating in such adjustments.

Also, most progovernment intellectuals in Egypt took it for granted that capitalism and the market were devices for exploiting the masses, and saw central economic planning as the wave of the future that would set their country on the road to rapid economic progress. They have taken the socialist countries as their model and embarked on a series of five-year plans with detailed programs of investment allocated between public and private sectors.

B. Hansen indicates that Egyptian society was a civilian one, in which the army had a very minor role and in which a considerable amount of political and intellectual liberty prevailed. By 1962 the picture was very different. Egypt had become a totalitarian socialistic state. A series of nationalizations and sequestrations had transferred the ownership of the main branches of the economy--industry, transport, finance, and foreign trade--to the government; the main form of wealth remaining in private hands was rural and urban real estate, and even here state control was tight. The government budgets accounted for some 60 percent of GNP, partly because direct taxation had risen very sharply but mainly because of the revenue yielded by the ever-increasing number of state enterprises.[1]

Much of the development has been achieved by contracting large foreign debts, the serving of which will constitute an increasing burden in the next few years. But actual development has been somewhat different from what was planned in so far as both investments and foreign borrowing have been running at a lower level than planned.

Public departments and enterprises now design and construct nearly all new capital projects while the greater part of the savings required to finance them originates from government sources. The government now is responsible for

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[1]B. Hansen, Development and Economic Policy (Amsterdam: North Holland Publishing Company, 1965).

some four-fifths of investment and other major economic decisions. The rate and composition of investment is determined by the central authorities.

Production capital formation is planned in the sense that virtually no investment takes place without permission from the government. The market mechanism continues to operate even though ministeries intervene with this mechanism to ensure that investment targets are met and the whole program keeps roughly on schedule. Centralized allocation does occur for some key inputs such as imported equipment, raw materials, and intermediate goods, pesticides, chemical fertilizers, selected seeds, irrigation water, and certain categories of skilled labor.

The government interferes pervasively and continuously with the price mechanism to achieve the ends of her economic and social policy. Prices of necessities are fixed in order to improve the distribution of income in urban areas. Profit margins for almost all producer goods are regulated to avoid the exploitation of consumers and to encourage enterprises to use particular inputs.

Thus the economy cannot be described as a modified free-market system, neither can it be described as a centralized, state owned, state directed, comprehensively planned economy. In operation Egypt's productive organization stands between the command economies of eastern Europe and the modified market systems of the west.

Agricultural Sector

Farm production, the dominant component of national output, increased over the present century but still not rapidly enough to prevent farm output per capita and per man employed in agriculture from falling steadily. The factor underlying this trend was a continuous decline in the amount of land available to each cultivator only partly offset by rising yields per feddan.

As a reaction to the shortage of land Egyptian farmers, with some encouragement from the government, attempted to raise the productivity of their plots. They reallocated land to more valuable crops and employed more scientific techniques of cultivation. As a result, average yields did increase, but the use of fertilizers, selected seeds, and pesticides did not proceed rapidly enough to compensate for the overall shortage of land. Moreover, as the government brought sub-marginal land into cultivation and the ratio of cropped to cultivated area increased, the fertility of the soil became impaired and the farmers found it progressively more difficult to maintain average yields.

Agricultural productivity obviously needed to be raised but Egypt's development strategy pointed inescapably towards industrialization. And in order to meet the growing pressure of population upon a relatively fixed area of land, productive capacity and opportunities for employment had to be created outside the primary sector.

Returns to human effort expended in agriculture are low. The value added, per agricultural worker is about $300. The cost of farm inputs is but 25 percent of the gross value of output--in sharp contrast with the United States, where the comparable figure is nearly 70 percent.

D. Mead indicates that in the late 1940's the agricultural sector provided directly some 70 percent of total employment and close to 50 percent of the income of the country.[1] Since that time, both output and employment in agriculture have continued to expand, but at a rather slow rate, so that the center of gravity of the economy has shifted slowly but decisively away from agriculture toward manufacturing and the services.

In spite of this fact, Egypt is in many ways still very dependent on agriculture. Not only is over 28 percent (1965) of the country's income and 50 percent of her employment currently derived directly from this sector; but also, a large part of her growing industrial base as well as a substantial portion of the activities in the fields of commerce, finance and transport are centered around the processing and handling of agricultural produce. This dependence on agriculture is most clear in the area of foreign trade; the overwhelming majority of the country's exports are agricultural, at least in origin, although some have gone

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[1] D. Mead, Growth and Structural Change in the Egyptian Economy (Homewood, Illinois: Irwin Press, 1967).

through substantial processing before export. Agricultural products account for about 86 percent of the total export value (1965), of which about 50 percent is export of cotton.

From 1945 to 1960, gross national product at constant prices grew at an average rate of 4 percent; this was achieved in spite of the fact that the agricultural sector grew by less than 1.7 percent per annum over this same period. Another way of expressing this is that the agricultural sector accounted for only some 14 percent of the increase in aggregate real income over this fifteen-year period.

For food there were periods when the growth of output kept ahead of the population; but in general, the race has been the other way. Over the whole period from 1937 to 1960, food production rose by 46 percent, while the population increase was 64 percent, resulting in a 10 percent fall in per capita food supply from domestic production. The situation for recent years is slightly better as shown in Table 2-3. The total agriculture production index (taking average 1957-59 as base year) has been rising while per capita agricultural index has been maintained.

Also Table 2-4 shows that for the last thirty-one years, area, production and yield for the following crops were: steady for cotton and wheat, slightly higher for berseem and corn but more than doubled for rice.

Table 2-3. Indices of total and per capita food and agricultural production in Egypt, annual 1954-1966

	Average	Year												
	1957-59	1954	1955	1956	1957	1958	1959	1960	1961	1962	1963	1964	1965	1966
Total agriculture	100	90	88	90	98	99	103	108	98	113	114	116	120	120
Total food	100	94	92	96	100	98	103	108	106	116	119	117	120	123
Per capita agriculture	100	98	94	94	100	99	101	103	91	102	101	99	100	97
Per capita food	100	103	98	100	102	98	101	103	98	105	105	100	100	100
Index of population (1958 pop. 24,655,000)	100.0	91.5	93.5	95.4	97.7	100.0	102.4	104.8	107.7	113.4	110.5	117.2	120.1	123.3

Source: USDA, ERS, Indices of Agricultural Production for the Near East and South Asia, December 1966.

Table 2-4. Land area, total production, yield per feddan of the main field crops in Egypt from 1952 to 1966 (1935-39 base year) in metric tons

	Cereals														
	Wheat			Maize			Rice			Cotton			Berseem		
Year	Area[a]	Production[b]	Yield[c]	Area	Production	Yield	Area	Production	Yield	Area	Production	Yield	Area	Production	Yield
Average 1935-39	1410	1248	0.89	1540	1606	1.04	446	685	1.27	1754	411	0.23	1643	..	....
1952	1402	1089	0.78	1704	1506	0.88	374	517	1.38	1967	446	0.22	2202	36	0.17
1953	1690	1547	0.86	2015	1853	0.92	423	652	1.54	1324	318	0.24	2142	40	0.16
1954	1795	1729	0.96	1904	1753	0.93	610	1118	1.83	1579	348	0.22	2268	38	0.16
1955	1523	1451	0.95	1834	1714	0.93	600	1244	2.07	1816	335	0.18	2350	38	0.15
1956	1570	1547	0.99	1836	1652	0.90	690	1495	2.17	1635	325	0.20	2318	35	0.16
1957	1514	1467	0.97	1769	1495	0.85	731	1624	2.22	819	405	0.22	2363	38	0.16
1958	1425	1412	0.99	1955	1758	0.90	518	1027	1.98	1905	446	0.23	2380	35	0.17
1959	1475	1443	0.98	1859	1500	0.81	729	1536	2.11	1750	457	0.26	2398	36	0.17
1960	1456	1499	1.03	1821	1691	0.93	706	1486	2.10	1873	478	0.26	2414	41	0.18
1961	1384	1436	1.04	1603	1617	1.01	537	1142	2.13	1986	302	0.15[e]	2448	39	0.17
1962	1455	1593	1.09	1832	2004	1.09	830	2038	2.44	1657[d]	457	0.27	2442	33	0.18
1963	1345	1493	1.11	1721	1867	1.08	952	2213	2.31	1627[d]	442	0.27	2435	27	0.19
1964	1295	1499	1.16	1660	1934	1.17	952	2036	2.12	1611	501	0.31	2480	27	....
1965	1356	1600	1.18	1760	2100	1.20	846	1862	2.20	1711	518	0.32	....	..	....
1966	1400	1620	1.16	1899	2200	1.17	950	2000	2.11	1873	479	0.26	....	..	....

Source: N.B.E. <u>Economic Bulletin</u>, XVIII, No. 4 (1967).

[a]Area in 1000 feddans. [b]Production in 1000 metric tons. [c]Yield in metric tons.

[d]Presidency of the Republic, Central Agency for Public Mobilization and Statistics.

[e]There was a great damage to the cotton crop due to a severe attack of cotton leaf worm.

Of all the countries for which yield figures are available from the F.A.O., output per acre in Egypt in 1964-65 ranked fourteenth for wheat, twelfth for maize, third for rice and fifth for cotton (nearly 30 percent above the United States).[1]

The average diet in Egypt is grossly deficient in protein. Recent biological research suggests that severe protein deficiencies result not only in danger to health and physical well being, but may cause permanent impairment of mental capacity as well.[2]

The economic reflection of this nutritional requirement is the fact that in Egypt the population will spend the major part of any increases in incomes on additional purchases of food, i.e., the income elasticity for food is relatively high. There has been a massive increase in net food imports, reaching 62 million Egyptian pounds in 1963. The share of net imports in the total domestic food supply may have risen from 2-3 percent in 1960 to 10-12 percent in 1967.

In order to introduce a much stronger measure of central control over farming the government had begun to transform agricultural institutions. The production unit

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[1]F.A.O., Production Yearbook, XVII (1965) (Rome, 1966).

[2]André Voisin, Fertilizer Application, English translation by C. T. M. Herriott (Springfield, Illinois: C. C. Thomas Publishers, December 1964).

now is a cooperative which combines a strong measure of central control with private ownership of land and only a limited amount of individual initiative. Local officials possess sanctions to make farmers obey. Throughout agriculture the allocation of essential inputs such as water, fertilizers, high quality seed, and credit are under state control and could be withheld from farmers who obdurately refuse to cooperate. And since the new cooperative institutions market nearly all crops, the officials in charge can easily decide what proportion of the cooperatives' income to invest in buildings, roads, or machinery. Moreover, with an increased flow of cash income paid to farmers and landowners passing through the hands of local officials, it is administratively feasible for the state to collect more direct taxes from agriculture. Alternatively, since most crops are sold to government agencies for resale to consumers in urban areas or overseas, the government could tax agriculture by purchasing produce from the farmers at one set of prices, and selling at higher prices.

Agricultural Cooperatives

Agricultural planners believed that the improved systems of crop rotation, the consolidation program, and the reformed techniques of cultivation recommended so enthusiastically by experts had not and could not be applied at the required speed without further extensions of state control over farmers. As they saw it, the regeneration of

agriculture required the continuous presence and pressure of government officials in the countryside. Plans, exhortations, even incentives were not enough. If yields were to rise rapidly a new mechanism of control had to be created and by 1963 plans had crystallized to transform voluntary into supervised cooperatives.

Farming in the new cooperatives is a mixture of collective and individual enterprise. The board decides how to allocate land among different crops and the appropriate rotation to be allowed in the light of soil surveys and technical advice from the agronomists. Ploughing, the application of chemical fertilizers, watering, treatment against pests and plant diseases, and harvesting are generally collective activities organized by the board and utilize equipment owned by the cooperative.

So cooperatives have become an alternative to land nationalization, and are considered semi-public institutions through which the influence of the state is brought to bear upon the process and composition of production. These organizations have taken up the functions of farm-supply and farm-product market organizations, educational service and credit organizations.

Membership is no longer voluntary, decisions do not appear to be taken democratically, and for good or ill farmers own but no longer fully control their own farms but cultivate in accordance with a wider or national interest,

as perceived by the government, and interpreted and implemented by cooperative managers.

Product Market

Government agencies have been increasingly active in the markets for agricultural products since the price and quantity interventions started during World War II. Cotton purchases and sales were handled by the Egyptian Cotton Commission while grain policies have been pursued through the Agricultural Cooperative Bank. Since the nationalizations of 1961, foreign trade in all major products has been conducted by government-owned companies, and the same has applied to much of the domestic wholesale trade in agricultural products. During the last six years, however, the cooperative societies have come to play the major role in the assembly of domestically marketed commodities.

The main aim of the market regulations claims the government has been to stabilize agricultural income at a suitable level and to influence the general income distribution in a way found appropriate. But the controversy of public-private sectors in agricultural marketing, has arisen, in part because of conflicting price-policy objectives: a simultaneous desire for low consumer prices and high farm prices. It has been widely held that both objectives could be achieved if the "wicked" private marketing sector were replaced by a government-managed system. Argument has centered on alleged private speculation, and inadequate

attention has been given to the valuable arbitrage function that the admittedly imperfect trade was performing. In addition, sufficient recognition generally was not given to the economic advantages of quick, decentralized decisions in the complex field of marketing, and on several occasions this public intervention has led to the worsening of conditions for both consumers and producers.

Fertilizer Factor Markets

Agricultural factor markets became increasingly important as Egyptian agriculture evolved from an almost complete dependence on resources avilable either within the farm family or produced on the farm itself, to an increasing dependence on inputs produced in the nonfarm sector. After the nationalizations of July 1961, most of the nonfarm produced inputs used by local cultivators were produced or imported and all were distributed by organizations within the public sector.

The Fertilizer Fund Organization estimates the annual fertilizer requirements, secures the money needed for the fertilizer budget, and receives offers from abroad for the difference between the total requirement and the locally produced fertilizers including the amounts, kinds, prices, and the time of delivery. After deciding upon the best offers for importation, the Agricultural Cooperative Bank concludes the contracts. At the same time, the locally produced fertilizers are shipped to some 316 storage centers

scattered over the country. The imported fertilizers on arrival are shipped also to these same storage centers. Every center receives its fertilizer allotment in amounts and kinds according to the planned requirements for all crops in its district. Each agricultural cooperative receives its fertilizer allotment for the season from the center and distributes it among its farmers. Chart 2-1 shows the distribution course that fertilizer marketing takes.

Agricultural and Cooperative Credit

In Egyptian agriculture, problems of finance and credit arise in large part from the seasonal cycle of production which is superimposed on a largely nonseasonal or steady pattern of total consumption. Even production inputs tend to be required either steadily throughout the year or at concentrated periods at times other than at harvest. Thus, provision for consumption and for production inputs requires either a saving process from the past harvest or credit borrowed against a future harvest. These problems are most marked in an agriculture with a single concentrated annual harvest.

Nearly all advances in production technology means an increase in cash costs and higher capital investments. Thus, to produce more, Egyptian farmers must spend more on improved seeds, pesticides, fertilizers and implements.

From the past data on fertilizer marketing, distribution and research (an Annual Estimate of Fertilizer Requirements) is made by the:

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<u>Fertilizer Fund Organization</u>

1. Estimation of locally produced and imported fertilizers
2. Preparing bids for foreign exporters
3. Receiving offers and evaluation
4. Taking decisions on offers
5. Regulate the time of delivery
6. Acquire the financial budget

↙ ↘

Agricultural Cooperative Bank ownership and financing — Egyptian Agr. Society[a]

1. Receiving fertilizer from locally-producing and foreign companies
2. Fertilizer transportation, handling and storage
3. Distribution to Co-ops.

↓ ↓ ↓ ↓

CO-OPS CO-OPS CO-OPS CO-OPS

1. Buying fertilizers from bank's main storage centers
2. Distribution to the farmer
3. Keeping credit records for the farmers

↓↓↓

Farmers

Chart 2-1. Fertilizer marketing and distribution course.

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[a]Recently the activities of the E.A.S. has been reduced to a minimum.

The major single cash expenditure is the amount spent for fertilizers.

Agricultural Credit Movement

Until 1930 there was no institution specializing in agricultural credit. Except for some credit borrowed from the purchasers of farm products secured by a lien on the crop, the bulk of credit was supplied by village userers at 30 to 40 percent interest.

In 1931 the Agricultural Credit Bank was founded with a capital of 1 million Egyptian pounds, of which the government supplied one-half and the principal commercial banks the other. The bank was authorized to grant loans to individual farmers and to cooperative societies (agricultural and nonagricultural) for reloaning to their members for any purpose other than the purchase of land.

Though the bank had partly fulfilled the need for short-term credit, it did not live up to the great expectations that had accompanied its foundation. State influence remained paramount in its management, despite the importance of the share of its capital owned by the private sector, and its lending policies were mainly directed to satisfying the demands of the large land-owners or the village mayors who had contrived to monopolize its services. The loans in cash and in kind obtained from the Bank were frequently

passed on to small farmers, but not without charging them exorbitant interest rates.[1]

The bank was unsuccessful in another respect. It has been preoccupied with reducing the interest rate, and thus with formal security against the loan, and has not provided the very personal services given by the money-lenders and the capacity of the farmer to repay (which must be regarded as the basic security of all agricultural credit).[2]

After 1953 the Bank attempted to dispense with the requirement of land as a collateral and instead to advance short term loans against the crops. But by 1957 they had turned to the advance of loans through agricultural cooperatives. Between 1957 and 1961 they were able to increase the value of loans by nearly 60 percent (100 percent if 1957 agriculture is compared with 1961 agricultural loans),

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[1]Y. A. Mohi El Din, "Egyptian Agriculture: A Case of Arrested Development" (unpublished Ph.D. dissertation, University of Wisconsin, 1966).

[2]Examining the Bank's program against the development needs of the farmers, the following shortcomings were evident: (1) ineffective follow-up on use of loan proceeds, and supervision, (2) failure to establish eligibility of borrowers and eligibility standards, (3) rigid and time consuming procedures for processing loan applications, (4) inadequate consideration of borrowers repayment and risk bearing ability, (5) inadequate financial projections and planning, (6) shortage of trained personnel and poor "esprits de corps" among employees, (7) no line of demarcation between policy-making and management functions, (8) no insulation against outside pressure, and departure from purpose for which credit institution was established.

largely through the addition of small farmers not previously served by the Bank. By 1962 the Bank had made a further increase in total loans and had completely ceased to make loans directly to individuals, Table 2-5.

The loan purposes of the credit emphasizes mainly fertilizer and agricultural cash expenditures, as shown in Table 2-5. Both of these items more than doubled between 1952 and 1961, but the loans for seeds increased even more rapidly.

Nearly all agricultural credit institutions are keyed to short-term needs, 98 percent, with little concern and pressure for intermediate and long-term credit. The general concensus is that such loans require large loans and mortgages and thus are not suitable for institutionalized credit. Also, land usually changes hands through inheritance.

In August 1961, a presidential decree declared loans from the Agricultural and Cooperative Bank interest free to those farmers who used these loans in ways approved by the government. In this free and supervised credit the government now possesses a useful instrument for bringing its influence to bear on the process of cultivation.

Table 2-5. Short term loans advanced for agricultural purposes, 1952-1961 (in Egyptian pounds)*

Year	Seeds	Fertilizers	Agriculture Cash Expenses	Against Crops	Total	Average Loan
1952	820,663	6,445,773	6,555,589	1,784,800	15,606,825	24,117
1953	1,359,408	7,817,704	6,209,236	626,367	16,103,215	15,072
1954	1,498,161	6,364,791	7,364,862	1,634,893	16,862,707	17,453
1955	1,495,234	6,376,272	9,175,237	1,185,087	18,231,830	20,619
1956	1,318,625	5,681,820	7,662,238	1,597,395	16,260,188	21,267
1957	1,436,463	6,962,706	8,416,472	1,476,599	18,292,240	22,052
1958	1,627,617	8,283,109	9,749,885	2,055,910	21,716,521	21,722
1959	1,831,979	10,272,675	10,996,386	1,954,878	25,055,918	16,882
1960	1,981,156	12,607,989	12,805,822	3,131,311	30,526,278	14,033
1961	2,355,856	14,750,461	15,467,992	11,908,750	33,765,184	13,738

*Compiled from Annuaire Statistiquie, 1951 to 1962.

CHAPTER III

PAST AND PRESENT FERTILIZATION PRACTICES

> "Agriculture history has passed through various stages in its development; at present it is in the fertilizer epoch."
>
> Lamber, The World Fertilizer Economy

To understand the potential for future changes in fertilizer practices it is useful to review changes that may have occurred in the recent past. Thus, the questions: What were fertilization practices? How have they changed over time? What are their present drawbacks and deficiencies?

In this chapter we shall proceed first with investigating past and present fertilization practices, a study of agronomic research results and fertilizer practices of the major crops and how crop yields could be increased through better use of fertilizers.

Past Fertilization Practices

The Nile alluvium that built up the fertile land of the valley was the first fertilizer. Nile water carries with it 110 million tons of alluvium every year, but only 13 million tons are deposited on the cultivated soil; the rest is deposited in the Nile bed or carried to the Mediterranean Sea (Table 3-1). The Egyptian soil is old in age only; were it not for this silt that rejuvenates or renews its youth every year, the soil would have been aged, exhausted and depleted long ago.

> It would seem that cultivation was first practised systematically in the Nile valley. At first crops were grown on the moist soil after the recession of the flood waters. Later, in order to take the fullest possible advantage of the Nile water and alluvium, great banks of earth were raised, tranversal to the river, dividing the land into basins. The banks served to retain the water a little longer during the flood and the basins were further irrigated by canals which brought them water from a slightly higher level upstream.[1]

This system of basin irrigation, still practiced in certain parts of Upper Egypt, by ensuring a regular flow of water and an annual fertilization of the soil, made Egyptian agriculture one of the most stable in the world. Its abandonment for perennial irrigation, though it has increased the return of the land, has upset a centuries-old balance and raised several acute problems.[2]

In time the Egyptians learned that certain soils would fail to produce satisfactory yields when cropped continuously. The practice of adding animal and vegetable manures to the soil to restore fertility probably arose from

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[1]Issawi, Egypt in Revolution (London: Oxford University Press, 1963).

[2]Not only has the water-table and soil salinity increased, but also pests and parasites have multiplied.

Table 3-1. **Amount** of Nile silt in millions of tons deposited on Egyptian soils every year

Place Where Silt is Deposited	Basin Irrigation Soils	Perennial Irrigation Soils in Upper and Middle Egypt	Perennial Irrigation Soils in Lower Egypt
River Nile and main streams	10.65	5.95	10.44
Secondary streams and drains	1.88	3.29	9.95
Agricultural soil	8.77	2.66	0.49
What is added to the soil from deepening of streams	not known	0.16	1.00
Total amount deposited on agricultural soils[a]	8.77	2.82	1.49

Source: Reproduced and translated from A. A. Mostafa, "Nile Silt and Its Relation to Soil Fertility," The Agriculture Magazine, July-August, 1967.

[a]Total amount deposited on all soils is 13.08 million tons each year.

such observations. The ancient Egyptians knew the value of manure, and how to apply it, and the reason that they worshipped the scarob was that they believed that it made manures richer and more beneficial to the plant. They also used gypsum and bird manure long before the Romans and the Greeks.

The use of what is now known as mineral fertilizers was not entirely unknown. Theophrostus recommended the mixing of different earths as a means of "remedying defects and adding heart to the soil." The old Arabians knew and appreciated the effect of marl and ash.

Not only did the ancients recognize the merits of manure, but they also observed the effect that dead bodies, and the soils derived from old tombs, had in increasing the growth of crops.

The value of green-manure crops, particularly those of a leguminous nature, was also recognized by the ancients. During the time of the Ptolemies-olive trees, the Sakia (water wheel) and Archimedes screw were introduced into Fayoum.[1]

Jumping to the more recent past, Mohamed Aly introduced cotton (1820) and began to convert the Delta to perennial irrigation by means of a series of canals (1816).

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[1]One of the provinces in Egypt, located fifty miles southeast of Cairo.

The American Civil War stimulated cotton production and Egypt became increasingly dependent on this one crop, which accounted for 93 percent of the total exports of the country between 1890 and 1914. There was also a gradual increase of cultivated area due to the spread and improvement in perennial irrigation (Delta Barrage 1890 and Aswan Dam 1902).

Since 1820 and until 1902 when the Royal Egyptian Society imported sodium nitrates from Chile, the Egyptian farmers depended largely on barnyard manure, Kafry and Marog manures for the fertilization of their crops.[1] The supply of nitrogen in these manures was supplemented by the growing of legumes in their rotation system.

The Royal Egyptian Society imported socium nitrate first in 1902 with commercial use starting actually in 1906. It was used mainly for cotton, wheat, and corn. Later it was applied to sugar cane, rice, orchards, and vegetables. Little was known about the rate and method of application of this fertilizer, and farmers were dependent upon the guidance of the importer's agents.

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[1]Kafry manure is only found in Egypt; it is the remains of ancient Egyptian towns and cities and through time the organic nitrogen is changed into nitrates. Hills of this manure are found in abundance in lower and upper Egypt, while Marog manure is found as natural deposits in the hills of Upper Egypt. Analyses of these manures shows a high percentage of sodium chloride.

In 1913, the Ministry of Agriculture was established in Egypt. The main concern of this ministry at the beginning was cotton breeding and seed production. By 1917, the Cotton Research Board was established to carry out such research as plant breeding, analyses of soil fertility, and the use of fertilizers. This Board, together with the research section of the Egyptian Agricultural Society, has engaged in research work ever since.

General recommendations for the use of nitrogen and phosphate (potassium fertilizers were not recognized at that time to any extent) fertilizers used to be issued by the Minister of Agriculture and communicated through the extension service section of the same ministry, and by the fertilizer dealers. Primary emphasis was given to nitrogen, as the most needed plant nutrient in Egypt.

However, Dr. M. T. Eid, director of the plant nutrition section of the Ministry of Agriculture, states that, "the phosphate availability for field crops was taken into consideration in Egypt first around 1903." Early observations of the effect of superphosphate of lime indicated an increase of berseem (clover) yields on sandy soils of Sharkia Province (30 miles N.E. of Cairo). Later, it was found that all legumes benefitted substantially from phosphate fertilizers not only on sandy soils, but also on any

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[1]M. T. Eid, Role of Phosphates in Egyptian Agriculture, Technical Bulletin No. 297, 1959.

soil in Egypt. At the same time, no clear effect of phosphate was reported for other field crops.

Previous work of Mosseri showed, through the determination of total phosphoric acid in several soil samples taken out of scattered fields in Egypt, that ample amounts of phosphorus were present in the soil. According to these studies, it was almost concluded that there was no need for phosphate application to field crops. Later the increase in yield of berseem on sandy soils because of the use of superphosphate necessitated deeper considerations of the problem.[1]

After further studies, Mosseri concluded that superphosphate of lime had considerable effect upon berseem yield only because it improved the chemical and physical properties of the soil through its contents of calcium sulfate.

Because of lack of scientific experiments, many errors were committed and fertilizers were misused. The kind, amount, time and placement of fertilizer were not adjusted to suit the requirement of each crop. For example, calcium and sodium nitrates, instead of ammonium sulphates, and basic slag, instead of superphosphates, were used on saline-sodic soils. Fertilizer was applied late in the season when the crop was near maturity, so the crops did not respond to fertilizers and in many cases fertilization caused a decrease in yields (in the case of cotton, late

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[1]Mosseri did not consider that while the soil might be rich in phosphorus, its availability to the plant could be limited.

application causes vegetative growth and retards maturity, so the crop becomes more susceptible to insect attacks late in the seasons).

Many other examples could be cited; the end result of these malpractices has limited faith in the use of fertilizers. The majority of farmers did not believe in the man-made artificial fertilizers and conceived the idea that crops in which natural organic fertilizers were used tasted better and had higher nutritive value.

Only after 1925 did the Egyptian farmer regain confidence in scientific experimentation initiated by British and Egyptian professors at the newly established Cairo University. (It was then called Fouad The First University.)

By the late 1930's Egypt was among the heaviest users of fertilizers in the world. Since most of the fertilizers were imported, the blocking of trade during the war cut the supply drastically, with major repercussions on the level of output. Thereafter, fertilizer usage climbed rapidly to return Egypt to its position as a heavy user of fertilizer.

> From 1937 to 1960 a dramatic development took place in the use of fertilizers and other chemicals. From 1937 to 1947 fertilizers fell by 25 percent (during the war the fall was much greater) while from 1947 to 1960 they trebled. With the input of labor more or less unchanged, total production in 1947 was at the same level as in 1937.[1]

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[1] Hansen and Marzouk, Development and Economic Policy (Amsterdam: North Holland Publishing Co., 1965).

This suggests that the 25 percent fall in fertilizers, plus delayed effects from the much lower supply of fertilizers and the unhappy crop-rotation during the war, was sufficient to wipe out the effects on total production of a simultaneous increase in land by 8 percent, animals by 22 percent, canals and drains by 17 percent and pumps by 14 percent. In fact, the only factor of production which could show a significant increase in average output-productivity 1937-47 was fertilizers. This demonstrates once more their importance.

Present Fertilizer Use

By 1960, consumption of fertilizer per acre of arable land in Egypt was considerably above that for most developing countries, although still far below the levels of a number of more advanced countries, such as Belgium, Japan and the Netherlands. But in the same year Egypt used five times as much nitrogenous fertilizer per acre of arable land as did the United States, approximately the same amount of phosphates, but only one-twelfth as much of potassium fertilizers.

Demand has increased most rapidly in areas where technical knowledge on fertilizer response is more recent, where commercial nutrient needs have increased as soil nutrients became depleted, and where new varieties and practices have most rapidly boosted fertilizer productivity.

C. Issawi argues,

> nevertheless, the use of fertilizers is inadequate, and total requirements in 1960 have been put at 1,140,000 tons of nitrogenous, 470,000 of phosphetic, and 19,000 of potash fertilizers. It has been estimated that over half the area planted to wheat receives less than 50 kg. of sodium nitrate per feddan a year; yet 100 kg. of sodium nitrate costing PT 270, raised the yield of wheat by 37 percent or by PT 562, and increased the protein content from 9.8 percent to 12.4. The application of 100 kg. of sodium nitrate per acre raised the yield of cotton from 3.89 to 4.48 kantars. Experiments carried out by the Agricultural Society showed that, on land left for two years without fertilizers, wheat yields fell by 34 and maize yields by 50 percent.[1]

While C. Issawi indicates that the total fertilizer requirement in 1960 was 1,629,000 tons, D. Mead[2] shows that total supply was only 1,069,000 tons as shown in Table 3-2.

Patrick O'Brian states that Egyptian farmers unlike those of more traditional societies are already familiar with a good deal of modern agrarian technology such as chemical fertilizers and selected seeds but the utilization of nitrogenous chemicals and hybrid seeds is certainly not optimal. Scope for further increases in yields certainly exists.[3]

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[1] C. Issawi, Egypt in Revolution (London, New York: Oxford University Press, 1963).

[2] D. Mead, Growth and Structural Change in the Egyptian Economy (Homewood, Illinois: Irwin Press, 1967).

[3] Patrick O'Brian, The Revolution in Egypts' Economic System (London, New York: Oxford University Press, 1966).

Table 3-2. Supply of chemical fertilizers (thousands of metric tons)

	Imports	Domestic Production	Total
1902	2.2	0.0	2.2
1907	23.1	0.0	23.1
1912	70.1	0.0	70.1
1917	36.9	0.0	36.9
1922	118.2	0.0	118.2
1927	225.4	0.0	225.4
1932	234.6	0.0	234.6
1937	641.8	n.a.	n.a.
1943	158.6	n.a.	n.a.
1947	459.4	15.0	474.4
1952	629.0	206.1	835.1
1957	620.1	385.5	1,005.6
1958	715.3	399.9	1,115.2
1959	355.3	412.3	767.6
1960	625.8	443.2	1,069.0

Source: Reproduced from Mead, Growth and Structural Change in The Egyptian Economy (Homewood, Illinois: Irwin Press, 1967).

He also adds that Egyptian farming cannot be called backward or traditional but it had certainly not achieved optimum efficiency.

As for the use of barnyard manure the story was and still is a sad one. Since the dawn of history manure was poorly handled and because of lack of any scientific knowledge concerning the proper application or nature of of organic manure, most of its direct and indirect beneficial effect was dissipated or not realized.

It is generally recognized that because of poor handling, only about one-third to one-half of the potential crop-producing and soil-conserving value of the manure actually is utilized.

In Egypt an estimated 40 percent of the animal excreta is burned for cooking and heating because wood is so scarce, provision of an alternative form of fuel would be an important means of raising food production.[1]

Fertilizer Practices for Five Major Crops

Fertilizer practices for any particular crop are related to an array of factors, including the previous and succeeding crops, the use of fertilizers on these crops, the soil characteristics as well as to economic and managerial

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[1] The irony or paradox here is that these people of the Middle East living on lands gushing with oil, cannot and do not use this oil, but use and destroy the plant organic matter that they need most for their livelihood and for the fertility of their soil.

variables. Before discussing present fertilizer practices on the five major crops, namely, cotton, rice, wheat, maize (corn) and berseem, it is necessary to review some of the technical aspects of fertilizer placement and time of application that determine fertilizer practices for these crops.

Determining the proper zone in the soil at which to apply the fertilizer ranks in importance with choosing the correct amount of plant nutrients in many instances. Fertilizer placement is important for at least three reasons.

1. Efficient utilization by the plant;
2. Prevention of salt injury to the plant;
3. Convenience to the farmer.

In order to be used by plants, nutrients must be placed where they can be dissolved by moisture in the soil. The rate and distance that plant-food elements can move within the soil depend on the chemical nature of the material that furnishes the nutrients, and the character of the soil.

Nitrogen moves rather readily, and the movement of potash is intermediate between phosphate and nitrogen. In commonly used fertilizer, the nitrogen and potash carriers are more readily soluble than the phosphate materials--therefore, they cannot be safely concentrated in as large amounts near the seed or roots of the plant because of the danger of "salt damage." For this reason, full return from the increased use of plant nutrients in Egypt will be limited by improper placement. In considering the placement of fertilizers it is important that the differences in salt effects among fertilizers be kept in mind. The higher analysis fertilizers have less of a tendency to produce salt injury than equal amounts of plant nutrients in the lower analysis fertilizers (Table 3-3).

Table 3-3. Salt index per unit of plant nutrients for representative materials

Material	Analysis (Percentage of N)	Salt Index per Unit Plant Nutrients
Ammonium	35.0	2.99
Nitrate	....	....
Ammonium	21.2	3.25
Sulphate	....	....
Sodium nitrate	16.5	6.06
Urea	46.6	1.61
Super phosphate	16.5	0.39
Potassium chloride	50.0	2.18
Potassium sulphate	54.0	0.85

Source: Tisdale and Nelson, Soil Fertility and Fertilizers (New York: Macmillan, 1961).

The placement of soluble phosphates in bands tends to reduce contact with the soil and should result in less fixation than broadcast application. With broadcasting and thorough mixing, the phosphorus comes into intimate contact with a large amount of soil.

Early stimulation of the cotton seedlings is usually advantageous. Of the primary nutrients, nitrogen and phosphorus are particularly important in early growth, and it is desirable to have them near the plant roots.

Under adverse conditions a fast-growing young plant is more likely to resist insect and disease attacks. Weed control is facilitated when the young cotton plants start off rapidly. Cultivation can be started before the weeds become established, and the number of cultivations may be reduced. If one cultivation is eliminated, this saving should be considered in calculating cost of fertilization. Particularly with vegetables, an early crop is in most cases of paramount importance to successful farmers. A delay of only three or four days may make a difference between a good price on an early market and a break-even proposition.

Practical experience has also shown that the time at which to apply a fertilizer is of vital importance in the hot arid Egyptian climate.

Temperature influences the availability of certain elements, for example, release of nitrogen and phosphorus from organic matter, nitrification, and the absorption of phosphorus by the plants. The nature of the crop itself will determine whether there is a need for split applications. A crop with a long growing season needs two to three nitrogen supplements, while for a fast-growing plant, such as the radish which reaches harvest stage in 40 days, one application of nitrogen should be adequate. Late

applications of nitrogen fertilizer may actually be detrimental to some crops. In Lower Egypt it is suggested that even ammoniacal nitrogen should be applied as close as possible to the time of use by the plant. As one goes farther south the temperatures would be more nearly optimum for nitrification all the year around. Ammoniacal nitrogen applied ahead of planting would thus be more subject to nitrification and leaching than if applied later. Since phosphorus and potassium move very little in the soil, the total quality needed during the season can be applied at the time of planting without fear of loss by leaching. Just how far in advance of planting can they be applied depends largely on the fixation capacity of the particular soil and the method of application.

Cotton

In spite of the development of other resources during the last twenty or thirty years, cotton still forms the basis of Egypt's agricultural income. The reasons for its popularity, in addition to its remunerativeness, have been that it is not consumable by peasants, and thus suited absentee landlords, that banks were always eager to lend against cotton, which can be easily graded and does not deteriorate, and that exporting firms were ready to advance to growers the funds necessary for cultivation in return for a lien on the forthcoming crop.

In the late 1950's, some 17 percent of the total cropped area was devoted to the cultivation of cotton. Gross and net returns per feddan of cotton were high; its share in the gross value of agricultural output of field crops was 34 percent, just double its share in cropped area. The share of cotton in Egypt's exports has declined throughout the twentieth century, although it still accounted for 65 percent of total merchandise exports in 1963.

Egyptian long staples are, with the exception of Sea Island and Pima, the finest in the world as regards length, resistance and glossiness. Among medium staples, Ashmouni, whose yields are well above those of long staples, continues to hold the field but has recently been joined by Dandara and Bahtimi 185.

The war caused a sharp drop in yields, owing to the exhaustion of the soil through over-planting of cereals and the lack of fertilizers, but in the last few years progress has been slowly resumed.[1] A leading British authority has stated that by the adoption of closer spacing and other improved methods, as well as a shift away from long to medium staples, the cotton crop could be raised from its present figure of 8-9 million cantars (about 400,000 tons) to 15 million.[2]

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[1] Issawi, Egypt in Revolution (London, New York: Oxford University Press, 1963).

[2] Al Ahram Daily Newspaper, April 6, 1962.

This crop gives best results if planted early in February in Upper and Middle Egypt, and in March in Lower Egypt. The best soil type is the heavy deep clay soils, but cotton is not as sensitive to saline-alkali soil as corn. Fertilizer practices recommended by the Ministry are: the application of 30 kilos of ammonium sulphates per acre mixed with the seed which is planted in the upper one-third on the southern side of the row, and then after planting the seeds are covered with 150 kilos of superphosphates. One hundred kilos of ammonium sulphate or ammonium nitrate is applied as a top dressing just after thinning and before the first irrigation, which takes place twenty-five days after planting. Another 100 kilos of ammonium sulphate is applied at the second irrigation, i.e., thirty days after the first one.

Practical experience has shown that foliar application of superphosphates in May, June and July have had good results in limiting vegetative growth and in encouraging boll formation. The application of 40 kilos of potassium sulphate plus 25 tons of barnyard manure on the light soils of Fayoum and Sharkiya Provinces is also recommended.

Because of the fear of insect and disease attacks, barnyard manure should not be applied to the cotton crop on heavy clay soils, but to the previous crop whether it is corn or rice. Owing to the pink boll worm attack, an early cotton crop is essential to give as early a rise and as high a maximum of the flowering curve as possible. This is imperative since the fate of the late formed bolls is doubtful.

Yield increases obtained for the first picking are the only ones which are reliable. Heavier applications of nitrogen always caused a prolongation of the flowering period and increased the proportion of the crop at the second picking, owing to the increased vegetative growth. The effect also depended on the season. With hot seasons in which the bolls are shed, the economic increases from nitrogenous fertilizers can be obtained only on first class land in favorable seasons. With fertile land and good season, maximum yields were given by 350 kilos of nitrates in combination with 150 kilos superphosphates.

The great majority of Egyptian farmers use about two-thirds of whatever they have of barnyard manure for cotton and the other third for corn. These are the only crops to which they apply manure. About 75 kilos of superphosphate (half of what should have been used) are applied broadcast before plowing. This increases the chance of its being fixed and unavailable to the cotton plants. The average farmer broadcasts 100 kilos of sodium nitrate (which increases soil alkalinity) at the first watering which takes place forty-five days after planting (this is twenty days later than is being recommended). Then he applies another 100 kilos of sodium or calcium nitrate just after thinning and before the second irrigation. Thinning should have taken place before the first fertilizer application. Besides using small quantities of fertilizer, the farmer does not use the right kind at the right time and the mode of application is not as recommended. All these practices reduce the response of cotton to fertilizer.

Concerning barnyard manure, the experiments at Bahtim showed that the plots receiving barnyard manure gave the highest increase in yield. The yield was higher than the basic yield by 56 percent in the one-year rotation, by 85 percent in the two-year rotation and by 100 percent in the three-year rotation. The yields were higher than the plots receiving nitrogen and phosphate by over 50 percent in the two-year and 10 percent in the three-year rotation.[1]

The practical farmer cannot afford to define his practices by lifting them directly from tables showing experimental works with fertilizers. He must consider his soil and the history of that soil in relation to that in the experiments. The tables can suggest a range of fertilizer application, but the farmer must deal with a number of variables. Provided the higher application is profitable, an increased level of fertilizer use is associated with the use of fertilizer responsive varieties, narrow spacing, early planting, adequate irrigation water, soils with a moderately large colloidal content, low carryovers from the fertilization of previous crops, a desire to provide carryover to a subsequent crop, the absence of salinity and alkalinity problems, and the use of pesticides.

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[1]A. F. Money-Kyrle, Agricultural Development and Research in Egypt (Lebanon: American University of Beirut, Publication No. 3, December, 1967).

Rice

Rice exports rank second after cotton in volume. Farmers consider its consumption a delicacy and not part of their daily diet. As a crop, rice production helps in washing away the harmful sodium chloride salts of saline soils and is also considered the second most profitable crop in Lower Egypt. In the absence of rain, the entire crop depends on artificial irrigation.

In the last thirty years, yield per hectare has increased 50 percent, most of it in the period 1953-1960 when average yield went up from 3,700 kg. to 5,840 kg. per hectare. "The cultivation of rice has greatly expanded as the old mixture of South-East Asian varieties was replaced by superior Japanese breeds."[1] Another factor explaining the rise in yields has been the extension of rice cultivation southward, to more fertile areas; formerly it was grown exclusively in the north of the Delta, on land which was being desalinated. Since rice requires three or four times as much water per unit area (20,000 cu. mt./hectare) as cotton, and three times as much as maize, its acreage is strictly determined by the water supply and in years of a very low Nile rice cultivation has to be curtailed.

Rice is probably the best managed crop in Egypt, both technically and economically. According to the F.A.O.,

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[1] Issawi, Egypt in Revolution (London, New York: Oxford University Press, 1963).

"the high yields of rice in the United Arab Republic are attributed to excellent control of the various factors affecting yield."[1]

Because of the many advantages transplanted rice has over broadcast, it represents 84 percent of total rice acreage. Transplanting allows the land to carry more than two crops per year, saves large quantities of water, and facilitates the control of diseases, pests, and weeds. The increase in yield more than offsets the extra cost of the labor required for transplanting.

In Egypt, nitrogen is the key element in the production of rice and gives by far the largest response. Paddy can absorb nitrogen in both the ammonical and nitrate forms, applied as chemical fertilizer, green manure, oil cake and animal manure. In recent years considerable interest has developed in the fixation of atmospheric nitrogen by the blue-green algae in the wet paddy fields, an additional source of this plant nutrient. Because of the water-saturated anaerobic conditions prevailing in wet paddy soils and the nature of the crop itself, the effectiveness of different nitrogen fertilizers depends appreciably on the time and method of their application. Ammonium sulphate has been regarded as the most suitable nitrogen fertilizer for wet

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[1]F.A.O., The Response of Rice to Fertilizer, Soil Survey and Fertility Branch, Report No. 70, Rome, 1966.

paddy. Also, urea has been shown to be very effective, especially in tests conducted in Middle Egypt.

"Countries in which the responses continue at rates up to 200 kg. per hectare are those, like Japan, the United Arab Republic and the United States, where rice culture is highly developed and the factors affecting yields are well under control."[1] The Ministry recommends the following for broadcast rice, 200 kg. of ammonium sulphate is applied twenty-one days after sowing, while with transplanted rice the nursery is fertilized by 25 tons of manure plus 30 kg. of P_2O_5, plus 240 kg. of ammonium sulphate per acre, and the soil to which rice is transplanted is fertilized by 200 kg. of ammonium sulphate plus 16 kg. of P_2O_5 applied ten days after transplanting.

Almost all farmers use the right kind of fertilizer at the right time, but they do not apply the required amounts. Only three-quarters of the recommended quantities are being used. In general, most of the recommended practices are largely followed. This explains the high response of rice to fertilizer.

The response of rice to phosphorus is more erratic and less universal than to nitrogen. But the high rates of nitrogen and use of high-yielding varieties may induce a deficiency of phosphorus.

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[1] Ibid.

For long it was thought that the yield of paddy would not be significantly increased by applications of potassium fertilizer. More recently, worthwhile responses have been recorded on sandy and coarse textured soils, but in general the increase in yields due to potassium is less than with phosphorus. "Even where yields of rice on the unfertilized check plots are high, there is usually a substantial response to nitrogen and a more moderate one to phosphorus."[1]

Practical experience has proved that a split application of nitrogen half at the time of puddling and half six weeks after transplanting proved to be superior to a single application. Also, the application of barnyard manure may cause the formation of certain strains of harmful algae. But because rice cultivation affects soil physical and chemical properties--increases soil alkalinity and makes the soil more compact--it is recommended that large quantities of barnyard manure, rich in organic matter plus one ton of gypsum per acre be worked into the soil as the rice crop is removed. And because the washing off of harmful salts also washes out some of the beneficial salts, clover planted after rice increases nitrogen and humus content of the soil.

The potentialities of rice cultivation are very promising in Egypt. It is expected that with the completion of the High Dam, acreage will increase from the present 0.8

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[1] _Ibid._

to 2 million acres; total production from 1.572 to 4.4 million daribas;[1] and exports from 0.4 to 1 million tons.

Wheat

Up to 1946, Egypt was an exporter of wheat, but since then its imports have increased year after year, so that in 1965, 2 million tons were imported and by 1970 are projected to at least 3 million tons costing over 100 million pounds.[2]

Because of better varieties, improved fertilization and other agronomic practices, yield per acre has increased 14 percent in the last 7 years. "Toson" is the best high-yielding variety used in Middle and Upper Egypt, while the new "Giza" varieties are best suited for Lower Egypt. The new Mexican varieties which are more responsive to fertilizers apparently have not yet been introduced into Egyptian agriculture. In Egypt wheat is a winter crop, and does well in any type of soil and is not as sensitive to soil salinity or soil physical properties; also variation in yield is not so pronounced as with corn. The range of variation in wheat yields is from 1,200 kg. to 1,600 kg. per acre, while for corn, yield ranges all the way from 800 kg. on saline to 3,360 kg. on fertile nonsaline soils.

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[1] A dariba equals 935 kilos of rice.

[2] R. Steano, Minister of Supply, Al Ahram Daily Newspaper, January 15, 1966.

For the farmer, wheat is considered a cash crop; it is not a part of his daily diet, only urban people eat wheat.

The Ministry recommends that this crop should be planted in November in two ways:

1. After the cotton stalks are removed the soil is irrigated and left to dry somewhat for 15 days after which 60 kilos of seed usually is sown mixed with 50 kilos of ammonium sulphate, and 100 kilos of superphosphate per acre; then the seeds are covered. At the first watering, which takes place 25 days after planting 75 kilos of ammonium sulphate is applied. This method of planting is best suited to the heavy fertile soils and for those with a lot of weeds.

2. The second method is best suited for the light saline soils. After plowing, leveling, and dividing the land into small basins, the farmer sows 75 kilos of seed and then irrigates the soil. All the fertilizer, 200 kilos of ammonium sulphate is applied thirty days after planting at the first watering. Increased amounts of seed and fertilizer should be used for the less fertile soils.

The above recommendations are not exactly followed by farmers. Most farmers do not mix any fertilizer with the seed (in the first method given above). Also superphosphates are not used at all, and only half of the recommended quantities of nitrogen fertilizer are applied.

Maize (Corn)

Corn, the staple diet of rural Egypt, has been the subsistence crop of every Egyptian farmer for many decades.

Although one and a half million acres of summer and half a million acres of fall crop are planted every year, production is far less than demand and imports were half a million tons in 1960 and have been increasing ever since. In recent years average production of almost all crops has been increasing, except for corn; its performance is disappointing. Despite the advent of high yielding hybrid varieties the yield decreased from an average high of 7.4 in 1939 to 6.45 in 1960, but increased again to 8 ardabs per acre in 1965.[1] The main reason for this appears to be the continuous deterioration of Egyptian soils. Besides planting his crop late, the farmer strips most of the leaves off the young plant to feed it to his buffalo. The high salt concentration in the soil, forced the farmer to use large quantities of irrigation water, apply his fertilizer broadcast instead of side dressing, and also to abandon the use of rows of planting his corn crop. All of these practices render the plants less responsive to fertilizer application.

Although the small farmer knows that his corn yield may not pay for the fertilizer applied, he still plants his saline-sodic field with the same local traditional corn varieties, year after year. In other words, the farmer

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[1]An ardab of corn is equal to 5.6 bushels or 140 kilos.

could usually buy corn cheaper than fertilizer, but the uncertainty of high priced corn in a bad year, makes him grow corn and produce it at high cost. He wants to feel secure and be assured that his family's main food is provided for.

Experimental work has dealt with spacing, date and rate of seeding, effect of defoliation on yield, fertilizer treatment, rotations, irrigation, and breeding. The experimental section of the Ministry of Agriculture compared the effects of sodium nitrate, ammonium sulphate, ammonium nitrate and ammonium nitrosulphate on the yield of corn in many experiments in different parts of Egypt and concluded that the best fertilizer was the one which supplied nitrogen at the cheapest rate.

The Ministry recommends the application of 25 kilos of nitrogen at the first irrigation and after thinning which takes place fifteen days after planting. Another 20 kilos of nitrogen should also be applied at the second irrigation. The Ministry does not recommend the use of any potassium or phosphate fertilizers for corn.

Over 90 percent of Egyptian farmers apply a total of 30 kilos of nitrogen at both the second and third irrigation, and thinning takes place just before the third irrigation. Besides using smaller quantities of nitrogen than those recommended, the farmer does not use the right kind at the right time. Also, this late thinning of corn plants reduces the available nutrients for those plants left in the field.

All these malpractices explain the low response of corn to fertilizer and the low corn yields in Egypt.

Berseem

By far the most important forage crop in Egypt is berseem, sometimes known as Egyptian clover, "Trifolium alexandrinum." It is the chief leguminous crop in the Egyptian rotation and is very important from the standpoint of nitrogen fixation. It occupies almost 30 percent of the total cultivated area in Egypt. There are three varieties of berseem commonly planted, Fahl, Saidi and Miskawi.

Four cuts are obtained from berseem, the first one sixty days after sowing followed by subsequent cuts at intervals of fifty, forty, and thirty-five days. Each cut may yield 5 to 8 tons per feddan with a crude protein content of 3.3 percent. A seed yield of 200 to 300 kilogram per feddan may be obtained sixty to seventy days after the last cut.

Most farmers also plant berseem so as to make use of the land between the time of the removal of the corn and rice crops in October and the time of cotton planting in March, and in that case only one or two cuts are obtained.

The Ministry recommends the application of 8 kilos of P_2O_5 plus 5 kilos of nitrogen at planting time and another 15 kilos of P_2O_5 after the first cut, not only to increase crop yield but also to increase nitrogen fixation and soil humus. This fixed nitrogen has about the same effect in increasing the subsequent corn crop as the application of 20 kilos of nitrogen.

Crop rotations that include clover at frequent intervals have contributed to the productivity of soils and to the permanence of Egyptian agriculture.[1] Clover has been one of the mainstays of good rotations for many years, and in most instances the main benefit has been from the nitrogen supplied. Maintaining an adequate supply of nitrogen in the hot Egyptian climate is one of the most important fertility problems, but with the development of the synthetic nitrogen industry and the manufacture of inexpensive nitrogen fertilizers, Egyptian agriculture is no longer dependent upon legumes for a supply of this element.

In addition to its ability to convert relatively insoluble phosphorus minerals into forms more readily available to other crops, clover, and some other deep rooted legumes tend to bring phosphorus up from the deeper soil layers and deposit it on or near the surface of the soil if not all of the top growth is harvested. The average farmer does not use nitrogen or any bacterial culture that increases the number of nodules on the roots, and applies only 10 kilos of P_2O_5 after the first cut, far less than recommended.

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[1]Dr. M. Y. Elshawarby states that legume crops fix about 85,000 tons of nitrogen per year in Egyptian soils. M. Y. Elshawarby, Chemistry of Fertilizers and Plant Nutrition (Cairo: Anglo-Egyptian Bookstore, 1962).

CHAPTER IV

AGRONOMIC FACTORS AFFECTING FERTILIZER USE IN EGYPT

"O why does agriculture lag?
The answers all are in the bag
But the bag in which the answer lies
Turns out to have enormous size."

K. Boulding

This chapter deals with the crop characteristics and environmental factors that might affect the efficient use of fertilizers. It will attempt to develop the technical foundations upon which decisions concerning fertilizer use are made, and will also discuss relevant agronomic findings affecting the computation of the optimal level of fertilization.

Crop Characteristics

It still is not clear just why one variety outyields another; however, it may be that one variety is more efficient in absorbing nutrients from the soil, either through a more extensive root system or through a stronger absorption mechanism at the root surface. This is very prominent in the new Giza corn varieties, that have more and stronger adventitieous roots which help not only to anchor the corn plant, but also help the main root system to absorb more nutrients. And since roots are the principal organs through which plant nutrients are absorbed, an understanding of the characteristic rooting habits and relative activity should be helpful in developing fertilization practices. If the rooting habits during the period of rapid growth are known, it should be possible to predict the most effective placement of fertilizer to be used by the plant during this period of growth. If a vigorous tap root is produced early, applications might best be placed directly under the seed. If many lateral roots are formed early, side placement may be best. At three weeks of age corn has, for example, an extensive root system while cotton has a more restricted system. These differences tend to persist up to three months after planting.

Many observations have shown that corn depends heavily on phosphorus near the seed or main roots early in the season. From the knee-high stage on, however, corn develops a very extensive root system and has a great capacity for utilizing the nutrients distributed through a large zone of the soil.

With soils requiring the addition of plant nutrients, the corn plant may extract water from a depth of only 3 to 4 feet on the unfertilized plots. On the fertilized plots the plant roots may be effective to a depth of 5 to 7 feet. If a crop can utilize an extra 4 to 6 inches of water from the lower depths, and if adequate plant nutrition encourages root development at lower depths, the effects in the arid regions of the Middle East are apparent. Experiments have shown that water requirement per ton of hay was 50 percent higher for the 100 pound P_2O_5 rate as compared with the 600 pound per acre rate, due mainly to the more limited root system at the former rate. The yields of corn and wheat per inch of water were much higher at the high nitrogen level than at the low nitrogen level. In the case of a potassium deficient plant, the plant is less turgid, the stomata are open more fully, transpiration is higher, and the water requirement is higher than in a plant adequately supplied with potassium.

Other crop characteristics such as stiffness and shortness of plant stalk are also important in affecting rates of fertilization. As an example, the "miracle" Rice IR-8[1] a new rice from the International Rice Institute in the Philippines or the Mexican Wheat variety have a high capacity for using large applications of fertilizers without lodging. One of the main reasons is that they have a stiff, strong and short straw, i.e., a good balance between the production of grain and leafy material (an architecture favoring efficient accumulation of carbohydrates as grain).

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[1]IR-8 matures quickly, allowing for two and sometimes three crops in a single year, also has a high tillering capacity, and is resistant to rusts.

Variety and Plant Nutrient Needs

A hybrid corn producing 120 bushels per acre will require about 50 percent more plant nutrients than one producing 80 bushels. This important fact has sometimes been overlooked by the Egyptian farmer when a shift to the higher yielding variety is being considered. Under low fertility conditions a given variety may not be able to develop the full potential of its yielding capacity. In fertile soils, a new variety will deplete the soil more rapidly and eventually problems will arise if nutrient supplements are not made. Practical experience has shown that cotton planted after hybrid corn needs heavier fertilization than that planted after the low yielding local varieties.

The approximate amounts of N, P_2O_5 and K_2O removed by certain crops are shown in Table 4-1. The values shown do not include the quantities contained in the roots. Since removal will vary considerably depending upon a number of factors, these data on the nutrient removal cannot be used as a very accurate guide in determining the amount of fertilizer to apply, but they are suggestive of the differences that exist in nutrient content among crops. It is revealing to calculate the amounts of nutrients being removed per rotation and compare this with the nutrients being added. Corn, for example, is a crop which removes large quantities of nitrogen in relation to the phosphorus and potassium. This nitrogen must come from the soil, or from fertilizer.

Table 4-1. Amounts of plant nutrients removed per acre by certain crops

Crop	Yield/Acre	N in Lbs.	P_2O_5 in Lbs.	K_2O in Lbs.
Corn				
grain	100 bu.	90	35	25
stover	3 tons	60	25	95
Cotton				
lint	500 lbs.	1.4	0.5	3
seed	1,000 lbs.	35	15	15
plants	2,000 lbs.	40	15	25
Wheat				
grain	40 bu.	50	15	25
straw	2 tons	20	6	40
Clover	2 tons	100	15	80
Alfalfa	4 tons	180	40	180

Source: Tisdale and Nelson, Soil Fertility and Fertilizers (New York: Macmillan, 1961).

Much potassium is contained in the stover, and if corn is harvested for silage or the stover is used for cooking and baking, large quantities of this element will be removed.

Variety-Fertility Interactions

In Egypt a number of workers have demonstrated that some varieties of crops respond differently from others to plant-nutrient applications. In general, varieties which have a small range of adaptation tend to show significant variety-fertility interactions while those with a wide range of adaptation do not. The IR-8, referred to earlier, seems to be an exception. In this case the lack of sensitivity to hours of daylight seems to be an inherited characteristic which permits this variety to be highly productive over a wide geographic area, and at the same time to be responsive to fertilizer. Perhaps, similar developments in other crops can broaden the range of adaptation.

As early as 1942 the Egyptian Ministry of Agriculture was recommending varieties of corn and rice on the basis of the fertility level of the soil. The varieties which were recommended for poor soils were entirely different from those suggested for the more fertile soils. But now the trend is to supply adequate plant nutrients on the low fertility soils, so that the recommendations for new varieties or hybrids do not need to be geared to the fertility level of the soil.

Results of rice variety trials conducted in India in the 1966 kharif season under auspices of the Indian Council of Agricultural Research with the Rockefeller Foundation cooperating are shown in Table 4-2 for two levels of nitrogen application. In these trials, conducted in all areas of India, local Indica varieties not only had appreciably lower yields than did new Dwarf India and Ponlai varieties, but also demonstrated an appreciably lower response to fertilizers. In applications of nitrogen up to 50 kilograms per hectare, the response of improved varieties exceeded that of local varieties by more than 10 units of grain per unit of fertilizer used. This suggests a total response ratio of

Table 4-2. Summary of yields of specified rice varieties in the Uniform Variety Trials, Khariff, 1966

Variety	Number of Locations Reporting	Yields of Grain with Nitrogen Applied at		
		50 Kg/Ha	100 Kg/Ha	Difference
Dwarf Indica	20	3,603	4,819	716
Ponlai	20	3,344	3,947	603
Local Indica	14	2,884	3,167	283

Source: U.S.D.A., Accelerating India's Food Grain Production, 1967-68 to 1970-71, Foreign Agricultural Economic Report No. 40.

more than 20 to 1 for the improved varieties, for this range of nitrogen application.

Also the new Mexican wheat varieties have a much higher fertilizer response coefficient than traditional varieties. "Fertilizer use for the Mexican varieties exceeded that for the Indian varieties by about 48 pounds per acre; average yield of the Mexican wheat was 2,070 pounds higher. Thus, the Mexican varieties yielded about 44 pounds of grain per additional pound of fertilizer."[1] Still another example is the combination of wheat and rye varieties into what are called the triticales, a new and exciting man-made species.

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[1]U.S.D.A., Accelerating India's Food Production, 1967-68 to 1970-71, Foreign Agricultural Economic Report No. 40.

The work of an F.A.O. rice expert in Egypt over the period 1953-58 has been exceptionally successful, even though rice yields were already high in Egypt. Outstanding varieties were brought in from other parts of the world; japonica and indica types of rice were crossed with the aim of creating a variety which combined the qualities of responsiveness to fertilizers and high potential yield of the former with the adaptability of the latter to the environmental conditions of the U.A.R. At the same time as these varieties were used, the cultivation and fertilizer practices were improved, with the result that the yield per hectare have been increased from 3.67 tons prewar to 5.2 tons in 1957-59 (41 percent). Total rice production in Egypt expanded from 650,000 tons to 1,800,000 tons from 1957-1965. A. Mosher[1] states that the addition of fertilizer is usually necessary for any substantial increase in crop yield. But the full increase that might be brought about by fertilizer cannot be realized without introducing or breeding new fertilizer responsive strains of crops. A different strain of plant is needed to make full use of additional fertilizer.

The superiority of these varieties over traditional ones is so pronounced that they are becoming an "engine of change" in rural areas; they are altering cultural practices,

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[1]A. Mosher, Getting Agriculture Moving (New York: Frederick A. Praeger Publishers, 1965).

the level and pattern of inputs used, cropping patterns, and the index of multiple cropping. To produce their high yields, the new seeds require far more fertilizer than traditional varieties can absorb. Fertilizer, inducing a demand for it, supplying it, teaching farmers to use it and putting it to work is one key to the Green Revolution.

It is clear that, in the short run, the greater responsiveness of the new varieties increases the profitability of fertilizer use and the demand for fertilizer, above what otherwise would have been, assuming no changes in factor and product prices. Over the longer run, two other possibilities need to be understood. First, the demand for fertilizer could be lower than otherwise since less fertilizer but applied only to highly responsive varieties would be required to achieve the previous (any given) level of food grain production, and if production exceeded this level, product prices would decline, thus discouraging the use of fertilizer on traditional and perhaps reducing the use on new varieties from what it otherwise would be. Second, and most probably, the increase in population requires an increase in production in Egypt (and elsewhere) so that both improved varieties and an increase in fertilizer is necessary to prevent relative increases in the prices of food grains. Thus, Egypt probably faces a continuing fertilizer deficit, requiring inputs, unless new plant construction is accelerated in the next few years.

But, as J. W. Mellor states, fertilizer and improved seed are more than just another improved technology; they are the two most important inputs in the modernization of agriculture.[1] They may play a critical role as a catalyst in an agricultural revolution, causing the farmers to break with tradition and to reconsider all of their present agricultural practices. But the new technology also requires a high level of performance within the infrastructure institutions serving agriculture. Some lags, however, occur for natural reasons.

The production of seed is characterized by an inflexible time lag, at least four years in the case of hybrid corn production. A second important feature of seed production is the necessity of performing technical tasks, such as detasseling of corn, roguing of cereals, and pruning of vegetables, at definite times during the growing season. Governmental agencies in Egypt have not been successful in producing and selling seed due to the critical timing involved in performing these tasks. The seasonal nature of the job, with the corresponding necessity of long hours and solid work peaks during these periods, is not compatible with the operations of a typical public agency. Other problems with government monopoly in seed production are inadequate inspection and the normal anonymity of government seed

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[1]J. W. Mellor, The Economics of Agricultural Development (Ithaca, New York: Cornell University Press, 1966).

producers which protects those government producers who are doing an inefficient job from being discriminated against by the Egyptian farmers.[1]

The critical problem in the production of improved seeds is the maintenance of purity. In general, seed of improved varieties does not differ in appearance from local varieties of seed, so that what is sold as improved seed may in fact be no better than the local varieties either because of fraud or, more likely, simply because the seed was not produced under tightly controlled conditions. This accounts for a good deal of the reluctance of Egyptian farmers to accept improved seed and the common failure when they do accept it.

Environmental

Environment is defined as the "aggregate of all the external conditions and influences affecting fertilizer efficiency." Of the environmental factors known to influence the efficient use of fertilizer, the following are probably the most relevant for our purpose: (1) Moisture supply, (2) Mechanization, (3) Biotic factors, (4) Mineral-nutrient balance, and (5) Interdependence among inputs.

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[1]G. Saab indicates that losses due to insufficient use of selected seed are estimated at about 10 million Egyptian pounds a year. G. Saab, "Nationalization of Agriculture and Land Tenure Problems in Egypt" (M.E. Econ. paper, American University Beirut, 1960).

Moisture Supply

It has been observed that absorption of nitrogen and potassium by plant is reduced by high moisture tensions, and utilization of applied fertilizers depends largely upon an adequate moisture supply.[1] These points are of particular importance in the consideration of fertilizer use in any balanced farm program in Egypt, for the application of fertilizer at rates inconsistent with the supply of available moisture is unwise and uneconomical. The converse is also true, for under conditions of excessive use of irrigation water on sandy soils that are subject to excessive leaching, the fertilizer applied may be removed in drainage waters before being used by the plants unless applied properly and in correct quantites.[2]

But this is not the simple matter of using less water since Nile water used for irrigation contains soluble salts, which become concentrated in the soil by evaporation and transpiration. To keep the salts in the soil solution from becoming so concentrated that they hurt crop growth,

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[1] Issawi states in his book Egypt in Revolution that experiments have shown that optimum yields are obtained by applying only 60 percent of the quantity of water generally used; the losses caused by the rise in the water table have been estimated at 40 million Egyptian pounds a year.

[2] Dr. M. Y. Elshawarbi argues that fertilizers should be applied 24 hours after irrigation on sandy soils. But, as Dr. R. Cook, head of soil science at M.S.U., points out, the new technology of using asphalt makes sandy soils less subject to leaching and water loss.

excess water must pass through the root zone and flush away, or leach out, soluble salts.

Crops may be affected in a number of ways by high water tables or excess soil moisture.[1] Some affect root development--aeration and temperature of the soil, nutrient uptake, and plant disease. Salinity problems may also develop and affect crop growth in the arid Egyptian soils where water tables are just under the surface. The roots of most cultivated crops will not penetrate saturated soil areas.

> The need for drainage was realized only after the First World War, when with the spread of perennial irrigation, it was perceived that the absence of drains was responsible for the accumulation of salts in the soil, thus diminishing its effective fertility, and for raising the level of the underground water table, which chokes the long cotton roots. Even today there is little doubt that the Egyptian farmer tends to be extravagant in his irrigation and that more economy would both raise yields and save water. During the last thirty-five years much work has been done in this field and Egypt is now provided with 13,000 kilometers of drains. Most of the land is still drained by free flow, but 1 million feddans in lower Egypt and 200,000 in Upper Egypt are served by lift drainage.[2]

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[1] The fact that well-drained soils warm up faster than saturated soils is of vital importance in the early planting of cotton in the first half of February. Early planted cotton escapes the damaging effect of aphids and boll worms late in the season.

[2] C. Issawi, Egypt in Revolution (London, New York: Oxford University Press, 1962).

Nevertheless, drainage is still a great weakness. Main drains are available everywhere, but they need deepening and more pumps, while field drains are inadequate, owing to the high cost of the land they occupy, and the difficulty in connecting with the main collectors through neighboring plots. Hence, since 1933, experiments have been made with pipe drainage, which at present serves 388,000 feddans. This system has raised yields by 32 to 75 percent, made it possible to shift from maize to cotton, reduced salinity and economized water; it also requires less upkeep. The replacement of field by pipe drains would save the estimated 750,000 feddans that open field drains now occupy.[1]

D. Mead states that the length of the canals and drains in the country has risen since the 1930's at a faster rate than that of cultivated areas, even slightly faster than the increase in the cropped area (Table 4-3).

But this rate of increase in drains does not seem to be high enough to alleviate the drainage problem that has been increasing year after year in Lower and Middle Egypt.[2] Drainage projects have considerable potential, and though less spectacular than the High Dam, they may, at less cost, make a significant contribution to production.

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[1]Closed drains for both field drainage and the collectors result in a saving of about 12 percent of the land drained, and the value of the land thus saved is greater than the total cost of the drainage system.

[2]Mosquitos and some disease problems in Egypt may be related to poor drainage.

Table 4-3. Length of canals and drains in Egypt, 1913-1960 (kilometers)

Year	Canals	Drains	Total	Crop Area in Acres
1913	24,496	5,926	30,422	7,662
1917	18,634	6,290	24,924	7,677
1927	18,711	7,088	25,799	8,661
1937	20,170	9,168	29,338	8,358
1947	22,073	12,064	34,137	9,230
1954	23,471	12,316	35,787	9,966
1960	24,804	13,330	38,134	10,370

Source: Reproduced from Mead, Growth and Structural Change in the Egyptian Economy (Homewood, Illinois: Irwin Press, 1967).

Mechanization

Agricultural machinery is generally thought of in connection with the more efficient use of labor rather than as a yield-raising input. There are a number of ways in which increased power and more efficient machinery can contribute to better fertilizer use. One of the most important of these is seedbed preparation, which requires a higher energy input than any other operation.

Another way in which power can improve crop response to fertilizer is in timely seedbed preparation. It has been estimated that there is, in general, a loss in yield for many crops of about 1 percent per day if seeding is delayed beyond the optimum period of ten to fifteen days. In many cases, rapid seedbed preparation by mechanical methods makes double or triple cropping feasible (i.e., increases the crop index from 1.75 to 2 or 3), where is otherwise would not be possible.

The extent to which accuracy in the placement of seed and fertilizer can increase yields is not generally realized. Tests conducted in India showed that yields of corn increased 40 percent over conventional practices through the use of an efficient machine which placed the seed at the right depth in properly spaced rows and simultaneously added fertilizer.[1]

Increased power can also improve yields by facilitating more efficient and timely harvesting and threshing. An experiment at Gemeza in Lower Egypt has shown that the yield of long-grain paddy decreases 2 percent for every day the harvest is postponed after the grain is ripe.

Tractors also can be used for such purposes as erosion control by more effective bunding and countour plowing, for the transport of soil, as well as crops. Still more important, tractors enable the farmer to break difficult soils or to eradicate (by repeated deep plowing) weeds that cannot be eliminated by hand or by the traditional wooden plow drawn by bullocks. Tractors are indispensable as instruments to reclaim hitherto unusable land and to extend the margin of cultivation.

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[1]Alahabad Agricultural Institute, Agricultural Implements and Power Development Center, Progress Report No. Alahabad, March 1966.

Other effects of mechanization in Egypt are the release of land which would otherwise be put under fodder crops for draft animals; speedier reclamation of uncultivated land; and the decreased supply of manure.

In recent years the number of tractors has risen sharply, from 1,200 in 1939 and 3,000 in 1945 to 7,600 in 1952 and 10,100 with an aggregate h.p. of 328,000 in 1960. Still in 1960 the number of horsepower of licensed machinery per working person was 0.1, while the number of horsepower per cultivated acre is as low as 0.05. The expansion in machinery is to a large extent concentrated on the big estates, the cooperatives, and Tahrir province, where newly reclaimed desert-land is cultivated by capital intensive methods. Agriculture in general, the great majority of small holdings outside the land-reform areas, is therefore still unaffected by the increased use of machinery for field operations. It is estimated that "about 10 percent of the crop is lost through hand and animal harvesting and threshing."[1]

Government policy now is to push new techniques and mechanized cultivation as far as possible in the hope that the use of tractors would release animals from draft work and encourage farmers to breed cattle for the production of meat and dairy products. But there are continual complaints

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[1]Report of the Sub-Committee on Agriculture, National Planning Commission, Cairo, 1960. (In Arabic.)

about delays in deliveries and difficulties in getting spare parts, and quality (from some Eastern Bloc countries) is often bad; but on the whole such shortages seem to be due to "red tape" rather than to conscious Government policies.

Maintenance is a bottleneck that must be broken before any degree of mechanization becomes possible. Repair facilities usually do not exist; the supply of parts is erratic; mechanics are scarce; and, perhaps most important, Egyptian farmers have not grown up around machines and therefore do not understand such requirements as oiling that are familiar to people from mechanized cultures. Under these circumstances the life of the machine in Egypt will continue to be short, as it is today. The proportion of some major items of farm machinery out of use awaiting repair range from one-fourth to one-half the total stock.

The present policy of pushing mechanization does not appear to be based upon a proper analysis of the costs and benefits involved.

The cheapness of labor and the skill of the farmer with his traditional instruments have held up the use of machinery. Further obstacles are very small size of individual plots and the planting of many different crops over a small area, the poverty of the farmers, the financial weakness of cooperatives, the fact that the fields are cut into small patches by canals and drains and are not always accessible by road, the lack of nearby repair shops, and the nature of cotton which does not lend itself to mechanization.

Biotic Factors

One important aspect of disease, related to fertilization, is that a plant in a state of balanced and adequate nutrition is usually more vigorous and hence more resistant to certain diseases, but other biotic factors also may limit plant growth. These factors present a constant hazard to farming operations in Egypt and constitute a potential threat in reduced crop yields, if not a complete crop failure. Heavier fertilization may encourage greater vegetative growth and create better environmental conditions for certain disease organisms. For example, in lower Egypt heavy rates of nitrogen on wheat or onions may encourage greater infestation of mildew, but the increased yields usually offset any detrimental effect of the mildew. Certain pests may increase the fertilizer requirement by the plant. Root knot nematode attacks the roots of certain crops and impairs the absorbing mechanism, and this necessitates a greater concentration of nutrient elements in the soil to provide reasonable growth.

The breeding and use of disease resistant varieties or hybrids may increase the responses from adequate fertilization, and such efforts now are a common part of genetic experiments conducted at the three colleges of agriculture and Ministry of Agriculture as well.

Closely allied with disease is the problem of insects. As with disease, a vigorously growing plant may be able to withstand a mild insect infestation, but heavier fertilization may encourage certain insects through greater vegetative growth. The cotton boll weevil and leaf worm are examples.

Practical experience has shown that the use of chemical pesticides needs to increase very rapidly as plant production is intensified. This observation in Egypt is supported by technical studies at the I.R.R.I. in the Philippines. Multicropping provides a year-round supply of plant life for disease and pests.

Accurate estimates of the direct loss of crops as a result of pests in Egypt have been impossible, but are known to be large, with minimum estimates of losses ranging from 25 percent to 35 percent of the total crop produced. Highly germane in planning for increases agricultural production is the extensive and convincing evidence that pest problems are intensified as yields are increased through the use of more fertilizer, better seed, better water management, and other modern production practices. If the maximum benefits are to be obtained from a system employing these production inputs, effective crop protection methods must be a part of the system.

The disastrous attack of the cotton-leaf worm in 1961, a major factor in reducing the crop by some 34 percent compared with 1960, also shows that much remains to be done in this field. In a symposium on the causes of the crop failure of 1961 the following reasons were given: failure of the Ministry of Agriculture to provide enough pesticides;

inadequate distribution by Agricultural Bank; insufficient cooperation of farmers with the authorities; and unfavorable climatic conditions.

B. Hansen indicates that insecticides, pesticides and weedicides are of great importance for the yield of crops in Egypt, and available statistics show a sharp increase in their use. While the total value of such chemicals was only about 0.1 million Egyptian pounds at the beginning of the fifties, it rose to 1.8 million Egyptian pounds in 1957. However, they are still used in rather limited quantities.[1]

Pest control is a "late" input. The return on investment in pesticides is likely to rise rapidly after the other inputs are in use; and is likely to be an indispensable input in a package providing for intensive cultivation.

Mineral-Nutrient Balance

Plants, like man, demand a balanced diet. The proper functioning of any one nutrient in plant nutrition requires that the other essential elements be present in adequate supply. If the supply of one or more of them is inadequate, the addition of much nitrogen, for example, to most of the common crops may produce limited and abnormal growth. Such plants often are unusually susceptible to diseases, and mature late. But if the nutrient balance and

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[1]B. Hansen, Development and Economic Policy (Amsterdam: North Holland Publishing Company, 1965).

total supply have been adequate from the seedling stage, plants throughout show the stock growth and dark green foliage that is a mark of health and vigor.

Likewise, maximum benefits from maintaining a high phosphate fertility level are not realized unless other nutrients are supplied at proper levels. Many experiments in Egypt show that only with adequate levels of nitrogen and potassium will the plant utilize high levels of available phosphorus. F. Elebrashy found no effect from phosphorus alone on corn yields, but phosphorus increased the yield 10.2 bushels when nitrogen was added.[1]

But in situations of high available levels of potassium and low nitrogen or phosphorus supply, "luxury consumption" of potassium is to be expected. (This term means that plants will continue to absorb an element in amounts in excess of that required for optimum growth.) This results in an accumulation of the element in the plant without a corresponding increase in growth. It represents, in other words, inefficient and noneconomical use of that particular element, because limited amounts of other minerals are available.

Interdependence Among Inputs

A progressive, high-productivity agriculture utilizes a wide range of inputs, many of which are highly

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[1] F. Elebrashy, "Corn Fertilization," Agricultural Magazine, September 1962.

complementary to each other. These inputs include a number traditional to economic analysis, such as land, unskilled labor, and certain forms of capital. Other complementary inputs represent forms less traditionally noted by economists. These are usually of a technical, educational, and institutional sort. Inputs characteristics of a modern agriculture have a number of features in common. First, they tend to be purchased off the farm which simply means that they are more cheaply produced under specialized, relatively large-scale production conditions.

With development, Egyptian farms depend less on organic fertilizer and abandon home-produced seed and simple tools, and use purchased improved seed, inorganic fertilizers and other chemicals and complex mechanical tools and equipment. An increase in off-farm purchases, which pull the farmer into the market economy, has a number of important ramifications for development policy. It increases his perceived risks, it increases cash needs and possibly credit needs, and it provides pressure for increased marketing.

Second, the off-farm inputs tend to be the product of research and to embody technological changes. These inputs may thus experience rising productivity and declining per unit cost. They are, however, unlikely to be used widely unless they are supported by a substantial applied research program and an informational service carrying new knowledge to farmers.

Third, they tend to have a low capital cost and to be used for a relatively short production span. In other words, they tend to be represented by variable costs rather than fixed costs (though this is an empirical rather than a conceptual generalization). Related to this, they tend to be highly divisible so that problems of lumpiness of investment do not arise. This means that a farmer may buy them with a very small capital investment by using them at low levels of intensity or on only part of the farm. This reduces the immediate capital and credit needs and also reduces the danger from risk. However, the capital they do use may be largely represented by high opportunity cost foreign exchange, industrial resources, and trained manpower. Also one could argue that they often tend to be associated together, so that if a farmer uses one, he should use several, and this does create a type of lumpiness of investment (including this knowledge about these interrelationships).

Fourth, most of these inputs increase production and efficiency through a direct effect on the level of crop yields. Hence, in this respect, their use is directly consistent with usual development objectives and resource availabilities.

The interdependencies among inputs are so strong that the effects of a package of factors are likely to be very different from the sum of the effects of each one applied by itself. Because of the intimate way in which different farm practices interact in affecting yields, it

frequently is desirable to introduce several changes of technology simultaneously. In some cases, only a whole package of new techniques can achieve such dramatic results.

Since a given technical improvement will be really remunerative only if other improvements are instituted at the same time, it seems inevitable that progress will be slow. This conclusion is reinforced if we consider the inherited agrarian structure and the attitudes fostered within that structure.

The interdependence of the factors affecting the farm enterprise has profound and general implications for the organization of programs for the promotion of agricultural productivity. G. Myrdal emphasizes the fact that a simultaneous change in almost all agricultural practices is needed for maximum results, or sometimes for any results at all, and this has serious implications for agricultural productivity.[1] He also adds that fertilizers, like other agricultural aids, will yield maximum results only if applied in the context of an overall improvement in farming methods.

Inorganic fertilizers by themselves often offer little prospect for significant aggregate impact on production within the context of Egyptian agriculture. This follows from the small absorption capacity and relatively low productivity of fertilizers when other aspects of

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[1] G. Myrdal, Asian Drama, Vol. II: An Inquiry Into the Poverty of Nations (New York: Panthean, 1968).

cultivation are held constant and from the small initial base of consumption. Huge increases in the use of inorganic fertilizers generally is a necessary condition of a technologically developed agriculture, but the striking effect from fertilizer comes only when (a) the level of use has been raised to a substantial absolute amount, (b) the rate of growth from that substantial base is rapid, and (c) most important, the productivity of fertilizer application is being rapidly raised by introduction of new production process through other technological and managerial advances.

If resources are highly complementary, existence of certain resources in very large quantity and of others in very small quantity will normally result in low marginal productivities of the abundant resources. Likewise, total output will remain at a low level as long as the availability and use of any of the complementary resources remain severely limited.

The peculiar position of agriculture in Egypt arises from the fact that many of the inputs requisite to high levels of productivity are available in very large quantity relative to other inputs to which they are complementary. The result is either use of the abundant resources at very low and even zero levels of marginal productivity and a withholding of scarce resources from production. Under such circumstances significant increases in production can only be obtained by increased input of a particular set of scarce resources.

The proper proportions of each of the inputs, of course, will vary with the specific situation under which plants are grown.

A. Mosher states that each item of supplies or equipment must have five qualities if farmers are to buy it and keep on buying it year after year.[1]

1. It must be technically effective.
2. It must be of dependable quality.
3. The price must be reasonable.
4. It must be available locally precisely when farmers need to use it.
5. It must be offered for sale in appropriate sizes or amounts.

He also adds that if the yield is higher, but the growing period is different, using this new variety or fertilizer may interfere with the cultivation of other crops or it may expose the farmer's crop to unusual damage by birds because his crop ripens at a different time from that of his neighbors.

Given the availability of inputs needed to improve technology and a sufficient final demand for increased output, how rapidly farmers will adopt the improved technology

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[1] A. Mosher, Getting Agriculture Moving (New York Frederick A. Praeger Publishers, 1965).

depends upon additional factors. Efficient sources of production credit may be important in enabling more rapid adoption by farmers of new technology that requires use of purchased inputs. Equally important is an organization of production that both permits and gives incentives to producers to increase their input.

Such issues now need to be examined.

CHAPTER V

ECONOMIC AND MANAGERIAL FACTORS AFFECTING DECISIONS ON FERTILIZER USE

"Economists, its plain to see
All think that prices are the key
For no economy will grow
With inputs high and outputs low."

K. Boulding

This chapter examines the role of management in making basic decisions that affect fertilizer use, the economic tools used by managers in their decision making and the environment in which these decisions are made. The complex of physical and biological factors characteristic of Egyptian agriculture makes it clear that new combinations of practices must be used, partly to adjust to recent and current changes in the irrigation environment, and partly to attain the full benefits from new crop varieties.

Change makes management necessary. If the future and technical coefficients were known, the entrepreneur would have little or no role to play. The essence of management, then, is the willingness to take risks, the ability to adjust factors of production, the determination of the level of production, and the decision as to the proportion of the goods and services to produce to anticipated conditions of the economy.

Contrary to the popular view, the historical record clearly shows that rapid change has characterized Egyptian agriculture in recent years. For the future, it appears certain that even more change is likely to occur. The magnitude of the underlying forces that affect both supply and demand conditions for agricultural commodities has not remained, and will not remain, constant.

Decision Making

Decision making is the core of the management process which is as old as civilization.

Ideally, the farm operator, not the production specialist or economist, should make the choice of the types and combinations of production factors or practices to be employed, as well as the types and amounts of products to be produced. He must make these selections in terms of his capital, his ability to withstand risks, the nature of his resources, and the family's goal as a consuming unit. The production specialist, or the economist, cannot supply a single "best answer" to a production problem since he cannot know in detail the technical possibilities and the goals of a firm-household combination.

It is possible to make some decisions for Egyptian farmers by administrative decree, but there are very narrow limits to what can be accomplished by this means. The enormous variations among farm units in soil, micro-climate, and local price relationships and the multitude of unpredictable problems arising from pests, disease, government actions and policies, and weather require, even in socialist and other planned economies, that many decisions be left to individual farm operators. Thus, the management function cannot efficiently be highly centralized but must remain flexible to deal with the peculiarities of current local situations. Society can affect the management process favorably through programs to provide knowledge, speed up learning and reduce risk and uncertainty (i.e., reduce the perceived price variability, reduce input costs, etc.). Government programs can often have the greatest impact when they support and reinforce, rather than supplant, the initiative and efforts of a nation's farmer.

Egyptian farmers have three basic decisions to make in their use of fertilizer: (1) the crops and the amounts of fertilizer to use per acre, (2) the cropping system, and (3) the form and source of nutrients.[1] The choices among alternatives in these three areas of decision making involve both agronomic and economic information. Agronomic information is necessary as a basis for determining the physical input-output, or response quantities, associated with fertilizer applied in different amounts, in different forms,

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[1]See Appendix for the discussion on the cropping system and the form and source of nutrients.

and by alternative methods on different crops. The economic principles are quite sterile without the response data to go with it. However, agronomic data alone do not provide the basis for efficient fertilizer use. These data must be combined with the correct economic principle if fertilizer is to be used in making the greatest contribution to farm profits and family living levels. Even though agronomic research provides precise knowledge of the responses expected from fertilizer on a particular soil, the optimum usage of fertilizer still depends on economic considerations. The optimum amount and kind of fertilizer to be used will differ between points in time and among farms having the same soil and response function. It would depend on the amount of capital available, the leasing system, the ability of the operator to shoulder risks, and uncertainties and variations in fertilizer and crop prices.

Thus, at each point of decision, the farmer must apply (implicitly) economic principles and information in the selection of a fertilization plan which is integrated into the profit maximization goal of the entire farm.

Planning What Crops to Fertilize and the Amounts of Fertilizer to Use

Three economic principles are especially important in deciding what crops to fertilize and when and how much fertilizer to use: (1) The substitution principle for deciding what combination of elements to use, or how far, for example, the farmer should substitute commercial fertilizer for legumes or barnyard manure and vice versa. (2) The opportunity cost principle. (3) The added cost--added return principle--the principle of diminishing returns and marginal costs--for deciding how much fertilizer to apply if the operator has unlimited capital.[1]

1. <u>The substitution principle</u>.--In deciding whether to substitute fertilizer for legumes in a rotation, one has to consider the nature of the soil and type of farming. Soil test summaries are very effective in illustrating the influence of legumes, forage crops, and barnyard manure on the status of soil fertility. The use of such summaries in research and extension programs should be helpful in formulating an approach to the problem of cropping and crop substitution as related to fertility requirements and maintenance.

Legumes may be the most satisfactory source of nitrogen, if the farmer is short of ready cash and may not have the money to pay for commercial nitrogen.[2] Too, at certain times commercial nitrogen is not available. In such a situation, a well-planned cropping system including legumes is

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[1]In essence, all are comparisons of marginal value product and marginal costs.

[2]F. E. Allison states in his article, "Nitrogen and Soil Fertility," U.S.D.A., <u>Yearbook 1957</u>, that legumes may fix 200 pounds of N an acre each year if effective strains of the proper rootnodule bacteria are present in the soil or are added to the seed as commercial innoculants.

essential to supply the nitrogen needed for growth of the nonlegumes. But it should be noted that the use of green manure is not a profitable practice at the present fertilizer crop price ratio, nor where there is a shortage of water.

Where legumes are used for forage in a livestock system of farming, the problem is different. The legumes serve the dual purpose of feed for livestock and a source of nitrogen for the grain crops. In such a system, legumes are generally essential. An alternative is to grow grass and use heavy applications of nitrogen. And, as pointed out before, Egyptian soils need certain types of cropping to maintain physical condition that will permit profitable response from fertilizer. The structure of the sandy and heavy clay soils require occasional legumes and grasses to keep them in good tilth.

2. The opportunity cost principle.--With respect to decisions on the crops to be fertilized, the farmer must select those crops which will give the greatest return from fertilization of specific crops to the return from the same capital used for livestock enterprises, or other investment opportunities within the farm business. This could be expressed in the following simple equation:

$$\frac{MVP_{xi(Y_1)}}{P_{xi}} = \frac{MVP_{xi(Y_2)}}{P_{xi}} = \frac{MVP_{xi(Y_j)}}{P_{xi}} = 1$$

(x_i are variable resources, x_1 to x_d used in the production of any number of crops or enterprises from Y_1 to Y_j).

In considering whether or not to substitute one crop for another, each farmer considers how it will fit in with his other crops. If a new variety of rice promises a 15 percent increase in yield but requires a twenty-day longer growing period, a farmer may reject it because it will prevent his planting the succeeding crop on time. He may likewise continue to grow a crop that does not seem very profitable considered by itself provided it fits well into his cropping system.

Risk aversion, an unwillingness to depend on the market as a source of corn for the family consumption may favor corn even when its monetary return seems to make it a less desirable choice. Thus, it is apparent that the role of management in planning farms for optimum fertilizer use involves the whole farm business family complex, tying all resources together, learning how the amount of one affects the productivity of the other and then deciding on the most profitable combination for the entire farm unit.

3. <u>Marginal cost-marginal revenue principle</u>.--It is apparent that equating marginal costs with marginal revenue, or marginal value product of the fertilizer with its price, is not a simple task for the Egyptian farmer. The production economist would even find it difficult to make such estimates because data are confused, inaccurate, and also because of the complex of the factors that influence yield.

Many natural factors and many management practices influence yield response and modify the operation of the above economic principles. Internal and external capital rationing,[1] and risk and uncertainty as to returns from an application of fertilizer keep Egyptian farmers from applying as much fertilizer as would be profitable (the optimum) if there were no uncertainties as to the result. Also, the cropping systems, inadequate information, and modifications in economic incentives and noneconomic influences might affect the environment which the economic theory has to function, and perhaps fail to be fully implemented.

Residual responses may also bring up important questions of proper fertilization rates on tenant farms. The best rate of application for a tenant who will move at the end of the year and get no return from the residual response is lighter than for the owner who will stay on his farm or for the tenant who knows he will be on the land for a long time. Thus, land tenure influences the decision of farm operators in a number of ways. The best fertilizer combination or the best rate of applying fertilizer will differ between owner-operated farms and rented farms, depending on the lease arrangement. If the lease is a cash contract, the

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[1]Because Egyptian farmers are short for cash and in debt most of the time and also have large families to support, they are likely to be under heavy pressure for immediate income. Then farm programs may include exploitive fertilization practices that will increase income now with a sacrifice of productivity in the future.

tenant's most profitable level of fertilization will be the same as for an owner-operator.

It can be shown that a tenant farmer paying all the costs of fertilization but getting only a share of the yields should not apply as much fertilizer for maximum profits as an owner or cash tenant.

Method of Analysis

The optimum or most profitable level of fertilization as farmers seek to maximize profits--in a decision-making environment of unlimited capital--is defined by the equation $\frac{dY}{dx} = \frac{Px}{Py}$ where the term to the left of the equality is the marginal yield or response and the term to the right is the price ratio (price per unit of fertilizer divided by the price per unit of output). The marginal yield is the derivative of yield in respect to nutrient; it is the slope of the response function for any particular input level.

It is obvious that the most profitable level of fertilization changes as the term to the right of the equality changes. (Likewise the optimum level of fertilization will change for the limited-capital farmer, as the price of the crop, fertilizer, or any other product or resouce for his farm changes.) How much change needs to be made in fertilizer use, as prices change, depends on the slope of the response function.

The above equation with a schedule of marginal physical product of any crop, could be used as a tool in finding the most profitable rate of fertilizer application. This could be done by dividing the cost of a unit of fertilizer (one kilo for example) by the price of one kilo of cotton; i.e., find out how many kilos of the crop could buy one kilo of the fertilizer (price ratios are presented in Table 5-9), then compare the marginal physical product as shown in Table 5-1 with the price ratio. The optimum amount of fertilizer in the case of "poor" light soils is 45 kilos and for the "rich" clay soil is at least 60 kilos of N.

Table 5-1. Average response of cotton in kilos per acre to one kilo of N at various levels of application, other yield influencing factors constant[a]

Soil Characteristics	At 15 Kilo Level	At Second 15 Kilo Level	At Third 15 Kilo Level	At Fourth 15 Kilo Level
"Poor" light soil	5.6	4.5	3.8	0.9
"Rich" clay soil	5.2	4.0	3.2	2.6

[a]Calculated from Table 5-2.

There are several methods which take into consideration both the cost of the nutrient and the price of the crop. In any case, the response of the crop in question to increasing rates of a nutrient must be known for the general soil condition. One method is shown in Table 5-3. The number of kilos of nitrogen required per bushel of corn for each 40 kilos increment of added fertilizer is first determined.

Table 5-2. The response of cotton to calcium nitrate on the Rodah and Mohamadiah farms and as calculated from equations

Experiment Location	N Fert. Added Kg.	Yield of Plots Lb/Plot 1	2	3	4	5	Average Yield Lb/Plot	Average Kintar/Fed.[a]	Calc. Yield Kintar/Fed.[a]
	0	18	11	17	18	18	16.4	3.47	3.67
	100	20	21	16	18	30	21.0	4.44	4.23
Rodah	200	28	20	27	16	24	23.0	4.86	4.68
	300	21	26	20	22	17	21.2	4.48	5.06
	400	16	23	29	25	30	24.6	5.20	5.15
	0	18	23	19	25	18	20.6	6.24	6.56
	100	26	25	21	31	16	23.8	7.22	7.08
Mohamadiah	200	29	29	20	20	28	25.2	7.65	7.48
	300	31	29	21	24	24	25.8	7.82	7.80
	400	27	27	26	27	24	26.2	7.94	8.06

Source: A. M. Balba, "Soils Department, University of Alexandria," Journal of Soil Science, The National Information and Documentation Centre, November 1964.

[a]One kintar equals 315 pounds; one feddan equals 1.03 acres.

Table 5-3. Quantity of nitrogen required for each bushel of corn as related to rate of applied nitrogen

Total N Applied (Kilos)	Additional N in Each Application (Kilos)	Additional Corn (Bu.) MPP	Quantities of N for Each Additional Bu. of Corn Addnl. N ÷ Addnl. Corn
0	..	..	....
40	40	26	1.54
80	40	20	2.00
120	40	11	3.64
160	40	5	6.67

When a bushel of corn costs approximately twice as much as a pound of nitrogen, the returns from the second 40 kilos increment of nitrogen will just pay for the nitrogen. The third 40 kilos increment is justified if the price of a bushel is 3.64 times the cost of a kilo of nitrogen. For example, with nitrogen at 15 piastres per kilo this increment would just pay for itself with corn at 55 piastres per bushel.[1]

The information in Table 5-4 was obtained by using the values from Table 5-3. This is helpful in determining the most profitable rate of nitrogen to apply to corn for any combination of costs and prices. For example, with a total application of 160 kilos of nitrogen (at 10 piastres per pound) the last 40 kilos application would just pay for itself with corn at 67 piastres per bushel. With nitrogen

[1]The Egyptian pound equals one hundred piastres.

Table 5-4. Price of corn necessary to pay for the nitrogen as related to cost of nitrogen

Cost of N per Kilo (piastres)	Price of Corn Necessary to Pay for the Last 40 Kilos			
	Levels of N Applied			
	40 Kilos N (piastres)	80 Kilos N (piastres)	120 Kilos N (piastres)	160 Kilos N (piastres)
8	12	16	29	53
10	15	20	36	67
12	18	24	44	80
14	22	28	51	93
15	23	30	55	100
16	25	32	58	107
18	28	36	66	120
20	31	40	73	133

at 18 piastres per kilo, however, the last 40 kilos addition would be profitable only if the value of corn were 120 piastres per bushel or more.

The cost of the nitrogen is plotted in terms of bushels of corn (C) (see Figure 5-1).

The area between the two curves, Y and C, are shown in Figure 5-1 represents the extra bushels of corn obtained from the fertilizer. The point at which the difference between the two curves is the greatest represents the point of maximum profit. The exact point (P) can be determined by drawing a line tangent to Y and parallel to C.

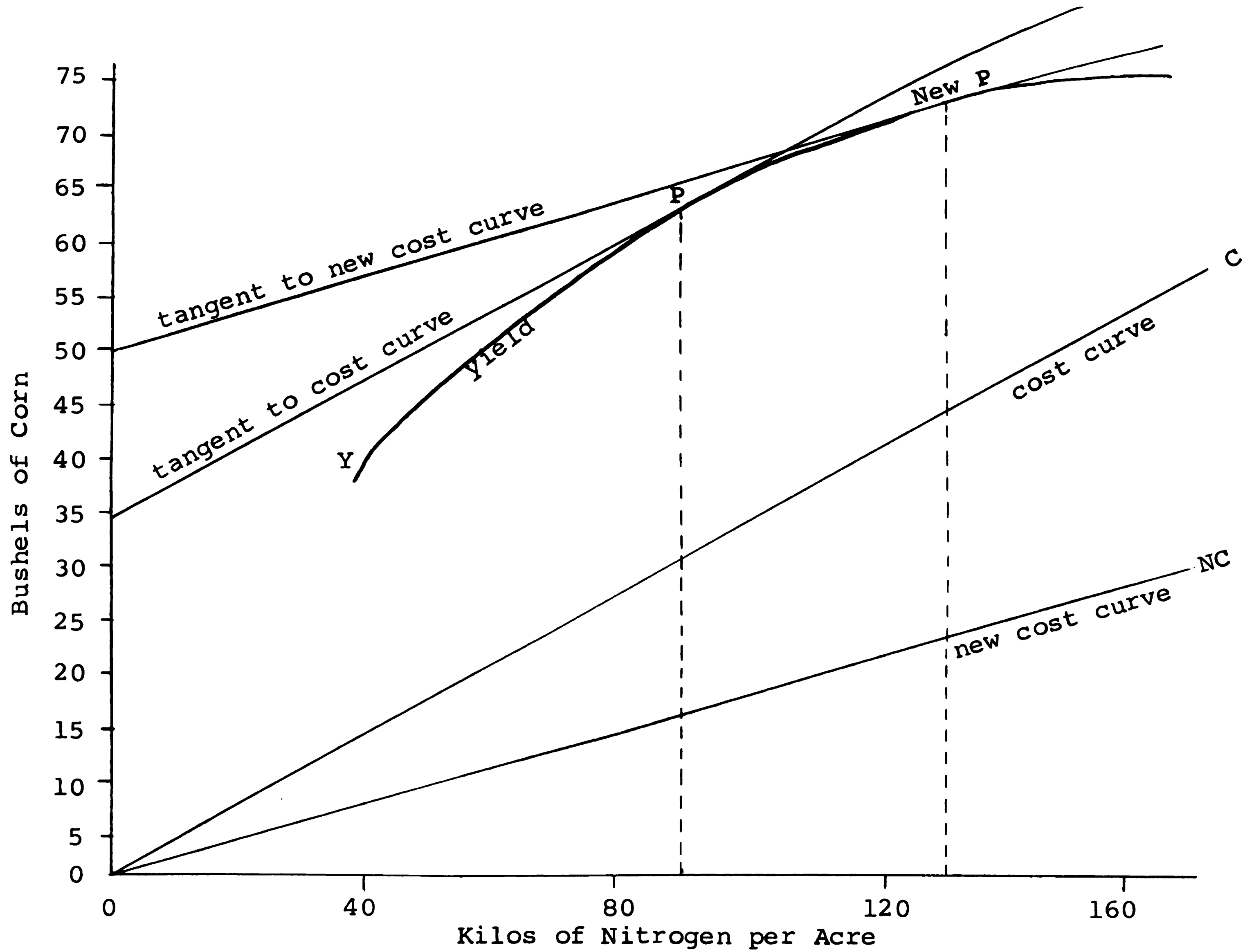

Figure 5-1. Optimum fertilizer use and profit maximization. (The cost of the fertilizer is shown in terms of bushels of corn. Only stage two of the normal production function is shown in the figure. When the price of corn went up the optimum rate of fertilization increased from 90 kilos of nitrogen to 130 kilos per acre. Everything else, including the price of the fertilizer, is kept constant.)

If the price of fertilizer or the expected crop prices change, the line representing the cost of fertilizer would be changed (NC in Fig. 5-1). For example, if the price of corn went up it would take fewer bushels to pay for 1,500 piasters worth of fertilizer. NC is the new cost line calculated on the basis of a higher price for corn, and since it is lower there is a greater spread between the Y and the NC line. A higher rate of nitrogen can then be used.

The hypothetical data for wheat shown in Table 5-5 illustrate how the optimum use of fertilizer changes with the change in the fertilizer prices, with everything else including the price of winter wheat kept constant. When the price of one kilo of nitrogen was 0.15 Egyptian pound the optimum rate of fertilization was 60 kilos of nitrogen per acre, but when the price of the fertilizer was reduced to 0.075 Egyptian pound the optimum rate went up to 90 kilos per acre.

To summarize, an increase in crop prices or a decrease in fertilizer price could be expected to increase fertilizer consumption.

One important problem that would confront us in our calculations here is the residual and cumulative effects upon the next crop that result from the use of commercial fertilizers and barnyard manure. Phosphatic fertilizers in particular are known to give substantial residual responses in certain areas. Repeated application of a single nutrient for a long period may, in some instances, gradually reduce

Table 5-5. Optimum use of nitrogen fertilizers for winter wheat

Rate of N (units per acre)	Response to N (in kilos)	Value of Response (in £.E.)[a]	Unsubsidized Fertilizer		Subsidized Fertilizer	
			Cost of N (£.E./acre)[b]	Profits from N Application (£.E./acre)[b]	Cost of N (£.E./acre)[c]	Profits from N Application (£.E./acre)
10	220	6.60	1.50	5.10	0.75	5.85
20	380	11.40	3.00	8.40	1.50	9.90
30	510	15.30	4.50	10.80	2.25	13.05
40	610	18.30	6.00	12.30	3.00	15.30
50	690	20.70	7.50	13.20	3.75	16.95
60	750	22.50	9.00	13.50	4.50	18.00
70	800	24.00	10.50	13.50	5.25	18.75
80	830	24.90	12.00	12.90	6.00	18.90
90	860	25.80	13.50	12.30	6.75	19.05
100	880	26.40	15.00	11.40	7.50	18.90

[a]Price of wheat is £.E. (Egyptian pound), 0.03/kilo.

[b]Price of N is £.E., 0.15/kilo.

[c]Assumed price of N is £.E., 0.075/kilo.

the response if other limiting factors come into operation. However, this requirement will be very difficult to apply with the paucity of Egyptian data on residual effects.

It should also be noted that results from experiment stations in Egypt are misleading. The fact that a certain fertilizer gives a substantial increase in yields on an experiment station does not necessarily mean that it will be profitable on farmers' fields. First, the basic physical conditions on the experiment station may be like those of only the immediately surrounding areas. Second, on an experiment station, practices and levels of other inputs may be such that they cannot be economically duplicated on farmers' fields. Third, there is a tendency for experiment stations to measure success in terms only of physical response, whereas the farmer is more concerned with returns above all costs, including discounts for risk and uncertainty. Fourth, Egyptian scientists are handicapped by the great shortage of resources necessary for conducting scientific experiments. Most of the experiments mentioned here are conservative in nature, lack concise measurements and do not cover all the necessary information needed for the purpose of this study. Thus, a certain amount of personal judgment, based on the author's (a period of fifteen years) practical experience, will be used when justified.

The calculations of the appropriate rates of fertilizer use, therefore, depend upon many factors; but only the following three concern us here.

1. The price of fertilizer, including the effects of new fertilizer technology.
2. The price of the commodity produced.
3. The response to fertilizer, at various levels of inputs and production.[1]

Optimum Fertilizer Use

More and more Egyptian farmers are asking what is the most profitable rate of plant nutrients. But the answer is difficult because of the several factors involved. There are often different combinations of plant nutrients that may result in the same yield, but one combination may cost less per acre than another. This aspect of the most profitable use of fertilizer has general implications as well as implications for individual farms. For example, if sulfur, which is used in the manufacture of phosphate fertilizer, should cost more in the future relative to other materials used in manufactured fertilizers than it has in the past, it might influence recommendations that should be made as to plant nutrient ratios for specific purposes. If, for example, more nitrogen and less phosphate will result in the same yield of a given crop, recommendations should reflect this fact if reserves of sulfur should become relatively short and more expensive. Such questions as this can be answered

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[1]Crop response will be discussed in the following chapter.

only by adequate information as to yield response at different rates and combinations of plant nutrients.

Fertilizer Prices and the Effect of New Fertilizer Technology

Originally derived only from organic materials, nitrogen fertilizer received a substantial boost with the discoveries of natural deposits, and the development of by-product nitrogen. This was followed by the rise of the synthetic industry drawing on the inexhaustible supplies of nitrogen in the atmosphere.

With these developments the on farm development and conservation of organic nitrogen usually is a too costly alternative, especially in Egypt where green manures and nitrogen fixing legumes are high cost competitors for the use of land.

In developed countries further changes in the technology of fertilizer production are occurring rapidly, and fertilizer is fast becoming a full-fledged chemical industry. New processes are being studied and adopted. New forms of fertilizer and new chemical compounds are appearing. The chemical industry in these countries is noted for its progressiveness and the avidity with which it seeks and adopts new processes. However, in Egypt the fertilizer industry is inefficient, cost of production is high and now the key problem that the Egyptian government must solve is that of importing, or producing, and of distributing to farmers fertilizers at prices that are consistent with the prices that now prevail in world trade. What is a country like Egypt to do in terms of economic efficiency in view of her many outdated fertilizer plants?

In the United States, the capital cost of a basic ammonia plant with a production capacity of 350,000 tons of ammonia per year would have been about $30 million in 1962, but in 1966 the capital cost of such a plant dropped to about $15 million. As a consequence of lower operating costs and lower capital charges, the production costs of ammonia have been reduced from $45 to $60 per ton in the older plants to $20 to $30 per ton in plants using the "new technology." This has been one of the most rapid and most dramatic technological changes in history.

Prices paid by farmers for fertilizer vary greatly from one country to another (Table 4-5). In general, prices are lowest in the industrialized countries. In Egypt, for example, fertilizer prices averaged about 80 percent higher than they did in Japan or the United States in 1962-63. In the United States more than 50 percent of nitrogen fertilizer is in the form of anhydrous ammonia or ammonia solution. These cost substantially less per pound of N than standard solid materials.

If current prices were available, they probably would show an even greater range, because of the impact of the new nitrogen technology and the discovery of new sources of phosphorus.

In the United States we notice that between 1938 and 1959 the price of fertilizer to farmers declined by 49 percent relative to the prices received for farm products, by 54 percent relative to the prices paid for all costs (production, farm machinery, interest, taxes, wage rate, etc.) and by 52 percent relative to the GNP implicit price deflator. It is also interesting to note that this decline occurred at the same time that the rise in the wage rate in the fertilizer industry exceeded the corresponding rise in the average wage rate in overall manufacturing by over 30 percent.

G. S. Sahota[1] indicates that the causes of the decline in the relative overall price of fertilizer resulting from developments in the nitrogen industry are due to a fall in input prices, an increase of competition, new processes and new products, and to increased nutrient concentration, economizing of transportation costs of bagging and tax tagging, of storing, loading-unloading, and other miscellaneous costs of distribution and reduction of the cost of filler materials.

Thus, the potential exists for a substantial drop in the cost of nitrogen in Egypt, provided a decision is made to utilize the new advanced technology, rather than to protect the capital investment in the existing and

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[1] G. S. Sahota, Fertilizer in Economic Development (New York: F. A. Praeger, Inc., 1968).

technologically obsolescent high cost plants. This may be done either through import policies which pass on lower world prices to the farmers (despite the foreign exchange problems entailed) or by developing new technologically advanced plants in Egypt and distributing these fertilizers at the lower costs such plants make possible.

Modern, highly efficient, nitrogen plants have capacities of 1,000 metric tons per day or more, but undoubtedly many less efficient smaller plants will be built to achieve compensating efficiencies in distribution within local areas or national boundaries.

Potash and phosphate mines must be quite large in order to be efficient. Mines should have an annual capacity of at least 500 thousand tons of K_2O or P_2O_5 to achieve the lowest cost.

In an open market economy price-cost ratios would allocate the scarce input to the areas in which farmers perceived the highest marginal returns, while profits to fertilizer producers would induce the development of new plants and an expanded supply.

But the Egyptian Government now controls both the production and distribution of fertilizer and their decisions appear to be conservative in reference to supply and faulty both in the geographical and in the commodity allocation of the available fertilizer. Thus, too little capital is allocated to the fertilizer industry, and malallocation exists within agriculture.

Crop Prices

As a part of Egyptian development policy, agricultural price policy has generally been used negatively--to keep bread and raw materials cheap for the growing industrial sector, and to maximize and transfer to the city for investment the profits and capital created by agricultural commodities. In other words, the terms of trade of agriculture are deliberately depressed.

In fixing prices the Egyptian authorities seem to have been mainly concerned with the average earnings of the farmers; the possibility of affecting supply does not seem to have played any great role. An important exception, however, is the increase in prices in 1954, which was intended in part to give farmers more incentive to grow cereals. It has been argued that although farmers in Egypt allocate fertilizer heavily to sugar cane, rice and cotton because of the substantial response in this use, the need of the country is more for food grains and therefore special steps should be taken to reallocate fertilizer toward food grains. Given the relative physical responses to fertilizer, a more profitable response in sugar cane, rice and cotton could be eliminated by a lower (or higher for wheat) relative price as compared to food grains. Against the background of this price fixing, it is remarkable that the average net returns on wheat and corn, with prices in line with "world market" prices, are much lower than the average net return on rice, with a price which is probably below the "world market" price.

In spite of the fact that rice prices are deliberately depressed, Table 5-6 shows that rice has a very substantial comparative advantage over most crops and warrants more resources, even taking water away from corn and other food grains leading to the export of rice and the import of corn. Column four and five show that rice is the most profitable crop, taking into consideration the fact that the growing period of rice is two-thirds that of cotton; also rice is less exhausting to the soil than cotton; and as a matter of fact, its production helps in washing away the harmful sodium chloride salts of saline soils. There is a great demand for Egyptian rice in the European markets, thus Egypt does not have to depend on cotton alone for export.

Table 5-6. Average net return on various crops, 1955-59[a] (per feddan in Egyptian pounds)

	Net Value Added (1)	Net Profit (2)	Rent of Land (3)	Surplus to Lessee Hiring Labour (4)=(2)-(3)	Surplus to Lessee Doing All Work Himself (5) = (1)-(3)
Cotton	63	46	21	25	42
Wheat	19	11	13	-2	6
Millet	24	14	8	6	16
Barley	20	14	10	4	10
Rice	53	39	8	31	45

Sources: Economic Review, C.B.E. 1961, pp. 217, 330-1, and Agricultural Economics (in arabic), several issues, issued by Ministry of Agriculture, for costs and rents.

[a](1) and (2) are estimated as average yields times average prices minus relevant costs of production.

Rice prices in Egypt are about one-third the price in the United States; also Egyptian farmers receive a lower price for wheat and rice than farmers in any of the six countries shown in Tables 5-7 and 5-8. Not only are crop prices the lowest but also fertilizer prices are the highest so that it takes seven and six kilos of rice and wheat, respectively, to buy one kilo of fertilizer, while in Japan and the United States it takes slightly over one kilo of rice, and about two kilos of wheat to buy one kilo of fertilizer. Also, Tables 5-8 and 5-10 show how many kilos of wheat and rice are required to buy one kilo of individual plant nutrients in fourteen countries, and Egypt seems to have the worst terms of trade in all plant nutrients, nitrogen in particular.

The report of the President's Science Advisory Committee on the World Food Problem, May 1967, indicates that a bushel of rice in the United States will pay for four times as much fertilizer in the United States as it will in Egypt. But in spite of this fact, Egyptian farmers use more than twice as much fertilizer per hectare than United States farmers. Obviously, the reason is the higher crop response to fertilizer application in Egypt than in the United States.

Table 5-7. Prices of rice and wheat and kilograms of these crops equal in value to one kilogram of fertilizer, selected countries, 1962-63

Crop and Country	Prices per Kilogram of Crop[a]	Kilograms of Rice or Wheat Equal in Value to One Kilogram of Fertilizer[b]
	Cents	Kilogram
Rice (Paddy)		
Japan	15.6	1.2
India	6.6	5.2
Philippines	7.8	3.4
Taiwan	9.0	3.5
U.A.R.--Egypt	4.9	7.1
Thailand	5.6	4.1
United States	13.6	1.5
Wheat		
Japan	11.6	1.7
India	9.4	3.7
Spain	9.3	2.3
U.A.R.--Egypt	5.8	6.0
United States	7.3	2.7
Netherlands	8.6	2.4

Source: F. W. Parker, Fertilizers and the Economics of Crop Production, U.N., Inter-Regional Seminar, Kiev Ukranian S.S.R., September 1965.

[a]Prices reported by Food and Agriculture Organization Production Yearbook 1963.

[b]N, P and K are held in constant proportions.

Table 5-8. Fertilizer prices, fertilizer consumption per hectare of arable land, and fertilizer expenditure per hectare of arable land, slected countries, 1962-63[a]

Country	Average Price per Kilogram of Fertilizer	Fertilizer Consumed per Hectare of Arable Land	Fertilizer Expenditure per Acre of Arable Land
	Cents	Kilogram	Dollars
Netherlands	21	518	109
Japan	19	270	52
Taiwan	32	190	60
U.A.R.--Egypt	35	95	33
Greece	20	50	10
United States	20	45	9
Spain	21	36	8
Malaya	26	17	4
Philippines	26	9	2
Venezuela	27	5	1
India	34	3	1

Source: F. W. Parker, Fertilizers and the Economics of Crop Production, U.N., Inter-Regional Seminar Kiev, Ukranian S.S.R., September 1965.

[a]Computed from data reported by F.A.O., Production Yearbook 1963. Prices cited are for major materials used, net of subsidy.

Table 5-9. Egyptian prices[a] of one kilogram of cotton, rice, corn, wheat and berseem, and kilograms of these crops equal in value to one kilogram of N, P and K

Crop	Price per Kilo in Piastres	Kilos of Crop Equal in Value to One Kilo of N	P_2O_5	K_2O
Cotton	15.0	1.0	0.5	2.3
Wheat	2.6	6.0	2.8	2.3
Rice	2.1	7.1	3.5	3.0
Corn	0.2	7.5	3.0	2.5
Berseem	0.21	72.0	36.0	28.0

[a]At the village level (1965).

Table 5-10. **Kilos of wheat or rice required to buy one kilo of fertilizer in fourteen different countries**

Country	Kg. of Wheat Required to Buy One Kg. of			Kg. of Rice Required to Buy One Kg of		
	N	P_2O_5	K_2O	N	P_2O_5	K_2O
Australia	4.20	1.13	1.61	....	....	....
Belgium	2.31	1.76	....	....	....	....
Canada	6.39	4.59	2.10	....	....	....
France	2.72	1.62	0.72	....	....	....
Germany	2.65	2.07	0.73	....	....	....
Italy	2.28	1.53	0.93	2.53	1.69	1.03
Japan	2.37	1.91	0.81	1.08	0.93	0.40
Netherlands	2.62	1.92	0.86	....	....	....
Pakistan	1.65	1.74	0.58	0.88	0.93	0.31
Taiwan (China)	....	....	....	3.21	1.73	0.91
U.A.R.--Egypt	5.40	2.93	1.53	4.60	2.51	1.31
United Kingdom	2.64	2.19	1.75	0.85	0.70	0.56
United States	4.03	3.26	1.46	1.42	1.15	0.51
India	3.74	3.15	1.34	3.80	2.36	1.00

Source: T.V.A.,"The Fertilizer Industry of India," paper presented at the Second International Training Course on Fertilizers, May 1966.

Risk and Uncertainty

How might the environment in which decisions are made inhibit the diffusion and adoption of new and better fertilization techniques? How might the risk and uncertainty farmers face affect fertilization practices? What are the ways and means of combating this risk and uncertainty and how can farmers be motivated to improve and increase the rate of fertilizer application and abandon age old practices and latch on to the gadgets of progress, through the creation of positive incentives?

M. F. Millikan states that farmers who have little capital to fall back on are reluctant to incur high fertilizer cost. Even, if at the input and output prices prevailing in the market, or determined by the government, the expected additional return is many times the additional cost, the rate of adoption may remain very low due to initial fears and uncertainties.[1] Often the government experts recommending the innovations are themselves uncertain about the results that farmers may expect because the innovations have not been tested under local conditions.

The fertilization rate figures the farmer gets from neighboring farmers, the extension agent or the government experiment station are probably averages for one particular location which had a certain previous set of practices.

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[1] M. F. Millikan, No Easy Harvest (Boston: Little, Brown and Company, 1967).

The experiment may have been on a soil with a good rotation and with no manure in the past. The results an individual farmer gets may be quite different, even on the same soil type, because he has been following a different set of practices.

Excessive caution in making changes, strong attachment to many customary practices, a low level of general education, a low level of literacy, a habit of devoting little time to reducing ignorance and to considering problems of management: traits such as these and other socio-cultural factors might inhibit the diffusion and adoption of new fertilizer practices.

The farmers entrepreneurial behavior suggests that the high risk and uncertainty, the shortage of capital and the time preferences of the farmers as they relate to consumption and investment, explain by far the greatest part of the farmers unwillingness to take up improvement suggestions. Only the promise of quite large additional returns can overcome the "wise" conservatism of farmers in the light of the risks and uncertainties.

Farmers are afraid that in attempting new fertilization practices, they may fail to produce as much as they know they can with their old methods, thus endangering their very survival. So close is life to the bone that their impulse to take a chance on gaining a whole loaf from new and untried techniques is inhibited by anxiety over losing the crumb they feel sure of getting from their old practices.

Innovations carry an immense risk for the uninitiated, and the risk is magnified by the very poverty they might escape by taking it. Operating at a bare subsistence level, a crop failure or a failure to cover the borrowed money by added harvests would be calamitous.

Another class of risks is that which arises from the failure of the government machinery to render its services to the farmers in an efficient manner. When the seed, fertilizer, pesticide, and irrigation water deliveries, and the grant of loans and material permits and other permissions by the government agencies are slow, untimely, and uncertain, farmers depending on them suffer losses. Fertilizers, for example, often arrive at local distribution points after the optimal time of their use. This lowers their productivity and thereby, discourages the farmer from planning to use fertilizer in the future. Thus, one solution would be that Egyptian farmers have access to alternative sources of supply for their inputs. Reliance on monopolistic suppliers, official or nonofficial, can be extremely risky. Ways of reducing these risks and uncertainties need to be considered in planning a fertilization program. The Egyptian farmer is unlikely to make use of credit facilities if the procedure for getting his fertilizers or a loan requires visits to several offices which may not be open or are staffed by officials who treat the farmer as an inferior.

The persistent condition of uncertainty and ideological antipathy which still envelops the Egyptian economy is hardly conducive to the confidence required for higher rates of private saving and investment. Reorganization of the economy has been under way for nearly seventeen years now as one wave of nationalization and plans for institutional reform follows another. Land has been openly taken from its owners, and the compensation allowed to those whose property in industry and commerce has been nationalized or sequestrated since 1960 conceals a large element of outright confiscation. The owners of the larger farms, often the more progressive and heavy users of fertilizer are more likely to have such concerns.

One other part of the general environment is the self-defeating agricultural development policies which are being employed in Egypt at present. Cheap food policies have blinded policy makers with regard to the function of farm prices as economic incentives for agricultural production. The roots of these cheap food policies are many and deep. Until they are eliminated, little real progress is possible.

Unsound generalizations about agricultural price incentives frequently have led the Egyptian government to adopt price policies intended solely to benefit industry and urban consumers on the assumption that prices "do not matter" to farmers. Industrialization in Egypt has been accomplished at the expense of agriculture. Certainly Egypt faces conflicting needs in trying simultaneously to industrialize and to increase agricultural productivity. But one of the things it cannot afford to do is to ignore the considerable responsiveness of market-oriented farmers to price incentives.[1]

Another root of a cheap food policy has been holding down the price of food to check inflation. But price-fixing to hold down the consumer price index gives the wrong economic instructions to consumers, and is very wrong in what it does to incentives in agriculture.

B. Hansen points out that the methods of Government price-fixing does not seem to be conducive to efficiency; the present pricing system tends to make the economy a shortage economy.[2]

Distorted prices he considers to be a more potent cause of inefficiency than all the delays and blunders of bureaucrats. Unfortunately almost nothing is known about the pricing rules adopted by ministries and public enterprises, but there is certainly no evidence to suggest that they are based upon correct criteria.

Issawi also indicates that by fixing buying prices for cotton and grains, the Egyptian government has abolished

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[1] Patrick O'Brian, The Revolution In Egypt's Economic System (London, New York: Oxford University Press, 1966).

[2] B. Hansen, Development and Economic Policy (Amsterdam: North Holland Publishing Company, 1965).

the market mechanism to which, by and large, farmers have shown themselves responsive and which secures a far better allocation of land.[1]

The appropriate monetary and fiscal measures for reducing the rate of inflation are well understood, but in practice all manner of things are done to control (hold down) the price of key items in the consumer price index. One of the consequences of these price controls is a distortion of the relative prices of farm products.

Indeed these price controls have reduced economic incentives in agriculture, for in general farm product prices are low relative to other prices within Egypt. This imbalance in prices blunts seriously the possibilities for increasing fertilization levels. This particular price imbalance is being corrected somewhat but it is still far from an optimum solution.

Patric O'Brian states "there is no doubt that government policy frequently conflicts with the requirements for efficiency at any point of time."[2]

Prices of agricultural inputs are not only high but are also distorted relative to each other. Although relatively cheap fertilizer opens the door to the promised land with its new and better opportunities for farmers, this door remains closed in Egypt. As a consequence, it has not been

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[1] Issawi, op. cit.

[2] O'Brian, op. cit.

profitable for farmers in Egypt to buy and use large additional quantities of fertilizer, because the advantage of providing nitrogen, phosphate, and potash has not to a large extent been extended to them.

The question is: why are fertilizer prices so far out of line in Egypt?[1] The domestic firms that produce fertilizer are, as a rule, sheltered by a policy of import substitution in order to encourage local industries. Since these local industries are high-cost procedures, the result is that the prices of essential agricultural inputs are both very high and badly distorted.

As for the prices and availability of the consumer goods and services that the Egyptian farmers buy, there has been all too little recognition of the economic importance of this set of prices, which really matter because they are the key to the purchasing power of the net income earned by farm people. In general, farm people in Egypt have come off badly in what they can buy with their earnings. While it is to be expected that the prices of consumer goods and services that are produced in urban areas will be somewhat higher when they reach the countryside, the difficulty is that these prices have been rising relative to the prices at

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[1]Besides having antiquated machinery and inefficient bureaucratic management, fertilizer plants have not adopted any of the new advanced technology. Sulphur instead of gypsum is still being used in the manufacture of ammonium sulphates, and sulphuric acid instead of nitric acid in the manufacture of superphosphates.

which farmers sell their products and, in many instances, the quality of the items they buy has been declining.

Thus, every effort must be made to provide a measure of economic stability consistent with a growing economy, measures to combat risk and uncertainty, measures to motivate managers through the creation of positive incentives, to increase learning, and to reduce capital rationing.

Combating Risk and Uncertainty

Society can afford to bear part of the cost of offsetting risk and uncertainty, because risk and uncertainty are not only a cost to individual farmers but they also result in waste and cost to society as a whole. Since yields and prices cannot be predicted accurately, Egyptian farmers may either overproduce or underproduce in a particular year. Society would have been better off if they could have predicted more accurately.

Society can combat risk by providing insurance and the kind of insurance most urgently needed in Egypt is "innovation insurance," that is, insurance against loss following the use of new crop varieties and new fertilizer practices. It is then necessary that any proposed new inputs and practices carry some insurance in the initial years of trial. And since any innovation program ought to be linked with a supervised credit system that makes loans to farmers covering the bulk of the cost of the new inputs, risk coverage could be provided in the form of the promise of relief from a part of the total loan in case the additional yield per acre turns out to be less than the yield equivalent to the cost of the innovation.

This insurance scheme makes the administration promoting the inputs a risk partner of the innovating farmer, instead of a mere adviser, and thereby stimulates interest in the successful adoption of the innovation.

A short term subsidy would be another possible alternative way of providing the needed incentive to use new inputs.

Precautionary measures to meet the uncertainty that surrounds new techniques or methods of production can take one or all of three related but distinct forms: (1) measures to reduce the variability of dispersion of income, such as flexibility, diversification and asset management, (2) measures to prevent profit from falling below some minimum and (3) measures to increase the farmer's ability to withstand unfavorable economic outcomes.

Economic and Noneconomic Incentives

Without motivated managerial capacity, attempts to improve the utilization of fertilizer and the general organization of the farm and family business are not likely to be very successful. The adoption of new crop varieties and new fertilization practices requires positive incentives to farmers and a positive response on the part of farmers to those incentives. While nations or other social institutions may

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may commit themselves to long-range objectives for the common good, the mass of individual citizens in a country rarely do so. Instead, they respond to incentives that affect themselves and members of their families quite directly. Incentives are influenced by a wide range of factors, from those of culture and psychology to economic institutions and practices.

In discussing fertilizer use in Egypt, no single factor is more important than the provision of adequate incentives for farmers to increase the rate of fertilizer application. The factors that influence incentives of Egyptian farmers to use more fertilizer are of three types. Some flow from the general cultural, political and economic characteristics. Some are effects of policies and programs designed to serve agricultural development but not primarily to affect incentives. Some are programs undertaken primarily to influence farmers' incentives and decision-making.

While the factors influencing the production decisions of farmers are many, it is the total effect of all factors that leads a farmer to adopt or to shun a new practice. In any single instance, factors that encourage the farmer to adopt a practice are weighed against others that discourage him.

Economic Incentives

The incentives that can be effective in getting farmers to increase their use of fertilizer and in turn increase production are primarily economic:

1. Remunerative price relationships.
2. The availability of goods and services that farmers sould like to be able to purchase for themselves and their families.
3. Development of expectations that change will, in fact, increase wealth and that the innovator will himself participate in the net increase in wealth which accompanies successful innovation.

All of these, together in combination, provide the strongest economic incentives to farmers.

In all societies, whether they are relatively free or are rigorously socialistic, prices play a leading role in guiding decisions about agricultural production and in directing the flow of commodities through marketing channels.

Recently more adequate recognition has been given to the influence of price policies in product and factor markets on creating incentives for farmers which, in turn, may encourage or discourage the adoption of new technology.

In a recent paper, Schultz emphasized the importance of the role of price, among three economic requirements for increasing agricultural production in the less developed countries. These requirements are: (1) an efficient system of prices for agriculture (farm product price, agricultural input price, and the price of consumer goods and services that farm people buy); (2) agricultural inputs that are profitable for farmers; (3) the discovery and development of such agricultural inputs through organized research.[1]

Farmers' incentives to invest in high productivity inputs such as fertilizers, would be increased if the ratio between cost and return is improved. This can be accomplished by higher and more stable product price or by lower costs for inputs.

The Report of the President's Science Advisory Committee on the World Food Problem, Volume II, states that a reduction in the price of a technical input relative to the price of a product (or a rise in the price of a product relative to the price of an input) is an important incentive for increased production. The report also adds that comparatively higher and more stable product price and the freer environment for farmers in selling their crops would increase farmer's incentives. Stable and higher product prices also reduce risks in investment in high productivity inputs and would have an indirect effect on increasing production.

There is increasing evidence that Egyptian farmers seek to increase the production per acre of a particular

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[1] T. W. Schultz, Increasing World Food Supplies--The Economic Requirements, National Academy of Science, Vol. LVI, August 1966.

crop when the price of that crop rises, particularly by purchasing increasing amounts of fertilizer for use on the crop. In the Aswan province where prices of vegetables had been held down, controls were abandoned in 1964 and prices allowed to seek their own level. Farm prices shot up, farmers became more interested in fertilizers and improved seed. Land was farmed more intensively and larger amounts of vegetables and other field crops came on the market.

It is recognized, however, that though an efficient system of prices is a necessary economic requirement for organizing and integrating the production decisions of numerous farmers among each other and with the rest of the economy; it is, however, not sufficient to assure increased food supplies in semisubsistence economies. The sufficient condition, according to Schultz' analysis is met by assuring the supply to the farmers of the new and profitable inputs. Concurring, Krishna argues that:

> the growth of agricultural output has to be induced primarily through institutional and technological improvements and a great increase in the supply of inputs embodying these improvements. But price movements can either accelerate, retard, or arrest these changes. Therefore, a favorable price policy is needed along side techno-organizational change.[1]

Fertilizer must be available in local markets and the crop varieties available to farmers must be responsive

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[1]Raj Krishna, Agricultural Price Policy and Economic Development, in Agricultural Development and Economic Growth, ed. by H. M. Southworth and Johnston (New York: Cornell University Press, 1967).

to fertilizer inputs before price incentives can have any impact on aggregate output. Price relationships are production incentives only where Egyptian farmers (1) have a considerable degree of freedom of action without general or specific cultural restraints, (2) have production alternative opportunities available provided through research and appropriate off-farm services to distribute farm inputs and to market, process, and distribute farm products.

The Presidential Report referred to earlier, indicates that price incentives are effective only in localities where the farm supplies and equipment necessary to increase output are physically available, where marketing channels for farm products are adequate, and where other influences which might oppose farmers' decisions to adopt yield-increasing technologies have largely disappeared.

It must also be noted that prices effect the incentives of only those Egyptian farmers who: (a) sell part of their produce in the market, (b) have access locally to fertilizer inputs at favorable prices and (c) know, or have access to means of learning, how to use these inputs.

Noneconomic Incentives

General cultural influences include traditions and values, social organization, and, particularly arrangements with respect to land ownership and tenure. These affect primarily each farmer's degree of freedom of action. They

determine whether he is under pressure to adhere to traditional ways or is free to innovate.

Habits, customs, and traditions change only when they are challenged by the emergence of problems they cannot solve. They wither under the impact of new products imported by trade. They are modified by the availability of new production techniques. When a farmer becomes concerned about a new problem, he will first try to solve it within the sanction of old traditions. Consequently, if a new practice can have an old sanction, it is more easily introduced. Eventually, if problems remain unsolved, the old way weakens, and traditions change or are replaced. In general, traditions and values are not subject to direct manipulation, instead they change under the impact of new opportunities and new pressures.

Political ferment, formal educational systems, and improved health all play important roles in developing a favorable personal and institutional attitude toward change.

Education introduces a logic and rationale to many aspects of life, broadens horizons and demonstrates change. Thus, education, by increasing an individual's "perception of the possible," can condition and predispose him to change. It can create in him a new level of dynamic behavior that is essential for innovation.

Education for development is the kind of education that is needed in Egypt. It is that education that introduces the Egyptian people to new knowledge, new skills, and new ways of doing things. It is an education that draws on the past experience of other societies to the extent that this will help it move in the desired direction of development.

In a developing society, education needs to be for people of all ages. All need to be taught the methods of scientific inquiry.

Farmers education for development must go to them where they are: on their farms and in their home villages. It must be about topics in which farmers are already interested: how to increase the margin between cost and returns, how to improve the quality of living for their own families in their own communities.

Any farmer education regarding fertilizer should be applied. Fertilizer must be available and each new of changed practice proposed must be technically sound and economically profitable. Otherwise the only result of the teaching is frustration and wasted time. Trying it out is an important part of a farmer's education for development. This step is usually easier if he has a "teacher and friend" to support him.

Information and technology should be extended in such a manner that the Egyptian farmer--the man who puts the information into the production machine--is himself educated by learning the "why," not merely the "what" or "how" of the innovation. Only in this way will he grow in his ability to adapt to changing circumstances. The ability of farm operators to receive and use myriad forms of information concerning new fertilizer practices and respond to current and prospective prices is heavily dependent on literacy, and it increases with each increment in pertinent general education. It motivates farmers and prospective farmers to change by giving them the means to change, and provides the factual information upon which improved decision-making is based.

The availability of diverse channels of communication is important. Modern technology of aural and visual mass communication offers many opportunities for transmitting information to those unable to read. Radio and television can be imaginatively used as complements to personal communication, demonstrations, and formal schooling.

Every effort must be made to provide a coordinated set of recommendations, via as many media as possible and in each of the local dialicts. Responsibility for the bulk of this effort logically lies with the Extension Service and the Bureau of Agricultural Information. Efforts are needed to provide the farmer with accurate and plentiful information about his production environment so that his decisions can be made with some degree of sophistication. Agricultural advisors and extension personnel must begin to think of the farmers' decision process as their guiding frame of reference. They must tailor their advice and activities toward the goal of helping the farmer to make the best decision possible, using his own initiative in an enlightened environment. Farmers must not be expected to accept a given recommendation on faith alone.

Not only the Extension Service but the agricultural research organizations as well must adopt this frame of reference. The scarcity of production economics data at the farm level is testimony to the neglect this field has suffered for decades.

It is argued that realistic, adopted research which creates the knowledge base for new fertilizer inputs, new input complexes and new flows of income over time are far more productive than marginal increments in capital equipment, irrigation water or the improvements that can be made in improved prices or reduced marketing costs. The creation of such knowledge which is a very important element in Egyptian agricultural development must eventually be reflected in fertilizer inputs. Only then can it affect the production function.

With the explosion of changes that are occurring in our society, investment in the human agent takes on increasing importance. Experience indicates that failure to train and develop management is one of the most crucial shortcomings in the Ministry of agriculture test demonstration program.[1] There is a great need for more ability in training farmers to make the most of their managerial capacity

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[1]Personal experience of the author.

they have, and to build into the whole agricultural process--from the farmer to the university research institute, from the field extension agent to the minister of agriculture--an attitude of experiment, trial and error, continued innovation, and adaptation of new ideas. Once this innovative and experimental spirit permeates the rural community, the farm supply and marketing industries, the bureaucracy, and the intellectual institutions concerned with agriculture, the gulf between city and country, between universities and farmers, between ministers and village officials will be bridged. Without this change in attitudes, improvements in performance, though they may occur, will be halting and transitory and thus will provide no lasting contribution to agricultural productivity.

CHAPTER VI

EVIDENCE OF CROP RESPONSE

> "But he that received seed into the good ground is he that heareth the word, and understandeth it; which also beareth fruit and bringeth forth, some a hundred-fold, some sixty, some thirty."
>
> Matthew 13:26

The results of crop response statistics not only provide the scientific information needed for giving reliable guidance to farmers on efficient fertilizer use, but also provide the basis for formulating national fertilizer policy in relation to agricultural development programs. Two of the most important uses of crop response data for this purpose are:

1. To determine fertilizer requirements for the three regions (Lower, Middle and Upper Egypt), or for the country as a whole.
2. To assess possible increases in production.

In this study we draw on all the available studies of crop response to fertilizer to estimate the probable response of cotton, wheat, rice, corn and berseem to nitrogen and phosphoric acid on saline-sodic and nonsaline-sodic soils. Potassium is used in only a few experiments as it is taken for granted that Egyptian soils have adequate amounts of it, based upon the few experiments conducted a few years ago that showed that most crops do not respond to it.

Cotton Response to Fertilizers

Most experiments are generally conducted with two nonzero levels of each of the nutrients, so that the full response curve cannot be established for the different nutrients. The relative responses to different sources of the same nutrient may differ with the level of application. Therefore, experiments with only a single level of each of the nutrients can give only very limited information about the relative efficiencies of the different nutrients, as shown in Table 6-1. This table also shows that the response of cotton to nitrogen is higher in Middle and Upper Egypt than in Lower Egypt. This higher response is due to the relatively salt free soils of Middle and Upper Egypt and also to the prevalence of short staple cotton varieties, in these two regions.

But the response of cotton to phosphate is higher in Lower Egypt than the other two regions; the reason for this seems to be the relatively colder weather in Lower Egypt.

The response of cotton to nitrogen is higher when planted after corn or rice, than when planted after fallow

Table 6-1. Average cotton yield and increase in yeild due to nitrogen application (in kantar per feddan) on different agricultural regions in Egypt

Kgs./Feddan		Northern Delta		Southern Delta		Lower Egypt		Middle Egypt		Upper Egypt		Middle & Upper Egypt		Average	
N	P_2O_5	Yield	Incr.	Yield	Incr.	Yield	Incr.	Yield	Incr.	Yield	Incr.	Yield	Incr.	Yield	Incr.
..	..	5.69	....	6.12	....	5.84	....	6.30	....	5.33	....	5.97	....	5.85	....
15	..	6.49	0.80	7.33	1.21	6.78	0.94	7.56	1.26	6.47	1.14	7.18	1.21	6.97	1.12
15	30	6.65	0.16	7.53	0.20	6.95	0.17	7.82	0.26	6.71	0.04	7.44	0.26	7.18	0.21
30	..	6.96	0.47	7.69	0.36	7.21	0.43	8.25	0.69	7.21	0.74	7.89	0.71	7.54	0.57
30	30	7.12	0.16	7.96	0.27	7.40	0.19	8.40	0.15	7.38	0.17	8.05	0.16	7.72	0.18
45	..	7.24	0.28	7.90	0.31	7.46	0.25	8.67	0.42	7.90	0.69	8.40	....	7.93	0.39
45	30	7.45	0.21	8.12	0.22	7.68	0.22	8.82	0.15	7.92	0.02	8.51	0.11	8.08	0.15
60	..	7.35	0.11	7.84	....	7.52	0.06	8.76	0.09	8.12	0.22	8.54	0.14	8.02	0.09
60	30	7.52	0.17	8.17	0.33	7.74	0.22	9.08	0.32	8.15	0.03	8.76	0.22	8.24	0.22
..	30	5.87	0.18	6.50	0.38	6.09	0.25	6.58	0.28	5.61	0.28	6.24	0.27	6.15	0.30
No. of Expts.		87		45		132		65		34		99		231	
Average Incr.		0.18		0.28		0.21		0.23		0.11		0.20		0.21	

Source: Reproduced from M. T. Eid, Role of Phosphate in Egyptian Agriculture, Technical Bulletin No. 297, Cairo, 1959.

or clover, while the response to phosphate fertilizers is higher when cotton is planted after clover, as shown in Table 6-2.

The average response of cotton to one kilo of nitrogen at various levels of application as shown in Table 6-3 (calculated from Tables 6-1 and 6-2) for Lower Egypt where most soils contain a high percentage of sodium chloride, and for Middle and Upper Egypt where soils are relatively less saline. It is apparent from this table that cotton response is higher on the salt free soils. However, there was a great difference in response to nitrogenous fertilizers, by different varieties. The position of the varieties arranged in descending order of response is Ashmouni, Giza 12, Giza 7, Maarad, Sakellarides. The increase in yield given per sack of nitrogenous fertilizer for Ashmouni is double or triple that of Sakellarides.[1]

Experiments conducted by the Ministry of Agriculture have shown that the application of fertilizer at planting time by burying it in pockets increased the response by 0.35 kantars per feddan over the normal method of applying a pinch of fertilizer to each side of the plant. For application at thinning time, there was an increase of 0.24 kantars from scattering the fertilizer along the bottom of the furrow. These results suggest that while the plants are young

[1]M. T. Eid, "Cotton Fertilization," The Agricultural Magazine, March 1962, Cairo.

Table 6-2. Average yield and increase in cotton yield (in kantar per feddan) due to phosphate and nitrogen fertilizers

Kilograms/Feddan		After Clover		After Fallow		After Corn		After Rice		Average
N	P_2O_5	Yield	Increase	Yield	Increase	Yield	Increase	Yield	Increase	Increase
5	0	9.49	....	8.66	....	7.02	....	5.80	....	....
	5	9.04	....	8.73	0.07	6.82	....	5.97	0.17	0.06
	10	8.58	....	8.72	0.06	5.94	....	5.65	....	0.06
10	0	9.23	....	9.30	....	7.01	....	6.14	....	....
	5	9.70	0.47	9.30	....	7.26	0.25	6.00	....	0.18
	10	9.77	0.54	9.60	0.30	7.32	0.31	5.62	....	0.29
	20	8.94	....	9.30	....	6.42	....	5.95	....	....
15	0	8.71	....	9.18	....	7.35	....	6.28	....	....
	7.5	9.90	1.19	9.25	0.07	7.32	....	6.15	....	0.31
	15	9.16	0.45	9.58	0.40	7.18	....	6.10	....	0.23
	30	9.21	0.50	9.22	0.04	6.18	....	5.69	....	0.14
20	0	9.11	....	9.13	....	6.69	....	5.63	....	....
	10	9.21	0.10	8.87	....	6.55	....	5.71	0.08	0.04
	20	9.42	0.31	9.26	0.13	6.24	....	5.67	0.04	0.12
	40	9.24	0.13	9.02	....	6.43	....	6.06	0.43	0.14
30	0	9.16	....	....	....	6.14	....	5.31	....	....
	15	10.08	0.92	....	....	6.63	0.49	5.28	0.03	0.40
	30	9.31	0.15	....	....	6.63	0.49	5.28	....	0.16
	60	10.10	0.94	....	....	7.07	0.93	5.21	....	0.46
Average Increase		....	0.40	....	0.09	....	0.19	....	0.05	0.18
No. of Expts.		6		2		12		5		25

Source: Reproduced from M. T. Eid, Role of Phosphate in Egyptian Agriculture, Technical Bulletin No. 297, Cairo, 1959.

Table 6-3. Average response of cotton in kilos per acre to one kilo of N at various levels of application[a]

Soil Characteristics	At 15 Kilo Level	At Second 15 Kilo Level	At Third 15 Kilo Level	At Fourth 15 Kilo Level
Saline-sodic[b]	8.0	4.7	2.8	1.1
Nonsaline-sodic	12.6	6.9	4.2	2.2

[a]Calculated from Table 6-1.

[b]Most soils in Lower Egypt are saline, while those of Upper Egypt are less saline.

with small root systems, the fertilizer should be locked up temporarily in pockets, so that it is not washed down below the zone of the roots.

Concerning phosphate fertilizers, experiments conducted in most government experimental stations have shown that superphosphates were most efficient when used with 40 kg. of sulphate of ammonia and that the increase in yield due to the application of 32 kg. of P_2O_5 per feddan was 0.7 kantars for ordinary superphosphate and 1.0 kantar for concentrated superphosphate (40 percent P_2O_5).

In the experiment of Gracie et al. the effect of phosphate was small and in only 10 out of the 90 experiments were there significant yield increases from phosphate. They suggested that phosphate should be applied to the preceding clover crop; unless applications of as much as 400 kg., nitrate were applied, then 200 kg. of superphosphate should be used for cotton.[1]

In the experiments at Bahtim[2] (see Table 6-4) which covered a period of 36 years the response to superphosphate was slight during the early years of the experiment, but later on it became pronounced and the increase in yield due to nitrate and phosphate in combination was 43 percent and 50 percent in the two and three-year rotations respectively, above those from nitrate alone. In these experiments the effect of the fertilizer treatment of the previous crop was important. In general, one could say that the phosphate applications to the preceding clover crop or by an application of 200 kg. of superphosphate if the higher levels of nitrogen fertilization are used.

Twenty-three experiments were made by Gracie *et al*. on the effect of potash in combination with nitrogen and phosphorus. In three of these, the potash gave increases in yield and in three it gave marked depressions.[3] It was suggested that the potash levels on some fertile Egyptian soils might even be too high for cotton. Similar results were obtained by the Agricultural Research Scheme, and at Bahtim

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[1] A. F. Money-Kyrle, *Agricultural Development and Research in Egypt*, Publication No. 3, American University of Beirut, 1957.

[2] Bahtim, experimental station located 10 miles north of Cairo.

[3] Money-Kyrle, *op. cit*.

Table 6-4. Effect of application of different levels of fertilizers on the yield of cotton (at Bahtim) (cotton yield in kentars/feddan)

Treatments[a]	Rep 1	Rep 2	Rep 3	Rep 4	Average Ken./Fed.	Average Kgs./Fed.
N0 P0 K0	12.57	10.89	10.77	13.71	11.98	1677.2
N0 P0 K1	12.93	11.84	11.37	11.94	12.02	1682.8
N0 P1 K0	13.66	10.44	14.35	11.91	12.59	1762.6
N0 P1 K1	12.05	10.79	12.02	12.02	11.72	1640.8
N0 P2 K0	7.20	11.03	13.05	11.62	10.72	1500.8
N0 P2 K1	12.76	11.69	15.60	10.63	12.67	1773.8
N0 P0 K0	10.24	13.56	13.26	13.48	12.63	1768.2
N1 P0 K1	11.43	10.82	11.10	11.07	11.10	1554.0
N1 P1 K0	14.72	12.87	13.68	12.32	13.39	1874.6
N1 P1 K1	13.26	11.66	12.57	13.13	12.65	1771.0
N1 P2 K0	12.10	12.89	13.68	14.50	13.29	1860.6
N1 P2 K1	12.41	13.82	12.03	10.45	12.18	1705.2
N2 P0 K0	13.43	11.94	10.19	11.76	11.83	1656.2
N2 P0 K1	12.12	14.19	13.54	12.46	13.08	1831.2
N2 P1 K0	12.36	12.18	12.31	10.99	11.98	1677.2
N2 P1 K1	13.64	12.16	12.66	12.82	12.82	1794.8
N2 P2 K0	14.03	12.08	10.93	11.55	12.15	1701.0
N2 P2 K1	13.39	12.88	14.10	13.11	13.36	1870.4
N3 P0 K0	13.55	12.65	12.01	11.63	12.46	1744.4
N3 P0 K1	14.37	10.87	12.22	11.49	12.24	1713.6
N3 P1 K0	11.91	12.51	14.06	13.15	12.91	1807.4
N3 P1 K1	12.75	14.57	11.20	10.38	12.22	1710.8
N3 P2 K0	12.85	11.98	12.06	13.05	12.48	1747.2
N3 P2 K1	13.91	13.82	14.42	12.97	13.78	1929.2

Source: H. Hamdi et al., Ain Shams University, "Fertilization of Cotton at Bahtim," Journal of Soil Science, II (1962).

[a]N1 equals 15 kilos, N2 equals 30 kilos, N3 equals 45 kilos, P1 equals 16 kilos, P2 equals 32 kilos, and K1 equals 12 kilos.

as shown in Table 6-4. This table also shows the interaction between N, P_2O_5 and K_2O), with the maximum yield obtained at N3P2K1 level while the minimum yield was at N0P2K0 level.

In general, the optimum levels of N and P, at the present price ratio (as shown in Table 5-9), for both Middle and Upper Egypt (where the relatively more responsive Ashmouni variety is grown) are 60 and 30 kilos, respectively. While for Lower Egypt this optimum is 30 and 60 kilos of N and P_2O_5, respectively.

Wheat Response to Fertilizers

Wheat experiments conducted by the Ministry of Agriculture show that yield increases of 2.0 to 3.0 ardabs per feddan could be expected from 15 kg. of nitrogen, and 3.5 to 5.5 ardabs from 30 to 45 kg. of nitrogen depending on variety, soil type and cultural practices (see Table 6-5). Both wheat varieties are more responsive to fertilizer application in Upper than in Lower Egypt (Table 6-6). There was no difference in yield if the total amount was applied at one time or half at sowing and the balance a month later. Lodging increased with the heavier application, but decreased slightly as less seed was planted per feddan. It was also found that the response of wheat to N and P_2O_5, was slightly higher in salt free soils than in saline-alkali soils, as shown in Table 6-7. The response was also higher when wheat was planted after cotton than when it was planted after

Table 6-5. Response of wheat to nitrogen fertilizers (in saline-sodic soils)

Without Fertilizer	15 Kg. of Nitrogen		30 Kg. of Nitrogen		45 Kg. of Nitrogen	
Yield per Acre in Ardabs	Increase in Ardabs	% Increase	Increase in Ardabs	% Increase	Increase in Ardabs	% Increase
3.94	2.0	40	3.0	60	3.5	70

Source: Reproduced and translated from S. Kasem, Fundamentals of Crop Production (Cairo: Anglo-Egyptian Bookstore, 1963).

Table 6-6. Yield of different varieties of wheat grown at different localities

				0N	1N	2N	3N
No. of Export	Variety of Wheat	Locality	Place of the Experiment	Grains Yield	Grains Yield	Grains Yield	Grains Yield
1	Hindi	Lower	Gemmiza	3.38	4.71	5.71	5.73
2		Egypt	Shabshir	4.42	6.09	6.71	6.89
4			Sakha	4.29	6.29	6.91	7.64
			Mansoura	6.24	7.07	7.51	8.20
11			El Kattawia	4.55	5.84	4.42	4.16
12			Mit El Faramawi	4.49	6.49	7.47	9.09
13			Buhet Shantanof	4.78	6.40	8.09	8.93
14			Kafr Batta	6.18	8.49	9.44	8.82
15			Namoul	4.38	6.04	6.47	7.00
16			Moshotohor	6.00	7.96	9.13	8.09
17	Hindi	Upper	Zat El Kom	3.74	4.62	5.80	6.33
18		Egypt	Dimoshya	6.07	8.18	9.13	11.93
19			El Fashn	6.00	7.93	9.47	11.27
20			Sids	5.51	7.27	9.84	10.02
21			A boca	7.62	8.44	9.49	11.53
22			Damaris	8.87	11.84	13.71	13.44
23			Abu Korkas	6.38	9.76	11.33	12.49
24			Mansat Semhan	6.07	8.33	10.20	11.00
25			Fazara	3.91	6.09	7.58	9.36
26			Menshat Bardees	5.11	6.42	6.84	7.16
28			Tahta	3.60	6.53	7.24	7.91
28			Shandawil	3.44	4.38	5.24	5.51
29			El Matana	2.60	5.51	6.60	7.40
30			Kom Ombo	5.82	6.49	6.82	7.36
3	Baladi	Upper	Ibshawai	4.60	7.09	7.62	9.09
5		Egypt	Mahalet Malek	6.22	7.24	8.04	7.73
6			El Shokha	3.09	3.93	4.80	5.56
7			Disounis	4.02	5.71	6.80	7.58
8			Kafr El Atrah	2.93	3.33	3.91	4.16
10			Bassandila	3.13	5.42	7.67	8.22

Source: H. Hamid et al., "The Utilization of Soil and Fertilizer Nitrogen by Wheat Plants," Journal of Soil Science, III (1963), The National Information and Documentation Center.

[a]1N equals 15 kilos, 2N equals 30 kilos, 3N equals 45 kilos.

Table 6-7. Average response of wheat in kilos per acre to one kilo of N at various levels of applications[a]

Soil Characteristics	At 15 Kilo Level	At Second 15 Kilo Level	At Third 15 Kilo Level
Saline-sodic	20	10	5.0
Nonsaline-sodic	22	12	6.8

[a]Calculated from Tables 6-5 and 6-6.

clover, and this response was much more significant during years of unfavorable weather conditions. More response to N was obtained when P_2O_5 was applied, and this response was higher under the three than the two year rotation (Table 6-8).

Table 6-8. Comparison of wheat yields in one and two year rotations with and without fertilizers

	Two Year Rotation		Three Year Rotation	
Treatments	Ardab per Feddan	Percent Gain	Ardab per Feddan	Percent Gain
None-check	3.6	....	4.5	....
N	4.8	33.3	6.2	37.8
N, P	6.3	75.0	9.1	102.0
N, P, K	6.5	80.5	9.0	100.0
Manure after fallow	7.8	116.7	9.4	108.8
Manure after berseem	8.1	125.0	9.5	111.0

Source: A. F. Money-Kyrle, Agricultural Development and Research in Egypt, Publication No. 3, American University of Beirut, 1957.

In general, the optimum level of fertilizers with the present varieties and crop-fertilizer price ratio (as shown in Table 5-9) is 30 kg. N and 8 kg. P_2O_5 in saline soils, and 45 kg. N and 8 kg. P_2O_5 nonsaline-alkali soils.

Rice Response to Fertilizers

Field experimentations on rice-fertilizer test, started in Egypt as early as 1912. It was thought at the time that rice did not respond to phosphate fertilizers. But later experiments showed that rice responds favorably to P_2O_5 especially at high levels of nitrogen application. The response of rice to fertilizers is not much higher in the salt free soils than in salty soils (Table 6-9). Transplanted rice has a higher response to fertilizer than broadcast rice but the least response was when rice was planted after clover. The response was higher (about 9 percent) when fertilizer was applied in the form of pellets buried deep in the soil (Table 6-11). For broadcast rice the best time for fertilizer application was three weeks after sowing, and for transplanted rice, two weeks after transplanting.

Table 6-10 shows the response of three rice varieties to nitrogen and confirms all experiments conducted by the Ministry of Agriculture, that the optimum level of nitrogen for Nahda variety (84 percent of rice acreage is planted to this variety) at the present crop-fertilizer price ratio is at least 45 kg. per acre.

Table 6-9. Average response of rice in kilos per acre to one kilo of N (ammonium sulphate) and one kilo of P_2O_5 at various levels of application[a]

Soil Characteristics	One Kilo of N			One Kilo of P_2O_5		
	At 15 Kilo Level	At Second 15 Kilo Level	At Third 15 Kilo Level	At 16 Kilo Level	At Second 16 Kilo Level	At Third 16 Kilo Level
Saline-sodic	20	20	7.5	9	5.8	2.1
Nonsaline-sodic	20	15	8.1	11	6.2	2.9

[a]Calculated from several tables pages 26-34 from M. T. Eid, Role of Phosphate in Egyptian Agriculture, Technical Bulletin No. 297, Cairo, 1959.

Table 6-10. Yield data obtained from a field trial conducted at Sakha in 1956 (tons paddy/hectare)

Variety	Nitrogen Levels (per hectare)				
	0 Kgs.	49 Kgs.	98 Kgs.	147 Kgs.	196 Kgs.
Nahda	4.74	5.43	7.37[a]	6.34	6.80
138/22	4.60	5.51	6.71	6.34	8.11
Formosa	6.00	5.20	6.17	7.48	8.37

Source: F.A.O., Report to the government of the U.A.R., on rice production, Report No. 1067, Rome, 1959.

[a]Using 49 kg./acre is still in stage one of production function, average and marginal product still increasing.

Table 6-11. Summary of pellet fertilizer tests for paddy (plant nutrition section data of 5 expt.)

Kgs./Fed. N	Kgs./Fed. P_2O_5	Form of Fertilizer and Time of Application	Ard./Feddan Yield	Ard./Feddan Incr.	% Incr.
..	..	No fertilizer	20.84	....	...
15	..	Amm. Sulfate at transplanting	23.32	....	...
15	15	Amm. Sulfate + Superphos. transplanting	23.82	0.50	2.1
15	..	Amm. Sulfate before planting	23.96	....	...
15	15	Amm. Sulfate + Superphos. planting	24.13	0.17	0.7
15	..	Pellet fertilizer of Amm. S. after transplanting	23.54	....	...
15	15	Pellet fertilizer of Amm. S. + Superphos. after transplanting	25.64	2.10	8.9

Source: Reproduced from M. T. Eid, Role of Phosphate in Egyptian Agriculture, Technical Bulletin No. 297, Cairo, The other two varieties Formosa and 138/22 introduced by the F.A.O. expert showed higher response to fertilizers (twice as much) than the local Nahda variety.

Corn Response to Fertilizers

Corn proved to be very responsive to nitrogen fertilizers, but it is still questionable if corn responds favorably to P_2O_5 at the present low nitrogen levels (Table 6-12). However, at high nitrogen fertilization rates, corn responds to phosphate and potassium fertilizers, and to keep the proper plant nutrient balance, about 10 kg. of P_2O_5 plus 12 kilos of potassium should be mixed with the applied manure or used separately at time of planting. The yield of corn was higher in a three than a two year rotation. The basic yield on nonfertilized land was 36 percent higher in the three than in the two year rotation. Barnyard manure applied to corn after fallow or clover gave higher yields than nitrogen alone or in combination with phosphorus and/or potash.

The relationship between the yield of corn and the amount of fertilizer followed very closely the mathematical expression of Mitscherlich relating to the law of limiting factors. A maximum yield of corn receiving nitrate was obtained with 16,000 plants per feddan.

Experiments conducted by the Ministry of Agriculture show that 45 kilos of nitrogen per acre is the optimum amount used in crop production. This could be true only for

Table 6-12. Number of cases of positive and negative response of corn to P_2O_5

Previous Crop	No. of Expts.	No. of Treat- ments	Positive Resp. to Phosphate: No. of Cases	Positive Resp. to Phosphate: % of Cases	Negative Resp. to Phosphate: No. of Cases	Negative Resp. to Phosphate: % of Cases
Wheat	7	134	65	48	69	52
Clover	3	54	24	44	30	56
Beans	2	36	19	52	17	48
General	12	224	108	48	116	52

Source: Reproduced from M. T. Eid, Role of Phosphate in Egyptian Agriculture, Technical Bulletin No. 297, Cairo, 1959.

the saline-alkali soils of Lower Egypt and the Fayoum province. The writer's practical experience suggests that the experiments were too conservative. They never left stage I of the production function. Much higher amounts of nitrogen (120 kg. per acre after wheat) in nonsaline soils were far more profitable at the existing fertilizer and crop prices than a mere 40 or 50 kg. as shown in Table 6-13.

Practical experience has also shown that the functional relationship between nitrogen application and crop yield is strikingly different in Matay as compared in Maghagha. As a result, the optiman level of fertilizer application and the financial returns to use of fertilizer are much lower under Maghagha conditions than Matay

Table 6-13. Average response of corn--local Baldi variety--to one kilo of N at various levels of application[a]

Soil Characteristics	At 15 Kilo Level	At Second 15 Kilo Level	At Third 15 Kilo Level	At Fourth 15 Kilo Level	At Fifth 15 Kilo Level
Saline-sodic	12.8	11	7.5	...	...
Nonsaline-sodic	23.0	20	16.0	11.5	8.4

[a]Calculated from a study on the application of composite design for characterizing response of corn to N, P, K, by F. Amer, Journal of Soil Science, pp. 1-8. The Science Council in collaboration with the National Research Center. Also calculated from Table 6-14. This study showed that 75, 32, and 24 kg. of N, P, K, respectively gave the highest yield of corn.

conditions. The differences in the production function are due primarily to the salt-free soils of Matay.[1]

As for corn planted in saline soils (if it is to be planted at all) then foliar application or use of a fertilizer low in salt index such as urea is the most appropriate for such soils. Rice instead of corn is the crop most suited for the saline soils of Lower Egypt and the Fayoum Province.

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[1]Maghagha and Matay are two locations, 100 and 120 miles south of Cairo where the author's farms were located and where Egyptian Agricultural Society and the Ministry of Agriculture conducted several experiments on such crops as wheat, corn, and rice.

Table 6-14 shows that response of corn to N is higher in Upper than in Lower Egypt. Also Table 6-15 shows that the response was higher when corn was planted after wheat than when it was planted after clover.

Table 6-14. Corn response to phosphate and nitrogen

Kgs./Fed.		Delta		Upper Egypt		Average	
N	P_2O_5	Yield Ard./Fed.	Incr.	Yield Ard./Fed.	Incr.	Yield Ard./Fed.	Incr.
..	..	5.96	....	7.58	....	6.77	....
15	..	8.22	2.26	10.04	2.46	9.13	2.36
15	30	8.44	0.22	10.33	0.29	9.39	0.26
30	..	9.54	1.32	11.64	1.60	10.59	1.46
30	30	9.72	0.18	11.92	0.28	10.82	0.23
45	..	10.63	1.09	12.77	1.13	11.70	1.11
45	30	10.74	0.11	12.41	....	11.57	....
..	30	6.40	0.44	7.98	0.40	7.19	0.40
No. of Expts.		148		111		259	

Source: Reproduced from M. T. Eid, Role of Phosphate in Egyptian Agriculture, Technical Bulletin No. 297, Cairo, 1959.

Table 6-15. Corn response to N when planted after wheat and clover

Total Kg. Nitrogen per Feddan	Yield of Corn After Wheat	In Kg. per Feddan After Clover
0	y	y + 300
15	y + 375	y + 600
30	y + 675	y + 750
45	y + 750	y + 900

Source: A. F. Money-Kyrle, Agricultural Development and Research in Egypt, Publication No. 3, American University of Beirut, 1957.

The new hybrids and Early American corn varieties give an average of two tons per acre of the fertile soil of Middle and Upper Egypt, compared with an average of one ton in Lower Egypt. Yield response was much larger for the hybrid than for the Baladi variety as shown in Table 6-16.

Table 6-16. Interaction of variety and fertilizer on corn yields 1960 and 1961 (kilograms per acre)

	Yield	Increase
Native Baladi variety no fertilizer	900	.....
Native Baladi variety plus fertilizer (65 kilo N)	1,200	300
Hybrid, no fertilizer	1,300	400
Hybrid, plus fertilizer (65 kilo N)	2,300	1,000

Source: Reproduced and Translated from F. Elebrashy, "Corn Fertilization," Agricultural Magazine, September 1962.

Berseem Response to Fertilizers

Results of the fertilizer experiments at Bahtim showed that fields receiving phosphorus in addition to nitrogen gave an increase of 47 percent over those receiving no fertilizer, while plots receiving nitrogen or potassium alone gave a negative response, as shown in Table 6-17.

Splitting phosphate fertilizers into two or more applications resulted in no greater yield than when the fertilizer was all applied in one application. The best time of application was found to be before planting or at sowing, as shown in Table 6-18.

Figure 6-1 shows the response of berseem to four different levels of phosphorus in saline sandy soils at Marg (10 miles north of Cairo) and in salt free soils at Giza.

Table 6-19 shows average response of berseem to one kilo of P_2O_5 at various levels of application in saline and nonsaline soils. This table also shows that berseem is more tolerant to salinity than most crops (except rice).

Thus, the optimum level of phosphorus at the present crop-fertilizer ratio, as shown in Table 5-9, for berseem planted in saline sandy soil is 30 kg. while it is 40 kg. in clay nonsaline soils.

A report titled, "Fertilizer in Africa," by the United National Economic and Social Council, Addis Ababa, 1864, states that experiments by Gracie and Khalili showed

Table 6-17. Response of berseem Miskawy to P_2O_5 and nitrogen (tons green berseem per feddan--Bahtim longterm experiments)

	Exp. (1)	Exp. (2)	Exp. (3)	Exp. (4)	Exp. (5)
	2 Cuttings	2 Cuttings	2 Cuttings	3 Cuttings	3 Cuttings
No Fertilizer	13.00	9.26	12.28	19.27	18.15
Sodium Nitrate	.....	8.19	12.38	16.82	17.06
Superphosphate + Nitrogen	12.50	12.55	15.91	28.16	26.18
Super + Potassium + Nitrogen	12.00	11.35	13.91	26.08	25.44
Potassium Sulphate	12.23	.....	.....	.....	.....

Source: Reproduced from M. T. Eid, Role of Phosphate in Egyptian Agriculture, Technical Bulletin No. 297, Cairo, 1959.

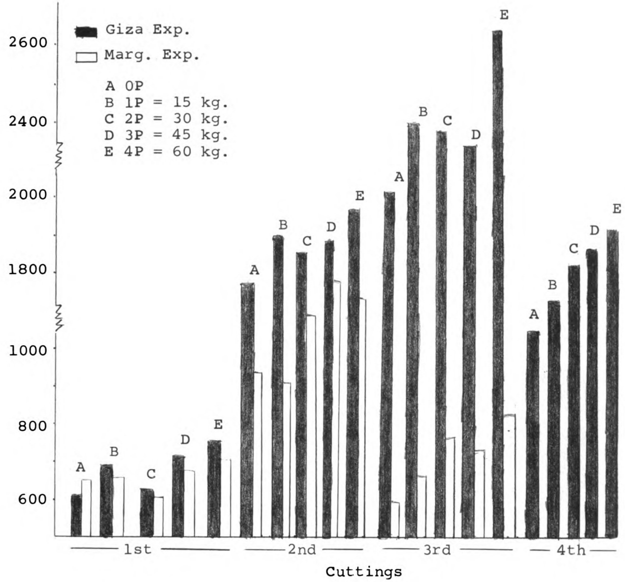

Figure 6-1. Yield of berseem under different phosphatic treatments. (Source: F. S. Hanna et al., "A Comparative Study of Phosphorus Uptake by Plant and Available Phosphorus Content in the Soils of Egypt as Determined by Chelating Compound Extracts," Journal of Soil Science, I (1961), National Research Centre.)

Table 6-18. Effect of time of phosphate application upon berseem (tons of green berseem per feddan)

		At Sowing		Split Applications at Sowing and at First Cutting	
No. of Expt.	Zero Fert.	15 Kgs. P_2O_5/Fed.	30 Kgs. P_2O_5/Fed.	15 Kgs. P_2O_5/ Fed.	30 Kgs. P_2O_5/Fed.
10	28.14	31.55	32.46	30.45	32.69
6	35.74	39.69	40.82	38.94	40.95
6	33.87	39.50	36.87	36.30	39.16
9	26.59	30.07	41.90	30.13	32.19
10	34.14	37.15	38.99	38.88	38.66
12	24.56	27.90	30.14	28.73	30.03
13	30.44	33.88	35.63	34.68	35.61

Source: Reproduced from M. T. Eid, Role of Phosphate in Egyptian Agriculture, Technical Bulletin No. 297, Cairo, 1959.

Table 6-19. Average response of berseem in kilos per acre to one kilo of P_2O_5 at various levels of application

Soil Characteristics	At 15 Kilo Level	At Second 15 Kilo Level	At Third Dose of 10 Kilo Level
Saline-sodic	227	60.6	30.4
Nonsaline-sodic	263	75.3	37.2

[a]Calculated from Table 6-18 and Figure 6-1.

that average responses to ordinary superphosphate applied at the rate of 238 kg. per hectare were (per kg. of P_2O_5):

Berseem (Trifolium alexandrum) . . .	42 kg.
Beans	6 kg.
Rice in hush	9 kg.

With twice that application, that is, with 476 kg./ha. of superphosphate, average responses were (per kg of P_2O_5):

Wheat	1.3 kg.
Barley	1.3 kg.
Maize	1.0 kg.

It was found that plants grown in plots treated with nitrogen and phosphorus absorbed about 50 percent more phosphoric acid than plants in plots treated only with superphosphate.

Summary

Table 6-20 summarizes the present, the recommended and the optimum level of fertilizer application at the present crop-fertilizer price ratio, as shown in Table 5-9, and with the current cropping system, cultural practices, soil characteristics and crop varieties. It shows that the present amount of nitrogen applied to the five major crops, is about two-thirds of the amount recommended by the Ministry of Agriculture, and is a little over half the optimum quantities suggested by the reviews of research just completed.

Present fertilizer practices for corn are far from the recommended or optimum levels while for rice the present

Table 6-20. Average yield and fertilizer application in kilos per acre at optimum, recommended and present levels

Crop	Present Application N	P_2O_5	K	Average Yield per Acre at Present Application
Cotton	30	8	0	750 kilos[a]
Wheat	20	0	0	1200 kilos
Rice	30	8	0	2433 kilos
Corn	30	0	0	1100 kilos
Beseem	0	10	0	

Crop	Recommended Application N	P_2O_5	K	Average Yield if Recommended Application Were Followed
Cotton	40	20	0	900 kilos
Wheat	30	8	0	1400 kilos
Rice	40	16	0	2900 kilos
Corn	45	0	0	1350 kilos
Berseem	0	20	0	31 tons

Crop	Optimum[b] Quantities N	P_2O_5	K	Average Yield per Acre If Optimum Quantities Are Used
Cotton	45	30	0	990 kilos
Wheat	40	8	0	1550 kilos
Rice	45	32	0	3000 kilos
Corn	50	0	0	1400 kilos
Berseem	0	30	0	33 tons

[a]Lint and seed.

[b]These optimum quantities are calculated at present crop-fertilizer price ratios, cropping system, cultural practices, soil characteristics and crop varieties.

It should also be noted that this optimum is the average of both optimums for the nonsaline soils which constitute about 50 percent of all cropped area and for saline-sodic soils which constitute the other 50 percent as shown in Table 6-21.

Table 6-21. Summary of optimum level of fertilization according to soil characteristics[a]

Crop	Optimum Level: Nonsaline Soil N	P	Saline-sodic Soil N	P
Cotton	60	40	30	20
Wheat	50	10	30	6
Rice	50	40	40	24
Corn	70	..	30	..
Berseem	..	35	..	25

[a]Other yield influencing factors constant.

level of fertilizer application is somewhat closer to the recommended and optimum levels.

Egyptian farmers have been applying about two-thirds of the phosphates recommended by the Ministry of Agriculture but less than half of the optimum quantities as shown by experimental evidence.

The tabulation also suggests that crop yield would increase by a substantial amount if the optimum quantities were used.

The validity of these research results in actual farm operations depends on a variety of interesting dynamic factors, to which attention will be given in Chapter VII.

CHAPTER VII

POTENTIAL FERTILIZER USE

". . . we were given but little knowledge."

The Koran, Sourat XVII

The problem of concern now shifts from the optimum level of fertilization within present price and cultural patterns to the development of the potential fertilizer use associated with each of a number of pending and possible changes in price ratios, in the use of technical knowledge, and in cultural patterns, including the use of the Aswan High Dam. The first part of this chapter delineates the potential stemming from the application of knowledge already known to be applicable to Egypt. The second and shorter part will discuss future potentials if some major technical changes tested in other parts of the tropics prove to be in some degree applicable to Egypt.

More specifically, under present potentials, the actual and recommended current use of fertilizer will be summarized under existing conditions. Following this, consideration will be given to the increase in fertilizer use stemming from:

Changing irrigation practices.
Changing the soil organic matter level.
Changing soil salinity.
Changing to highly responsive crop varieties.
Changing the cropping system.
Changing fertilizer-crop price ratios.

The second section will show existing projections to 1975, the revised projection based upon the potential changes reviewed in the first section, and then incorporate the increased fertilizer potentials due to the completion of the Aswan High Dam, the change from basin to perennial irrigation, and from open field to covered pipe drainage.

Present Potentials--Current Practices

Actual Versus Recommended Fertilizer Use

C. Issawi indicated (Chapter III) that the total fertilizer requirement in 1960 was 1,629,000 tons which represents 240,000, 80,000 and 10,000 tons of N, P_2O_5, K_2O, respectively.

But D. Mead shows that total consumption in the same year was only 1,069,000 tons of N, P_2O_5, K_2O. In other words, Egyptian farmers used only 65 percent of the total amount required and recommended by the Ministry of Agriculture.

C. Issawi also indicates that Egyptian farmers could double their nitrogen application for wheat and still make a 100 percent profit on their investment at the then existing crop-fertilizer price ratios.

M. T. Eid and Mahmoud show in Table 7-1 that nitrogen and phosphate consumption in 1965 was two and a half times that of 1950.[1]

Even though the increase in the use of inorganic fertilizer during the period 1950-65 has been impressive, Egyptian farmers were using only 70 percent, 36 percent and 5 percent of the total amounts of N, P_2O_5, K_2O, respectively that were recommended for the five major crops by the Ministry of Agriculture in 1965.

Had the 1965 fertilizer recommendations been followed, Egyptian farmers would have used a minimum of 368,100, 116,400 and 10,000 tons of N, P_2O_5, K_2O, respectively as shown in Table 7-2. Yield per acre would have increased from an average of 750 to 900 for cotton (lint and seed), 2,433 to 2,900 for rice, 1,100 to 1,350 for corn, 1,200 to 1,400 for wheat and 22,500 to 23,900 kgs. for berseem. Yields of these crops would not only have increased in quantity but their quality and nutritive value would have also improved.

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[1]The table also shows that in 1950, 33 percent of the nitrogen consumed came from organic sources while the rest came from commercial fertilizers, but about 85 percent of phosphorus and almost all the potassium came from organic manures. If we compare 1950 with 1965, we note that only 15 percent of nitrogen and 70 percent of phosphorus came from organic sources in 1965. This emphasized the increasingly important role that commercial fertilizers play each year in Egyptian agriculture, and that Egypt will have to depend more and more on commercial fertilizers in the future if she is to maintain high crop yields.

Table 7-1. Organic and inorganic fertilizer use in Egypt

Year	Organic Fertilizer in Millions of Tons	Amounts of N, P_2O_5, K_2O in Thousand Tons in Organic Fertilizer			Inorganic Fertilizers N, P_2O_5, K_2O in Thousand Tons						Total N, P_2O_5, K_2O in Inorganic and Organic Fertilizer		
		N	P_2O_5	K_2O	N	% Increase	P_2O_5	% Increase	K_2O	% Increase	N	P_2O_5	K_2O
1950	55	33	88	220	70	..	16.2	..	.72	..	103	104.20	220.72
1955	57	34	91	228	120	71	21.75	34	1.00	40	154	112.75	229.00
1960	60	36	96	240	181	160	36.60	126	2.30	220	217	132.6	242.30
1965	62	37	99	248	267	281	48.75	200	0.57	-20	304	147.75	248.57
1967[a]	65	39	104	260	302	317	63.00	288	1.20	66	341	167.00	216.20
1975[a]	67	40	109	273	340	350	113	390	10.00	900	380	222.00	283.00

Source: Compiled and translated from several articles by Drs. Mahmoud and Taha Eid in "Meglit Elfilaha," *The Agricultural Magazine*, July-August 1967, The Society of Graduates of Agricultural Institutes of Egypt, Cairo.

[a]Projected. It has been reported by T.V.A., Estimated World Fertilizer Production Capacity as Related to Future Needs, 1967 to 1972-80 that actual consumption in 1966 was 285,000, 55,000, 1,000 tons of N, P_2O_5, K_2O, respectively, and in 1967 was 250,000, 55,000, 1,000 tons of N, P_2O_5, K_2O, respectively. This decrease in fertilizer consumption was not due to a decrease in demand, but to limited supplies, due to a decrease in imports because of foreign exchange shortage.

Table 7-2. Total amounts of N, P_2O_5, K_2O that should be applied to different crops, as recommended by the Ministry of Agriculture for the year 1965[a]

Crop	Recommended Inorganic Fertilizers in Kilos/Acre		Cropped Area 1965	Total Amount Implied by Recommendation for Each Crop in Tons	
	N	P_2O_5		N	P_2O_5
Cotton	40	20	1,700,000	68,000	34,000
Wheat	30	8	1,360,000	40,800	10,800
Corn and sorghum	45	0	2,200,000	109,000	0
Sugarcane	70	0	220,000	15,400	0
Rice	40	16	850,000	34,000	13,000
Vegetables	90	10	700,000	63,000	7,000
Fruits	80	10	200,000	16,000	2,000
Legumes	0	20	2,480,000	0	49,600
Other crops	30	0	730,000	21,900	0
Total			10,440,000	368,100	116,400

Source: Compiled and translated from several issues of the Agricultural Economics Publications of the Ministry of Agriculture, 1966.

[a]As for K_2O total requirement was given as 10,000 tons.

Egyptian scientists and F.A.O. experts working in Egypt, report that the protein content of wheat, corn, cotton seed and rice would increase by at least 10 percent, and cotton lint would be stronger, longer and softer, as a result of an increase in fertilizer use.

Recommended Versus Optimum Fertilizer Use in 1965

The fertilizer levels recommended by the Ministry of Agriculture for the five major crops are somewhat conservative in nature and are at least 30 percent below the optimum computed in the previous chapter as summarized in Table 6-31. Also, this computed optimum is believed to be below the real economic optimum that could have been precisely calculated had the fertilization experiments been carried up to the end of stage two of the production function, and had the fertilizer increments in these experiments been in smaller units than those used. But taking this computed optimum as the best one that can be obtained at present and assuming that the difference between the recommended rates of fertilization and the optimum for the five major crops[1] represents the difference between the recommended and the optimum for all crops, we can say that the optimum amount of nitrogen and phosphorus for all crops is 630,000 tons. Had Egyptian farmers used this optimum level of fertilization then total

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[1] The Annuaire Statistique, C.B.E., Econ. Revue No. 2, 1966, show that these five major crops occupy about 82 percent of the cultivated area.

cotton, wheat, rice, corn and berseem production would have increased by 2.5 million kantars 45,000, 57,000, 880,000 and 10 million tons respectively. That means that Egypt would have earned 52 million Egyptian pounds more in cotton and rice export at existing prices, and also would have saved 22 million Egyptian pounds in corn and wheat imports.

Present Potentials--Changing Practices

Now the question is, what would happen to this computed optimum if we relax some of the factors that were assumed constant?

If, for example, the existing fertilization, irrigation and cultural practices were administered according to good husbandry recommendations, the production function changes to another production function, and the total, average and marginal physical product curves will all shift upward. In that case, the computed optimum will not be the optimum anymore because the M.P.P. will increase; so to reach the new optimum level, more fertilizer needs to be used up to the point where M.P.P. equates the fertilizer-crop price ratio. How much more fertilizer should be applied to reach this new optimum? This question can not be answered except through new experimental investigations that show the shape and slope of the new production function. Although a few sophisticated production functions exist at present, there are very few available functions that suit the purpose of this study.

Changing Irrigation Practices[1]

Water supply from the Nile is very limited during the period from April to the beginning of August. Careful allocation of water between the different crops is needed especially during this period in order to achieve optimum utilization of land and water resources.

About one-third of the arable land in the delta could not grow any crop during June, July and early August because of lack of water. More water during these months would mean that more land could be cropped or more water would be available per area unit, or both. Now, this shortage of water can be alleviated to a great extent by using the stored water from the High Dam or by developing underground water which appears to be plentiful in Egypt. The hidden river below the bed of the Nile is reported to carry several hundred billions of cubic metres of water per year, or several times the flow of the Nile itself. It is the generally held opinion in Egypt that the underground water in the region south of Contour 5 which lies several tens of kilometers south of the Mediterranean coast is sweet enough to grow any crop. This opinion seems to be confirmed by the fact that there are already some 1,000 deep wells in use in the delta.[2]

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[1]It is implied that other factors affecting yield are kept constant.

[2]Extensive use of this water would probably draw salty water southward.

With pump irrigation from deep wells, rice can be grown without depending on irrigation from the Nile, which would mean growing more rice on land which otherwise would be planted to corn after the arrival of the Nile flood in August. Deep well water could alleviate the water shortage for rice, also one more extra irrigation could be given to the wheat crop in the winter.

According to C. L. Pan, F.A.O. rice production expert in Egypt, rice production has increased from 12 to 25 percent through the use of deep well water. Also according to the Wheat Branch of the Plant Breeding Section, this extra irrigation for wheat would increase yield by 450 kg. per hectare (210 kg. per acre), i.e., an increase of 20 percent.

A. Kamel has found that shortening the irrigation cycle for cotton and corn from 18 to 15 days would increase cotton yield by 16.54 percent, 18.52 percent and 23.45 percent in North, South and Middle Egypt, respectively, and for corn, yield increase would range from 15 to 25 percent.[2]

Now we have a new production function with the new irrigation practices as a new input, but we do not know what is the shape or slope of this new response curve. All we can say is that a given amount of fertilizer is more

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[1] C. L. Pan, F.A.O., Rice Production Export, Report to the Government of the U.A.R., No. 1067, Rome, 1959.

[2] A. Kamel, "Crop Irrigation," Agricultural Magazine, February 1964, Cairo.

profitable than before (because its efficiency has increased) so to get to the new optimum level one has to use more fertilizer. Also the variable and fixed costs of the digging of the well, installation of the pumps and the operating cost of the pumping and water distribution processes are modest in relation to the streams of income created.

Thus adequate irrigation water would shift the response curve by 15 to 25 percent.

Changing Soil Organic Matter Level

The maintenance of a satisfactory level of organic matter, presents a problem of particular severity in Egypt where high temperatures lead to its rapid decomposition and where the ability of soils to retain moisture and nutrients is especially dependent on organic matter. In Egypt, practically all parts of the plant except the roots are removed from the soil. Wheat straw is used as cattle feed, bean straw as camel and sheep feed, cotton and corn stalks are used for cooking, heating, baking, brickmaking, and even for such uses as a source of heat for milling processes. At present, the Egyptian soils contain an average of less than 1.5 percent organic matter which is too low for the maintenance of good chemical and physical properties.[1] If this

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[1]Table 7-1 shows that manure quantities used in 1967 were 65 million tons containing 6.5 million tons of organic matter, but M. T. Eid argues that the minimum requirement is 15 tons of barnyard manure per acre, so total amount required for the present area would be 90 million tons that contains 9 million tons of organic matter.

low average is to increase to 2 percent which is stated as the minimum for optimum crop production, then an additional quantity of 2.5 million tons for the present cultivated area plus 45.5 million tons of organic matter as a result of the increase in cultivated area in absence of Nile silt, would be required in 1975. The full use of 12,182,730 tons of plant residues, 350,000 tons of sewage, 2,600,000 tons of city garbage plus the byproducts of slaughtering and leather tinting firms, and market places could make up for part of the extra 48 million tons of organic matter.[1]

M. A. Mohamed and A. Shalaby indicate that for crop production in Egypt organic matter is the second most important limiting factor after irrigation water, and that maintenance of a satisfactory level of organic matter could increase crop yield by at least 15 to 40 percent depending on type of soil, crop variety and organic quality.[2] Thus, the response curve will shift by at least 15 percent.

Changing Soil Salinity

How do nonsaline soils increase crop response to fertilizer? What will be the additional quantities of fertilizer required if we assume that the new network of

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[1]The cost of the organic matter is likely to be high, it may be so costly that little really is done.

[2]M. A. Mohamed and A. Shalaby, "Is Organic Matter Important for the Fertility of Our Egyptian Soils?" The Agricultural Magazine, July-August 1967, Cairo.

drainage system is completed, and as a result, water-table will be lowered, soil salinity and alkalinity reduced, or in other words soil physical and chemical properties are improved, and nutrient supplying-power of all Egyptian soils increases?

Because the Egyptian soil is made up of the Nile silt that has been deposited on the sand of the desert over millions of years, it contains large amounts of sodium salts, Table 7-3. Chemical analysis of the Nile silt, Table 7-4 shows that it contains a high percentage of sodium oxide. Also Nile water has been found to contain a high percentage of sodium salts.

Table 7-3. Chemical analysis of five samples of Egyptian soils

Soil Sample	Basis	P_H	Al_2O_3	CaO	MgO	K_2O	Na_2O	SO_2
Sample 1	12.03	8.04	1.710	7.10	2.48	0.59	0.338	17.63
Sample 2	8.44	8.10	4.050	6.00	2.90	0.55	0.292	22.64
Sample 3	12.70	8.05	1.422	5.23	2.40	0.66	0.319	15.54
Sample 4	6.28	8.45	2.916	4.20	3.10	0.86	0.477	22.00
Sample 5	2.41	7.95	7.340	5.78	2.60	0.44	0.162	15.79

Source: Reproduced and translated from A. Shalaby, "Is It Necessary to Increase Egyptian Soil Organic Matter in Order to Raise Yields?" The Agricultural Magazine, July-August 1967.

Table 7-4. Chemical analysis of Nile silt

Element	% of Total
Silicon dioxide	50.44
Iron oxide	9.91
Aluminum oxide	19.01
Titanium oxide	0.23
Magnesium oxide	3.43
Calcium oxide	4.16
Potassium oxide	1.07
Sodium oxide	0.95
Inorganic sulphur	0.09
Carbon dioxide	1.03
Phosphoric acid	0.24
Organic matter	2.48

Source: Reproduced and translated from A. A. Mostafa, "Nile Silt and Its Relation to Soil Fertility," The Agricultural Magazine, July-August 1967.

Many attempts have been made to reduce the sodium salts in the black alkali, Egyptian soils by the application of electric current which also makes the nitrates and the phosphates in the soil concentrate in the upper layer where it is available for the plant and which also activates and makes soil microorganisms more beneficial. It was also suggested that a certain plant called "Salckbush," if ploughed into the soil as it is done in Sudan, would reduce the sodium salts. But all these attempts are not as practical and economical as the use of gypsum which is found in abundance in the Fayoum desert that lie between Fayoum and Beni-Suef, provinces (70 miles southeast of Cairo) also at Balah near Suez.

The improvement of alkali soils involves (besides drainage and leaching) the replacement of adsorbed sodium by calcium or magnesium and the use of practices that develop good soil structure. When gypsum is applied to the soil, (calcium sulphates)[1] the calcium ions replace the adsorbed sodium which is in turn removed in percolating waters as sodium sulphates.[2] Also large amounts of organic fertilizers and/or a green manure should be added to the soil to improve the physical and chemical properties and to enhance the displacement of the sodium carbonate salts.

Saline soils are improved by establishing artificial drains if a high ground-water table exists and by subsequent leaching with irrigation water to remove excess soluble salts. Siepage must be reduced by lining canals with cement, buried asphalt membranes, or more commonly with earth of low permeability. Careful leveling of land makes possible a more uniform application of water and better salinity control. Practical experience has shown that the best way to do so is by planting paddy rice in such soils. The very same practice of muddying is the most effective way not only in leveling the land but also in dissolving the sodium chloride salts.

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[1] Two hundred and thirty thousand tons are being produced now at Kafrel-Zaiat (30 miles south of Alexandria) and Abu-Zaabal (15 miles north of Cairo).

[2] To encourage the use of gypsum, the government has been selling it below cost. Thus costs are modest in relation to the streams of income created.

Practical experience has shown that crops grown on salt free soils have the capacity of absorbing higher doses of fertilizer than crops grown in saline-alkali soils. This is true for most field crops, vegetables and fruit trees. In the case of corn or sugarcane, up to 120 kgs. of nitrogen per acre could be profitably used in Matay where the soil is free of the harmful sodium salts, while in the saline-alkali soils of Maghagha, the use of more than 30 kgs. per acre tends to produce salt injury to plants (fertilizer is a salt and so increased use of it adds to the high soil salt concentration). When 120 kg. nitrogen per acre were used for corn in Matay, the average yield was 18 ardabs, while that of Magaga was only 7 ardabs.

The semi-aquatic conditions under which rice is cultivated necessitate a heavy soil through which the irrigation water will not easily percolate, for the demands of the plant regarding water are more precise than are its demands on soil conditions. Thus, the effect of soil on rice yields is less than the effect of soil on the yields of other crops. But in spite of this, C. L. Pan, the F.A.O. rice expert referred to earlier, states that rice yields in salt free soils are at least 15 percent higher than in saline soils.

The same is true of berseem, a very tolerant crop to soil salinity, but field experiments have shown that yield is at least 18 percent higher in nonsaline soils.

Even the improvement of alkali soil aggregation by the application of synthetic aggregates reduced the toxic effect of E.S.P. (exchangeable sodium percentage) and increased berseem yield almost 30 percent, as shown in Table 7-5.

It has been shown in the previous chapter that the optimum fertilizer level for wheat (other things being equal) is 30 and 45 kg. per acre in saline and nonsaline soils, respectively.

Thus, leaching harmful sodium salts from Egyptian soils would increase yield from 20 to 100 percent depending on the crop and degree of sodium salt concentration.

Table 7-5. The effect of improving the aggregation of alkaline soil on the increase of berseem yield

E.S.P.[a]	Yield of Berseem (kilos/pot)	
	Soil + Aggregates	Soil Without Aggregates
10	13.0	10.0
20	11.0	9.0
30	10.0	8.5
40	9.5	6.1
50	6.5	2.4
60	0.3	0.0

Source: A. A. Abdel Barr *et al.*, "Calcium/Sodium Ratio in Alkali Soils and Its Effect on Soil Properties under Laboratory and Pot Tests," *Journal of Soil Science*, V, The National Information and Documentation Center, 1965.

[a]E.S.P. equals exchange sodium percentage.

Changing to High Responsive Crop Varieties, Other Things Being Equal

New rice varieties.--In Egypt a number of workers have demonstrated that some varieties of crops respond differently from others to plant-nutrient applications, as shown in Table 6-21. The optimum for the best variety of 1959 was 196 kg. of N per hectare compared with 98 kgs. for the least responsive. Some of these changes have already occurred as average yields of rice increased from 3.67 tons in 1953 to 5.2 tons in 1959 (41 percent).

The effects of the new IR-8 rice variety referred to in Chapter III have not yet been reported for Egypt, but in most of the countries (the Philippines, Taiwan, etc.) in which it was planted, farmers have been applying more fertilizer (35 percent) than was used for the Formosa local variety. So if we even assume that fertilizer requirement of IR-8 has the same response as Formosa variety, then the optimum fertilizer level will be 82 kg. instead of 41 kg. N per acre. When the U.S.D.A. experts tried IR-8 in South Vietnam, it yielded twice as much as the best local rice variety.[1]

New berseem varieties.--The Egyptian Agriculture Society has developed a new variety of berseem that has a longer and thicker stem, more branches and wider leaves. This variety is more responsive to P_2O_5 and gives much

[1]U.S.D.A., Agricultural Research, July 1968.

higher yields than the local meskawi berseem variety. Experts at Bahtim have given instructions to farmers using this new berseem variety to use at least half a sack of superphosphates (8 kg. P_2O_5) more than they use for the meskawi variety. These instructions are somewhat conservative, because practical experience has proved that a whole sack (16 kg. P_2O_5) of superphosphates instead of half, was more profitable.[1]

New wheat varieties.--The Ministry of Agriculture has developed many new wheat Giza varieties that are more responsive to fertilizers than Hindy, Balady or Toson varieties. The new varieties have a thicker and stiffer stalk, and when more fertilizer is applied they do not lodge. These varieties could be similar to the Mexican wheat varieties, but this is not certain. What is certain is that fertilizer recommendations for the new wheat varieties are 20 percent higher than recommendations given for old varieties, although in other countries, such as India, Mexico and Pakistan, the new Mexican varieties respond to twice as much fertilizer as the local ones. But if we accept this conservative increase of 20 percent for the new varieties then the optimum level will be 50 kg. N per acre instead of the 40 kg. which was the optimum level for the old local varieties.

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[1]Author's personal experience.

New cotton varieties.--M. T. Eid indicates that the new Menoufi cotton varieties are more responsive to fertilizer than the old Karnak varieties, and that if the high-yielding potentialities of these new varieties are to be reaped, the farmer should use 50 percent more fertilizer than he did with the old ones. He also adds that the farmer should use up to 60 kg. N per acre when Ashmouni or Bahtimi 185 (a new responsive variety developed by the Egyptian Agriculture Society) cotton varieties are used.[1] Practical experience has shown that there is some exaggeration in Dr. Eid's recommendations, because cotton is very sensitive to N application (gives vegetative growth, retards maturity and makes the plant susceptible to insect attacks). But these recommendations might be feasible for the large quantities of P_2O_5 (35 kg. P_2O_5) so as to have the nutrients in a state of balance. So if we assume that insecticides and P_2O_5 are used by all farmers, then the optimum level for Ashmouni and Bahtimi 185 varieties is 60 kg. N per acre, and 40 kg. per acre for Menoufi varieties.

New corn varieties.--The high responsiveness of hybrid corn varieties to fertilizer is well known, and throughout this study the superiority of hybrid varieties in absorbing and utilizing large quantities of fertilizer relative to local corn varieties has been reported. Practical

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[1] M. T. Eid, "Cotton Fertilization," The Agricultural Magazine, March 1962, Cairo.

experience has proved that twice the application of nitrogen used for local corn varieties planted side by side, in Matay, was more remunerative than yields of local varieties. We can visualize the two production functions for local and hybrid corn varieties as in Figure 7-1. Thus, the optimum level for hybrid corn planted in salt free soils is at least 120 kg. N per acre. Also, 10 kg. P_2O_5 will be required when this high level of nitrogen is used.

Changing Cultural Practices

We have seen in Chapters IV and VI that placement, time and mode of application and kind of fertilizer, time of planting and watering, number of plants per acre and depth of ploughing, play an important role in shifting the response curve. The magnitude of this shift ranges all the way from 10 to 60 percent depending upon crop variety, soil characteristics, and weather conditions. As an example, Table 7-6 shows that deep placement of fertilizer for rice increased yield 9 percent. Also, Table 7-7 shows that depth and mode of ploughing could make a difference of 9 percent, 7 percent and 18 percent in cotton, wheat and corn yields, respectively. Absence of one irrigation for corn at the time of pollination (corn gets 10 irrigations) would reduce yield by 60 percent. Many other examples have been cited already throughout this thesis.

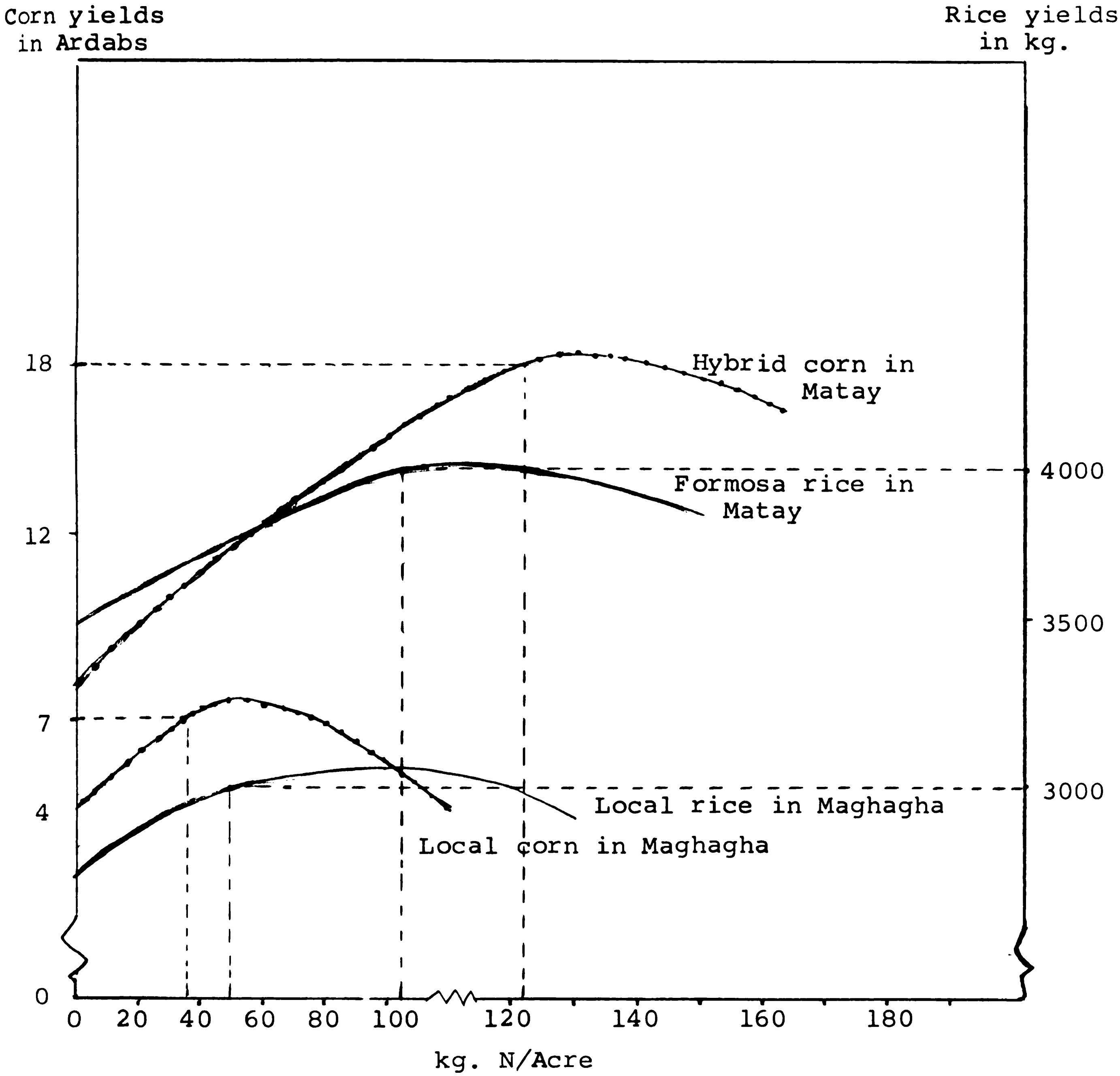

Figure 7-1. Four hypothetical production functions for corn and rice planted in Matay and Maghagha. (Optimum nitrogen levels for hybrid corn and Formosa rice planted in Matay is 120 and 90 kg. per acre respectively, and yield is 18 ardabs and 4,000 kg. while for local corn and rice planted in Maghagha is 33 and 45 kg. per acre and yield is 7 ardabs and 3,000 kg. per acre respectively.

Table 7-6. Yield with deep-placement expressed as percentage of yield with surface-placement

Experiments Conducted		Deep Placement Yield in Percentage of Surface-Placement Yield
Location	Date	
Sakha	1954	108.6
Sids	1955	108.2
Gemmeiza	1955	106.4
Sakha Exp. (1)	1956	100.0
Sakha Exp. (2)	1956	107.2
Sids (1)	1956	118.9
Sids (2)	1956	106.2
Gemmeiza	1956	112.7
Sids	1957	107.7
Gemmeiza	1957	113.4
Average		108.9

Source: F.A.O., Report to the government of the U.A.R., on rice production, Report No. 1067, Rome, 1959.

Changing Cropping System

We have seen in Chapter VI that using the three year rotation system would increase crop yields 15 to 25 percent over the two year rotation system, depending upon crop variety, cultural and fertilization practices. That means that with the three year rotation, crop response shifts up, and that fertilizer use is more profitable with the three than with the two year rotation. Thus, more fertilizer could be used up to the point where M.P.P. equals fertilizer-crop price ratio. How much more, depends on the shape and slope of the new production function. But supposing farmers find that wheat is more remunerative than other crops, or the government decides to follow a policy of self sufficiency

Table 7-7. Effect of depth and mode of ploughing on cotton, wheat and maize yields

Mean Cotton Yield/Feddan

Ploughing Depth	Type of Plough					
	Native		Chisel		Moldboard	
	Kg.	Kantar	Kg.	Kantar	Kg.	Kantar
13 cm.	948.150	6.02	946.575	6.01	941.850	5.98
25 cm.	952.875	6.05	916.650	5.82	1009.585	6.41

Mean Wheat Yield/Feddan

Ploughing Depth	Type of Plough					
	Native		Chisel		Moldboard	
	Kg.	Ardab	Kg.	Ardab	Kg.	Ardab
13 cm.	1375.19	9.16	1358.21	9.06	1435.41	9.75
25 cm.	1409.16	9.39	1443.14	9.62	1591.37	10.61

Mean Maize Grains/Feddan

Ploughing Depth	Type of Plough					
	Native		Chisel		Moldboard	
	Kg.	Ardab	Kg.	Ardab	Kg.	Ardab
13 cm.	1078.22	7.70	1118.25	7.99	1120.22	8.00
	XX		XX		X+	
25 cm.	1194.38	8.53	1283.63	9.17	1284.94	9.18

Source: A. M. Balba, "Soils Department, University of Alexandria," Journal of Soil Science, The National Information and Documentation Centre, November 1964.

concerning wheat and compels or adopts policies which induce the farmers to use the two year rotation, i.e., plant it again on half of their land the first year, then plant it again on the other half the second year, or farmers go to the extent of planting the whole area into wheat each year. In these cases, more fertilizer has to be used if a given quantity of yield is desired. How much more is hard to say without experimental work to show how the new production functions behave. This information if it exists, is not available. But what can be said for certain is that the increase in wheat acreage would be a decrease in berseem and/or cotton acreage. So if we assume that half of the berseem and/or cotton acreage will be put into wheat, then we shall not only need 40 kg. N per acre for wheat fertilization (we will save 20 kg. P_2O_5 per acre which is the difference between wheat and berseem phosphate fertilization), but also have to use more nitrogen fertilizer to compensate for the nitrogen (also the organic matter) that could have been fixed by berseem into the soil, and which amounts to 30 kg. nitrogen per acre.

Because of recent corn shortage (the result of cutting United States aid), the Egyptian government has been urging farmers to plant two corn crops in the same year instead of one (i.e., one early crop from April to July and the second from August to November). So if we assume that only half of the farmers feel compelled to follow this

this practice, then at least an extra 50 kg. nitrogen per acre will be required for half the present corn acreage.

We may also assume that some of the new crop varieties might have a shorter growing season (such as IR-8 rice variety or some of the new cotton varieties) or, that the Egyptian farmer might be able to use modern machinery in preparing the soil and in harvesting, thus saving time which could be utilized in crop growing. In all these cases, the present crop index (1.7) will increase, and if we assume that this increase is 10 percent, then total fertilizer requirement will increase 10 percent.

Changing Fertilizer-Crop Price Ratio, Other Things Being Equal

Price ratios more favorable to Egyptian cultivators can be brought about both by lowering the prices of inputs to the farmer and by raising output prices. Each course of action has its positive and its negative features, and will be discussed in Chapter VIII.

But by narrowing the price ratio, the left side of the equation ($MPP_F = P_F/P_C$) has to be lowered to keep the equality. Thus, more fertilizer should be applied up to the point where this equality is restored.

We have seen in Chapter VI that lowering nitrogen-wheat ratio from $\frac{5}{1}$ to $\frac{5}{2}$ has moved the optimum level from 60 to 90 kg. nitrogen per hectare. Thus cutting the fertilizer price to half what it used to be, or increasing the crop price by 100 percent does not mean that the optimum level will increase by 100 percent. The change depends upon the shape and slope of the MVP curve (which is the same as the fertilizer demand curve). Any change in fertilizer price makes us move along the same demand curve, while change in crop price shifts demand up or down depending on the direction of the initial change. The research has not permitted the development of production functions to the end of stage two. Thus a precise new optimum cannot be identified.

But in the case of berseem, better data are available (Figure 6-2) so that a close approximation can be made. Thus, when the ratio shifts from 36:1 to 24:1 (a 33 percent drop in phosphate prices), application would increase to 60 kg. P_2O_5 per acre, at which the MPP is 29, the closest we can come to the new optimum level.

The contrary case is shown for cotton. In two Upper Egypt experiments at the highest level of N application, 62 kg. per acre, the MPP was 5 while the price ratio was 1:1. Thus, an application in excess of 62 kg. is suggested. Similar limitations apply for corn and rice, with maximum applications of 60 and 90 kg. per acre, despite price ratios favorable for additional applications.

<u>Summary</u>

Now it is necessary to draw all these together into an estimate of the fertilizer that could have been used if these changes would have taken place. Changing irrigation and cultural practices, soil organic matter level, physical and chemical soil characteristics, crop varieties, cropping systems and fertilizer-crop price ratio will certainly increase the efficiency of fertilizer and increase the previously computed optimum for all crops. It is impossible to say precisely what this new optimum is without more adequate data. A multitude of production functions that must be carried well into stage two of the production function for each crop is needed if we are to pinpoint the optimum level for each crop when the above changes occur.

By making conservative estimates of the changes that certainly would occur, new overall estimates of the desirable application of fertilizer can be made. These are shown by individual crops in Tables 7-8 and 7-9 and aggregated in Table 7-12, middle column. The change in price ratio, for example (a 33 percent reduction in phosphate prices) will move the optimum level from 30 to 60 kg. per acre for berseem. Also using the new rice and corn varieties in salt free soils will increase the optimum level for both crops from 45 and 50 to 82 and 120 kg. N per acre respectively.

Thus, most of the increase in the quantities of nitrogen would come from the change in corn and rice varieties and a change in soil characteristics. Most of the increase in phosphates was the result of a reduction in phosphate-berseem price ratio as shown in Table 7-8.

It is obvious from Table 7-9 that the total and average quantities of fertilizer after change are more than three and a half times as much as the total quantities used

Table 7-8. Optimum fertilizer level and yield in kg. per acre before and after change

Crop	Computed Optimum Level with Present Conditions (no change)		Yield Before Change	Optimum Level After Change		Yield After Change
	N	P_2O_5		N	P_2O_5	
Cotton	45	30	990 kilos	60	38	1,400
Wheat	40	8	1,550 kilos	50	11	1,900
Rice	45	30	3,000 kilos	82	35	4,000
Corn	50	0	1,400 kilos	120	10	2,500
Berseem	0	30	33 tons	5	60	40 tons

Table 7-9. Total[a] quantities of fertilizer use at present (1965), recommended and at computed optimum level before and after change (in thousands of tons)

Nutrient	Present Fertilizer Use	Recommended Quantities	Optimum Quantity Before Change	Optimum Quantity After Change	Optimum Quantity with an Increase of 10% in Crop Index
N	267.00	368.1	415.5	765.0	851
P_2O_5	48.75	116.4	214.2	340.0	374
K_2O	0.57	10.0	15.0	25.0	27
Total N, P_2O_5, K_2O	316.32	494.5	644.7	1,135.0	1,252
kg./cropped acre	30.00	47.0	61.5	108.0	108
kg./cultivated acre	52.5	80.0	103.7	183.6	...

[a]Because the five major crops constitute 82 percent of the cropped area, it is assumed that the change in the quantities of the fertilizer used for these five crops represents the change in total quantities of fertilizers used for all crops.

in 1965. We notice also that if the crop index increases by 10 percent (i.e., through changes in crop rotation) total quantities after change will be four times as much as quantities used at present.

While the magnitude of these changes seem large, the level of consumption if all these changes take place and all the fertilizer is used (440 kg. per hectare), the use of fertilizer will still be smaller than the Netherlands, Belgium and New Zealand, but eight times larger than the United States, as shown in Figure 7-2.

Potential Fertilizer Use in 1975

The year 1975 is not arbitrarily chosen; it is the year in which the present projects such as the conversion of the basin irrigated land to perennial irrigation, the conversion of open field to covered pipe drainage, and the Aswan High Dam and all the projects connected with it, are all scheduled to be completed.

The construction of the High Dam will make it possible to reclaim 1.5 million acres, to convert 970,000 acres from basin to perennial irrigation. An additional 750,000 acres result from change from open field to covered pipe drainage. But, as shown in Table 3-1, the construction of the High Dam will allow only one million tons of silt to be deposited on the cultivated land while the rest will be retained by the dam. The soil will be deprived of 12 million

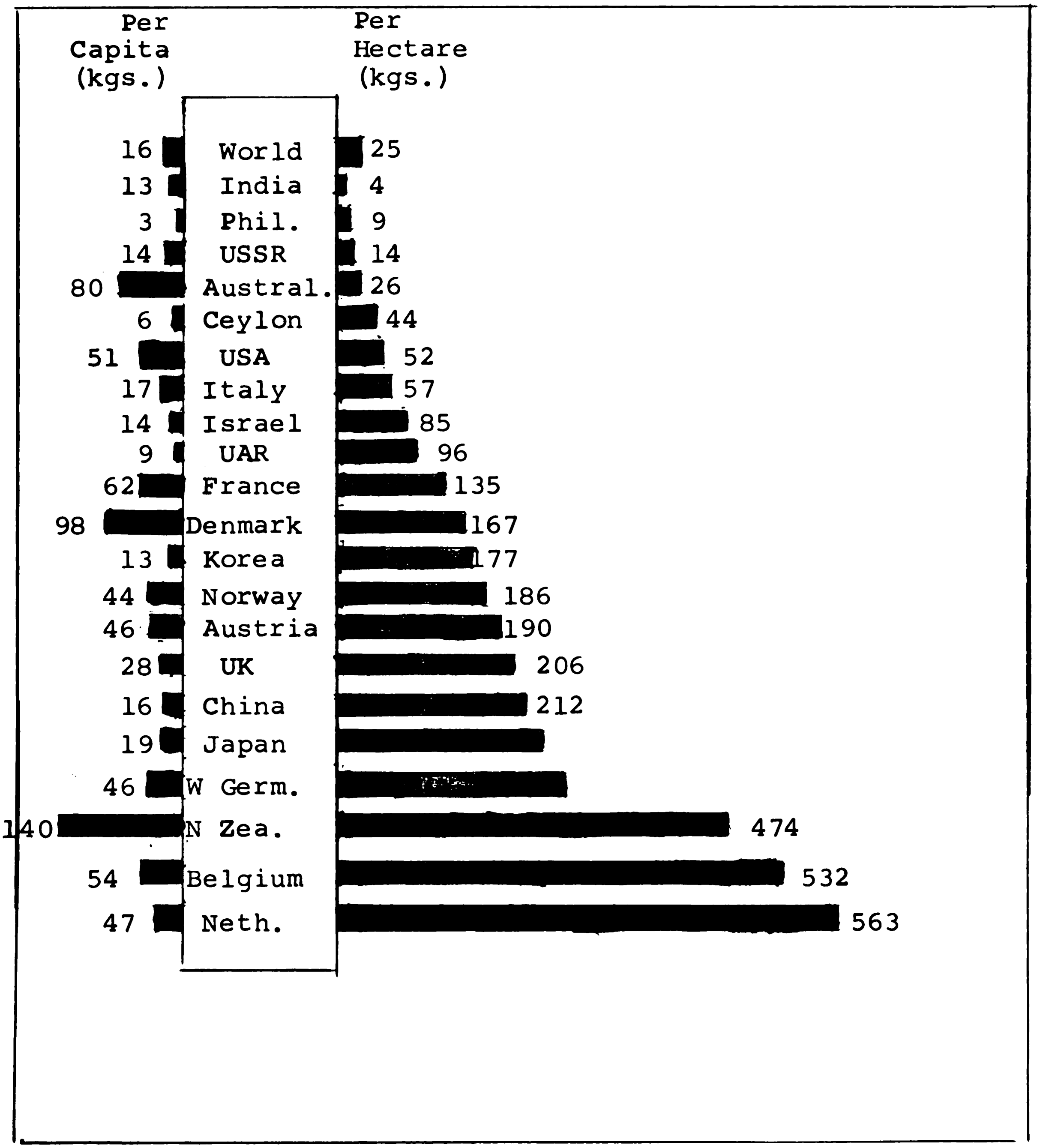

Figure 7-2. Per hectare and per capita consumption of plant nutrients (1963-64).

tons that contains about half a million tons of organic matter, 1,000 tons of nitrogen, 3,000 tons of phosphorus, 120,000 tons of potassium and large quantities of valuable secondary and minor elements.

Projection of the Present Trend

One Egyptian authority, T. Eid estimates that future inorganic fertilizer consumption in 1975 (Table 7-1) will be 340,000, 113,000 and 10,000 tons of N, P_2O_5, K_2O, respectively. His projection is based only on the recent trend of fertilizer consumption.[1] Despite the need for an estimate to reflect any acceleration of technological and economic changes, the High Dam, the increase in cropped and cultivated area, or the absence of the Nile silt. The last two items will require at least 123, 25 and 120 thousand tons of N, P_2O_5, K_2O respectively. This simple adjustment raises total requirements in 1975 to 463, 138 and 139 thousand tons of N, P_2O_5, K_2O, respectively.

Concerning organic fertilizers, Eid projected that 67 million tons will be used in 1975 as contrasted with 138 million tons that ought to be used. The newly reclaimed desert soil will need larger quantities of organic matter per acre than the present cultivated land, and it seems likely that some of this addition will be provided.

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[1]Both the least square regression and the free hand graphic methods show the same trend (see Figure 7-3).

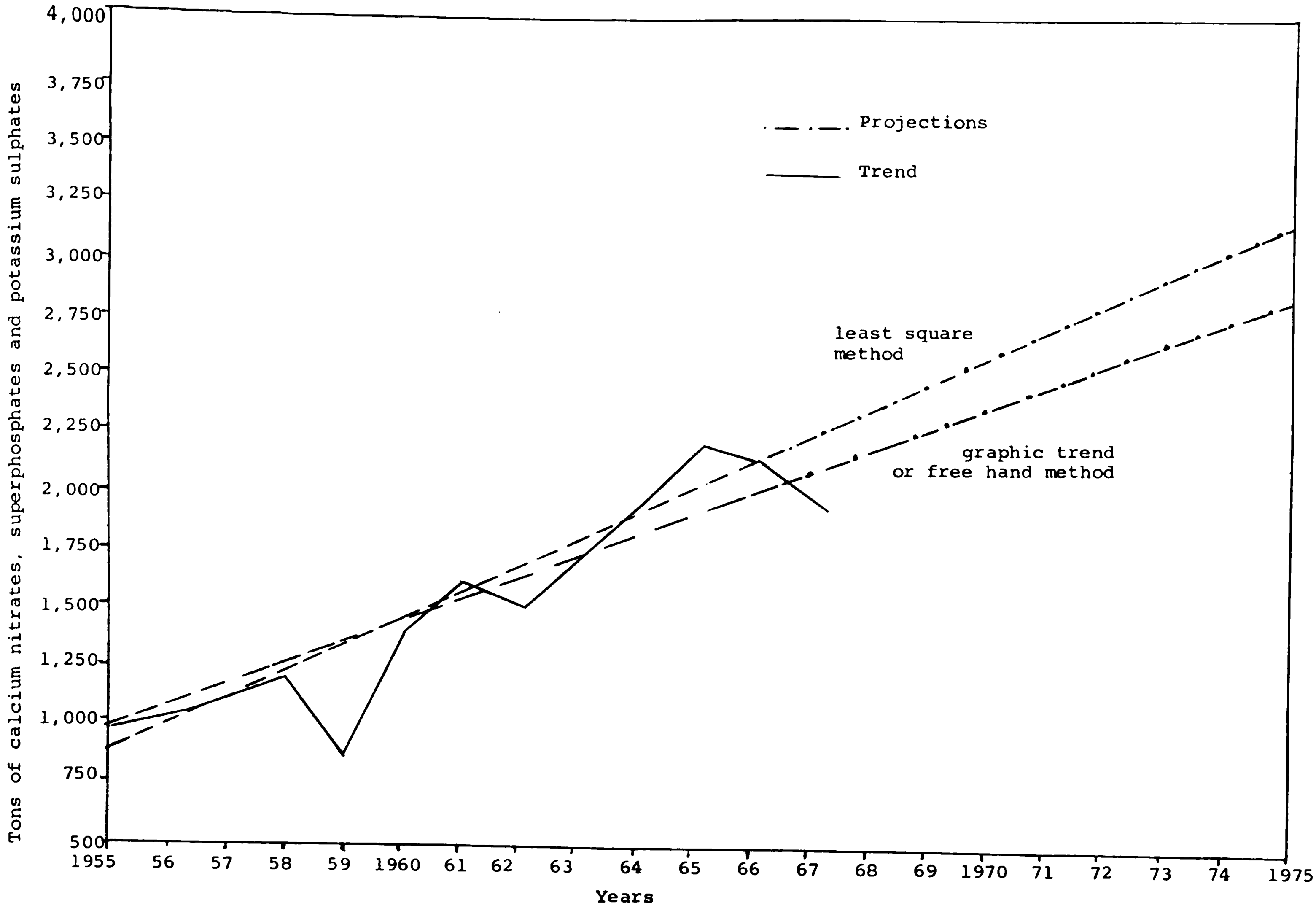

Figure 7-3. Trend and projections of fertilizer consumption, 1955-1975.

The F.A.O. has developed an interesting method to estimate the amounts of fertilizer that would be necessary to increase agricultural production by various percentages, up to and including 100 percent. Essentially the F.A.O. projection assumes that the level of fertilizer used is related to the yield of crops per hectare of cultivated land.[1] F.A.O. used data from 41 developed and developing countries to produce a curve showing the average relationship between fertilizer use and the yield index of crop production, the latter representing an approximation of productivity. This curve is used to estimate the quantity of fertilizer a country will need to attain a given level of crop production (Figure 7-4).

The level of crop production derives from the predicted rate of population growth to 1975 and 1985. It is assumed that the increased use of fertilizer will be accompanied by necessary and appropriate increases in other inputs required for improved farming practices. It is further assumed that the increased production will come largely from increasing yields on lands already in production. The new lands that may be added during the next two decades will contribute to the improvement of the diet beyond the highly inadequate level available to many people today. For Egypt, if the population in 1975 and 1985 is projected at 34.5

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[1]A Report of the President's Science Advisory Committee, The World Food Problem, Vol. II, The White House, May 1967.

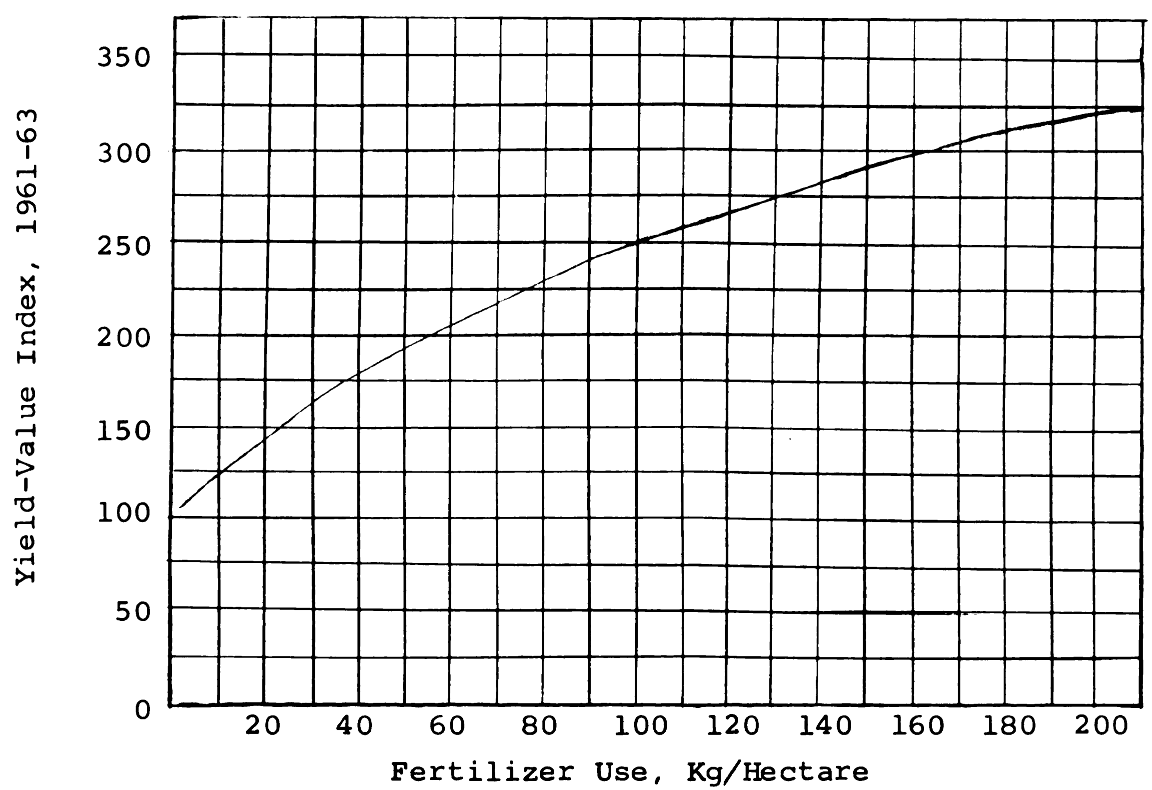

Figure 7-4. Yield-value index vs. fertilizer use--1961-1963. (Source: F. W. Parker, Fertilizer and Economic Development, in Fertilizer Technology and Usage, edited by M. H. McVickar, Soil Science Society of America, 1963.)

million and 53.1 million, respectively, i.e., an increase of 34.7 percent and 77 percent by 1975 and 1985, respectively, then agricultural production would increase by the same percentage to maintain the present per capita production. The fertilizer required will be 1,200,000, 215,000 tons of N, P respectively for 1975, and 2,487,000, 410,000 tons of N, P_2O_5, respectively for 1985 (Table 7-10).

Table 7-10. Fertilizer needed to increase agricultural production on acreage now under cultivation in Egypt by the percentages indicated utilizing the F.A.O. yield value index[a]

Percent Increase in Agricultural Production	Tonnage of Plant Nutrients Needed in 1,000 Tons		Percent Increase in Fertilizer Use
	N	P_2O_5	
..	300	50	..
10	550	90	80
20	800	133	165
30	1,080	180	257
40	1,340	223	345
50	1,630	271	440
60	1,910	318	535
70	2,240	373	645
80	2,600	433	765
90	2,960	490	885
100	3,031	506	1,000

Source: Calculated from Table 6-3, p. 382, A Report of the President's Science Advisory Committee, The World Food Problem, Vol. II, The White House, May 1967.

[a]The 1965 fertilizer consumption reported by the F.A.O. and taken as the base year is slightly higher than the figures reported by M. T. Eid.

Future Fertilizer Requirement

Analytical estimates of the potential quantities of fertilizer that could be utilized in 1975 on the present cultivated land and that scheduled to be added depend upon several assumptions. The assumptions and consequent estimate of fertilizer use are listed in increasing order.

1. The existing fertilizer use on present land continues, is extended to the additional land to be cultivated in 1975, and increases in fertilizer are provided to allow for the change from basin to perennial irrigation (two crops per year instead of one) and for the absence of silt. Under this assumption the estimated use is 390, 74 and 121 thousand tons of N, P_2O_5, K_2O, respectively (Column 2, Table 7-11). This may be compared to the smaller figure, last line, Table 7-1 for inorganic fertilizer.

2. The above assumption as adjusted by Dr. Eid's projection of recent trends is incorporated. The estimated usage is 497, 167 and 135 thousand tons of N, P_2O_5, K_2O, respectively (Column three, Table 7-11).

3. Egyptian farmers expand the use of fertilizer to the level of the 1965 recommendations of the Ministry of Agriculture for present and new lands, and with adjustments for perennial irrigation and the absence of silt. The potential use in 1975 then becomes 538, 173 and 135 thousand tons of N, P_2O_5, K_2O, respectively (Column four, Table 7-11).

Table 7-11. Potential use of fertilizer in 1975 (in thousands of tons)

Added Area in Millions of Acres	Based on Present Conditions and Practices (1960 Level)			Based on Recent Trend (Based on Eid's Projection)			Based on the Recommendations of the Ministry of Agriculture			Based on Computed Optimum Before Change			Based on Optimum After Change + Increases of 10% in Crop Index		
	N	P_2O_5	K_2O	N	P_2O_5	K_2O	N	P_2O_5	K_2O	N	P_2O_5	K_2O	N	P_2O_5	K_2O
Total fertilizer used for present 6.0 acres	267.0	48.75	0.5	340.0	113.0	10.0	368.1	116.4	10.0	415.5	214.2	15.0	851.0	374.0	27.0
1.5 reclaimed	66.7	12.00	0.2	85.0	28.1	2.5	92.0	29.0	2.5	103.6	53.5	3.7	212.7	93.5	6.7
0.97 changed to perennial irrigation	22.2	4.00	...	28.0	9.3	0.8	31.0	9.6	0.8	34.4	17.8	1.2	70.9	31.1	2.2
0.75 changed to covered drainage	33.2	6.00	0.1	42.5	14.0	1.2	46.0	14.5	1.2	51.8	26.7	1.8	106.3	46.7	3.8
Absence of deposited silt	1.0	3.00	120.0	1.0	3.0	120.0	1.0	3.0	120.0	1.0	3.0	120.0	1.0	3.0	120.0
Total of additional requirement	123.1	25.00	120.3	156.5	54.4	124.5	170.0	56.1	124.5	190.8	101.0	126.7	390.9	174.3	132.7
Total fertilizer requirement in 1975	390.1	73.75	120.8	496.5	167.4	134.5	538.1	172.5	134.5	606.3	315.2	141.7	1241.9	548.3	159.7

4. No further technological change, but farmers use the calculated optimal level of fertilizer for 1965, developed earlier in this thesis. Usage then becomes 606, 315 and 142 thousand tons of N, P_2O_5, K_2O, respectively (Column five, Table 7-11).

5. Technological changes discussed in the first part of this chapter occur, and farmers use the conservatively calculated optimums, and adjustments indicated above. The potential fertilizer use in 1975, on this basis, becomes 1,242, 548 and 160 thousand tons of N, P_2O_5, K_2O, respectively (Column six, Table 7-11).

These required quantities based on the optimum level after the technological and economic change might seem large, but this estimate is a conservative one. If we have had all the production functions necessary for this study, this quantity almost certainly would have been even larger.

As a matter of fact, it can be argued that the phosphate and potassium quantities are inadequate (especially for the sandy soils) because the balance between the three nutrients should be maintained somewhere around 3:2:1, depending on soil type, crop variety and the other crops in the rotation. Unless barnyard and green manure or silt is used to compensate for this shortage in P and K, plant growth may be severely limited. Since the construction of the High Dam will deprive the new and the already cultivated soil of the rich Nile silt, the whole burden of providing potassium will fall on barnyard and green manure.

If these technological and economic changes are to take place, and if we are to attain these fertilization potentials, the existing policies and institutions need to be examined. This will be the subject matter of the following chapter.

CHAPTER VIII

POSSIBLE STRUCTURING OF POLICIES AND INSTITUTIONS TO ATTAIN FERTILIZER POTENTIALS

> "Markets and competition now
> Must be the hand that speeds the plow
> Making, in one Rostovian leap
> Corn dear, and fertilizer cheap."
>
> K. Boulding

Knowledge of fertilizer technology must keep changing if the Egyptian agricultural productivity is to continue to increase. Well directed and competent research is the chief means to this end.

Research results should be available to the supervisors and cooperatives who in turn extend these findings in a simple and digested manner to the farmer.

Credit to buy fertilizer and other complementary inputs is certainly needed.

The infrastructure necessary for efficient, convenient, and timely distribution of fertilizer is equally important.

Price policies and improved product and factor marketing can have a very influential role in affecting and in creating the incentives necessary for better fertilizer use.

Attaining fertilizer potentials requires development and refinement of a whole host of institutions and organizations which link Egyptian rural villages and the outside world in a vast network of service exchange. These institutions are highly complementary, so that provision of one or two will not provide the desired results until the others are brought along as well. The interdependencies are so strong that the effects of the package are likely to be very different from the sum of the effects of each institution by itself.

All these institutions are already well established in Egypt; hence, the realistic question is not how to start new institutions from scratch, but, are the present organizations adequate to accomplish the technological and economic changes presented in the previous chapter, handle and allocate the large quantities of fertilizer needed in the future? What changes in the structuring of these institutions and policies will facilitate attaining the indicated fertilization potentials?

Research

Importance of Research

The success or failure of any fertilizer program in Egypt will depend in considerable measure on the extent to which relevant, competent, and imaginative research facilitates the task that policy makers and administrators face in finding rational answers to questions crucial to the formulation of fertilizer policy. Because new lands are scarce or will be nonexistent, Egypt must turn to research and education to provide the technology for continued increased yields on the land now in use.

Systematic research is the base upon which a modern agriculture is built. Through research, the productivity of existing resources is increased, and even more important, it becomes possible to utilize an increased quantity of fertilizer resources at higher levels of productivity and profitability than previously. Thus, increased production is achieved by constantly shifting production functions up and to the right.

Research regarding optimal fertilization levels under a variety of relevant conditions is very important for public policy formulation. Knowledge of the production response, moreover, can help governments in allocating the scarce fertilizer supply among areas and crops. It will also help in determining the allocation of foreign exchange and industrial capital to fertilizer supply.

Concerning the kind and organization of research, there are two questions to be raised. First, are the individual projects of the research program the most fruitful and best-suited to the country's needs? Second, is the research program organized in an effective manner and located in the right place of places? In answering these questions we must look at the steps necessary in effective fertilizer research.

Fertilizer research in Egypt would involve three major steps:

1. Determining the research needs;
2. Carrying out the research; and
3. Drawing upon this research for recommendations to agencies, etc., and farmers and for other ways to implement the relevant findings.

Determining Research Needs

This thesis has definitely shown that a multitude of production functions that must be carried well into stage two of the production function for each crop are needed, if we are to pinpoint the optimum level for each crop, when changes in the economic and cultural practices occur.

Research concerning the marginal rate of substituting one nutrient for another, or fertilizer for land is vitally important for agricultural development in Egypt.

Determining research needs is a research job in itself. If fertilizer research is to have a substantial effect on Egyptian agricultural production, it is crucial that research be tuned to actual operating problems of the Egyptian farmer. This means that somehow research personnel in the various fields, particularly in the biological sciences, must have contact with farmers and farmer's problems. Such contact is facilitated by bringing research into close contact with extension, either by involving research personnel in the extension process or by stationing extension personnel at research locations. In Egypt it is, in practice, difficult to establish close rapport between farmers and biological science research personnel because of gaps in background, education and culture.

Research in the natural sciences provides the prime basis for technological advance. The contribution of economics and the behavioral sciences cannot become evident until the natural scientists have provided a stock of innovations which may then be studied as to the economic conditions of their success and as to the behavioral reactions of farmers regarding their spread and acceptance.

Many results from experimental work on fertilizer use cannot be applied with confidence in the absence of detailed soil surveys and other soil studies in both the experimental areas and the areas to which these results might be extended. Soil surveys themselves are of practical value only when the data they provide are integrated with the knowledge of other sciences to provide interpretations of the potential of the various soils.[1] Soil scientists should be in close touch with the planning and extension services, and be aware of the economic and social implications that their recommendations may have.

A host of technical problems is raised by the desire to maintain optimum nutrient levels. These offer large

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[1]The High Council for Sciences was founded in 1956 to plan and coordinate scientific research.

fields of research, including the sensitivity of nutrient balance in soils with low exchange capacity, with related problems of nutrient antagonism and nutrient fixation, particularly well recognized in the case of phosphorus; problems of nutrient availability under extremes of soil reaction; and problems related to the importance of secondary nutrient elements, such as magnesium, sulphur and calcium, and the trace elements, particularly when soils are cropped at high yields following applications of the primary nutrients. Associated with research on these problems, research on the time and method of fertilizer application, and into new and improved forms of fertilizer, is required to meet the needs of individual environmental conditions. There should be careful pretesting of new fertilizer and new varieties under local conditions before they are introduced. A succession of failures, due to lack of or improper testing may generate long-run skepticism.

Carrying Out the Research

The continuum of the research process in Egypt could be broken into four discrete sections: basic, developmental, adaptive, and test demonstration research. This breakdown might be useful for pointing out the nature of the research job in the development process and from that, deriving the nature of needed research institutions. These four levels of research are arranged in descending order of transferability. This suggests that the administrative levels might be organized in the form of a pyramid. Basic research[1] would be done by possibly one or two very well staffed and equipped central experiment stations in Giza and Alexandria.[2] Next, developmental research stations would be placed in the three different regions of the country (Upper, Middle and Lower Egypt). Drawing upon basic research from the central station and from other nations turning out research results of immediate value to the indigenous agriculture. Next would come a larger number of adaptive research stations turning out results very specific to the local agriculture of each province.

Finally, a test demonstration program would radiate out from the adaptive research stations.

Recommending Research Results

One of the most important aspects of fertilizer research in Egypt is that of choosing which research results to recommend to farmers. This choice requires, first, economic measures of profitability of the new fertilizer practice and, second, a decision as to the minimum acceptable level of profitability. The estimated increase in production must be sufficient to cover error due to inadequately trained

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[1]Only basic research that is more relevant to subtropics and saline-sodic soils, but drawing on other countries for other basic research.

[2]In the Middle East where clusters of small countries cover similar physical conditions, it might prove useful to have only one regional basic research station drawing its staff from and disseminating results throughout the region.

research and extension personnel, incomplete research, individual variations, and imperfect execution by the farmer, also including a substantial risk premium.

When the profitability test has been passed, the research result cannot be recommended to farmers until it is certain that the production and distribution of the fertilizer and other complementary services will occur and that farmers can be taught their proper usage.

The organization of each Egyptian experiment station needs two special qualities in addition to the normal requirements of good organization. First, it should be such that research specialists of different technical fields are able to and encouraged to cooperate on individual projects. Second, it should assure that each new technique being developed or tested is assessed from the standpoint of its effect on the whole farm business.

Thus a long term policy for fertilizer research needs to be formulated; this should estimate the national requirements for research stations, personnel, equipment and funds. A vigorous training program for research workers should be inaugurated. Funds and resources should be made available to put long term fertilizer research programs into effect, and emphasis should be concentrated on adaptive research that can give quick results for application under field conditions. In planning such research, economists and especially farm management planning specialists, must be involved in the design of such trials and in identifying the bottlenecks that hamper farmers in adopting improved fertilizer practices.

Extension

Role of Extension in Affecting Fertilizer Use

If we assume that we have a package of viable new inputs to offer the Egyptian farmer, economic policies to make their adoption feasible, and a research system that steadily improves and adds to our supply of technology, then the need remains for means to bring the package to the producer, from the Egyptian Ministry of Agriculture and research station to the farm itself. Without this process the package is incomplete and the other factors will remain barren.

A broader comprehension of the potential role of extension in Egypt is required if fertilizer programs are to have a maximum effect on agricultural production. Extension programs not only can "take research results to farmers" and "impart knowledge and skills," but also can substitute new attitudes for old traditions and values, overcome reservations about the risks and uncertainties involved in innovation, speed the learning process, stimulate the development of local auxiliary services, and generally make agricultural planning more realistic and practical.

The full potential of investment in research will not be realized without complementary investment in extension programs.

But in the development of an extension program there are many specific problems on which only analysis by careful development of data can shed light. An example is the question of the type of extension organization. Should extension be carried out by a department of government (as it is done at present), by the cooperatives, by the universities, or by semi-autonomous bodies? Should the number of advisors be 1 per 1,000, 5,000 or 500 farmers? Should it be 1 to 5 villages or 10? Should the decision be on the basis of the number of farmers to be reached, or the intensity of the service, or the degree of specialization? Is the farmer approached in a language he understands in terms that are relevant to his experience and desires--and by the people he trusts and respects? Are his customs and beliefs insulted? Is he subject to humiliation and red tape? In planning and improving the extension system, questions such as these should not be answered arbitrarily but by the results of a carefully planned study of all significant factors.

Hence, extension needs self-analysis and a spirit of experimentation with alternative procedures, replacing failing procedures with successful ones.

We shall not attempt to make any meaningless statements as to what type of organization is the best for Egypt. We only hope to put the basis as to what extension should do, and what extension agents should be like if extension is to succeed in helping farmers attain fertilizer potentials.

What Extension Should Do

If extension is to work well, it must communicate with research stations. It must also carry questions or problems back to the stations so that the research programs can be properly and effectively oriented. It is probably ideal that extension organizations and research organizations be based in the same physical locations, but there are alternative ways to stimulate real communications.

In carrying fertilizer results to farmers, extension staffs must give farmers sufficient information to be able to help in adapting the fertilizer technology to suit the conditions of their farms and to aid in diagnosing the reasons for failures. Given correct diagnosis, extension staffs must then be able to prescribe corrections or carry questions back to research stations for further work.

The extension worker must make the Egyptian farmer aware of alternative opportunities, impart the necessary knowledge and skills, and give the farmer emotional support in his first ventures in innovation.

Hence, two-way communication between the Egyptian farmer and those functioning in the agriculture infrastructure is essential for bridging the present gap between the producer and the agent of change. The urgent need is for return communication from farmer to bureaucrat.

Conferences and workshops to bring together research workers, extension staff, cooperative managers, and other administrators, and farmers to discuss problems and to interact with each other may prove to be highly rewarding. Assisting farmers to do specific things on their farms accelerates progress much more than an approach of educating farmers through lectures in technology.

It has been observed that response to extension work is usually greatest among farmers on the better land, who are owner-operators, and whose farms are of medium to large size by local standards. Hence, concentrated extension efforts are favored over diffused efforts. There is danger that such a diffusion of effort will provide virtually no benefits for anyone. We do not argue that concentration is socially attractive or equitable--but that it is probably the only method that can hope to succeed.

There are challenging possibilities for improving the effectiveness of extension by using farm leaders as agents of change, but granting responsibility to local leadership means taking power away from the center; raising the status of agriculture implies lowering the prestige, at least in relative terms, of the government elite.

The Extension Worker as an Agent of Change

The agent of change must thoroughly understand the workings of the local culture--the forces that motivate the Egyptian farmers, and those that inhibit them. He must learn as well as teach, which means he must be willing to learn from "ignorant farmers." The environment of the bureaucracy must encourage the growth of the "will to develop." Change agents must become respected among the people with whom they work if they are to be effective. Obviously, he must know the technical side of his job if his advice is to be worth hearing. He must also be deeply committed to innovation, which means that he must accept the painful personal adjustments that come with rapid social evolution, and above all he must be an "encouraging companion."

Thus, Egyptian extension agents require training not only in mechanical methods of transmitting knowledge, but also in technical knowledge of current fertilizer practices and of new technologies. Even more important is knowledge of the supporting sciences which is necessary to understanding innovation, for diagnosing failures, and for adapting fertilization practices to variable conditions.

<u>The Present Rural Combined Units</u>

One of the greatest achievements in the field of extension work in Egypt is the Rural Combined Units.[1] These units constitute the most important measures of their kind carried out in the Moslem world. They provide villages with

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[1]Rural Combined Units are not connected with co-ops, they are completely independent.

a variety of social, economical and technical services by resident specialists.

Workers consist of an agricultural-social worker, and a health and welfare nurse, both of whom are carefully selected and trained, and wherever possible, by a doctor and laboratory assistant.

Referring to these units C. Issawi states, "Much has been done to make the life of the peasant healthier, pleasanter, and more peaceful, and to dissipate the fog of ignorance which surrounds him. It has been noticed that the service which attracts peasants most is medicine, this serves as a bait which makes them accept the other activities."

Their achievement has been impressive, and to a large extent, the future of the Egyptian villages and therefore of the nation as a whole, is probably bound up with their fate.

Credit

Credit is obviously an imperative in any program to induce farmers to increase their use of nonfarm produced inputs.

Provision of credit through a system tailor-made to the production needs of farmers through convenient local outlets provides an additional incentive to adopt improved fertilizer practices.

Formal Versus Informal Credit Institutions

Agricultural credit and financial institutions in Egypt are usually grouped into two types according to whether they are a private, informal, such as the traditional money lender and/or public or institutional, such as the cooperatives.

The comparative efficiency of these two types of credit sources is a research problem by itself. The issue in relation to fertilizer is mainly on ways and means of improving the institutional performance, and strengthening their structure so that credit could be an effective instrument in attaining fertilization potentials.

Many leaders of credit take for granted that the much lower rates of interest[1] charged by their agencies must result in the private money lender-trader-shopkeeper being ousted. Experience shows, however, that low rates of interest alone very often are insufficient to make institutional credit attractive in the eyes of the average Egyptian farmer. Many farmers prefer applying for noninstitutional credit even at higher cost since it is provided with a minimum of delay and discomfort and without red tape, awkward questions and supervision of the manner in which it is to be spent.

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[1]In our opinion, credit should not be cheap nor completely free as it is at present; it should be given at "reasonable" rates compared with the productivity of the added inputs.

Thus the actual role of traditional money lenders deserves careful empirical study as part of a broader study of the relative efficiency of alternative systems for providing credit. Money lenders have many operational advantages: intimate familiarity with borrowers, readiness to grant risky loans, quick and low-cost loan management, and a high rate of loan recovery. Measures should therefore be devised to build upon the advantages of their system while eliminating any monopoly power or gains they may enjoy. One idea that might be tried is a system of rediscounting credit instruments between the farmer and the money lender under specified conditions. The rediscount system would increase the flow of funds through the traditional system, facilitate the entry of new moneylenders, break the islands of monopoly, and lower the level of interest rates.

The channels through which public credit flows need to be set up so as to minimize delays in making it available for use. If the processing of the loan takes too long, the delay may interfere with the purpose for which it is made. Also, the cooperative should be prepared to reschedule any loan repayment where the borrower is affected by a calamity outside his control, and also to consider refinancing agricultural loans.

The productive element of agricultural credit can increase only when the borrower has learned to make a proper use of credit facilities by adapting better farming practices. And to encourage the use of these improved practices, supervision of credit may be desirable and should be tied to a package of inputs and practices. Loans should be granted on condition that the borrower agree to adopt a package of recommended inputs and practices. Loans should be made primarily on the basis of the increased production potential of the package rather than upon the security of land or other assets.

We are concerned here with short-term production credit which must be timely, have a convenient repayment program suited to the money flows from the cropping cycle, and the procedures for obtaining it must be reasonably simple.

It is not always realized that expanding credit before an adequate quantity of extension work has been done does more harm than good. A very close coordination between credit and extension work is essential for making agricultural credit instrumental to increasing production.

Agricultural credit loses a good deal of its impact if the farmer needs of fertilizer are not available at the proper time, in the proper place and at reasonable prices. The productive element in agricultural credit is then weakened and the consumptive element may even be unduly increased.

Also, prices should be such that profits provide incentives, otherwise the contribution that agricultural credit can make may be neutralized to a large extent or even become completely illusory. Thus, one of the most important aspects of the increase in agricultural production, is therefore, the marketing problem.

So tying of credit programs with programs for processing and marketing on the one hand and for input supply on the other has advantages. It would also facilitate loan repayment. The other side of this same coin is the advantage to the farmer of an assured market.

Price Policy

Effect of Price Policy on Fertilizer Use

A vertical expansion in agriculture and a rapid increase in the level of production, requires the use of technical and organizational measures to increase the physical outputs obtainable from given fertilizer inputs. These measures will be more fully adopted if economic policies take advantage of the price responsiveness of supply and factor demand wherever it is positive. In many situations the rate of absorption of new knowledge and inputs may depend critically on the price and risk milieu.

Price supports or price guarantees at levels 10 to 15 percent below current market prices could assist Egyptian farmers to organize their productive activities more effectively by eliminating some of the risks and reducing the range of price expectations. Yet such a guarantee usually will involve very minor financial commitments by the government. Prices at or above current prices would induce the

Egyptian farmer both to use his currently available resources more intensively and to adopt a package of improved inputs and cultural practices. But this could involve a significant financial and organizational commitment by the Ministry of Agriculture. Since the rate of actual absorption of inputs and knowledge by farmers depends very much on the ratio between the expected return from the recommended package and the cost of the package, floor prices can improve this ratio. They may raise it directly by increasing the actual average return per unit of output sold, and indirectly by reducing the "risk factor" which the farmer may be supposed to use in calculating the expected average return net of risk. The very fixation of a floor price reduces the risk of buying the package. If fertilizer are effectively subsidized, the estimated cost of the package will be lower, and a correspondingly lower floor price will attain results. But no matter at what levelprices for individual farm products are guaranteed, if they are guaranteed for a considerable period into the future, farmers are in a far better position to plan their production, and make longer term investments in land improvements.

It should be pointed out that if the supplies of fertilizers and the other nonfarm produced inputs are not sufficiently elastic, a price support program may only raise their prices, and hence, the incentive effect of the support price will be reduced. This consideration underlines the necessity of associating a price support program with a vigorous policy to increase input supplies at a sufficiently rapid rate.

It is also important to recognize that prices cannot be regulated merely by passing a law. Complicated programs of inspection, and usually of government purchase, storage, and sale of those commodities for which prices are regulated are necessary. In view of the complications, it is best to limit price regulation to only those few commodities of which increased production is most needed. And for these commodities, the first aim should be to increase the certainty of prices, at levels that will be remunerative to efficient producers. Hence, the effectiveness of any price policy on the use of fertilizers depends on how well it is articulated.

Product Price Guarantee Versus Fertilizer Price Subsidization

Now the question is, if the aim is to increase levels of fertilization and the growth of agricultural output, is it better to subsidize fertilizer or to guarantee minimum prices of outputs? Several considerations can be adduced in support of subsidization. If product prices are raised, Egyptian peasants may or may not take to improved cultivation. They may continue present practices and simply spend the extra income on consumption; if so, government expenditures on support will be wasted. Higher product prices add to the income of both noninnovators and innovators. This windfall income may cancel out some or all of the incentive to increasing production by permitting the marginal preference for leisure relative to labor to be more fully expressed. If, on the other hand, fertilizers are subsidized, the benefit of government expenditure can be derived by the peasants only in proportion to their use of the fertilizer. Fertilizer subsidization avoids raising food and raw material prices against the growing industrial sector. Also, the cost to the economy as a whole of increasing agricultural output is likely to be lower in the case of subsidies and can be borne through the tax system.

Fertilizer price subsidization is not a complete substitute for product price guarantees in Egypt. In fact, both are needed as complementary instruments of policy, for different reasons. If guaranteed product prices are cost-based the fertilizer inputs are cheapened by subsidies the lower will be the required guaranteed prices.

Product price guarantees are needed in addition to fertilizer subsidies because it is not a matter of indifference whether the profitability of a crop is increased by raising the price of the crop or by lowering the prices of fertilizer. Where it is a matter of indifference, a government can use either input subsidies or product guarantees for inducing a given output response. But there are several reasons why, in Egypt, the same response cannot be obtained by input price manipulation as by product price manipulation.

The insurance peasants need urgently is the insurance against downward fluctuations in product prices rather than against upward fluctuations in the cost of purchased fertilizer which form a small part of their total cost. Secondly, product price guarantees induce the better use of organic as well as inorganic fertilizer, whereas input price subsidies can cover only the purchased inorganic fertilizer.

The case for higher product prices can turn some of these same arguments to its advantage. The very fact that a program of fertilizer subsidies costs less than a program of product price supports means that the agricultural sector derives a smaller income from subsidies than from supports.[1]

Finally, fertilizer price manipulation cannot discriminate between products, while product price guarantees can be used to induce changes in the output of specific crops. So no blanket preference can be given either to general price supports or to input subsidies. The relative efficacy of the two means of improving the price ratio of crops to fertilizer depends on the existing level of fertilizer use, the technological character of the measures necessary to increase productivity, the relative importance of low cost and provision of a cushion for risk-taking to the cultivator, the crops for which an expansion is desired, and

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[1]But it could also be argued that production could be larger with cheap fertilizer than with price guarantees and that added income derived from this production could be larger. Hence, the answer depends on relative prices and subsidies, and also on the price elasticity of demand.

a value judgment about the distribution of incomes between the agricultural and nonagricultural sectors.

Product and Factor Marketing

The Increasing Importance of Marketing in Egypt

Agricultural product and factor markets in Egypt became increasingly important as a result of the combined effect of rapid population growth, increased commercialization and intensification of agriculture, and rapid urbanization and industrialization.

Usually this process also is associated with an increase in per capita income, and not just an expansion in the aggregate G.N.P., although an excessive population growth rate can limit the rise in per capita income. This process implies an explosive rate of growth in the flow of products from farm to city, and agricultural inputs from city to farm.

The rising incomes often cause particular growth in demand for commodities which are perishable and which, therefore, entail difficult and costly marketing processes. Rising incomes also increase the demand for marketing services, which have higher income elasticities than the farm produced product itself. Also the increased use of fertilizer, and other technical inputs, increase production which requires more and better marketing facilities.

Public Versus Private Market Sectors

To perform these functions and meet the challenges of growth, Egypt has chosen a combination of public agencies and private sector activities. It appears that the allocation of these responsibilities has been done on an ad hoc or pragmatic basis rather than by a formula or philosophical basis.

The new government controlled cooperatives seem to have advantages through their contact with government agencies, including research and extension, in pioneering the effective provision of new forms of inputs and new marketing services.[1]

Private agencies on the other hand perform the valuable arbitrage function and have the economic advantages of quick decentralized decisions in the complex field of marketing.

Private marketing organizations with modern efficient structures and equipment, with adequate credit, and with far flung trading connections continue to market the bulk of the crops. It appears, that with a small amount of help, they can develop the physical and institutional organizations that are basic to an efficient marketing system.

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[1]Egyptian authorities attached considerable importance to the development of cooperatives as means of meeting a dual goal of increased efficiency and increased social justice.

Thus, pragmatic considerations suggest that the cooperatives can be used as instruments for innovation, and probably can function more effectively if their role is deliberately limited to supplementing rather than supplanting.

Coordinating Marketing Activities and Improving the Necessary Market Infrastructure

Getting the fertilizer from factory or dock to the farmer requires extensive planning and a complex infrastructure. The fertilizer must be transported to the region where it will be used and stockpiled well in advance of application, which requires adequate transportation facilities and local storage facilities. Timing is crucial. The fertilizer is of no use if it arrives after the time when it must be applied. The critical factors here are physical infrastructure and effective management.

The supply-production-procurement chain in Egypt has arteries and veins, but poorly developed capillaries. Very simple improvements such as the use of pneumatic tires on carts or the development of relatively primitive feeder roads may yield the greatest economic returns. And the elimination of major transportation bottlenecks may provide a more general opportunity to reduce marketing costs substantially and thereby provide increased product and decreased fertilizer prices.

Effective vertical coordination in marketing channels between producers and consumers plays an important role in reducing uncertainties, eliminating unnecessary marketing effort and lowering waste and spoilage.

Thus, improvements in marketing may encourage increased production largely through the direct or indirect effect of higher prices to producers. The effect may work directly as reduced marketing costs pass directly to producers in the form of higher prices. The process may also work indirectly through lower prices to the consumer, which, due to relatively high price elasticities, expand the market considerably and thereby increase total revenue to producers. Other indirect effects may include reduction in uncertainty, lower prices and greater availability of a wider variety of consumer goods that may increase incentives of farmers to earn more, thereby encouraging greater input of fertilizer and other resources. The capacity and willingness of Egyptian farmers to buy nonfarm inputs may be closely related to the profit incentives transmitted to the producer.[1]

Also improved factor markets should stimulate and facilitate intensification, and should be considered important social institutions in the communication network, in addition to their function as commodity exchange centers.

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[1]Improved marketing may also generate pecuniary and technological internal and external economies, may draw subsistence producers into the exchange economy and can increase the elasticities of supply and demand.

Hence, marketing is as critical to better performance in Egyptian agriculture as farming itself and should be regarded and developed as such. If farm production were increased as seems technically possible, and if food protection were exploited to conserve what is produced then the present marketing system would need to be expanded greatly. Integration of the expansion of market facilities with expansion of production is vital for sustained momentum.

CHAPTER IX

SUMMARY AND CONCLUSIONS

> "I understand a good many things as I didn't understand before; but whether it was worth while going through so much to learn so little, as the charity boy said when he got to the end of the alphabet is a matter of taste."
>
> Tom Weller, in "Pickwick Papers"

Intensification, difficult though it may be, constitutes the major intermediate term policy alternative available within agriculture, concomitant with policies to control population growth. One of the most effective technical measures for raising production is the increased use of fertilizers. This research seeks to identify the present and future potential (1975) use of fertilizer in the "vertical expansion," or intensification of Egyptian agriculture.

Three hypotheses are examined, namely: (1) The increased use of fertilizer is profitable and can be demonstrated by experimental data, (2) Sufficient experimental data exists to calculate appropriate levels of fertilizer use for principal crops under present economic and cultural conditions, (3) Evidence can be gathered in sufficient detail to estimate the optimal level of fertilization as farmers adopt a number of fertilization and cultural practices, and as national agricultural policy changes price and resource parameters.

To identify the present and future potentials, we reviewed the past and present fertilization practices for the five major crops, and sought to understand how (a) agronomic, (b) economic, and (c) managerial factors may effect fertilizer use.

The principal around which the data are being arrayed is the optimum usage of fertilizer. The basic ideas are based on economic and agronomic data and principles. Even though agronomic research provides knowledge of the responses expected from fertilizer on a particular soil, the optimal usage still depends on economic considerations.

The optimum or most profitable level of fertilization as farmers seek to maximize profits in a decision making environment of unlimited capital is that level at which the marginal physical product of fertilizer is equal to the fertilizer crop price ratio. Hence, of the many factors upon which the calculations of the optimum level of fertilization depends, only the following three factors were employed in this study: crop response to fertilizer and crop and fertilizer prices.

This study has shown that the leasing and the cropping systems, the amount of capital available, the ability of the Egyptian farmer to shoulder the risks and the uncertainties, modifications in economic incentives and noneconomic influences will affect the environment in which the theory has to function and somewhat hinder its implementation.

The analysis indicated that with present crops, area cultivated and cultural practices there was still substantial opportunity to use more fertilizer. Despite nitrogen and phosphate consumption two and a half times that of 1950, farmers in 1965 were using only 267,000, 48,750 and 570 tons of N, P_2O_5, K_2O, respectively. Quantities recommended by the Ministry of Agriculture in the same year were 368,000, 116,400 and 10,000 tons of N, P_2O_5, and K_2O, respectively. These recommended quantities may seem relatively large, but it was found that they are somewhat conservative in nature and are at least 30 percent below the optimum computed in this study. (Even this computed optimum may be below the real economic optimum since the fertilization experiments were not carried to the end of stage two of the production function.) But taking this computed optimum as the best one that can be obtained at present, Egyptian farmers could have profitably used 630,000 tons instead of the 316,000 tons of nitrogen and phosphorus that were used in 1965. Total cotton, wheat, rice, corn and berseem production would have increased by 2.5 million kentars, 45,000, 57,000, 880,000 and 10,000,000 tons, respectively.

This computed optimum is based on present practices. Whole new sets of estimates came into view as one and more advances in production practices are introduced and utilized widely in agriculture. An increase in crop response to fertilizer is brought about through the use of more responsive crop varieties, change in fertilization, cultural and irrigation practices, improved soil aggregation, salinity and organic matter level, and change in cropping systems and crop index.

The Formosa rice varieties were introduced in Egypt by the F.A.O. in 1959, and it was found that the optimum fertilizer level (82 kg. per acre) was twice as much as that for local rice varieties.

Recommendations for the new wheat Giza varieties developed by the Ministry of Agriculture are 20 percent higher than these given for old varieties. Also, experts at Bahtim Experimental Station have given instructions to farmers using the new berseem (clover) variety developed by the Egyptian Agriculture Society to use at least half a sack of superphosphates (8 kilos P_2O_5) more than they use for the Meskawi variety. As for corn and cotton, the Ministry of Agriculture recommends the use of 50 percent more fertilizer for hybrid corn than for the local corn varieties, and 40 percent more, for the new Menonfi cotton variety than for the old Karnah varieties.

Using pump irrigation from deep wells to supplement Nile water, and shortening the irrigation cycle would increase rice, corn and wheat yields by 16 to 23 percent.

It was shown that the optimum fertilizer level for wheat is 30 and 45 kg. and for cotton it was 30 and 80 kg. per acre in saline and nonsaline soils, respectively. Even rice and berseem yields (both tolerant to soil salinity) in salt free soils are at least 15 percent higher than in saline soils. Leaching harmful sodium salts from Egyptian soils would increase yield from 38 to 75 percent (50 percent for cotton, 20 percent for wheat and 75 percent for corn) depending on the crop and degree of sodium salt concentration.

Maintenance of a satisfactory level of organic matter could increase crop yield by 15 to 40 percent, i.e., the response curve will shift by at least 15 percent, depending on type of soil, crop variety, other crops in a rotation, and organic quality.

Cultural practices such as placement, time and mode of application and kind of fertilizer, time of planting and watering, number of plants per acre and depth of plowing, play an important role in shifting the response curve. The magnitude of this shift ranges all the way from 10 to 60 percent depending upon crop variety, soil characteristics, and weather conditions. Deep placement of fertilizer for rice increased yield 9 percent. Also the depth and mode of plowing could make a difference of 9 percent, 7 percent and

18 percent in cotton, wheat and corn yields, respectively. Improvement of alkali soil aggregation by the application of synthetic aggregates reduced the toxic effect of ESP (exchangeable sodium percentage) and increased berseem yield almost 30 percent.

Cropping systems also affect soil organic matter, soil tilth and plant nutrient supply. Using the three year rotation system would increase crop yields 15 to 25 percent over the two year rotation system. Also, raising the crop index, through the use of modern machinery in rapid seedbed preparation, harvesting and threshing, or planting crop varieties with shorter growing season, would increase total fertilizer requirement.

This computed optimum is also based on present fertilizer crop price ratios. If we narrow this ratio more fertilizer should be applied. A drop of 33 percent in phosphate prices increased the optimum level from 30 to 60 kg. per acre for berseem. As for the other crops, the paucity of data has not permitted the computation of new optima when the price ratio changes.

Precise estimates of the new optimum cannot be made without more adequate data. The multitude of production functions that must be carried well into stage two of the production function for each crop are not available. But by making conservative estimates of the changes that appear certain to occur, new overall estimates of the desirable application of fertilizer were made.

It was found that the present potential after the change of the above practices was 1.25 million tons of N, P_2O_5, K_2O which is twice the computed optimum (644,000 tons) before change, and four times as much as actual quantities (316,000 tons used in 1965).

Analytical estimates of the potential quantities of fertilizer that could be utilized in 1975 on the present cultivated land and that scheduled to be added depend upon several assumptions. The assumptions and consequent estimates of fertilizer use are listed in increasing order.

1. The existing fertilizer use on present land continues, is extended to the additional 0.75 million acres converted to covered drainage and 1.5 million acres of reclaimed land to be cultivated in 1975, and increases in fertilizer are provided to allow for the change from basin to perennial irrigation (0.97 million acres) and for the absence of 12 million tons of silt. Under this assumption the estimated use is 390,000, 74,000 and 121,000 tons of N, P_2O_5 and K_2O, respectively.

2. The above assumption is adjusted by the principle fertilizer specialist in the Ministry of Agriculture. The estimated usage is 497,000, 167,000 and 135,000 tons of N, P_2O_5 and K_2O, respectively.

3. Egyptian farmers expand the use of fertilizer to the level of 1965 recommendations of the Ministry of Agriculture for present and new lands, and with adjustments for perennial irrigation and the absence of silt. The potential

use in 1975 then becomes 538,000, 173,000 and 135,000 tons of N, P_2O_5 and K_2O, respectively.

4. No further technological change, but farmers operate on the basis of the calculated optimal level of fertilizer for 1965. Usage then becomes 606,000, 315,000 and 142,000 tons of N, P_2O_5 and K_2O, respectively.

5. Technological changes occur, and farmers use the new calculated optimums and adjustments indicated above. The potential fertilizer use in 1975, on this basis, becomes 1,242, 548 and 160 thousand tons of N, P_2O_5 and K_2O, respectively.

Attaining these potentials requires development and refinement of a whole host of institutions and organizations which link Egyptian rural villages and the outside world in a vast network of service exchange. These institutions are highly complementary so that provision of one or two will not provide the desired results until the others are brought along as well.

The success or failure of any fertilizer program in Egypt will depend in considerable measure on the extent to which relevant, competent, and imaginative research facilitates the task that policy makers and administrators face in finding rational answers to questions crucial to the formulation of fertilizer policy. Research not only provides details on how best to use present knowledge but can also push back the frontiers so that new dramatic potentials exist.

If the results of relevant research are to be channeled into actual production processes and affect the levels of production of crops and use, then substantial effort is needed to make such results available to supervisors of cooperatives for transmittal to farmers in simple, digested form. Similarly, credit to buy fertilizer and complementary inputs would help make it possible for farmers to use optimum amounts. Such developments would require both an expansion and an improvement in the level of functioning of the marketing of inputs, products and other elements of the infrastructure.

All these institutions are already well established in Egypt, hence, they only require structural transformation that might enable the Egyptian farmers to accomplish the technical and economic changes presented in this study, to facilitate attaining the indicated fertilizer potentials and to further the cause of agricultural development.

At the overall policy level, a number of changes also would facilitate attainment of the optima. A change in price policy to make product price fertilizer cost ratios more consistent with real costs, such as reflected in world prices, would promote a substantial economic stimulus to fertilizer use and expanded production.

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APPENDICES

APPENDIX A

PLANNING THE CROPPING SYSTEM

The cropping system for a field or farm strives to insure efficient production over a period of years, and depends upon soil conditions, market conditions, and the alternative production possibilities. But every cropping system should provide flexibility, so that the acreage of crops can vary with changes in the natural environment and in the cost-price ratios. A main advantage of a rotation is to benefit from complementarity, when the output of one crop leads to an increase in the output of a subsequent crop, or when, as in Egypt, two or more crops can be grown in a single year. Special agronomic features applying to Egypt are considered next, followed by a discussion of important economic features applying to choice of rotations.

Effect on Organic Matter and Soil Tilth

Cropping systems affect the organic matter in Egyptian soils in two ways: (a) Tillage of the soil makes for greater aeration, thus stimulating more microbial activity, and increases the rate of disappearance of soil organic matter. A cropping system with a large proportion of row crops (such as cotton and corn) thus encourages a much more rapid loss of organic matter than a cropping system with a large proportion of close-growing crops. (b) Cropping systems differ in the amount of plant residues which they contribute. Because decomposing organic matter provides substances that help to cement sandy soil particles into stable aggregates, the crops that return large amounts of organic residue usually have a beneficial effect on structure. Also the roots of certain crops also affect the structure of the lower horizons. The thick tap roots of crops such as cotton, clover, and alfalfa penetrate some soils to considerable depth, and when these roots die and decompose, they leave a channel or pore through which excess water can drain from the profile and down which the roots of the next crop can grow more easily.

Effect on Plant Nutrient Supply

Crops have different effects on the supply of mineral nutrients. Some crops can feed better than others on the less available forms of some of the mineral nutrients. When these strong feeders are grown, turned under, and decomposed, the minerals they take up are converted to readily available forms for the following crops.

In addition, crops may differ considerably as to the zone in which they absorb nutrients, making the choice of crops and the cropping sequence of considerable importance in plant nutrition. Deep-rooted crops absorb more of certain nutrients from the subsoil, provided that the nutrients are present at these lower depths. As residues from these crops decompose in the surface soil, shallow-rooted crops may then reutilize these nutrients. Such an effect may be one of the important benefits of cropping systems or rotation, particularly for the elements which are not being applied in fertilizers.

The Principal Rotations

In Egypt we find at present two predominant crop-rotation systems in operation, a triennial system with one cotton crop each third year and a biennial system with one cotton crop each second year. The crops alternating with cotton within these two main systems may differ, but as typical examples we may have:

Example of biennial crop-rotation with cotton as one crop in four

Grown During	Crops
Year 1	One or two cuttings of clover from year 0 (growing season from September to January), then cotton is planted in March and picked in September.
Year 2	Plant wheat or barley or horse beans in September or October and harvested in June. Maize is planted in June and harvested in September or October.
etc.	etc.

Example of triennial crop rotation with cotton as one crop in six

Year 1	One or two cuttings of clover from year 0, cotton.
Year 2	Wheat or barley from year 1, maize.

Year 3 Clover, four cuttings or horse beans, rice.

etc. etc.

Under the triennial rotation, which is observed by a minority of progressive landowners and in the lands managed by the Agrarian Reform Committee, only one wheat, one maize, and one cotton crop are grown in three years, thus allowing for a long period of rest and summer flooding between the crops. This rotation is much less exhausting for the soil and gives yields exceeding by as much as 20 percent those of the biennial rotation.[1]

The necessity for following a rotation under which grain crops alternate with cotton, and not with other grains, was vividly demonstrated during the war years, when the restriction of the cotton acreage, combined with the lack of fertilizers, caused a sharp fall in yields. Experiments have shown that the succession of two cereal crops reduces yields by 20 percent.[2]

Cotton and rice, though the latter is only possible where water is abundant, usually are by far the most profitable crops. But for growers living near towns or factories, the profitability, per feddan, of vegetables, fruits, and sugarcane is even higher than that of cotton and rice.

The completion of the High Dam will make it possible to regulate the flow of water over the course of the year in virtually any way which the authorities choose. In the past, the cropping pattern in the agricultural sector has been closely determined by water availability; now that this natural flow pattern need no longer dominate, the country faces the possibility of reorganizing its crop rotation without being constrained by the seasonal pattern of water availability. In a highly stimulating and informed discussion of the problems and possibilities of this restructuring it has been argued that Egypt should stop producing wheat, concentrating her land and water in products where she has greater comparative advantage, such as rice, cotton, onions and oil crops, as well as sugar and vegetables.[3] This would

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[1] Sayed Kasem, Professor of Agronomy, Agricultural College, Assiut University, Egypt, Fundamentals of Crop Production (Cairo: Anglo-Egyptian Bookstore, 1963).

[2] M. Y. Elshawarby, Professor of Agricultural Chemistry, Cairo University, Chemistry of Fertilizers and Plant Nutrition (Cairo: Anglo-Egyptian Bookstore, 1962).

[3] Kasem, *op. cit.*

imply a growing dependence on imported wheat; but if this is matched by exports of alternative crops, with higher value, it is no cause for concern, but rather for satisfaction.

What then would happen if the Egyptian farmer changes his cropping systems and shifts to high fertilizer consuming crops, such as vegetables and fruits, or takes on new crop varieties with a short growing season that would increase the crop index from the present 1.7 to 2 for example. Questions such as these were dealt with in Chapter VII.

APPENDIX B

RELATIVE EFFICIENCY OF CHEMICAL NITROGENOUS FERTILIZERS

In Egypt a large number of trials have been carried out to assess the relative efficiencies of urea, ammonium sulphate, aqua ammonia, calcium cyanamid, ammonium nitrate, and calcium nitrate as sources of nitrogen. Similarly, different phosphatic materials compared, as shown in Table B-1. These studies indicate:

1. Rice planted in clay soils has a higher response to urea than to other nitrogen sources
2. Corn and cotton planted in sandy soils have a higher response to ammonium nitrates than to other nitrogen sources, while ammonium sulphates and calcium nitrates are most efficient in corn and cotton production in clay soils
3. Wheat has a higher response to aqua ammonia when planted in clay soils and to calcium nitrate when planted in sandy soils
4. Calcium cyanamid is the least efficient in both sandy and clay soils.

Table B-1. Relative efficiency of chemical nitrogenous fertilizers as measured by increase in yield over control using 100 for ammonium sulphate as a base

	Crop							
	Rice		Corn		Wheat		Cotton	
Source of Nitrogen	Clay Loamy Soil	Sandy Soil	Clay Loamy Soil	Sandy Soil	Clay Loamy Soil	Sandy Soil	Clay Loamy Soil	Sandy Soil
Calcium nitrate	74.4	..	97.2	185.14	114.0	103.1	160.5	177.6
Ammonium sulphate	100.0	..	100.0	100.00	100.0	100.0	100.0	100.0
Aqua ammonia	92.7	..	98.8	-23.5	116.3	66.3	92.5	4.2
Ammonium nitrate	110.9	..	99.9	186.9	111.6	94.6	131.9	192.2
Urea 126	126.6	..	90.9	154.9	111.0	92.1	129.0	125.0
Calcium cyanamide	59.7	..	99.7	-35.2	73.6	54.5	103.9	-32.2

Source: M. Riad *et al.*, "The Fertilizing Values of Nitrogenous Fertilizers," *Journal of Soil Science*, II (1962).