PN-AAM-708
263001762

EWUP TECHNICAL REPORT NO. 9

IRRIGATION AND PRODUCTION OF RICE IN ABU RAYA, KAFR EL-SHEIKH GOVERNORATE

By:

Kafr El-Sheikh Team

As Compiled By

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January 1983

EGYPT WATER USE AND MANAGEMENT PROJECT

22 El Galaa St., Bulak, Cairo, Egypt

IRRIGATION AND PRODUCTION OF RICE IN ABU RAYA, KAFR EL-SHEIKH GOVERNORATE

TECHNICAL REPORT NO. 9

Prepared under support of

WATER DISTRIBUTION RESEARCH INSTITUTE, WATER RESEARCH CENTER

MINISTRY OF IRRIGATION, GOVERNMENT OF EGYPT

Contracting agencies

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Ft. Collins, Colorado 80523
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All reported opinions, conclusions or recommendations are those of the writers and not those of the supporting or contracting agencies.

ABSTRACT

The work and findings resulting from over 4 years of on-farm studies of the Egypt Water Use and Management Project (EWUP) as related to rice irrigation and production in the Abu Raya area of the Kafr El-Sheikh Governorate are reviewed. Included are irrigation system description and operation,cropping system description, problem identification studies to define constraints to improved rice irrigation and production, assessment of solutions and implementation of pilot demonstration programs for improvements.

Irrigation water delivery studies show modification of the rotation schedule to provide extra water during long off periods during the rice nursery period which would enhance seedling development. Also, the 4-on 4-off rotation for rice irrigation could be curtailed by up to one month at the end of the season when the rice is drying in the fields. This would reduce the water flowing directly into the drains.

On-farm rice irrigation and production studies show that high on-farm conveyance losses, unlevel fields and losses through perimeter bunds hamper effective on-farm water control, cause increased irrigation frequency and total application of more water than necessary. A critical 25 cm demand for irrigation water for puddling fields at transplanting time is not met by current supply in the delivery system. Micronutrient deficiency of zinc reduces yield. Soil salinity levels may affect seedling development, but rice cultivation has been shown as an effective means for reducing soil salinity. Rice water requirements were measured to be near 8000 m^3/*feddan* which is slightly more than the Ministry of Irrigation's water duty for rice. Fifty percent of this is for evapotranspiration while 50 percent goes to percolation.

Precision land leveling to dead level and dead level border strip irrigation design improved rice irrigation efficiency and resulted in

14 percent water savings in one set of field trials. Field trials to test the effect of zinc application to nurseries produced significant yield increases. Mechanical transplanting of seedlings has been demonstrated, however, the necessity of special matted nurseries may limit wide-scale use.

A pilot demonstration program to improve on-farm water management which includes land leveling, selection layout and design of the irrigation system,improvement of the on-farm water delivery and distribution,water and crop management advisory assistance and elimination of nonessential in-field surface drains is currently being implemented in Kafr El-Sheikh. Available results of the program for the 1981 rice crop are included.

Finally recommendations to the Ministry of Irrigation to improve rice irrigation and production are provided.

64 Pages, 12 Figures, 17 Tables

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مستخلـــــــــص

يتضمن هذا البحث استعراض لأعمال ونتائج الدراسات الحقلية لمشروع تطوير الرى المتعلقة برى وانتاج الأرز فى منطقة أبو رية بمحافظة كفر الشيخ . ويشمل هذا الاستعراض وصف لنظام الرى وكيفية عمله ووصف للنظام المحصولى ودراسات تحديد المشاكل للتعرف على معوقات تحسين رى وانتاج الأرز وتحديد الحلول واقامة برامج ارشادية للتحسينات .

وقد أظهرت دراسات توزيع مياه الرى تعديل فى نظام دورة الرى لاعطاء مياه زائدة خلال فترات البطالة الطويلة وذلك اثناء فترة مشاتل الأرز والتى تتسبب فى اعاقة تطور البادرات . كما أن دورة رى الأرز (٤- عمالة، ٤ - بطالة) يمكن اختصارها بحوالى شهر فى نهاية الموسم عندما يجف الأرز فى الحقول وهذا يقلل من جريان الماء مباشرة الى المصارف .

وقد اتضح من دراسات الرى الحقلى للأرز وانتاجه أن الفواقد العالية لنقل الماء فى الحقل والحقول الغير مستوية والفواقد خلال حدود الحقول التى تعوق التحكم الفعال فى مياه الحقل ، كل ذلك يسبب زيادة تكرار الرى وكذلك اضافة كميات كبيرة من المياه عن الضرورى . ولايتيح نظام التوزيع الحالى للمياه توفير الحد الحرج المطلوب لمياه الرى للحقول خلال فترة الشتل وهو ٢٥ سم . كما أن نقص عنصر الزنك يقلل من المحصول . هذا وقد تؤثر مستويات ملوحة الأرض على تطور البادرات ولكن زراعة الأرز وجدت انها طريقة مؤثرة لتقليل ملوحة الأرض .

قدرت احتياجات الأرز للمياه بحوالى ٨٠٠٠ م٣ / فدان وهى أعلى قليلا مما تحدده وزارة الرى للأرز ويستهلك ٥٠ ٠/٠ من هذه الاحتياجات فى البخرنتح بينما تذهب البقية فى الرشح .

وجد فى مجموعة من التجارب الحقلية أن نظام تسوية الأرض الدقيقة لتصبح مسواه تماما وكذلك التسوية الثابتة لخطوط الرى قد أدى الى تحسين كفاءة رى الأرز كما نتج عنه وفر فى مياه الرى بنسبة ١٤ ٠/٠ .

اظهرت التجارب الحقلية لاختبار تأثير اضافة الزنك الى المشاتل زيادات معنوية فى المحصول . كما تم عرض لعملية شتل البادرات ميكانيكيا ، وعموما فان الحاجة الى شاتل خاصة قد يعيق استخدام ذلك على نطاق واسع .

هذا وينفذ حاليا برنامج ارشادى فى كفر الشيخ لتحسين وترشيد الرى الحقلى وهو يشمل تسوية الأرض واختيار وتصميم نظام الرى واعطاء التوصيات الارشادية الخاصة بالمحصول والمياه وكذلك استبعاد المصارف الحقلية السطحية الغير أساسية . ويوجد بهذا التقرير النتائج المتاحة من برنامج محصول الأرز لعام ١٩٨١ .

وفى النهاية فانه يوجد ايضا توصيات الى وزارة الرى لتحسين رى وانتاج الأرز .

٦٤ صفحة ، ١٢ شكل ، ١٧ جدول

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PREFACE

This Technical Report is a combination and updating of two previous papers prepared by EWUP for presentation at technical meetings.

These reports are:

EWUP Staff Paper No. 63: Rice Related Studies of EWUP-Irrigation, Micronutrients, Fertility and Mechanization, which was presented at the First Review and Planning Conference of the National Rice Institute, February 21-24, 1981 and published in the conference proceedings; and

ASAE Paper No. 81-5502: Small Farm Rice Irrigation in Egypt. Abdel Fattah Metawie, Thomas W. Ley and Richard L. Tinsley. Presented at a special session of American Society of Agricultural Engineers' Winter Meeting, Palmer House, Chicago, December 11 to 14, 1981.

The combination and updating of these papers effectively summarizes the rice work of EWUP through its first five years. The consolidation was done by Thomas Ley and Richard Tinsley, however, it represents the work of the entire Kafr El-Sheikh team as supported by the main office staff. Individual contributions will be acknowledged as they occur in the text and supporting tables and figures. The individual efforts of each professional staff member are hereby acknowledged and appreciated by those responsible for preparing this manuscript. In addition, the support and contributions of the EWUP main office staff as well as the many Kafr El-Sheikh technicians, laborers, drivers and administrative staff if hereby acknowledged. Without their support this work would not have been possible. The following individuals were part of the Kafr El- Sheikh professional staff contributing to this report.

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I. INTRODUCTION

The Egypt Water Use and Management Project

The Egypt Water Use and Management Project (EWUP) was designed to assist the Egyptian farmer by improving his on-farm water management. It is a joint program for technical assistance administered by the Egyptian Ministry of Irrigation and the Ministry of Agriculture.

Since EWUP's research concerns the management of water at the farm level, its area of interest is defined as reaching from the Ministry of Irrigation's last control structure on a canal through to the smallest units of the distribution network--the *mesqas*, *marwas*, and drainage ditches which serve individual farms. Prior to the establishment of the joint project, this area has fallen between the interests of the Ministry of Irrigation and the Ministry of Agriculture to form a kind of "no-man's land." All of EWUP's research is conducted in the field on actual working farms, rather than in separate experimental stations, and technical backup is confined to laboratory analyses of soil and water samples.

The major goal of the Project is to improve the socio-economic well-being of Egyptian farmers by developing ways to improve on-farm water management without sacrificing crop yields. To do this, EWUP studies the irrigation system using an interdisciplinary approach that calls upon the expertise of irrigation engineers, rural sociologists, agronomists and agricultural economists.

Engineers concentrate on the design, operation and maintenance of the irrigation delivery system, the method of distributing and supplying water to farms and ultimately, the operation, management and layout of the on-farm irrigation system.

For equitable distribution of irrigation water and proper maintenance of local watercourses, a degree of organization and cooperation among

farmers is desirable. It is therefore in EWUP's interest to promote and develop local farmer organizations. By improving communications, such organizations provide the project with a mechanism for informing farmers "in advance" of proposed changes in the irrigation system, soliciting farmer opinions about the changes and evaluating the acceptability of various irrigation interventions to farmers. This is done primarily by project sociologists.

Since irrigation works in the service of agriculture, EWUP agronomists study the entire cropping system within the area for its irrigation needs relative to the present operations, and evaluate the impact of suggested improvements to the on-farm irrigation system on crop production. Agronomists also examine the crop production problems which presently face farmers and which might have some bearing on their water needs. They introduce simple technological improvements--often in the form of proper pesticides or fertilizers--which will maximize the effects of improved irrigations, increase crop yields, and make changes in present methods of water management more acceptable to the farmer.

Finally, agricultural economists maintain farm records that document current farmer irrigaion methods and activities. The economist also evaluates the possible returns of various interventions to determine their economic feasibility in the long and short run.

The technical work is currently organized into various pilot programs at the field level where all of the on-farm work is carried out and the basic data is accumulated, and into eleven task groups in the main office. The task groups focus on specific problems, with a goal to integrate the data of the various pilot programs and disciplines into final reports and recommendations for consideration by the Ministry of Irrigation (Egyptian and American Team, 1980).

The work of the project has been carried out in a four phase research-development process (Clyma et al., 1981; Clyma et al., 1977; Shaner et al., 1982). The first phase involved reconnaissance and problem identification. The second phase consisted of testing various interventions in search of solutions to the problems identified in phase one. The third phase is evaluation and assessment of solutions tested to determine a package of practices which are most feasible and will have the greatest impact on improving irrigation efficiency and agricultural production in a given area. The fourth phase is the implementation of the most feasible package of practices in demonstration pilot programs. It is expected that these pilot programs will prove successful in the three pilot areas administered by the project, and will eventually be introduced on farms throughout Egypt.

II. AREA AND SYSTEM DESCRIPTION

A. Abu Raya Pilot Study Area

The Egypt Water Use and Management Project has three pilot study areas (Figure 1) of which Abu Raya, Kafr El-Sheikh Governorate, is the only one where rice is grown. Abu Raya is a village and farming community of 2,000 *feddans* (840 ha) some 25 km north of Kafr El-Sheikh City, at the end of the Dakalt Canal. Most of this area is composed of reclaimed land. The area is characterized by heavy clay soils, larger land holdings relative to the rest of Egypt, major drainage and salinity problems, and a lift irrigation system. Further descriptions of the area are given in the Problem Identification Report for Kafr El-Sheikh (Egyptian & American Field Team, 1980).

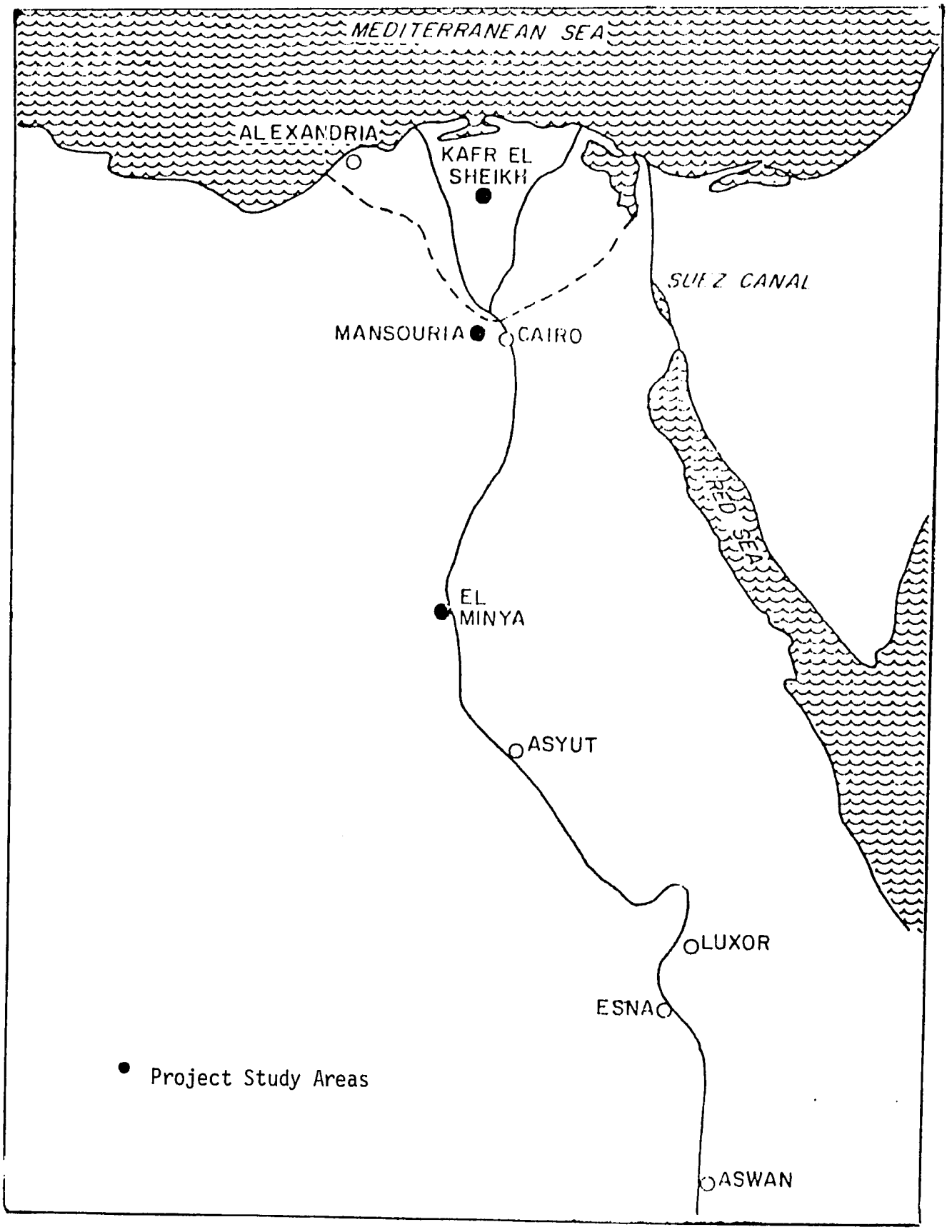

Figure 1: Location Map for EWUP Study Areas.

B. The Cropping System

The basic cropping system of Abu Raya, similar to that of most of the Delta, is a two-year rotation with 2 cropping seasons per year. The crop seasons are based on seasonal changes in termperature, the major seasonal climatic variable in Eygpt (Table 1). The temperature varies from a summer high/low of 34.0/19.0°C to a winter high/low of 19.4/6.1°C. As in most arid areas, diurnal temperature fluctuations can be great. In the Delta, diurnal temperatures fluctuate as much as 13°C in winter and 17°C in summer. Summer night temperatures often fall below 20°C, the critical temperature for growing rice.

The agricultural year officially starts November 1, with the preparation and planting of winter crops. This begins the two-year, four-crop rotation of wheat--rice--*berseem*--cotton and back to wheat (Figure 2). In some cases, maize will be substituted for cotton, or rice, and broad beans and flax will be substituted for wheat. Onions will sometimes precede cotton, with the cotton being planted directly into the onion rows. Sugar beet is a new crop which is currently being introduced in winter to replace wheat or broad beans. The government allocates the area to be planted with cotton and rice at approximately 50 percent for each.

C. Irrigation Water Delivery System

An extensive system of public canals delivers water throughout the irrigated area of Egypt to the farmer free of charge. Water is distributed through main canals to branches and finally to private *mesqas*, from which farmers are required to lift the water for application to their fields. The lifting at the farm level is designed to place a nominal cost on the water, and encourage water conservation.

Table 1. Mean Monthly Maximum and Minimum Temperatures at Sakha[a/], Kafr El-Sheikh Governorate.

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
	°C											
Maximum	19.4	20.6	23.0	27.1	31.2	32.0	34.0	33.6	32.1	29.9	25.9	21.5
Minimum	6.1	6.3	7.9	10.4	14.2	17.0	19.0	18.4	17.7	15.6	12.6	8.3
Difference	13.5	14.3	15.1	16.7	16.7	15.0	15.0	15.2	14.4	14.3	13.3	13.2

a/ Source: Abu Kahled, A. et al., Research on Crop Water Use, Salt Affected Soils and Drainage in the Arab Republic of Egypt. FAO, Cairo.

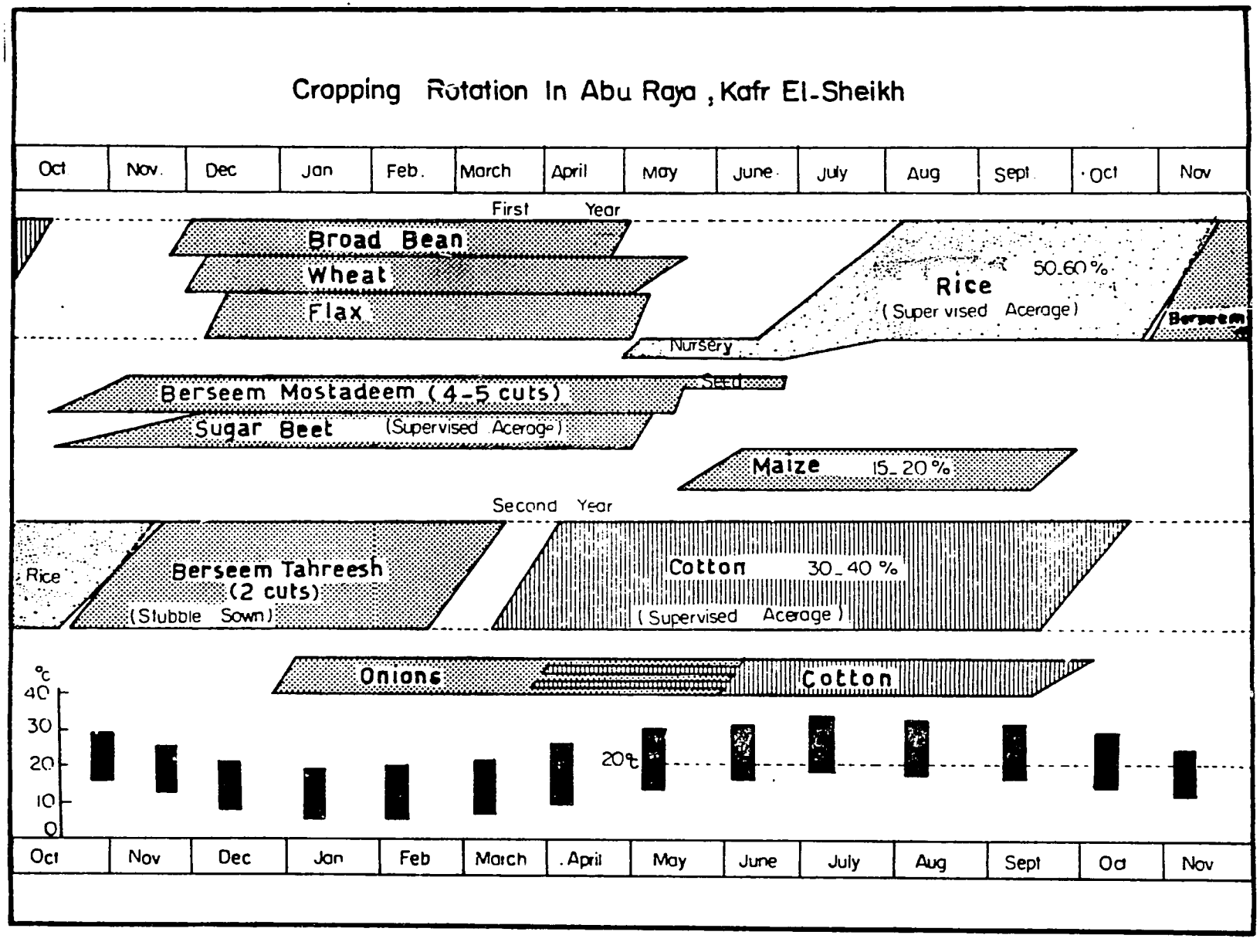

Figure 2: General Two-Year Four-Crop Rotation and Alternatives for Abu Raya As Related to Monthly Maximum-Minimum Temperature Range (EWUP, 1981a).

Abu Raya obtains irrigation water from the Mit Yazid Canal (a main feeder canal) via the Dakalt Canal (a branch canal). The Dakalt Canal is 11.4 km long, and serves Abu Raya from the section of the Canal north of the Helal regulator (Figure 3). This is the last control structure currently in use on the canal. Below the Helal regulator, water is supplied to individual farms by four main *mesqas*: the tail end of the Dakalt Canal itself, and three smaller *mesqas*. Each of the main *mesqas* is approximately 2 km long and supplies about 200 *feddans* of land. The *mesqas*' inlets are simple pipe vents of a given length and diameter, without gates or control structures.

The project activities have concentrated on three *mesqas* in the Abu Raya area: Hamad, Om Sen and Manshiya. All of these *mesqas* are designed for lift irrigation, mainly by animal-powered waterwheels or *saqias*, though there is an increasing number of small diesel pumps. Each *mesqa* has over twenty lifting devices.

The entire area served by Dakalt Canal is under the same system of irrigation rotations. Water is provided to the system according to the Ministry of Irrigation's rotation plan which is adjusted for winter or summer crops (Table 2). In winter, the rotation is 7 days "on" and 7 days "off" or 5 days "on" and 10 days "off" depending on time of year and whether sugar beets are grown in the area. In summer it is 4 days "on" and 4 days "off". The summer rotation is designed to accommodate rice with an irrigation every 8 days. Even though the rotation is rigid, the control structures leak, and there is some water in the canals at all times. This allows limited irrigation during the "off" periods, provides water for animals and domestic use, and gives the system some flexibility for farmers who are unable to irrigate during the scheduled "on" periods.

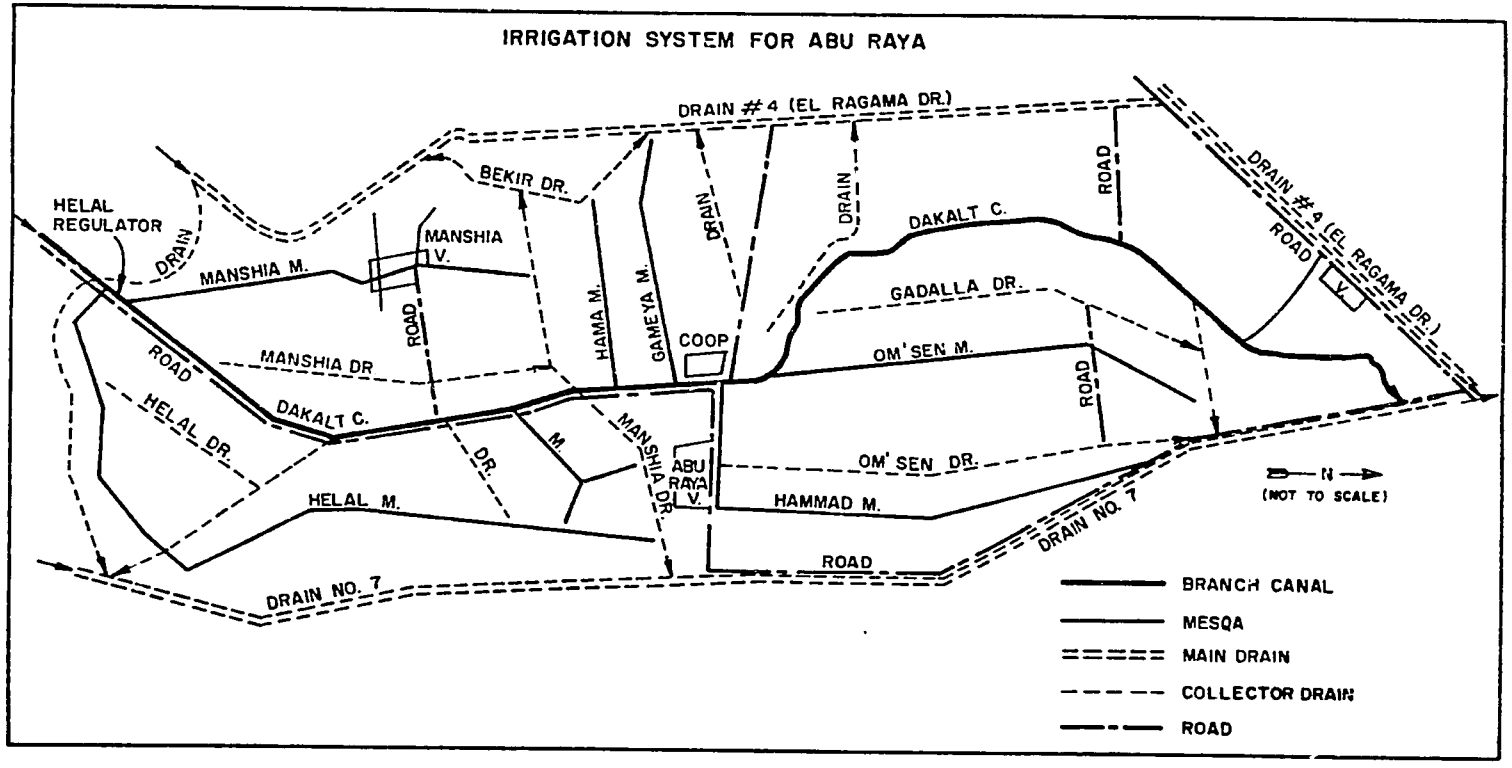

Figure 3: Schematic Diagram of Irrigation and Drainage System for Abu Raya.

Table 2: Irrigation Rotations for Kafr El-Sheikh

Dates	Rotations	Influencing Crop
	Days on-off	
	Areas with sugar beets	
Oct. 15 to Closure[a/]	5-5	Sugar beets
Closure		
Closure to Mar. 15	5-10	
Mar. 15 to May 25	7-7	Cotton & Sugar beets
May 15 to Oct. 15	4-4	Rice
	Areas without sugar beets	
Oct. 15 to closure	5-10	
Closure[a/]		
Closure to Mar. 15	5-10	
Mar. 15 to Apr. 15	7-7	Cotton planting
Apr. 15 to May 25	5-10	
May 25 to Oct. 15	4-4	Rice

[a/] Closure means the annual canal closure period when water releases from the Aswan High Dam are stopped for a period of approximately 3 weeks to one month so that repairs, maintenance and cleaning operations can be done on structures and watercourses. In Abu Raya, the closure period is generally from January 20 to mid-February. Often a general irrigation period (no rotation) of ten days to two weeks follows the closure.

D. Drainage System

The entire Abu Raya area suffers from generally high water table conditions. Seasonal averages of water table depth below ground surface range from 0.6 m to 1.0 m. This condition is typical of areas in the Nile Delta served only by open surface drains such as in Abu Raya. Over the past several years extensive areas of the Delta have been provided with subsurface tile drains. The effect of subsurface drains on rice cultivation seems qualitatively to be an increase in the amount of water used by farmers. This observation is based on the farmers' tendency to plug the subsurface collectors when they cultivate rice in an effort to keep the crop submerged.

EWUP has observed a general trend for drainage conditions to affect the amount of water applied to rice (Egyptian and American Field Team, 1980). The Abu Raya area (Figure 3) can qualitatively be categorized according to the location of collector and main drains. The eastern boundary of the area is Drain No. 7, a large deep main drain. Measurements of water table elevations in the proximity of this drain range between 1.0 to 1.5 m below ground surface. Within the Abu Raya area drainage conditions are poor; open collector drains are often choked with weeds and they are cleaned only on an irregular basis. In such areas, water table levels are found to vary between 0.6 to 0.8 m below the surface. In such an area, water applied to a rice crop was found to be significantly less implying that poor drainage and high water table conditions significantly reduce the deep percolation and lateral seepage components of water used.

E. The On-Farm Irrigation System

The on-farm irrigation system consists of a complex layout of water distribution ditches (*marwas*), irrigation basins and in-field drainage ditches (Figure 4). Farm size is small, nearly three-quarters of the

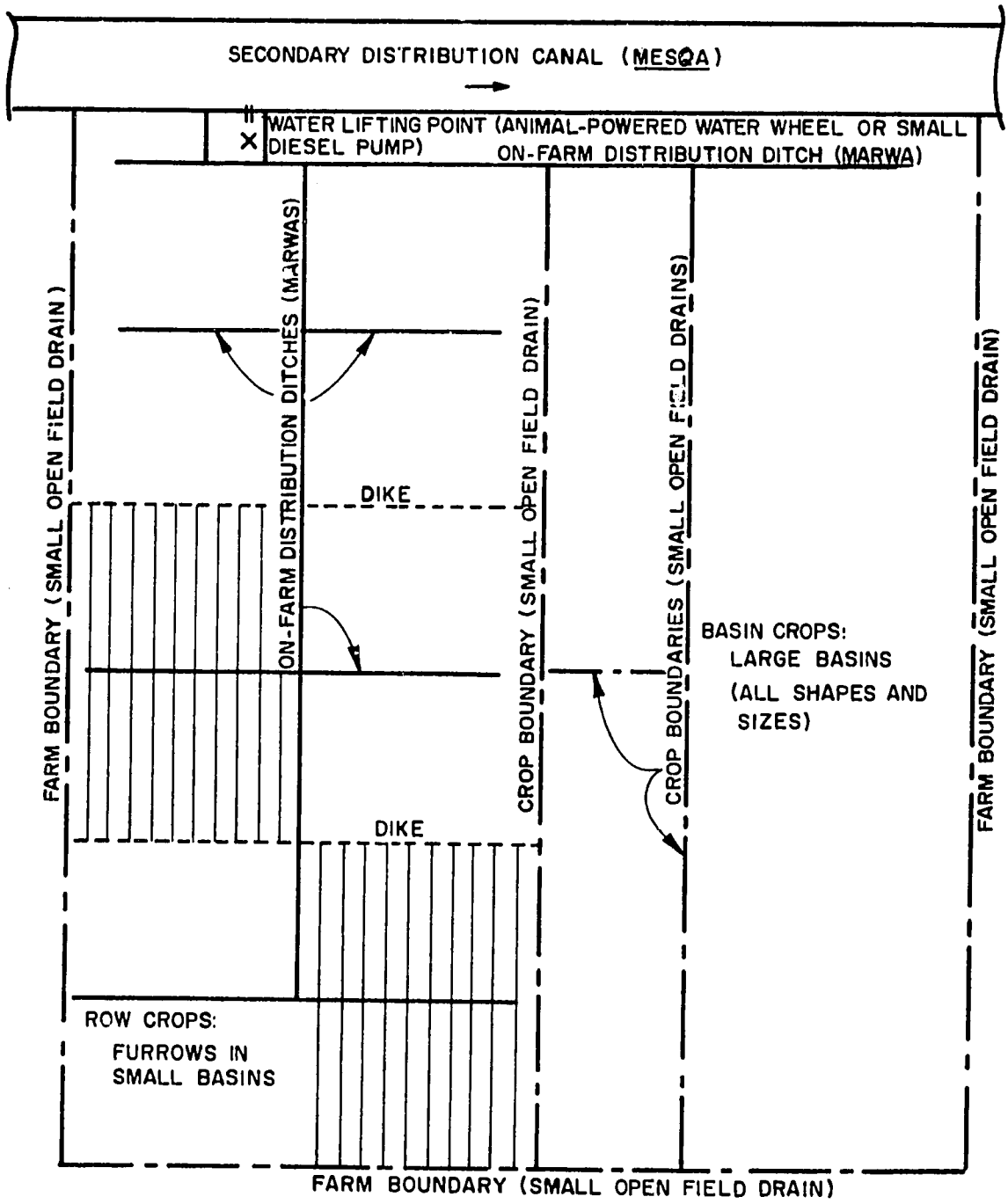

Figure 4: Generalized Example of Current On-Farm Irrigation System, Kafr El-Sheikh, Egypt.

farmers in Abu Raya own less than 2.1 ha. Ownership patterns are irregular and thus individual irrigation basins are of all shapes and sizes. Row crops are grown on ridges in small basins while broadcast crops are grown in basins with flat surfaces.

Once water has been lifted to the farm it is distributed to the basins through the system of *marwas*. The water application method has evolved from wild flooding, and because the flat topography approaches level basin irrigation.

Farm and crop boundaries are often delineated by small open field drains. These small drains are remnants of land reclamation practices when they effectively helped reduce salinity. Now, they serve only to facilitate removal of excess surface water applied. They generally open into larger open collector drains, which eventually feed into Drain No. 7, the large open main drain. Farm surveys have shown the field drains to be approximately 2 m wide and 100 m or more long, so that between 10 percent and 15 percent of productive farm area may be occupied by these field drains.

III. SYSTEM STUDIES

A. Rice Cultivation in Eygpt

1. Timing

Rice is the second most important crop of Eygpt and occupies an area of more than 420,000 ha in what is termed the "rice belt", the northern half of the Nile Delta (El-Tobgy, 1974). Rice is grown almost exclusively as transplanted rice. The recommended procedure for rice is for nurseries to be sown in late April or early May, so that the growing time in the nursery corresponds with the harvesting and on-farm processing of broad beans and wheat. The rice is planned for

transplanting to start in early June following five weeks in the nursery. Rice matures in early to mid-October and is harvested in late October to early November, after cotton. The actual nursery and planting dates are delayed about 2-3 weeks beyond the planned date. Thus the nurseries are actually sown in the last half of May and transplanting does not begin until mid-June and continues well into July (Figures 5a and b).

The total growing season extends for nearly five months. This is considerably longer than in other areas of the world, where select varieties of rice mature in 100 days or less. This has led EWUP to consider ways in which the season might be shortened. EWUP's interest in a shorter rice season is largely in order to promote water savings. Shortening the growing season, however, may be difficult. Compare resutls of an experiment in which the same cultivars were grown at Sakha (Agricultural Experiment Station in Kafr El-Sheikh) and in Thailand during the 1977 IRON trials sponsored by the International Rice Research Institute (Table 3). The cultivars at Sakha Experimental Station showed an average delay of 35 days in reaching maturity, and even early-maturing cultivars (IR 30, IR 36, BG 34-8) required between 140 and 155 days to mature at Sakha. This was more than a month longer than required by these varieties in Thailand. The earliest cultivar at Sakha was CN 44-33 from India, which matured in 132 days compared to 97 days in Thailand. The local check used in the trial also matured relatively early for Sakha, requiring 142 days. The reason for delayed maturity at Sakha is not entirely known, but the cool night temperatures (Table 1) could be a major factor, particularly in the nursery and early maturing periods.

2. Extent

Of the two crops, cotton and rice, which are regulated by the government, the farmers seem to prefer rice and tend to grow it on more land

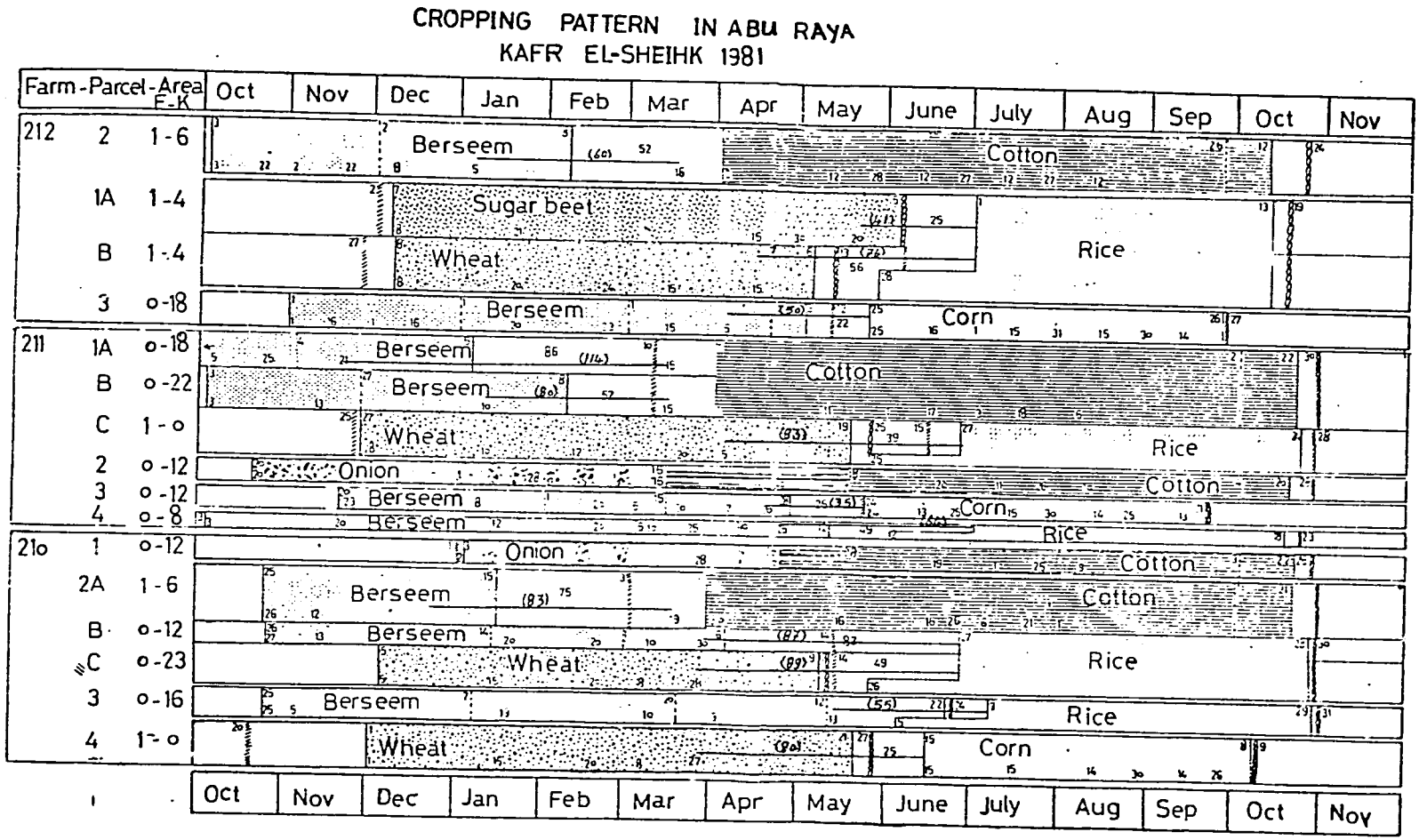

Figure 5a: Cropping Patterns on Selected Abu Raya Farms, 1981. Adapted from unpublished work of M. Meleha and S. Elewa. Numbers at the top of bars are dates of agronomic activities; numbers at the bottom are dates of irrigations; numbers in the middle between crops are fallow days between crops, and number in ( ) are days of irrigation gaps.

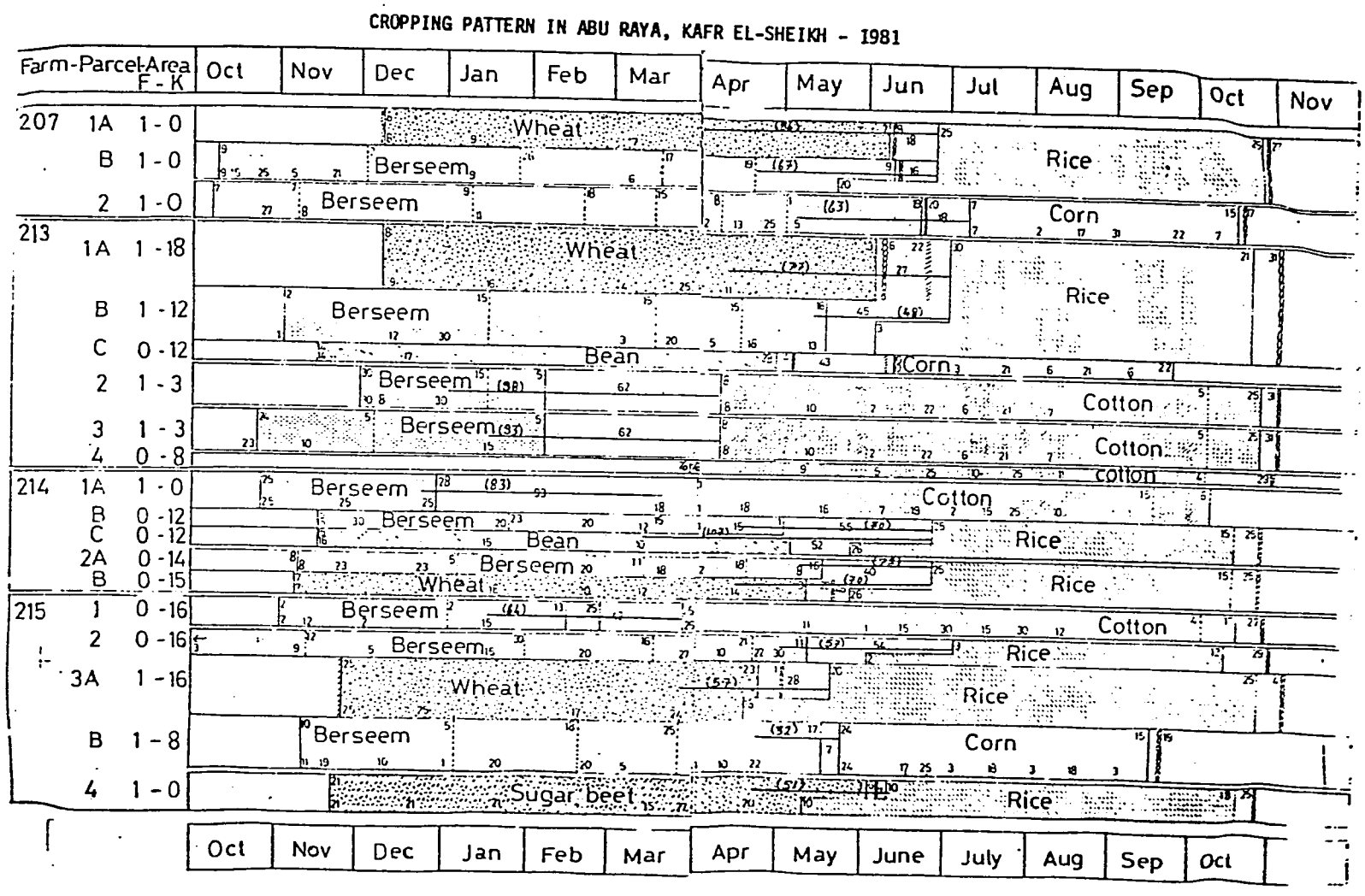

Figure 5b, (continued): Cropping Patters on Selected Abu Raya Farms, 1981. Adpated from unpublished work of M. Meleha and S. Elewa Numbers at the top of bars are dates of agronomic activities; numbers at the bottom are date of irrigations; numbers in the middle between crops are fallow days between crops; and number in ( ) are days of irrigation gaps.

Table 3: Maturity Difference of Various Rice Cultivars between Sakha and a More Tropical Location.

Cultivar	Origin	Sakha	Thailand	Difference
		----------days----------		
BG 34-8	Sri Lanka	154	100	54
BG 90-2	" "	149	127	22
DJ 346	Senegal	160	132	47
2526	Liberia	163	132	31
FAROX 36-30	Nigeria	158	141	17
229/54	Iran	139	104	30
IR 20	IRRI	165	123	39
IR 30	"	139	106	33
IR 36	"	147	106	41
CN 44-33[a/]	India	132	97	35
Local check		142		
		$\bar{x}$ 150.6±11.3	115.4±14.6	34.9±11.0

[a/] Earliest maturing at Sakha of entire IRON study.
Source: Extracted from 4th IRON 1977, IRRI. Total trial exceeded 350 cultivars

than required. Rice is therefore grown on approximately 60 percent of Abu Raya's total arable land, but the percentage can be as high as 80 percent to 90 percent on some *mesqas* (Figure 6). Such extensive rice cultivation occurs when areas planned for maize and cotton are in fact planted to rice.

3. Salinity Control

Irrigated rice developed as a main summer crop in the Northern Delta because of the potential benefits of growing a submerged crop on land requiring leaching of salts from the soil. Rice cultivation is thus an integral component of land reclamation in the area. Internationally, rice production is frequently encouraged for salt-affected soils because the continuous flooding and percolation can suppress salinity (Mooreman and Van Breeman, 1978).

Analysis of soil samples taken before and after rice crops of the 1980 and 1981 seasons in the Abu Raya study area shows soil salinity (EC) reductions for the 0-90 cm profile averaging close to 40 percent (Table 4). The reductions measured are from levels that would normally be detrimental to crops to relatively safe levels. This salinity suppression may be only temporary, i.e., the salinity levels in the soil may increase again during the 3 non-rice crop seasons between each rice crop season . Soil salinity levels are being measured during the non-rice seasons. It is being studied to determine whether rice cultivation every 2 years, when combined with improved on-farm water management for all crops, will establish a favorable salt balance for crop production in the area, and help to stabilize and /or decrease soil salinity levels. Further information on soil salinity problems in the Abu Raya area and its effect on crop yields has been given in the Problem Identification Report for Kafr El-Sheikh (Eygptian & American Field Team, 1980). Additional data are also provided in a later section of this report.

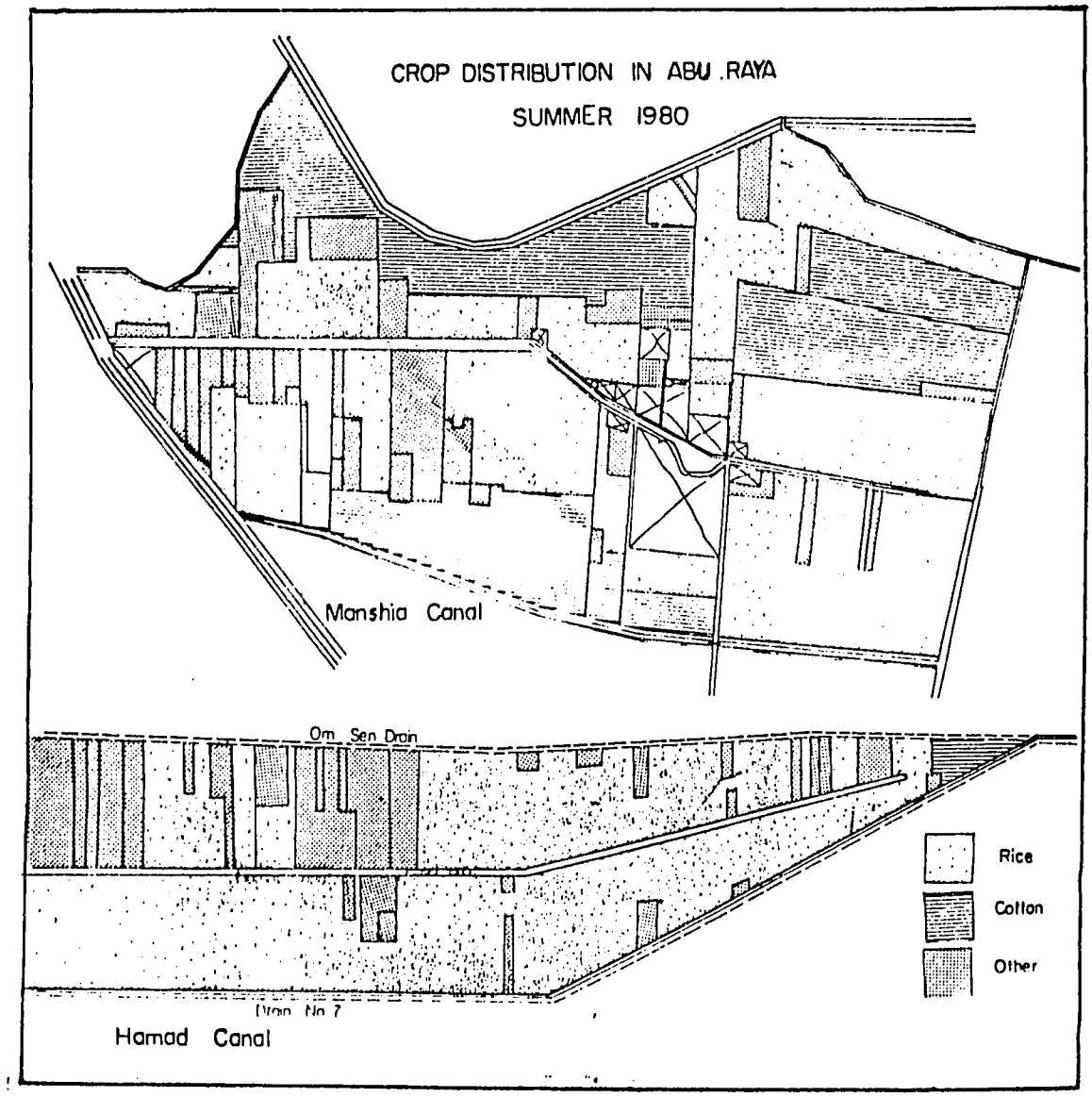

Figure 6: Distribution of Major Summer Crops on Study *Mesqas* of Abu Raya, 1980. Compiled by A. Ismail, A. El-Kayal, M. Meleha and M. Said.

Table 4: Change in Soil Salinity Before and After Rice Cultivation, Abu Raya, Kafr El-Sheikh

Season	Depth	Before Rice	After Rice	% Decrease
1980[b]	0-20	2.03 ±0.88[a]	1.33 ±1.01	34
	20-40	3.11 ±1.58	1.83 ±0.90	41
	40-60	3.55 ±2.17	2.34 ±1.68	34
	60-90	3.49 ±2.01	2.02 ±1.15	42
1981[c]	0-20	1.65 ±1.40	0.78 ±0.49	53
	20-40	1.93 ±1.11	1.20 ±0.87	38
	40-60	1.94 ±1.01	1.26 ±0.67	35
	60-90[d]	4.58 ±0.51	2.25 ±0.48	51

[a] Values are average + standard deviation.
[b] Combined averages of 9 samples taken at 3 locations.
[c] Combined averages of 15 samples taken at 5 locations.
[d] Average of 3 samples at 1 location.
Source: Data compiled by A. Ismail, M. Awad, M. Said and M. Meleha.

B. Irrigation of Rice

The irrigation of rice can be divided into four parts:

- The nursery: from seeding to transplanting,
- Transplanting: when seedlings are put in the final fields,
- The growing period: from transplanting to grain filling, and,
- The maturing period: from grain filling until harvest.

1. The Nursery Period

The Ministry of Agriculture recommends the rice nursery to begin around May 1, but it usually occurs during the last two weeks of May. The nurseries occupy about 1/8 of the rice land area or a total of about 1/16 the total agricultural area (assuming 50% of the total area to be rice and 50% cotton). This is a very critical period for the rice as the nurseries must be kept wet, but should not be flooded to a depth that will submerge the seedlings until they are tall enough to stay above the water level. The planting of the nursery comes during a period of generally low water demand when large amounts of water flow directly into the drains during irrigation "on" periods. So there is sufficient water for wet preparation of the nursery areas. However, the rotation during this period is 7 days "on" and 7 days"off" in the sugar beet areas and 5 days "on" and 10 days "off" in other areas (Table 2). This could result in insufficient water towards the middle and end of the 7 or 10 day "off" periods for the farmers to keep the nurseries saturated without submerging the seedlings. Farmers are generally irrigating using water from canal storage and/or head gate leakage at this time, but the amount available may not be uniform through the entire system. An extra release or two of water to the "off" canals during the middle of the "off" period could correct this, even if it meant the "on" canals missed an "on" day (or part of an "on" day). This could be essentially a 3 on/1 off/3 on/3 off/1 on/3 off rotation for the 7 day on/7 day off sugar beet areas, with something similar for the 5 day on/10 day off rotation of other areas.

Adams et al. (EWUP, 1980a) reported that farmers irrigate the rice nurseries on intervals of one to five days. Rice nurseries are grown for 30 to 35 days. Approximately 5 to 20 cm are applied at each irrigation. If there is enough water in the canal, farmers will drain the ponded water before irrigation; otherwise, they merely add more water. The total depth applied to the nursery as a function of the nursery area is between 1.5 m to 2.0 m. As a function of the total paddy area, this depth becomes 20 cm to 25 cm.

2. The Transplanting Period

The transplanting period is a very brief period of exceptionally high demand. It is recommended to begin the 1st day of June, which is consistent with the recommended nursery planting date of May 1. The irrigation rotation shifts to 4 days on/4 days off on May 25 in anticipation of the early June transplanting date. The land preparation sequence of events for the main rice field or paddy is:

- The land is plowed,
- Bunds are formed around the perimeter,
- A heavy irrigation is applied, and
- The soil is puddled under the saturated condition.

The puddling process is called *talweet* and is carried out by using animals to draw a heavy timber over the flooded soil. This process breaks down soil structure by dispersing the soil causing the plate-like clay particles to become oriented as they settle and thus reduce the surface porosity. The puddling process results in reductions in soil surface porosity or infiltration rate, and is a means to reduce total rice water use. Transplanting occurs immediately following the irrigation and puddling. The actual or observed transplanting dates range from June 15 to July 8 (Tables 5 and 6). This is consistent with the delay in nursery planting, and would indicate a possibility

Table 5: Water Applications at Time of Transplanting and Puddling and Dates of Applications, Abu Raya, Kafr El-Sheikh.

Farmer and Strip ID	Water Applied	Date
	-- mm --	
	1978	
3-03-1(01)	196	June 25
3-03-1(02)	240	June 15, 16
3-03-1(03)	240	"
3-03-2(01)	240	"
3-03-2(02)	240	"
3-03-2(03)	240	"
3-03-2(04)	196	June 25
3-03-3(01-03)	100	June 26
3-03-4(01-02)	403	June 5, 6
3-03-4(03)	403	"
$\bar{x}$ ± s.d.	250 ±107	
	1979	
3-01-2(01)	149	June 10
3-01-5(01)	281	June 8
3-01-6(01)	274	June 8
3-02-1(08)	145	June 9
3-02-1(09)	226	June 9
$\bar{x}$ ± s.d.	215 ±66	
	1980	
3-10	320	June 23
3-11	247	June 17
$\bar{x}$ ± s.d.	284 ±38	
	1981	
3-01	256	June 17
3-25-1	190	June 16, 17
3-25-8	190	June 23, 24
3-25-2, 3	160	June 17
$\bar{x}$ ± s.d.	199 ±40	
Overall mean	250 ±67	

Source: Adapted from unpublished data compiled by A. F. Metawie, S. Ezz El-Din, K. Ezz El-Din and A. El-Kayal

Table 6: Irrigation Gap Between last Irrigations of Wheat and *Berseem* and the First Irrigation of Rice.

Farm	Area	Last irrigation of wheat	First irrigation of rice	Duration
	F Q	----------Dates----------		---Dates---
		Wheat		
212	1-4	April 15	July 1	76
211	1-0	April 5	June 27	83
210	0-23	March 8	June 27	109
205	1-12	March 21	June 26	97
206	2-0	March 24	June 22	90
	0-12	April 1	July 3	93
207	1-0	April 1	June 25	85
213	1-18	April 11	June 30	80
202	1-16	April 6	June 15	70
203	1-0	April 5	June 27	83
	1-19	April 4	June 25	82
204	1-0	March 20	June 18	90
215	1-16	March 24	June 20	88
Total	17-0=25.6%			86.6 ±9.8
		Berseem		
205	1-0	May 2	June 26	65
206	1-0	April 23	June 22	59
	0-12	May 21	July 3	43
	0-18	April 26	June 24	58
201	0-8	April 25	July 7	74
210	0-16	May 13	July 7	55
	0-12	March 30	June 27	88
202	2-0	March 23	June 20	89
	1-16	March 23	June 20	89
203	0-15	April 22	June 27	66
	1-0	May 10	June 26	47
204	0-12	April 30	June 18	49
207	1-0	April 19	June 25	67
213	1-12	May 13	June 30	48
214	0-12	April 15	June 25	71
	0-14	May 8	June 25	48
	0-16	April 30	July 3	64
Total:	14-19=22.2%			$\bar{x}$ 63.5 ±15.0

Source: Adapted from unpublished work of M. Meleha and R. Darwish

to change the beginning of the 4 on/4 off rotation to a later date by about 3 weeks.

The water required for transplanting has been measured at an average of 250 mm or 1050 m^3/*feddan* (Table 5). This volume of water is needed because most fields have not been irrigated since late March to early April, for wheat as the previous crop, or late April to early May for *berseem* as the previous crop. These "irrigation gaps" of 87 and 63 days, respectively (Table 6) mean that the soils are extremely dry and deeply cracked. The 250 mm is essential to fill the cracks, allow the soil to swell shut, and then saturate the soil with a minimum amount ponded on the surface for effective puddling. This 250 mm depth actually represents approximately 15% of the total water application for rice.

This condition places heavy demand on irrigation water delivery. *Mesqa* inlets from branch canals are designed on the basis of providing an estimated maximum water duty of 50 m^3/*feddan*/day (approximately 11 mm) and on the assumption that no more than 50% to 70% of the area served will be planted to rice. This heavy 250 mm demand on the delivery system is compounded by the farmers' preference to grow rice on more than the planned areas. As mentioned previously, actual rice area can exceed 80% to 90% of a *mesqa* (Figure 6). During this two to three week period an acute shortage of water is observed and represents the only time of year when Abu Raya farmers complain of insufficient water. This period also represents the maximum water demand during the summer season as well as the entire year. When more of an area served by a *mesqa* is planted to rice than the designed inlet can allow, water shortages will occur during the critical transplanting period.

3. The Growing Period

The growing period extends from transplanting in the second half of June until the last irrigation in mid-September when the grain filling is completed and the crop is beginning to dry out. During this period the farmer's water management objectives are to maintain a flooded condition on the field. Obtaining a continuous flooded condition usually means bringing the water level to a 12-15 cm depth. To do this, farmers irrigate from 20 to 25 times during the 90-day growing period for an average of once every 3.6 to 4.5 days (Figure 7, Table 7). Such frequent irrigation is inconsistent with the 4 on/4 off rotation which implies an irrigation every 8 days. The farmers are thus either irrigating twice during a 4 day "on" period or occasionally during the "off" period if sufficient leakage or storage water is available. The data in Table 7 represents only those irrigations actually recorded by the team. Additional irrigations at night may have gone unrecorded. With rice, such additional irrigations cannot be detected as easily as on upland crops.

4. The Maturing Period

The maturing period extends from the last irrigation until harvest. During this period the crop is senescing (dying), and the grains are drying to a moisture level for safe handling. During this period no irrigation is required, and actually would slow down the drying process. This last irrigation usually takes place before mid-September (Table 8). However, the irrigation system continues on a 4 on/4 off rotation until October 15. Because there is no demand for water during this maturing period, the fall and winter rotation could begin October 1 or earlier.

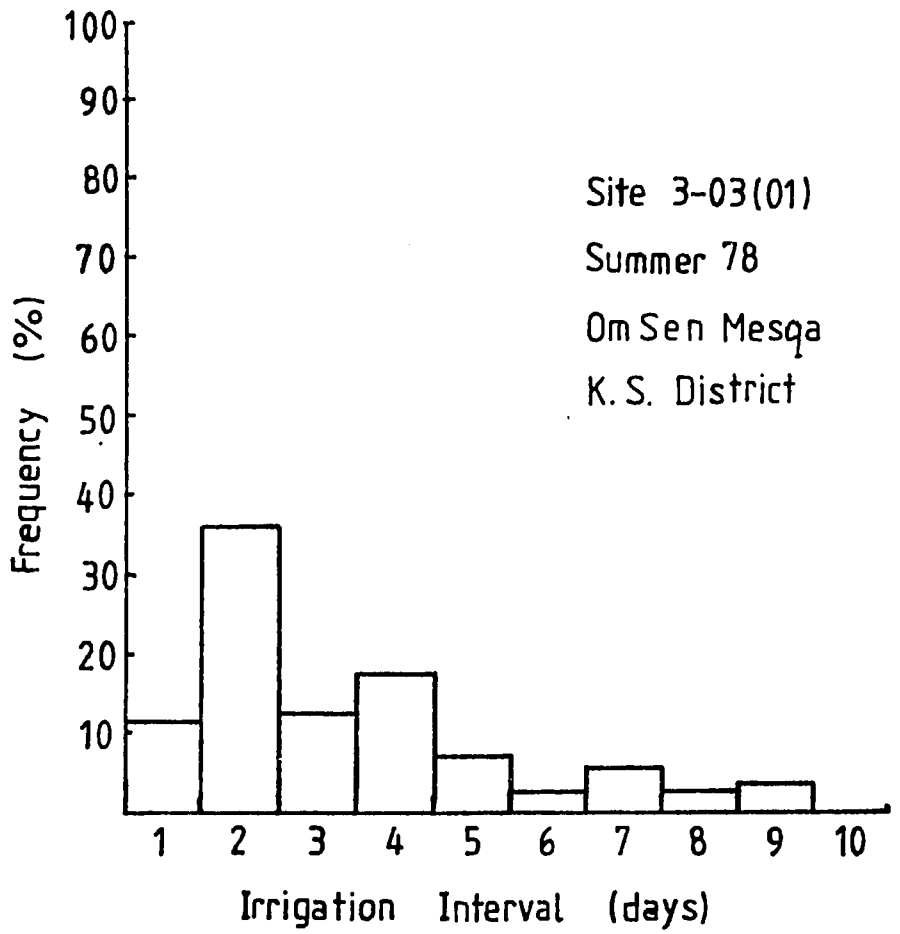

Figure 7: Example of Rice Irrigation Frequency, Kafr El-Sheikh (After Egyptian and American Field Team, 1980).

Table 7: Irrigation Depths Applied to 3 Rice Fields in 1979, Abu Raya, Kafr El-Sheikh

Farm No.	Day of Month																														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
	cm																														
	May																														
3-01-2																				1.4*											
3-01-5																	7.0*											1.4*			
3-01-6																			2.7*									0.9*			
	June																														
3-01-2						1.3*		1.1*	1.1*	14.9													8.3		6.1						
3-01-5			1.6*		1.8*			28.1		6.2								4.0					7.7			8.0		4.0			
3-01-6					1.3*	1.6*		27.4	7.6							6.9							8.0			6.0					
	July																														
3-01-2		6.3	5.2						10.0			7.8													7.1						3.3
3-01-5		7.1	6.3						11.2	6.1											4.1										
3-10-6	8.0	17.0						5.6																4.1				8.6		8.3	
	August																														
3-01-2					5.5									6.8					6.7	7.1							7.0			5.5	
3-01-5	5.3			9.4						4.4					4.9					7.0										5.8	
3-01-6						6.9							5.3			6.0				4.9											
	September																														
																						Totals									
3-01-2					5.9																	113.5 cm									
3-01-5																			6.4			136.0 cm									
3-01-6					6.0	4.4		4.4					5.7			5.2						156.3 cm									
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31

* Application to nursery not included in totals.

Source: Unpublished data compiled by S. El Din.

Table 8: Irrigation of Rice by Farmers in Abu Raya, 1980 and 1981 [a]

	Period									
Farm No	5/1-5/15	5/16-5/31	6/1-6/15	6/16-6/30	7/1-7/15	7/15-7/31	8/1-8/15	8/15-8/31	9/1-9/15	9/16-9/30
	Fed. irrigated [b]									
					1980					
201			1.25	13	13	6.5	6.5	6.5	13	
202			1.67	16.02	13.35	13.35	16.02	16.02	5.34	5.34
203			5	30	15	15	30	30	10	10
205			7	21	10.5	10.5	21	21	7	7
207			4	12	6	6	12	12	4	
					1981					
201				6	8	6	4	4	10	
202				9.39	12.52	9.39	6.26	6.26	15.65	
203				15.99	21.31	15.99	10.66	10.66	26.65	
205				10.38	13.48	10.38	6.92	6.92	17.3	
206				10.5	14	10.5	7	7	17.5	
207				7.5	10	7.5	5	5	12.5	
208				25.5	34	25.5	17	17	42.5	
209				13.5	18	13.4	9	9	22.5	
210				6.39	8.52	6.39	4.26	4.26	10.65	
211				6.16	5.32	6.16	2.66	2.66	6.65	
212				6.99	9.32	6.99	4.66	4.66	11.65	
213				9	12	9	6	6	15	
214				6.63	8.84	6.63	4.42	4.42	11.65	

[a] Adapted from farm records, as reported in EWUP Internal Memorandum--Draft Working Paper No. 88. Irrigation Practices Reported by EWUP Farm Record Keepers (Abyuha & Abu Raya sites 1979-1980 & 1980-1981). Farouk Abdel Al & Melvin Skold.

[b] Numbers represent the total land area to which water was applied and is equal to the farmer areas times the number of irrigations. The data do not include water applied to nurseries.

C. On-Farm Irrigation System Studies

1. On-Farm Water Losses

In accomodating the water needs for rice, farmers in Abu Raya are forced to deal with several involuntary water losses; these include on-farm conveyance losses, losses due to seepage and leakage through perimeter bunds, and losses caused by unlevel fields.

(i) Conveyance Losses.

On-farm water delivery is accomplished through a system of *marwas*. These *marwas* are difficult to maintain in good condition because the expanding nature of the prevailing soils causes repeated cracks during drying periods, which allows direct seepage through the cracks, deteriorates the cross sections, and prevents successful compacting of *marwa* banks. Significant on-farm conveyance losses to leakage and dead storage have been found between *saqia* and point of application. Measurements have shown these losses to range up to 70 percent of total water lifted, depending on length of the *marwa* (Figure 8). *Marwa* length in Abu Raya can exceed 400 m. Such on-farm conveyance losses increase the amount of time and labor the farmer and animals must spend in irrigation. Furthermore, the losses contribute to high water table conditions and near water logged conditions exist along some on-farm conveyance channels. This can be particularly detrimental to upland crops, but does not adversely affect flooded rice.

(ii) Paddy Size and Shape

The ease of maintaining a 12 to 15 cm flooded depth on a field, depends on the extent of seepage and/or leakage through the retaining perimeter bunds. Basin sizes in Abu Raya are commonly between 0.15 ha and 0.90 ha, with typical dimensions

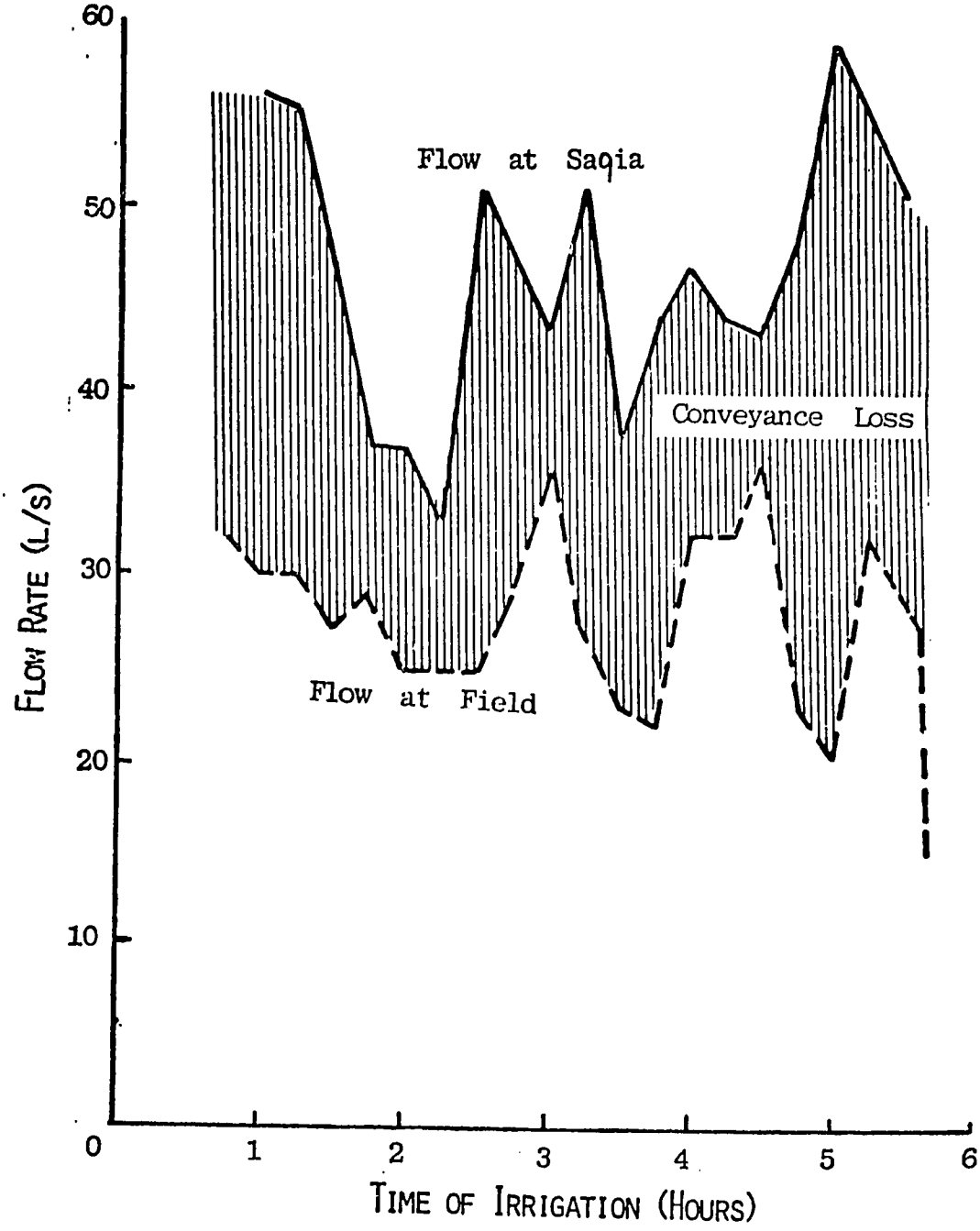

Figure 8: Example of On-Farm *Marwa* Conveyance Losses During a Single Irrigation, Abu Raya, Kafr El-Sheikh (Contributed by Metawie).

of 15 to 40 m wide and 70 to 220 m long. Such basins are always irrigated as undivided units and at times several basins may be simultaneously irrigated regardless of available stream size. Perimeter bund length increases with basin area and when combined with the unlevelness of the fields, these conditions hamper the farmer's ability to control water at the boundaries and maintain a flooded depth. Boundaries are often open field drains which the farmers attempt to close to reduce water losses. Consequently these drains are full of water throughout the rice season. When upland crops, such as maize or cotton, are grown adjacent to these drains, these crops can suffer from waterlogged conditions along a 2 to 4 m width. The same soil conditions that increase conveyance losses also make bund maintenance difficult and encourage perimeter seepage. Many observations of water seepage through the perimeter bunds have been made but quantifying such losses is extremely difficult in an on-farm working situation. Such losses directly affect the irrigation frequency and total amount applied.

(iii)Field Levelness.

Another reason for maintaining a 12 to 15 cm flooded depth is that the fields are generally not precision leveled, and this depth is required to assure the higher areas remain reasonably flooded. For acceptable water application uniformity and efficiency, level fields should be within ±0.015 m (USDA, 1974) of the mean field elevation. Numerous grid surveys conducted by the EWUP Kafr El-Sheikh team on different fields indicate a definite need for precision leveling (Table 9). The elevation range for all the basins surveyed is at least twice the ±0.015 m acceptable standard and more than 80 percent of the fields have a range actually greater than three times the acceptable

Table 9: Summary of Field Elevation Variation Data for Selected Fields in Abu Raya, Kafr El-Sheikh.

Farm and Strip ID	Mean Strip Elevation[a/]	Elevation[a/] Max.	Elevation[a/] Min.	Range	Standard Deviation	Time of Year[b/]
	Meters					
3-01 (1)	1.36	1.40	1.32	0.08	0.03	Nov '79 (after rice)
3-01 (2)	1.33	1.39	1.30	0.09	0.02	Nov '79 (after rice)
3-02 (2)	1.55	1.61	1.49	0.11	0.03	Oct '79 (after cotton)
3-02 (3)	1.57	1.62	1.52	0.10	0.02	Oct '79 (after cotton)
3-02 (4)	1.56	1.59	1.53	0.06	0.02	Oct '79 (after cotton)
3-02 (5)	1.51	1.57	1.48	0.09	0.02	Oct '79 (after cotton)
3-02 (6)	1.49	1.56	1.45	0.11	0.03	Oct '79 (after cotton)
3-08	1.31	1.35	1.25	0.10	0.02	Nov '79 (after rice)
3-09	1.03	1.08	0.98	0.10	0.02	Nov '79 (after rice)
3-10	1.58	1.64	1.55	0.09	0.02	Nov '79 (after rice)
3-12	1.50	1.58	1.47	0.11	0.03	Nov '79 (after rice)
3-02 (10)	1.47	1.52	1.32	0.20	0.04	Nov '80 (after cotton)
3-02 (11)	1.48	1.56	1.41	0.15	0.03	Nov '80 (after cotton)
3-21 (5)	1.66	1.83	1.59	0.24	0.04	Nov '80 (after cotton)
3-23 (1)	1.43	1.49	1.37	0.12	0.03	Mar '81(after berseem)
3-25 (5)	1.60	1.64	1.57	0.07	0.02	June'81 (after wheat)
3-25 (4)	1.63	1.68	1.59	0.09	0.03	June'81 (after wheat)
3-01	1.64	1.72	1.55	0.17	0.03	June'81 (after wheat)

a/ Elevations given are relative to local benchmarks.
b/ Relative to 2-year crop rotation and time when rice is cultivated (Refer to Figure 2).
Source: Compiled from unpublished data collected by S. El-Din, A. F. Metawie,, A. El-Kayal, K. E. El-Din, A. Dardir, M. Awad.

standard. EWUP has found similar results in the Mansuriya Project area (El-Kady et al., 1979).

Precision leveling is a prerequisite for application of the proper amount of water as well as for deriving the benefits of good water management and proper inputs for increased crop production (Johnson et al., 1978). Studies by Ali, Clyma and Early (1975) of level systems in Pakistan have shown that deviations from level of only 0.03 m (twice the levelness criterion) significantly affect farmer irrigation practices. The effects of unlevel fields on rice irrigation are numerous. The unlevelness will reduce irrigation efficiency, require rice farmers to maintain a greater flooded depth with resulting greater perimeter losses, and large differential crop growth between high and low parts, giving a general uneven apprearance to the fields.

Farmers in Abu Raya attempt to level their fields in two ways. First they use a simple scraper to move soil from one part of the field to the next according to their memory of the high and low spots. However, this is done without surveying and with a total tractor-implement length insufficient for precision planning or smoothing of high spots and low spots to dead level. The second method is during the *talweet* or puddling process, when farmers, using animal power, drag a large board across the field. Although the water in the field can effectively indicate high and low places, the method cannot move soil sufficient distances to effectively level the land. An improvement may be possible if cage wheels were available for the tractors. They could then work in the wet fields, with an implement of sufficient capacity to move the necessary soil. Wet leveling also requires significant stirring up of the soil through wave action such that a uniform slurry is formed,

which will settle evenly over the field upon completion of the opertion.

2. Water Application

Measurements of total water applied to rice have been made every rice season since the Project began using 0.2 x 0.9 m cutthroat flumes (Skogerboe et al., 1973) installed near the *saqia* (Table 10). Table 10 is a summary of measurements which include the 1978 and 1979 problem identification work and 1980 field trials. These results would represent the farmer's current rice irrigation practices. The 1978 and 1979 records may be incomplete as this was in the early stages of the Project, before cooperating farmers fully understood the Project. Some irrigations, such as at night, may not have been recorded. This is most likely the case for those farms recording a total water application of less than 1300 mm to 1400 mm. It is felt the 1980 field trial data best represent the actual range and mean of total water application to rice under the current farmer methods. The total application includes the amount applied at transplanting, which was always the largest single application.

D. Water Requirements of Rice

Preliminary estimates of actual rice water needs were made in the summers of 1980 and 1981 by measurements of field surface water level recession in simple lysimeters. The lysimeters used in this case were empty oil drums. Measurements of evaporation, evapotranspiration and evapotranspiration plus percolation were made or calculated using bottomed, unbottomed, planted and unplanted barrels buried to the normal field water levels. There were 3 barrels in a set. Two sets were measured in 1980 and 3 sets in 1981. From these data the mean daily rates shown in Table 11 were calculated . The daily rate averaged 13.6 mm and 14.9 mm for each year respectively, which result in 109 mm and

Table 10: Water Applied to Rice by Farmers in Abu Raya, 1978, 1979 and 1980.

Farmer and Strip ID	Total Water Applied	Maximum single application amount[a/]	% of Total
	---------- mm ----------		
		1978	
3-03-1(01)	1510	196	13.0
3-03-1(02)	1563	240	15.4
3-03-1(03)	1654	240	14.5
3-03-2(01)	1592	240	15.1
3-03-2(02)	1525	240	15.7
3-03-2(03)	1644	240	14.6
3-03-2(04)	1322	196	14.8
3-03-3(01-03)	1288	160	12.4
3-03-4(01-02)	1599	403	25.2
3-03-4(03)	1643	403	24.5
3-02-1(03,04)	2660	200	7.5
3-02-1(05,06)	2100	380	18.1
$\bar{x}$ ± s.d.	1675 ±370	262 ±85	15.9 ±4.9
		1979	
3-01-2(01)	1135	149	13.1
3-01-5(01)	1360	281	20.7
3-01-6(01)	1563	274	17.5
3-02-1(08)	1386	145	10.5
3-02-1(09)	1373	226	16.5
$\bar{x}$ ± s.d.	1363 ±154	215 ±66	15.7 ±4.0
		1980	
3-10 A_oB_o[b/]	1975	320	16.2
A_oB_1	1927	320	16.6
3-11 A_oB_o	2043	247	12.1
A_oB_1	2031	247	12.2
3-02 A_oB_o	1540	-	-
A_oB_1	1510	-	-
$\bar{x}$ ± s.d.	1838 ±246	283 ±42	14.3 ±2.5
overall $\bar{x}$ ± s.d.	1691 ±324[c/]	255 ±75	15.5 ±4.2

a/ Always the first or puddling irrigation.
b/ Field trial strips:
A_o refers to farmer's current irrigation methods.
B_o refers to farmer's current agronomic practice.
B_1 refers to EWUP's recommended agronomic practice.
c/ Without values less than 1300 mm.

TABLE 11: Measured Daily Water Use and Estimates of Irrigation Needs for Rice, 1980 and 1981, Abu Raya, Kafr El-Sheikh

Month	Evaporation (mm/day)	Evapotranspiration (mm/day)	Transpiration (mm/day)	Percolation (mm/day)
		1980		
July (13)[a]	6.8 ± 2.4	7.1 ± 1.1	1.1 ± 0.8	3.5 ± 4.0
August (22)	4.6 ± 0.5	7.0 ± 0.8	2.5 ± 0.7	4.6 ± 2.2
September (30)	3.2 ± 0.4	6.6 ± 0.7	3.4 ± 0.8	9.9 ± 4.1
Average (67)	4.4 ± 1.7	6.8 ± 0.8	2.6 ± 1.1	6.8 ± 4.4
Total Season (mm)[b]	537	830	317	830
Irrigation needs per on period (6.8 + 6.8) 8 = 109 mm				
Irrigation needs per season 830 + 830 = 1660 mm = 6972 m^3/feddan[c]				
		1981		
July	5.8 ± 1.0 (n=78)	8.3 ± 0.9 (n=78)	2.5 ± 0.8 (n=78)	5.4 ± 2.9 (n=41)
August	4.4 ± 1.3 (n=90)	6.7 ± 1.2 (n=90)	2.4 ± 0.8 (n=90)	7.2 ± 2.6 (n=60)
September	3.3 ± 1.4 (n=83)	5.3 ± 1.4 (n=87)	2.2 ± 0.9 (n=83)	11.1 ± 6.9 (n=60)
Average	4.5 ± 1.6 (n=251)	6.7 ± 1.7 (n=255)	2.3 ± 0.8 (n=251)	8.2 ± 5.3 (n=161)
Total Season (mm)[b]	549	817	281	1000
Irrigation needs per on period (6.7 + 8.2) 8 = 119 mm				
Irrigation needs per season 817+ 1000 = 1817 mm = 7631 m^3/feddan[c]				
		Average of two years		
Total Season (mm)[b]	543	824	299	915
Irrigation needs per season (824 + 915) = 1739 mm = 7304 m^3/feddan[c]				

[a] Number of observations comprising averages.

[b] Assuming transplanting on June 15 and maturity on Oct. 15 = 122 days.

[c] Does not include 200 mm needed for puddling soil. When included, this adds 840 m^3/feddan for a total of 7812 m^3/feddan in 1980 and 8471 m^3/feddan in 1981 and 8144 m^3/feddan for the average of two years.

Source: Evaluation of unpublished data compiled by S. El-Aref, S. A. Hafez, M. Awad, and A. El-Kayal.

119 mm respectively per 8 day " on" period. This implies that a depth of 120 mm would be needed to accomodate water needs over the "off" period, if the farmer irrigated only once per "on" period as planned. Seasonal irrigation needs (including a 200 mm puddling depth) were estimated to be 1860 mm (7812 m^3 /*feddan*) in 1980, 2020 mm (8471 m^3 /*feddan*) in 1981, and 1940 mm (8144 m^3 /*feddan*) as an average of the 2 years. This is reasonably close to the Ministry of irrigation's estimation of the water duty for rice to be 7500 m^3 /*feddan*.

For the 2- year average values, the amount to evapotranspiration is roughly equal to the amount to percolation, being 824 mm and 915 mm, respectively. Evapotranspiration was found to be approximately the same for each year. However, percolation rates were 20% greater during the second year, also percolation rates were found to increase as the season progressed each year. The reason for the seasonal increase in percolation is not known. As these values indicate, the amount for evapotranspiration may be reasonably stable over large areas and different seasons because it is primarily due to climatic factors. The percentage lost to percolation would be considerably less stable, being a function of specific local soil characteristics. Percolation values will need to be determined locally for accurate water duty estimates, and estimates will have to take the trend for increasing percolation as a season progresses into account.

E. Other Related EWUP Studies

In addition to irrigation work, EWUP has conducted studies on related subjects, some of which were simple inventories of existing conditions and others were actual interventions in farmer operations.

1. Soil Survey Studies

Two basic soil surveys were conducted in Abu Raya. One was a broad-

based soil characteristics survey, using a 10-*feddan* grid sampling procedure (Abdel-Wahed et al., 1982). The survey delineated three basic soil series with several additional phases for each series. The most common soils were the Typic Torrerts of the Vertisol order, common throughout the alluvial soils of the Nile Valley and Delta. Vertisols are heavy expanding clay soils that crack upon drying but when kept wet have a low infiltration rate. Such soils are generally well suited for rice production.

Of more direct impact to rice are the maps of salinity and sodicity levels taken from these soil samples (Figures 9 and 10). These maps indicate that, while the surface soils are relatively free of salts and have a low SAR, there is a substantial increase in both values below 25 cm. As illustrated before, the growing of flooded rice can successfully reduce the salinity levels.

The second soil survey conducted by EWUP concerned soil fertility (Zanati et al., 1982). Limited areas were sampled intensively and analyzed for extractable nutrients and other parameters of fertility. The survey indicated that soils in Abu Raya were possibly deficient in both phosphorus (P) and zinc (Zn) (Figures 11 and 12). In view of the sodic and calcareous soil conditions, deficiency in availability of these nutrients would be expected. For rice, however, the problem of possible P-deficiency may not be a major concern, since P-availability frequently increases after flooding (Ponnamperuma, 1977). The availability of Zn, on the other hand, decreases with flooding (Ponnamperuma, 1978).

2. Mechanization Studies

After observing the intensive labor necessary for transplanting rice, EWUP decided to examine the possibility of using mechanical transplanters. This was done in cooperation with Tanta Motors, which provided

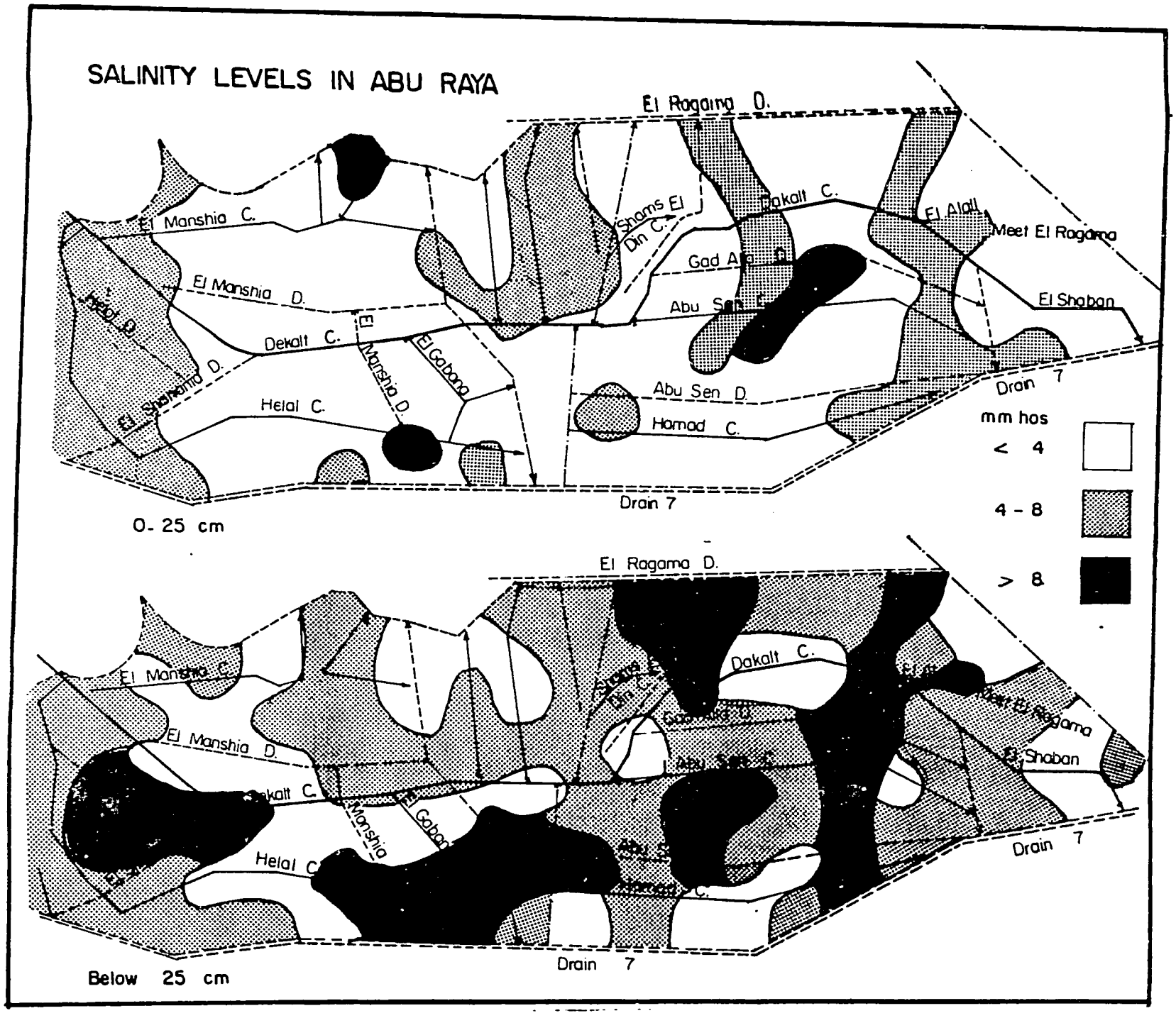

Figure 9: Soil Salinity Levels in the Surface and Subsurface Soils at Abu Raya. Source: EWUP Technical Report No. 34: Soil Survey Report For Abu Raya Area.

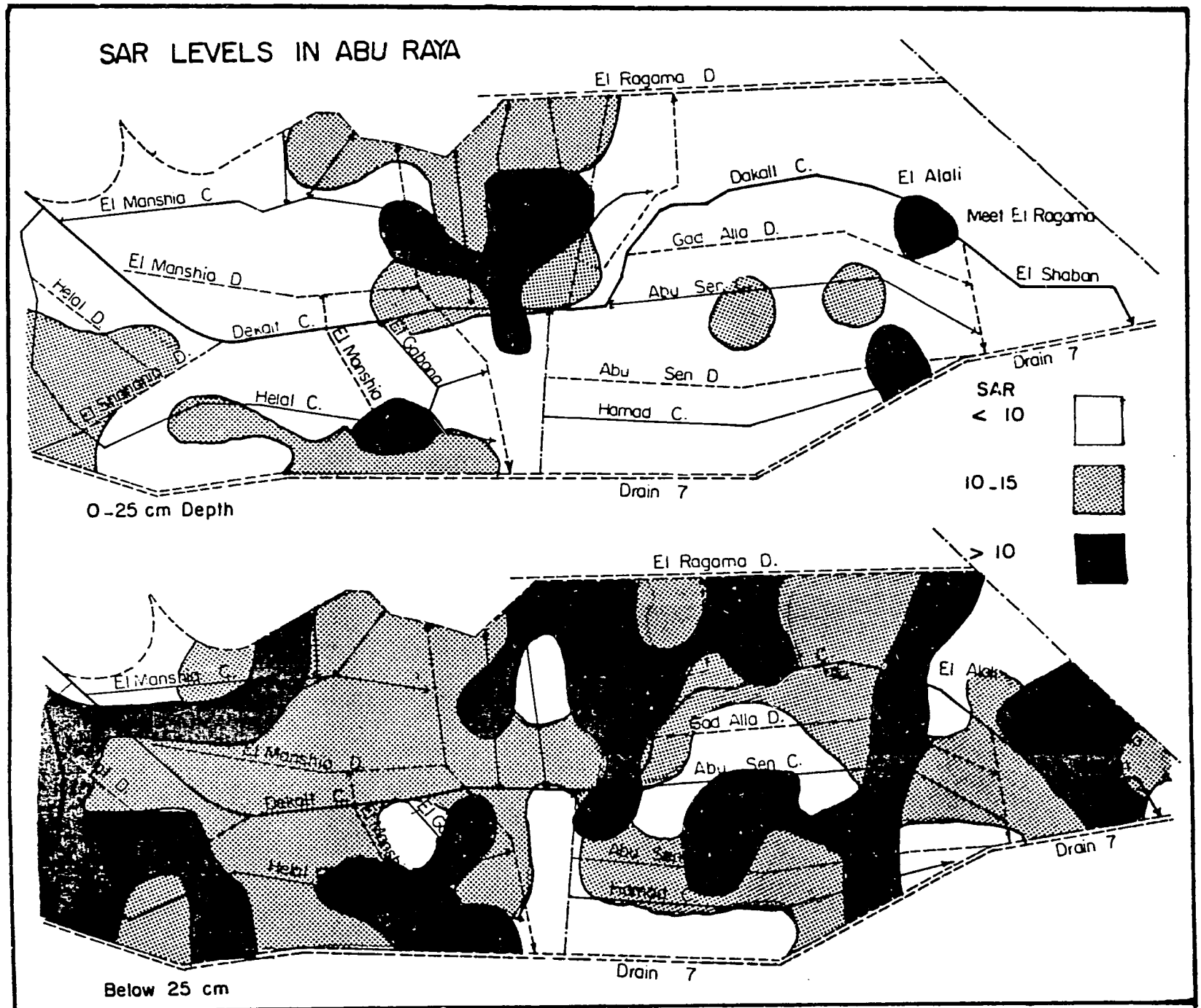

Figure 10: Sodium Adsorption Ratios in the Surface and Subsurface Soils at Abu Raya. Source: EWUP Technical Report No. 34: Soil Survey Report For Abu Raya Area.

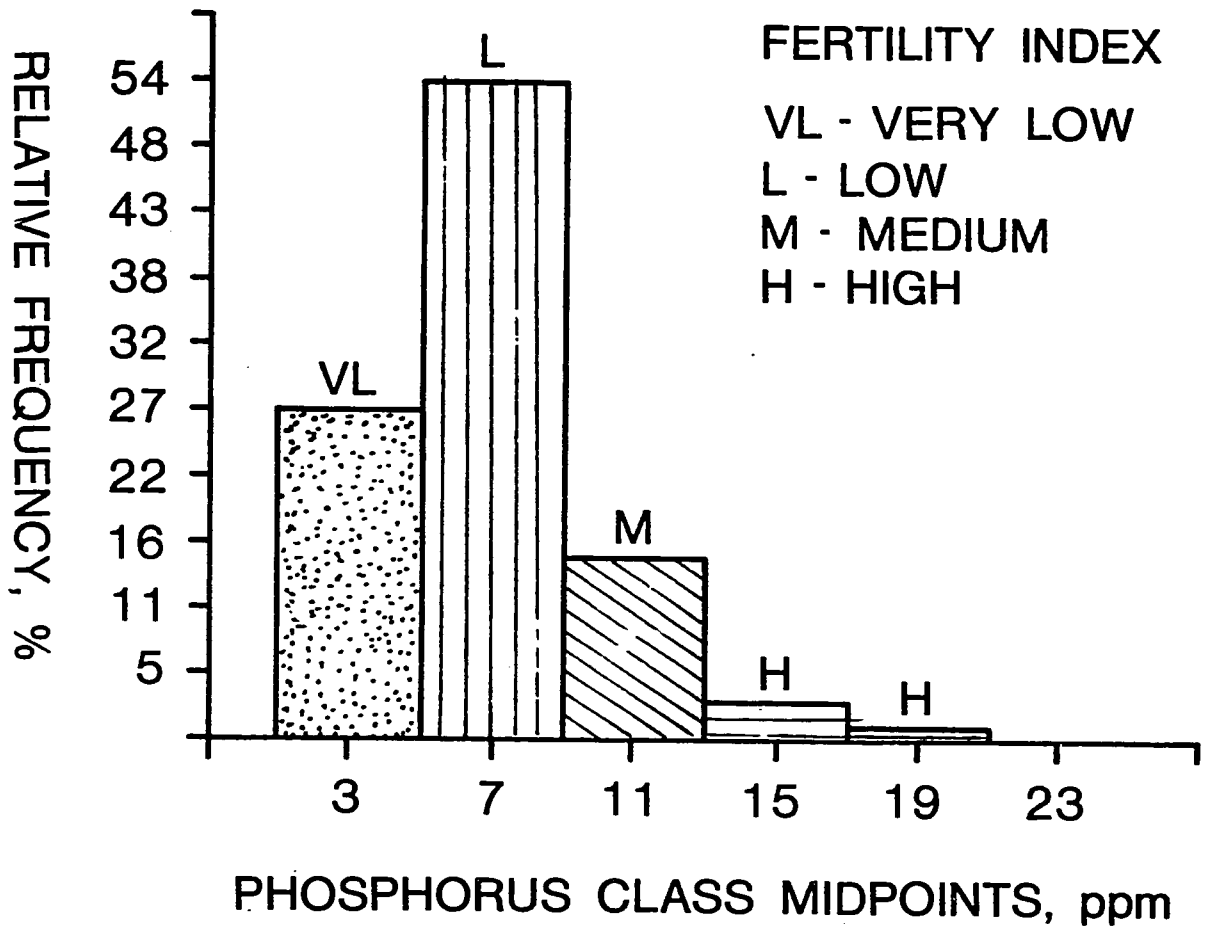

Figure 11: Percentage of Soils Analyzed with Varying Levels of Phosphorus in Abu Raya. Prepared by G. Ayad and M. Zanati.

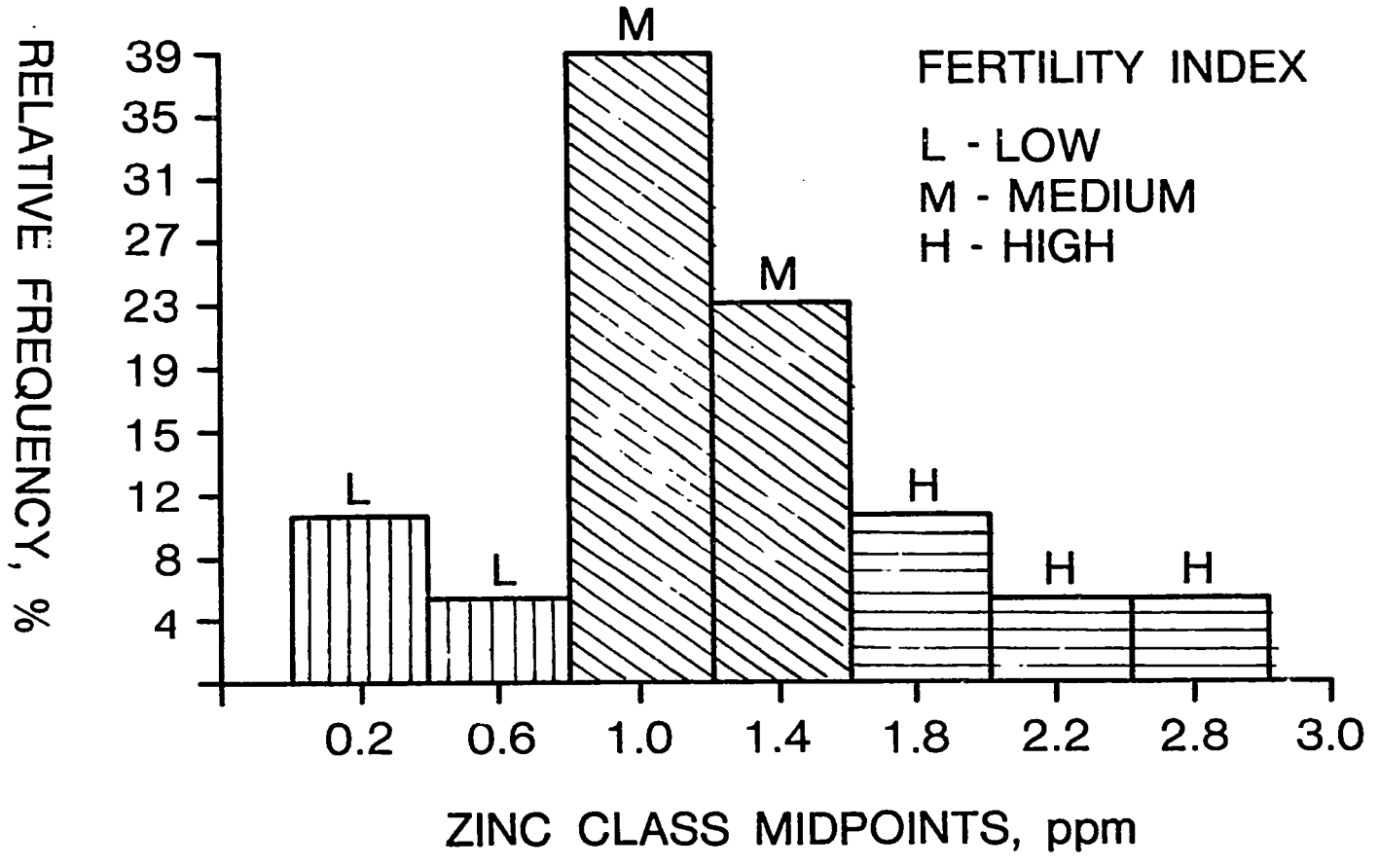

Figure 12: Percentage of Soils Analyzed with Varying levels of Zinc in Abu Raya. Prepared by G. Ayad and M. Zanati.

a two-row and a four-row power transplanter. An IRRI designed manual transplanter was also obtained from the Ministry of Agriculture (Farm Machinery Department). The study showed that there is some potential for mechanizing rice transplanting, but also brought to light some of the problems involved (EWUP Staff Paper #7).

One such problem is the need to have a matted nursery of proper seedling size. Such nurseries have more narrow limits for seedling age at transplanting than the normal wet-bed nursery, and thus requires closer coordination of equipment and seedlings. Also, as with all wet-land equipment based on flotation, the equipment demands exceptionally good preliminary puddling to work effectively. This may be beyond the capability of the present system to provid this quality of puddling over a wide area. A substantial influx of power land-preparation equipment, capable of working under flooded conditions, might be necessary to obtain this quality. Finally, economic analysis indicated that, for a power transplanter to compete with the present system, it would need to work 300 hours per year, which, at six hours per day, means fifty days in operation. This would require transplanting from mid-June to August. However, it is unlikely that seedlings young enough to be used in the mechanical transplanter in late July would mature before cool temperatures in November set in and severely reduce yields.

3. Economic Studies

EWUP's Economic Section maintains comprehensive records on thirteen case study farmers within the Abu Raya area. From these farm records, the economists prepare crop enterprise cost summaries. These include information on income, variable costs, fixed costs, labor distribution and irrigation. A preliminary crop enterprise summary for rice is presented in Table 12. These records are also used to look at the total cropping systems and irrigation practices. Figures 5 and Tables 5 and 8 were obtained from farm record data.

TABLE 12: Crop Enterprise Cost Study*. Rice at Abu Raya Area (1)

Item	Unit	Number of Units	Price or Value per Unit L. E.	Total Income or Costs L. E.
Income				
Rice grains	Ton	2.5	65,000	162.50
Rice straw	Camel load	4.0	1,500	6.00
TOTAL INCOME				168.50
Variable Costs				
Org. Fert. Transportation	Donkey load	250.0	0.050	12.50
Labor to spread org. fert.	Man hour			
Plowing	Tractor hour	2.0	1.250	2.50
Puddling	Puddling/F	1.0	4.000	4.00
Nursery planting seeds	Kilo	6.0	0.800	4.80
Labor to spread seeds	Man hour	1.0	0.200	0.20
Nursery plants pulling	Man hour	18.0	0.200	3.60
Transplanting	Boy hour	30.0	0.100	3.00
Weeding	Boy or Girl hour	24.0	0.100	2.40
CHEMICAL FERTILIZER		0.0	0.000	0.00
Ammonium Sulphate	Kg.	150.0	0.050	7.50
Super Triple	Kg.	50.0	0.070	3.50
Labor to spread Chem. Fert.	Man hour	6.0	0.200	1.20
IRRIGATION (2)		0.0	0.000	0.00
Sakia rent	Sakia hour	157.0	0.080	12.56
Cow or buffalo rent	Cow or buffalo rent	157.0	0.300	47.10
Labor to spread water	Man hour	157.0	0.200	31.40
HARVESTING (3)		0.0	0.000	0.00
Labor for harvesting	Man hour	30.0	0.200	6.00
Labor for bundling	Man hour	8.0	0.200	1.60
Labor for loading	Man hour	3.0	0.200	0.60
Transplanting by camel	Camel hour	6.0	1.000	6.00
Thrashing	Machine hour	2.0	1.500	3.00
Winnowing	Machine hour	2.0	1.500	3.00
Total Variable Costs				157.66
Return Above Variable Costs				10.84
Fixed Costs				
Land Rent	Month	6.0	7.000	42.00
Management charge	Month	6.0	1.000	6.00
TOTAL FIXED COSTS				48.00
GRAND TOTAL COSTS				205.66
Return Above All Costs				- 37.16

Footnotes:

* This study for an area of one feddan.

(1) These data were collected from 4 study cases at Abu Raya site by Ibrahim El Shinnawy, Mohamed El Gazzar, Abdel Halim El Sherbini, and Med. Salama. Students from Faculty of Agriculture at Kafr El Sheikh, Economic Department.

(2) Rice needs adding water day after day and sometimes everyday, 1 F needs about 8800 cu meters.

(3) Rice nurseries are planted in late April and in eary May. Young plants transplanted to the fields one month later, usually during June. Harvesting of rice starts in October and continues in November.

TABLE 12 Continued. Crop Enterprise Cost Study*. Rice at Abu Raya Area

	Labor Distribution			Water Use
	Man Hours	Woman Hours	Boy/Girl Hours	
October	41	0	0	0
November	0	0	0	0
December	0	0	0	0
January	0	0	0	0
February	0	0	0	0
March	0	0	0	0
April	0	0	0	0
May	24	0	0	960
June	48	0	30	1568
July	47	0	12	2520
August	47	0	12	2520
September	22	0	0	1232
TOTAL	229	0	54	Total Water Applied = 8800 cu meters

Footnotes:

- Water use based on our project research stations data.
- Working day = 6 hours

Source: EWUP Staff Paper #7

4. Informal Observations

Since EWUP personnel are generally stationed on farms, they are able to make observations outside of the particular studies. These are often instructive concerning the cropping system as a whole, and of rice in particular, especially when compared with rice-producing practices common throughout the world.

Slow Crop Development

As mentioned previously, rice in the northern Egyptian Delta seems to take longer time to mature than in other rice-producing areas. This is particularly noticeable in the seedling stage, when a 10-day-old seedling will be only 3 cm tall, as compared to 10 cm in many tropical countries. The cause of the slow growth could be the cool night temperatures. This raises the question of whether hot seed beds similar to those used in South Korea might be feasible in Egypt, or, at the very least, whether seedlings might be covered with plastic sheets at night.

Mechanization of land Preparation

In Egypt, once the fields are flooded, all operations are done exclusively with animals, either buffaloes or cows. In other countries, such as Sri Lanka and Vietnam, it is common to see large tractors equipped with tandem cage wheels working in the flooded fields. It would seem that there is a potential use for cage-wheel equipped tractors in Egypt. A reasonable number of tractors are already available to farmers, and the use of cage wheels could expedite land preparation, perhaps allow for better land leveling, and free the manpower necessary for transplanting. It could also reduce the water needed for initial puddling. The overall effect should be a reduction in the total time needed for transplanting.

Logistical Support

There appear to be certain problems with the support offered to farmers by the government's agricultural administrative infrastructure. This often results in supplies of seed, fertilizer, and pesticides being unavailable to the farmer at the time when he needs them. Another management problem arises when government banks take too much time to approve credit to farmers. Without the credit, farmers usually have difficulty in obtaining necessary supplies, and their entire crops are in jeopardy. A special problem for the rice farmer is that supplies are sometimes diverted for use with the cotton crop, which gets priority over rice.

IV. PRIORITY PROBLEMS IDENTIFIED

As a result of the system studies performed, the following priority problems which affect rice production in the Abu Raya area were identified:

1. Irrigation water delivery rotations need to be adapted to better accomodate the nursery growth period, the maturing period, and water requirements.

2. The 25 cm water demand for puddling at transplanting time, a period of 3 weeks from mid-June to early July, is not met with the current supply.

3. On-farm conveyance losses are significant and cause increased time and labor inputs from the farmer when he irrigates.

4. Unlevel basins affect farmer control of water and reduce irrigation efficiency.

5. Substantial perimeter losses of water by leakage through bunds occur due to poor maintenance. Soil conditions and unlevel fields compound this problem. This results in increased irrigation frequency.

6. Irrigation basins are not designed in consideration of the local design parameters. Some basins are too large. Farmers need assistance in determining basin dimensions and layout plus how to irrigate them effectively given the local conditions.

7. Field drains within paddy rice areas occupy up to 15 percent of the productive land area and serve limited beneficial purpose. Boundary drains, i.e., between upland and submerged rice crops, need better maintenance.

8. Soil salinity levels, especially at the beginning of the season may have a negative effect on nursery and seedling establishment contributing to reduced crop yields.

9. Zinc deficiency and reduced availability due to flooding may be reducing rice crop yield.

10. Significant labor input is required for transplanting. Shortages of laborers and increasing costs for labor are evident.

Further discussion of problems identified is found in the Problem Identification Report for Kafr El-Sheikh (Egyptian and American Field Team, 1980).

V. FIELD TRIALS OF SUGGESTED SOLUTIONS

As a result of problem identification studies of rice production in the Abu Raya area, the EWUP Kafr El-Sheikh Team formulated a list of possible solutions to the problems identified. Field trials on working farms have been conducted to test some of these solutions. Briefly, the results of the major on-farm trials are:

A. Zinc Studies

Due to suspected zinc deficiencies, EWUP began a series of zinc field trials. In the first trial, zinc sulphate ($ZnSO_4$) was applied to both nursery and field during the 1978 rice crop (Table 13). The results showed a statistically significant 66 percent increase in yields for the trial in which $ZnSO_4$ was applied to the nurseries. The following summer, Zn was applied over a wider sampling base of twenty-five farms, and results showed increases in both grain and straw in all but one case, with most farms having a 20 percent or greater increase (Table 14). One of EWUP's more substantial contributions in Abu Raya has been to demonstrate the response of rice to Zn for the farmers.

Following other experiment station work, the Ministry of Agriculture began recommending $ZnSO_4$ be applied to rice nurseries, and started importing Zn, for that purpose, in ever increasing annual amounts. The Abu Raya cooperative, however, was unable to get any $ZnSO_4$, until Spring 1982, when senior project personnel specifically requested the Credit Bank to supply it to the Abu Raya Co-op. Once available in the cooperative, the supply was quickly used by the farmers.

B. Planting Techniques

Rice planting trials were conducted during the 1979 summer

Table 13: Effect of $ZnSO_4$ Applied to Rice in Abu Raya, 1978.

Factor	Control	Zn Applied	
		In Field	In Nursery
Plant height, cm**	93.9	105.2	111.4*
No. of tillers**	31.6	31.6	38.2*
No. of effective** tillers	29.0	29.4	35.1*
Grain yield, T/ha**	5.4	7.5	9.0

* Significant at 5% probability.

** Plant height, no. of tillers, no. of effective tillers are means of 18 counts. Yield of grain means of 9 counts.

Source: Dotzenko, Keleg, and Abdel Hafez. Response of Rice to Application of Zinc, EWUP Staff Paper No. 59.

Table 14: Response from 25 Farms to $ZnSO_4$ Applied to Rice Nurseries, 1979.

	Percentage of Response						
	<0	0-10	10-20	20-30	30-40	40-50	>50
	No. of farms						
grain	1	3	5	4	3	3	6
straw	1	7	4	4	3	1	5
	% of farms exceeding lower values						
grain	4[a]	96	84	64	48	36	24
straw	4[a]	96	68	52	36	24	20

a/ Percent with negative response.

Source: Adapted from unpublished data of M. Zanati and A. Keleg.

season. The traditional transplanting method was compared with a dry-seeding method, a wet-seeding method and the use of a mechanical transplanter. Results showed rice production to be greatest for the mechanical transplanter method followed by the traditional method, the wet-seeding method and the dry-seeding method, respectively. Qualitative observations of total water application followed the same order with the mechanical transplanting strips using the least amount due to a decrease in use during nursery preparation. Usage of a mechanical transplanter has been discussed in an earlier section of this report.

C. On-Farm Irrigation

In relation to on-farm irrigation water management for rice, suggested solutions to problems were precision land leveling to dead level, dead level border irrigation system design, removal of unnecessary in-field drains, reduction of ponded depth of water and better maintenance of perimeter bunds. All of these practices were aimed at improving water use efficieny and saving of water while maintaining or increasing yield levels.

Rice field trials to test these practices, in addition to the agronomic recommendations of proper timing and use of fertilizers, use of zinc, herbicides for weed control and soil fungicides for better nursery germination, were conducted during the 1980 summer season. Mechanical transplanting of at least one strip on each of the field trial farms was also tried. The results for the transplanter were not successful, however, due to slow growth of the matted nurseries. The improved practices were tested in various combinations and compared to the adjacent strips where the farmer's current methods were employed. The trials were conducted on four strips on three different farms. The irrigation improvements resulted in 14 percent less water

applied than the traditional methods. Total yields were increased due to elimination of some field drains, however, unit area yields were essentially equal for all four treatments (Table 15).

The irrigation and cropping practices tested were considered succcessful. The same types of suggested improvements to on-farm water management were also tested on other crops of the 2-year crop rotation and successful results were found (EWUP, 1981b; EWUP, 1981c). On-farm irrigation system design improvements in particular, must be adaptable to all of the crops in the system in Abu Raya.

VI. THE DELIVERY SYSTEM PROBLEM

The field trials only considered problems related to on-farm irrigation practices. The problems concerning the delivery system were not addressed because the coordination of this fell outside the mandate of EWUP. However, EWUP has formulated some possible solutions.

1. The first possible solution would be for the Ministry of Irrigation to limit rice area on each *mesqa* in accordance with the capacity of the *mesqa* to deliver water. This would mean the continuation of the same 4 "on"/4 "off" irrigation rotation for the entire area, and would allow for some of the area which had been designated for maize or cotton to be planted to rice. The present deviation from the area allocation may, in fact, be the major cause of the imbalance between water supply and demand.

2. The second possible solution would be to increase the *mesqa* inlet so the capacity will be high enough that the entire area could be grown to rice. Water control would then

Table 15: Summary Results of 1980 Rice Crop Field Trials, Abu Raya. Averaqes of Resutls on 3 Farms.

Treatment	Mean Yield (ton/fed)		Total Water Applied (mm)
	Grain	Straw	
A_oB_o	3.5	6.7	1853
A_oB_1	3.6	6.9	1823
A_1B_o	3.4	6.5	1680
A_1B_1	3.2	6.7	1670

A_0 B_o: Traditional farmer's irrigation and agronomic practices.

A_o B_1: Traditional farmer's irrigation practices with improved agronomic practices.

A_1 B_o: Improved irrigation practices with farmer's agronomic practices.

A_1 B_1: Improved irrigation and agronomic practices.

be placed at the entrance to each *mesqa*. In alternate years, rice would be allocatd to the right bank, then the left bank, of the main Dakalt Canal. The rice side could be irrigated with a 4 "on"/4 "off" rotation and the other side with a 4 "on"/12 "off" rotation suitable for cotton and maize. By putting the cotton "on" period during a rice "off" period, the Ministry of Irrigation could realize water savings of nearly 8 percent, according to a preliminary study (Table 16). This would also provide the extra conveyance capacity needed to meet the peak demands. This system would also help insure that farmers were conforming to official crop designations.

VII. ON-FARM WATER MANAGEMENT IMPROVEMENT PILOT PROGRAM

In developing its package of improvements, EWUP took into account possible effects not only on the rice crop, but also on other crops of the entire two-year rotation. The pilot program deals with each of the four subsystems of on-farm irrigation: delivery, application, use, and removal. Improvements in the on-farm delivery of irrigation water were meant to reduce conveyance losses and to improve the layout of the distribution system. Measures for improving application of the water included redesigning farm layouts, leveling land and introducing dead level basins and long furrows. EWUP recommends the esablishment of an advisory service to convey information to farmers concerning when to irrigate, and how much as the best method for insuring efficient water use. For the improvement of the water removal system, EWUP found that a good number of in-field drains could be done away with, while those which remained needed better cleaning and maintenance.

Close contact and collaboration with the farmer is stressed throughout the program. EWUP has experienced considerably successful results with its land leveling and irrigation systems design improve-

TABLE 16: Preliminary Evaluation of Alternative Rotations in Rice - Cotton Cropping System of Abu Raya

Alternative		Days During 16-Day Irri. Cycle 1-4	5-8	9-12	13-16	TOTAL
		--------- % capacity ---------				
Same mesqa	rice -	off	100	off	100	1/2 time at 100% = 50%
	cotton					1/2 time off
Separate mesqa	rice	off	70	off	70	1/2 time at 70% + 1/4 time at 30% = 42.5%
	cotton	30	off	off	off	1/4 time off
	Saving:	50% - 42.5% = 7.5%				

Source: Unpublished analysis of Kamal Ezz El-Din

ments. Significant increases in efficiencies, savings of water, time and labor, and increases in yield are direct benefits achieved through these practices on typical farms in the Abu Raya area (EWUP, 1981a; EWUP, 1981b).

Rice crops of the 1981 summer season were included in the pilot program implemented on farms in Abu Raya thus far. Land leveling proved again to be an important factor in improving the on-farm irrigation systems. Results in terms of water applied and crop production for the pilot program rice farms are given in Table 17. Water applied was measured on two farms. The average depth was 1790 mm. Pilot farm yields were greater than those measured as average for the area.

VIII. SUMMARY AND CONCLUSIONS

Rice in Egypt is grown exclusively as a summer crop in the Nile Delta. Nurseries are planted in May; seedlings are transplanted in June and July. Harvest occurs from mid-October to early November. Rice is cultivated on small farms in basins ranging between 0.15 ha to 0.90 ha. The Egypt Water Use and Management Project identified several problems inherent in the on-farm distribution and delivery of irrigation water in the Kafr El-Sheikh Governorate. These problems affect all crops, including rice, in the two-year cropping scheme. Such problems include:

1. Unlevel fields with surface elevation variations generally exceeding the dead level irrigation system levelness criterion by more than three times.

2. Irrigation system layouts (distribution system and basin configurations) which are not based on good irrigation design considerations.

Talbe 17: Results of Pilot Program Efforts on Rice Farms in Abu Raya, Kafr El-Sheikh, 1981 Summer Season.

Farm	Total Depth Applied (mm)	Yield (ton/feddan)[1/]	
		grain	straw
3-01	1630	2.3	4.3
3-35(08)	1950	3.7	7.4
3-25(01)	--	3.6	7.1
3-25(02, 03)	--	3.3	5.3
3-35(04, 05)	--	3.6	6.0
3-25(06, 07)	--	3.6	6.5
3-10(01)	--	3.0	6.9
3-10(02)	--	3.1	7.0
3-22	--	2.9	5.4
Mean	1790	3.3	6.2

[1/] Mean yields for the Abu Raya area were measured at 2.6 ton/*feddan*, grain, and 4.9 ton/*feddan*, straw.

Source: Unpublished data of Kafr El-Sheikh Team.

3. Irrigation water delivery and rotation that:
   a. Has too long an "off" period during the nursery stage,
   b. Does not meet a critical demand for water during transplanting,
   c. Continues the rice irrigation rotation for one month after farmers stop irrigating rice.

Other problems include micronutrient deficiencies of zinc, soil salinity is at levels potentially damaging to crop production before rice cultivation, labor shortages forcing increased labor cost at transplanting, and inadequate farm infrastructure support.

EWUP has observed over a period of three years that farmers average total water applications to rice (including puddling) are near 1700 mm. Approximately 16 percent of this total is applied in the first puddling irrigation. Farmers tend to irrigate on intervals of two to six days, even though the water rotation for rice is four days "on" and four days "off". The average application is between 50 and 100 mm and the ponded depth generally ranges between 120 mm to 150 mm. Farmers tend to irrigate rice 20 to 25 times in the season using either *saqia* (water-wheel) or diesel pump to lift water from the *mesqa*. Estimates of rice water requirements for two seasons of data average 8144 m^3 per *feddan*. EWUP has estimated nearly 50 percent of this water goes to evapotranspiration and the other 50 percent to deep seepage.

Suggested solutions to problems have been tested in farmers' fields. The main emphasis has been on land leveling, irrigation system design and irrigation advice to farmers about when to irrigate and how much water to apply. These efforts have met with success for all crops, including rice. Improved irrigation efficiencies, water savings, and reductions in the time and labor required for irrigation have been the major benefits. These practices are currently being implemented as a

package to improve on-farm water management on farms in the Abu Raya area. Field trials to test the response of rice to zinc application have resulted in significant yield increases.

In conclusion, an attempt has been made to describe and define rice irrigation practices and the system used for rice production in Eygpt. The findings described herein are the results of four years of on-farm research in a rice-producing area of the Nile Delta. First problems were defined; solutions were then tested and a package of the most practical and effective solutions developed for implementation on farms to improve on-farm water management.

Recommendations for the Ministry of Irrigation

Based on the work done by EWUP with rice, the following recommendations are put forth for consideration by the Ministry. If adopted, these recommendations should improve the overall operational efficiency of the irrigation system, both in water delivery to farms as well as distribution and application on farms. These recommendations should save substantial amounts of water, and keep the water from flowing directly to the drains. The recommendations are:

1. Develop a large-scale program for land leveling in the rice-producing areas of Egypt. This could include evaluation of mechanical work within the wet paddy fields to take advantage of flood water to indicate high and low areas.

2. Establish an advisory service with engineering support to help the farmer in removing nonessential drains, relocation of *marwas*, design appropriate size basins for efficient irrigation, and assist farmers with determining when to irrigate and how much water to apply.

3. Examine ways to provide some additional water for the rice nurseries without turning on the entire irrigation system for only 1/16 of the land area. Also, postpone the 4 "on"/4 "off" rotation until early June, just before the transplanting period actually begins, and terminate the 4"on"/4 "off" rotation before October 1, after the farmers have stopped irrigating and are allowing the crop to mature and dry.

4. Work with the Ministry of Agriculture to either make certain the area allocated to rice on any *mesqa* does not exceed the delivery capacity of the *mesqa*; or allocate all land on a *mesqa* to either rice or cotton and provide appropriate control structures at the *mesqa* inlet level for control of irrigation rotations.

5. Inform the Ministry of Agriculture of the problems the farmers are having in impelementing recommended rice production practices such as obtaining $ZnSO_4$, certified seed, adequate fertilizer and insecticide.

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AMERICAN EQUIVALENTS OF EGYPTIAN ARABIC
TERMS AND MEASURES COMMONLY USED
IN IRRIGATION WORK

Land Area	in *sq meters*	in *acres*	in *feddans*	in *hectares*
1 acre	4,046.856	1	0.96335	0.40469
1 *feddan*	4,200.8335	1.03805	1	0.42008
1 hectare(ha)	10,000.00	2.47105	2.38048	1
1 *sq* kilometer	100×10^4	247.105	238,048	100.00
1 *sq* mile	259×10^6	640.00	616.4	259.00

Water Measures

1 billion m^3 = 810,710 acre-feet
1000 m^3 = 0.81071 acre-foot = 9.72852 acre-inch
1000 m^3/*feddan* = 0.781 acre-foot/acre = 9.372 acre-inch/acre
(= 238 mm of rainfall)

Other Conversions

1 *ardeb* = 198 liters = 5.62 bushels (U.S)
1 *ardeb/feddan* = 5.41 bushels/acre
1 kg/*feddan* = 2.12 lb/acre
1 donkey load = 100 kg
1 camel load = 250 kg
1 donkey load of manure = 0.1 m^3
1 camel load of manure = 0.25 m^3

Egyptian Unit for Field Crops

Crop	Eg. Unit	in kg	in lbs	in bushels
Lentils	*ardeb*	160.0	352.42	5.87
Clover	*ardeb*	157.0	345.81	5.76
Broad beans	*ardeb*	155.0	341.41	6.10
Wheat	*ardeb*	150.0	330.40	5.51
Maize,Sorghum	*ardeb*	140.0	308.37	5.51
Barley	*ardeb*	120.0	264.32	5.51
Cottonseed	*ardeb*	120.0	264.32	8.26
Sesame	*ardeb*	120.0	264.32	
Groundnut	*ardeb*	75.0	165.20	7.51
Rice	*dariba*	945.0	2081.50	46.26
Chick-peas	*ardeb*	150.0	330.40	
Lupine	*ardeb*	150.0	330.40	
Linseed	*ardeb*	122.0	268.72	
Fenugreek	*ardeb*	155.0	341.41	
Cotton(unginned)	*metric qintar*	157.5	346.92	
Cotton(lint or ginned)	*metric qintar*	50.0	110.13	

Egyptian Farming and Irrigation Terms

fara[1] = branch
marwa = small distributer, irrigation ditch
masraf = field drain
mesqa = small canal feeding from 10 to 40 farms
qirat = cf. English "karat," A land measure of 1/24 *feddan*, 175.03 m^2
qaria = village
sahm = 1/24th of a *qirat*, 7.29 m^2
saqia = animal powered water wheel
sarf = drain (vb.), or drainage. See also *masraf*, (n.)