THE ARAB REPUBLIC OF EGYPT

MINISTRY OF DEVELOPMENT, HOUSING AND LAND RECLAMATION
GENERAL AUTHORITY FOR REHABILITATION
PROJECTS AND AGRICULTURAL DEVELOPMENT

FEASIBILITY STUDY
ON
THE NORTH HUSSINIA VALLEY & SOUTH PORT SAID AGRICULTURAL DEVELOPMENT PROJECT
VOLUME. III

H. IRRIGATION
I. DRAINAGE
J. LAND RECLAMATION PLAN
K. LAND DISPOSAL PLAN
L. STRUCTURES DESIGN
M. RURAL DEVELOPMENT PLAN

JUNE 1984

JAPAN INTERNATIONAL COOPERATION AGENCY

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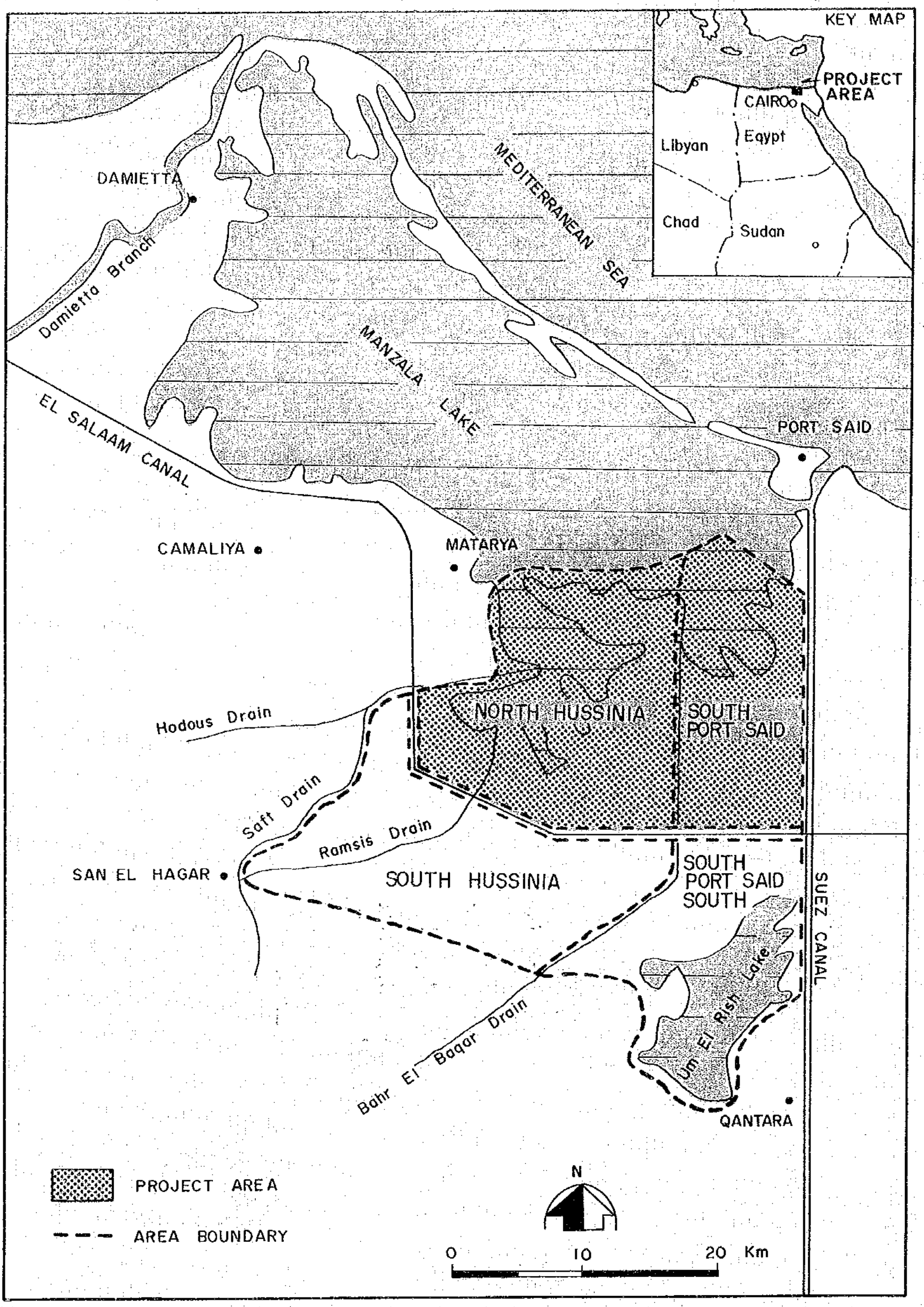
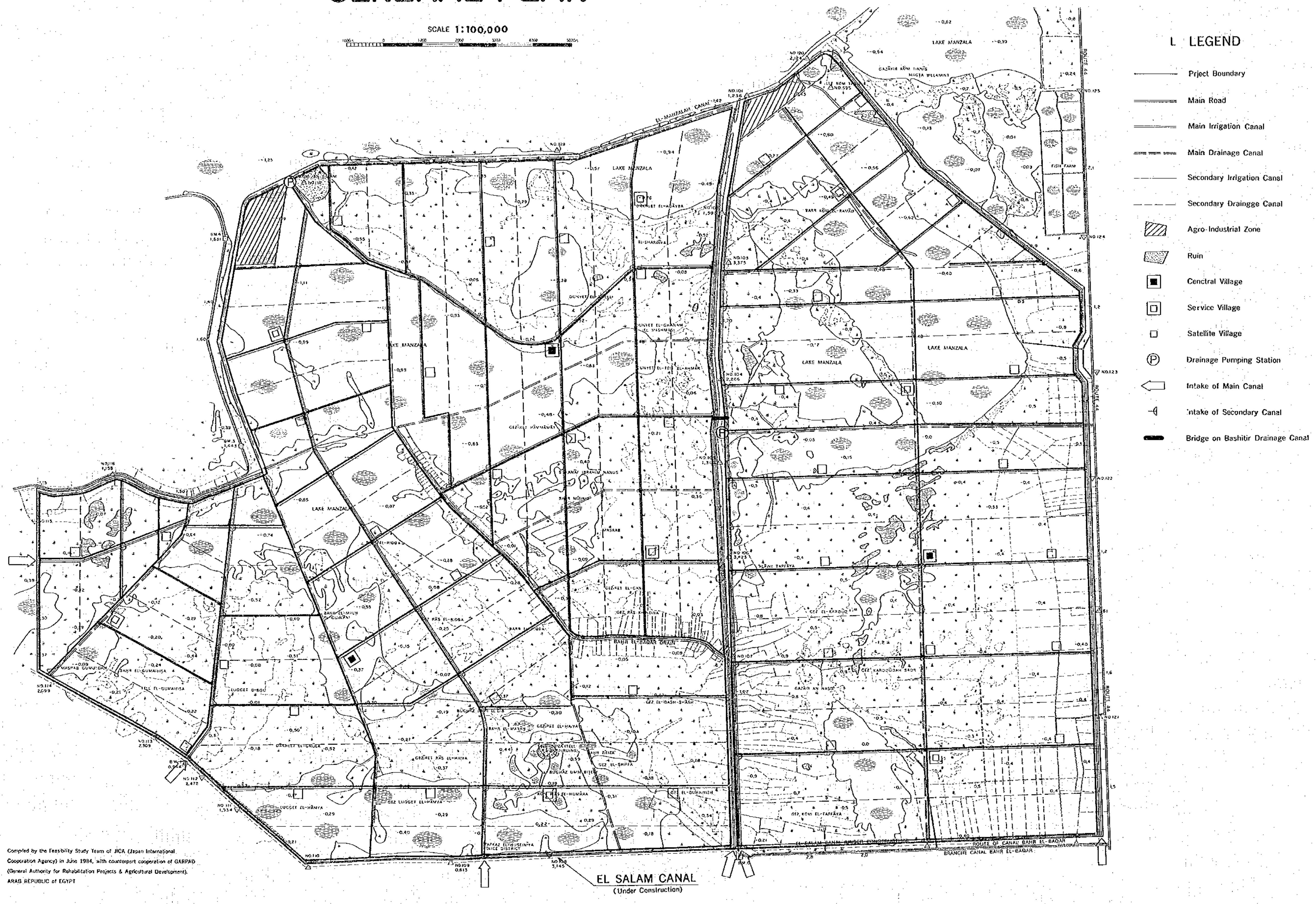
NORTH HUSSINIA VALLEY AND SOUTH PORT SAID
AGRICULTURAL DEVELOPMENT PROJECT
LOCATION MAP



NORTH HUSSINIA VALLEY AND SOUTH PORT SAID AGRICULTURAL DEVELOPMENT PROJECT

GENERAL PLAN

SCALE 1:100,000



Compiled by the Feasibility Study Team of JICA (Japan International Cooperation Agency) in June 1984, with counterpart cooperation of GARPAD (General Authority for Rehabilitation Projects & Agricultural Development).
ARAB REPUBLIC of EGYPT

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H. IRRIGATION

1. Present Condition of Irrigation and Drainage System

1-1 Irrigation

Most of the cultivated land in the Project area is extended along the main drains with the width ranging from 500 to 1,500 m, and the rest is scattered over Kom Ibn Salam and the regions along smaller drains. The distribution of the cultivated land is as follows:

Cultivated Land within the Study Area

Location	Approx. Size (feddan)
Bahr El Baqar Drain	3,790
Ramsis Drain	570
Hadous Drain	480
Kom Ibn Salam	100
	4,940

Sources of irrigation water are the drainage canals in the valley regions and the brackish water of the Lake Manzala on the islands. The drainage water contains much salt, 600 PPM to 3500 PPM,and the water flowing along Bahr El Baqar is mixed with sewage water from Cairo.

Irrigation by gravity method is prevalent as the farmland is usually about 50 cm below the water-level of the drains as well as of Lake Manzala. Where farmland elevation is higher than the external water-level, centrifugal pumps (3 to 4 inches) are used (also for drainage purpose). Farrow irrigation method is widely applied for upland crop cultivation except Berseem.

1-2 Drainage

Where farmland evelation is higher than the neighboring drain water, drainage is treated with "Sakkia" wheel driven either by cattle (old style) or gasoline engine, and sometimes, by portable centrifugal pump. Drainage canals are distributed with an average interval of 10 to 15 m.

Field drains are distributed with the interval of 10 to 15 meters having the depth of 0.50 to 0.60 meters, and these drains are connected with the main drainage canals having the depth of more than 1.0 meter.

1-3 Other Facilities

(1) Cultivated land

Size of field lots is between 3 to 5 feddan and are separated by irrigation-drainage canals or small farm-road. Most of the field lots have an inlet and an outlet individually.

(2) Tidal dyke

The tidal dyke for the South Port Said Project area was already completed, and alignment of the tidal dyke for the North Hassinia Project area has been provided in the Five Year Development Plan, 1983-1987.

The bench mark for construction of the North Hassinia tidal dyke was set up at the existing Mataria Pumping Station, whose elevation was derived at from the nearest national bench Mark.

2. Irrigation Plan

2-1 Selection of Irrigation System

(1) Irrigation Method

The irrigation methods, except flooding method used for rice cultivation, which can be adopted on a flat terrain would include:

- Surface Irrigation ....
  - Furrow irrigation
  - Border irrigation
  - Basin irrigation
- Spray Irrigation (Sprinkler) ...
  - Hand-moved
  - Fixed system
  - Side Roll
  - Center Pivot
- Drip Irrigation

The choice of these depends on such factors as topographic conditions particularly gradient, soil conditions and the basic intake-rate, wind velocity in case of spray irrigation, and variety of crops in particular.

a) Gradient

Surface-and drip-irrigation is not suitable where the gradient is more than 5° except for furrow irrigation when it is effected counterline-wise. Spray irrigation suffers no restriction from gradient. Since the Project Area is generally even leveled and its gradient is mostly less than 5°, any one of the above-mentioned irrigation methods can theoretically be adopted. However, a center pivot system is not suitable because of the location of drainage canals.

b) Basic Intake-rate

In case the basic intake-rate is less than 5 mm/hr., none of these methods would be effective, surface irrigation would be useless when the basic intake-rate is more than 100 mm/hr. As a result of the survey, the dryland portion of the Project Area may be broadly divided, in terms of their basic intake-rate, into three parts: (1) less than 5 mm/hr.; (2) 10 to 50 mm/hr., and (3) 100 mm/hr.

Most of the underwater area is presumed to have a basic intake-rate of below 5 mm/hr., or at the highest, less than 50 mm/hr. Soil improvement procedures proposed under the Project aim to attain the minimum basic intake-rate of 5 mm/hr. all over the area, and this is assumed possible.

c) Wind Velocity

Wind velocity gives a direct influence on the efficiency of spray irrigation. Wind velocity possibly obtainable in the Project Area may be presupposed from that at Port Said, namely: maximum 6.0 m/s in March and September. This means that a considerably strong wind is blowing all through the year and, consequently, sprinkler irrigation would not attain high efficiency even with windbreaks.

d) Crops

Almost all the ridge-grown crops can be properly irrigated by furrow-, spray- and drip-irrigation methods. Pasture grass such as Berseem is mostly irrigable by border- and basin-methods. Spray irrigation by side rolls and/or center pivots is not advisable for orchards as the fruit trees are too high.

e) Others

Each method has its own merits. Surface irrigation does not require any investment for equipment, but its irrigation efficiency is low at about 70 percent compared to 80 percent of spray irrigation, and 90 to 95 percent of drip irrigation. Much water is required for supplementary leaching, which is technically the easiest method for desalting.

The spray method has a high irrigation efficiency and results in less salt accumulation but requires a large investment cost amounting to almost LE 700 to 2,100/feddan in terms of terminal spray facilities, pipe-line, and pump to give 4 to 5 kg/cm^2 pressure.

The drip method, on the other hand, has the highest irrigation efficiency but also requires a considerable investment cost of about LE 1,400 to 3,300/feddan for drip-hose, pipe-line, and pump to give 1.5 to 2.0 kg/cm^2 pressure. (See Table H-2-2)

Table H-2-1 shows the adaptability of each irrigation method.

f) Selection of Irrigation Method

Surface irrigation method is adopted for this Project for the following reasons.

i) The construction cost for spray and drip irrigation is high.

ii) Any irrigation method is adoptable in terms of the natural condition and the farm management condition.

iii) Most crops can attain the target yeild under relatively extensive cultivation.

iv) At the initial stage after the land reclamation and the settlement, the soil structure is not adequately improved. Farming technologies such as cultivation techniques, farm mechanization, water management, and marketing are also incomplete. Under these conditions, it is not effective to introduce high cost irrigation systems.

Table H-2-1 Irrigation Method and Adaptability

Items \ Irrigation Method		Surface Irrigation			Spray Irrigation					
					Sprinkler					
		Furrow	Border	Basin	Hand-moved	Fixed	Side Roll	Center Pivot	Drip	Note
Topographical Gradient	0 to 5%	O	O	O	O	O	O	O	O	
Basic Intakerate	5 mm/hr	Δ	Δ	O	Δ	Δ	Δ	Δ	O	
	10 to 50 mm/hr	O	O	O	O	O	O	O	O	
	100 mm/hr and over	Δ	Δ	Δ	O	O	O	O	O	
Wind velocity	4 to 6 m/sec	O	O	O	Δ	Δ	O	O	O	Data: Port Said
Crops	Grass Egyptian Clover	×	O	O	O	O	O	O	×	
	Field Crops	O	Δ	×	O	O	O	O	O	
	Vegetables	O	Δ	×	O	O	O	O	O	
	Fruits	Δ	Δ	×	O	O	×	×	O	
Irrigation Efficiency		Δ	Δ	Δ	O	O	O	O	O	
Salt Accumulation		Δ	Δ	Δ	O	O	O	O	O	

Note: O: suitable
Δ: moderate
× poor

Table H-2-2 Construction Cost of Irrigation Facilities

(Unit: L.E./feddan)

Irrigation Method	Cost
Surface Irrigation	-
Sprinkler	700 to 2,100
Side Roll	1,600 to 1,900
Center Pivot	1,600 to 2,000
Drip	1,400 to 3,300

Note: The Canals for surface irrigation will be used for paddy in common.

Since spray and drip irrigation systems, however, have the following advantages, they may be introduced in the future.

i) Spray and drip irrigation except hand-move system can save labor, and therefore the surplus time can be used for enlargement of the farm land and/or for raising the farming technique.

ii) These irrigation systems are suitable for soil moisture control. Therefore, it is possible to attain high crop productivity.

In order to introduce these irrigation systems, it is necessary to improve the whole agricultural technology. It is also necessary to establish the organization of water management for canals, and to improve supporting services and marketing.

(2) Model Plan of Irrigation

Irrigation plans for furrow irrigation is as follows:

a) Basic Criteria of Irrigation

i) Irrigation Water Requirements

Irrigation water requirements in summer peak are 11.6 mm/day for field crops (8.7 mm/day ÷ 0.75 = 11.6 mm/day).

ii) Effective Root Zone

Readily available soil water is determined by the range of the zone where roots are abundantly distributed and by the groundwater depth. The effective root zone is 80cm for berseem and vegetables and 100 cm for other crops.

iii) Irrigation Interval

On the basis of available soil water and crop evapotranspirations, the irrigation interval in summer peak has been computed at 8 days.

Table H-2-3 Readily Available Soil Water and Irrigation Interval (July)

Items \ Crops	Soybeans	Sorghum
Available Soil Water (Sa)	200 mm/m	200
Fractions of Available Soil Water (P)	0.5 m	0.55
Readily Available Soil Water (P.Sa)	100 mm/m	110
Correction for ET crops	0.7 m	0.7
Rooting Depth (D)	1.0 m	1.0
Readily Available Soil Water (P.Sa)D	70 mm	77
ET Crop	8.6 mm/day	7.7
Irrigation Interval	8 days	10

Data: FAO Irrigation and Drainage Paper No. 24

iv) Water Requirement per Irrigation

Water requirements per irrigation are determined by the product of the water requirement multiplied by the irrigation interval.

Up-land crop 11.6 mm/day x 8 days ≑ 93 mm

b) Surface Irrigation Plan

In surface irrigation, the area controlled by the tertiary canal is irrigated in one day in order to accomplish easy water management for water diversion from the secondary canal to the tertiary canal.

i) Southern part of the Project area consists of clay soil

In furrow irrigation, one irrigation time is determined by the time necessary for infiltration and the time that the advancing front reaches the lower end of the furrow.

A 70 percent of irrigation efficiency can be expected by making the reaching time to the furrow end one fourth of the infiltration time.

$$I = KT^{n}$$

$$T = \left\{\frac{60\ D\ (n+1)}{K}\right\}^{\frac{1}{n+1}}$$

where:

- I : Intake rate of the soil, in mm/hour
- T : Time that water is on the surface of the soil, in hours.
- K,n : Constant
- D : Depth of water absorbed by the soil. (93 mm)

From the field survey result, the intake rate (I) at the southern part of the Project Area is;

$$I = 27.2\ T^{-0.16}$$

$$T = \left\{\frac{60 \times 93 \times (-0.16 + 1)}{27.2}\right\}^{\frac{1}{-0.16 + 1}}$$

$$= 460 \text{ min}$$

$$= 8 \text{ hr}$$

$$\frac{T}{4} = 2 \text{ hr}$$

The velocity of flow must be greater than 0.02 m/sec to irrigate a 100 m furrow within 2 hours. In case of a 2.0 liters/sec flow rate, with a furrow grades of 1/2000, the flow velocity is 0.09 m/sec, which is greater than 0.02 m/sec.

Since the total available water for the field crops, in this case, is 188 liters/sec per 33.3 feddan, 76 furrows can be irrigated per time. The irrigation time is 1.8 hours with 16 moves per day.

ii) Northern part of the Project area consists of loamy clay soil

$$I = 75.5\ T^{-0.26}$$

$$T = \left\{\frac{60 \times 93 \times (-0.26 + 1)}{75.5}\right\}^{\frac{1}{-0.26 + 1}}$$

$$= 223 \text{ min}$$

$$= 3.7 \text{ hr}$$

$$\frac{T}{4} = 0.9 \text{ hr}$$

Thus vegetables must be irrigated within 0.4 hour. In this case, the length of a furrow is determined at 75 m. For this furrow, a flow velocity of 0.05 cm/sec is high enough. In case of 0.5 liters/sec of flow rate with 1/2000 of furrow grades, the flow velocity is 0.06 m/sec, hence the time required for the flow to reach the furrow-end is 0.35 hour.

In this case, the total available water is 74 liters/sec, and 148 furrows can be irrigated per time. The irrigation time is 1.6 hours with 15 moves per day.

2-2 Water Requirements

Project water requirements are the water requirements which must really be supplied to this project through the main canal and are computed by multiplying the gross water requirements by the arable rate since the gross area includes not only the arable area but also the area provided for irrigation facilities, houses, etc. The net water requirement is used to compute the gross water requirement with the irrigation efficiency, and shown in depth (mm/day). Calculation procedures of project water requirements are explained below. Since the Ministry of Irrigation regulates the intake water volume to this project at 40.0m^3/day/feddan, the probable project requirements are to be compared with the regulated volume. Such study is discussed at the end of this chapter.

(1) Net Water Requirement of Crops

a) Requirements for Evapotranspiration

Evapotranspiration is the water requirements for crop production. The requirements of each crop are computed based on the evapotranspiration (ETo) and crop coefficients (Kc); this requirement is called crop evapotranspiration (ET crop). Thus, evapotranspiration and crop evapotranspiration are discussed below:

i) Evapotranspiration (ETo)

FAO Irrigation and Drainage Paper No. 24 suggests four methods: Blaney-Criddle method, Radiation method, Penman method and Pan-Evaporation method.

i-1) Blaney-Criddle Method

$$Eto = c\{P(0.46T + 8)\}$$

where,

ETo : reference crop evapotranspiration in mm/day for the month considered

T : mean daily temperature in °C over the month considered

P : mean daily percentage of total annual daytime hours obtained from a given month and latitude

C : adjustment factor which depends on minimum relative humidity, sunshine hours and daytime wind estimates

The estimated total value per year is accurate, although the accuracy is easily influenced in particular climate. Further, some errors appear in estimating the variance within a year.

i-2) Radiation Method

$$ETo = c(W.Rs)$$

where,

Eto : reference crop evapotranspiration in mm/day for the periods considered

Rs : solar radiation in equivalent evaporation in mm/day

W : weighting factor which depends on the temperature and altitude

c : adjustment factor which depends on mean humidity and daytime wind conditions

As to the accuracy, large errors appear in the estimation for summer.

i-3) Penman Method

$$ETo = c\{W.Rn + (1 - W).f(u).(ea-ed)\}$$

where,

ETo : reference crop evapotranspiration in mm/day

W : temperature-related weighting factor

Rn : net radiation in equivalent evaporation in mm/day

f(u) : wind related function

(ea-ed) : difference between the saturated vapor pressure at mean air temperature and the mean actual vapor pressure of the air, both in mbar

c : adjustment factor to compensate for the effect of day and night weather conditions

Despite the most accurate empirical formula among them, excessive values in estimation appear with a low soil moisture content, which may occur during high temperature days in summer, and in other conditions.

i-4) Pan-Evaporation Method

By multiplying the measured pan evaporation values with Class-A-Pan by evaporation ratios, accurate estimation can be achieved for particular conditions. Location of the Pan placed according to the growth stage of crops is of great importance.

Since evaporation data was not available, this method was not applied here.

Values were calculated by the other three methods with the month as shown in Table H-2-4.

These values do not have large differences, although the Penman method indicates relatively higher values than the others. Under this situation, any method is applicable to this study without causing any large difference. Therefore, the ETo values estimated by the Blaney-Criddle method were adopted for this project as the moderate values.

Table H-2-4 Evapotranspiration Value by Each Method

(Unit: mm/day)

Month / Method	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Total (mm/y)
Blaney C.	3.4	4.3	5.0	6.4	7.5	8.4	8.7	7.4	6.8	5.8	4.5	3.5	2,184
M. Penman	3.4	4.4	6.4	7.6	8.8	9.5	9.1	8.3	7.3	6.0	4.2	3.0	2,376
Radiation	2.9	3.8	4.8	6.0	7.2	8.2	8.5	7.2	6.2	4.9	3.6	2.8	2,014

ii) Crop Evapotranspiration (ET crop)

Crop evapotranspiration is calculated by the following formula:

ET crop = Kc.ETo

where,

ET crop : Crop evapotranspiration in mm/day

Kc : Crop coefficients

ETo : Reference evapotranspiration in mm/day

Kc values were determined from the references shown in FAO Irrigation and Drainage Paper No. 24, and shown in Appendix tables and figures.

The estimated crop evapotranspiration values are shown in Table H-2-5.

Table H-2-5 Crop Evapotranspiration Values

Crop	Month / ETo	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
	ETo	3.4	4.3	5.0	6.4	7.5	8.4	8.7	7.4	6.8	5.8	4.5	3.5	mm/year
Rice	Kc						0.17	0.89	1.15	1.08	0.28			
	ET crop						1.4	7.7	8.5	7.3	1.6			813
Berseem	Kc	1.05	1.05	0.82	0.06						0.47	0.96	1.05	
	ET crop	3.6	4.5	4.1	0.4						2.7	4.3	3.7	704
Soybeans	Kc				0.06	0.47	0.96	0.99	0.39					
	ET crop				0.4	3.5	8.1	8.6	2.9					720
Sugar Beet	Kc	0.99	1.10	0.98	0.53	0.10				0.04	0.21	0.46	0.74	
	ET crop	3.4	4.7	4.9	3.4	0.8				0.3	1.2	2.1	2.6	706
Sorghum	Kc						0.26	0.76	1.02	0.62	0.03			
	ET crop						2.2	6.6	7.5	4.2	0.2			635
Vegetable (Winter)	Kc	1.06	0.94	0.51	0.08						0.05	0.38	0.81	
	ET crop	3.6	4.0	2.6	0.5						0.3	1.7	2.8	466
Vegetable (Summer)	Kc					0.17	0.60	1.03	0.75	0.03				
	ET crop					1.3	5.0	9.0	5.6	0.2				649

Notes: ET crop: Crop Evapotranspiration (Kc.Eto, mm/day)
Eto: Evapotranspiration (mm/day)
Kc: Crop Coefficients

b) Leaching Water Requirements

The leaching requirements are calculated for the different yield potentials of 100 percent and 90 percent as tabulated in Table H-2-6. In the calculation, the leaching efficiency is assumed to be 0.5. The leaching requirement (LR) is expressed by the ratio of the equivalent depth of the drainage water to the depth of irrigation water (LR = Ddw/Diw). The drainage requirements are calculated, using 100 percent of yield potential for all the crops except berseem for which 9070 yield potential will be used by considering the relatively large value of the LR and the low yield.

Table H-2-6 Leaching Requirement (LR)

(Unit: mm)

Crops	Yield Potential 100% ECe	100% LR	90% ECe	90% LR
Rice	3.0	0.21	3.8	0.16
Berseem	1.5	0.46	3.2	0.19
Soybeans	5.0	0.12	5.5	0.11
Sugar Beet	7.0	0.08	8.7	0.07
Sorghum	4.0	0.15	5.1	0.12
Vegetable (Tomato)	2.5	0.25	3.5	0.17

Note 1) Leaching Rquirement (LR)

$$LR = \frac{ECw}{5ECe - ECw} \times \frac{1}{Le}$$

Where: ECw : electrical conductivity of the irrigation water in mmhos/cm,
: 1.4 mmhos/cm (900ppm, 25°c)

ECe = electrical conductivity of the soil saturation extract for a given crop appropriate to the tolerable degree of yield reduction

Le : leaching efficiency (0.5)

The time for leaching depends on the salinity content and the labor made available for leaching at that time. Salt in soil is accumulated by irrigation, e.g., if salt is accumulated at 2.2 to 2.5 mmhos/cm per crop production, and the primary value is 2.0 mmhos/cm the salinity content after one cropping will be 4.2 to 4.5 ms/cm. Fig. H-2-1 shows the cumulative salinity content by irrigation.

Leaching will need to be practiced once per crop production, preferably immediately after harvesting season is over in view of utilizing idle time of the labor force, to remove cumulative salinity content. However, as far as vegetables are concerned, leaching is required once a month because vegetables have low tolerance to salinity.

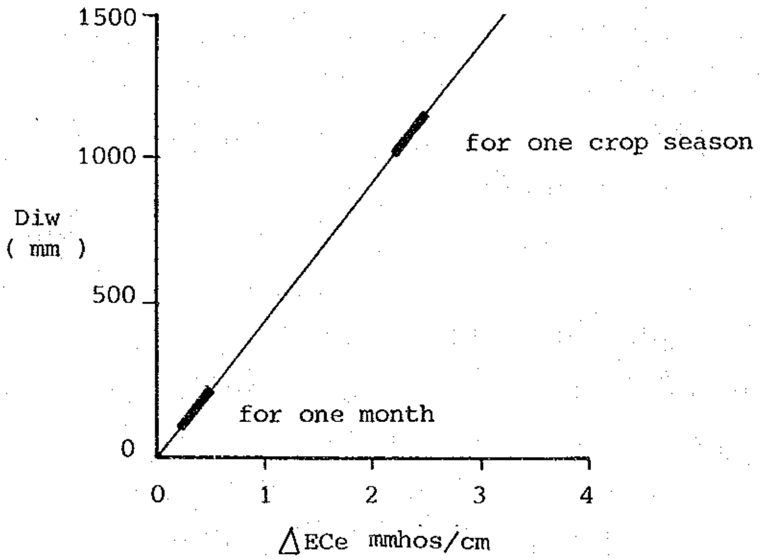


Fig.H-2-1 Cumulative Salinity Content

Note:

$$\frac{Diw}{Ds} = \frac{ds}{dw} \cdot \frac{sp}{100} \cdot \frac{\Delta ECe}{ECiw}$$

where,

Diw : Irrigation water (mm)

Ds : Soil depth (1,000 mm)

$\frac{ds}{dw}$: 1.1 apparent-specific gravity of soil

sp : Water content (saturable, 60%)

ΔECe : Increase of the electrical conductivity of the soil saturation extract for a given crop appropriate to the tolerable degree of yield reduction (mmhos/cm).

$ECiw$: Electrical conductivity of the irrigation water (1.4 ms/cm = 900 ppm, 25°C)

$$Diw = 1{,}000 \times 1.1 \times 0.6 \times \frac{\Delta ECe}{1.4}$$

$$= 471\ \Delta ECe$$

c) Water Requirements for Paddy Rice Cultivation

Water requirements for cultivation of paddy rice include those for puddling, percolation, and nursery planting.

i) Puddling Water Requirements

Puddling work is assumed to last for 1 month (May-June) and the puddling water requirements comprise (a) replenishment of soil moisture which has been lost through evaporation during 1 month period from harvesting to the commencement of puddling work, and (b) water requirement for flooding the paddyfield to enable puddling work.

The volume of water to replenish the lost moisture has been estimated as follows :

Paddy rice evapotranspiration rate	:	8 mm/day
Evaporation efficiency	:	0.13
Period of time	:	30 days

8 x 0.13 x 30 = 30 mm

Paddyfield will need to be flooded to the depth of 50 mm for puddling work. Thus, the total water requirements for 1 month puddling season would be :

30 mm + 50 mm = 80 mm

ii) Percolation

Water requirement to replenish percolation is estimated over the whole growing period of paddy rice. It depends on the variety of soil as well as the kind of drainage/underdrainage system. Based on the planned distribution of open drains and underdrainage pipes, 2 mm/day is estimated for such requirement.

iii) Nursery

Nursery farm would probably occupy one-tenth of the total paddy field, and its water requirement has been assumed to equal to growing stage water requirement.

The total water requirements for paddy rice cultivation are shown in Table H-2-7.

Table H-2-7 Total Water Requirement for Rice Field

(Unit: mm/day)

Month	Growing Stage			Nursery Stage			Total
	ET crop	Percolation	Puddling	ET crop	Percolation	Puddling	
May	0	0	0	0.2	0	0.1	0.3
June	1.4	0.4	1.8	0.6	0.1	0.1	4.4
July	7.7	1.7	0.9	0.2	0	0	10.5
August	8.5	2.0	0	0	0	0	10.5
September	7.3	1.8	0	0	0	0	9.1
October	1.6	0.5	0	0	0	0	2.1

d) Summary of the Net Water Requirement

By summing the consumption for crop production and the water requirements for leaching/growing paddy rice, the net water requirement of each crop (mm/day) is calculated as shown in Table H-2-8.

e) Effective Rainfall (ER)

There is 73 mm of rainfall in the Project area occurring from September to May through a year. These rainfalls are useful for winter crops for the Project. Effective rainfall is estimated by an effective ratio of total amount of rainfall. The sixty percent of the total amount of rainfall is adopted for the project effective rainfall. (See Table H-2-9)

Table H-2-9 Effective Rainfall

(Unit: mm/month)

Month	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
Rainfall	13.5	11.7	8.8	3.7	2.2	0.0	0.0	0.0	0.2	6.3	8.9	18.0	73.3
E.R.	8.1	7.0	5.3	2.2	1.3	0.0	0.0	0.0	0.1	3.8	5.3	10.8	44.0

* Five to ten millimeters of initial rainfall is included for effective rainfall.

(2) Irrigation Efficiency (Ep)

FAO Irrigation and Drainage Paper No. 24 (Table 37) shows :

$$Ep = Ec \cdot Eb \cdot Ea$$

where,

Ec : Conveyance efficiency

Eb : Field canal efficiency

Ea : Field application efficiency

As discussed elsewhere, irrigation efficiency adopted for the project is as follows :

Ec : 0.9
Eb : 0.95
Ea : 0.75

Consequently, the irrigation efficiency assumed for this project is as follows :

$0.9 \times 0.95 \times 0.75 = \underline{0.64}$

Table H-2-8 Total Net Water Requirement of Each Crop

(Unit: mm/day)

Crop / Month	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
ETo	3.4	4.3	5.0	6.4	7.5	8.4	8.7	7.4	6.8	5.8	4.5	3.5	
Rice					0.3	4.4	10.5	10.5	9.1	2.1			mm/year 1,130
Berseem	4.3	5.4	4.9	0.5						3.2	5.1	4.4	840
Soybeans				0.4	3.9	9.1	8.6	4.3					806
Sugar Beet	3.7	5.1	5.3	3.7	0.9				0.3	1.3	2.3	2.8	766
Sorghum						2.5	6.6	9.6	4.8	0.2			727
Vegetable (Winter)	4.5	5.0	3.3	0.6						0.4	2.1	3.5	584
Vegetable (Summer)					1.6	6.3	9.0	9.3	0.3				815

Note: The requirement for rice does not include leaching requirements.

The irrigation efficiency of 64% is apparently high as a surface irrigation.
However, Egypt has a plan to improve the irrigation efficiency and it will be possible to apply this value on maintaining sufficient water management. For that, the water management group, organized with farmers, should be put under the leadership of the government official or the cooperative association. However, since an established water management system is un expectable in the initial one to five years, a lower value than in the fully developed stage should be applied for the initial years. 0.55 of the initial efficiency was determined.

(3) Project Water Requirements

a) Gross Area and Arable Rate

The total gross area is 110,000 feddan as follows:

Cropping pattern No. 1:	83,854 feddan
Cropping pattern No. 2:	26,146 feddan
Total	110,000 feddan

Fig. H-2-2 explains the area for cropping patterns No. 1 and No. 2. Arable area in the gross area was estimated as 78 percent of the gross area (arable area/gross area).

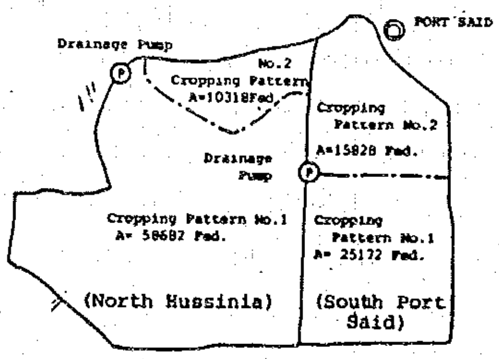


Fig. H-2-2 Area for Cropping Pattern

b) Net Water Requirements

The net water requirement was calculated before (see Table H-2-8). To calculate the net water requirement over the whole area, crop requirements water are integrated for each month, based on the growing area of each crop determined by the cropping patterns, by the following formula:

$$NWR = \sum^{\text{all crops}} NWR\ crop \times AR\ crop$$

where,

NWR : Net water requirement over the whole area (mm/day)

NWR crop: Net water requirement of each crop (mm/day)

AR crop : Area ratio of each crop

$$= \frac{\text{The total growing area of each crop}}{\text{The whole proposed area}}$$

It should be noted that the area in this formula means the gross area. The net water requirements are explained in Table H-2-8.

c) Gross Water Requirements

The gross water requirements are calculated from the above net water requirements and the irrigation efficiency by following formula:

GWR = NWR/Irrigation efficiency

where,

GWR : Gross water requirements (mm/day)

d) Project Water Requirements

Project water requirements are calculated from GWR and arable rate; here the gross area is modified into net arable area with the arable rate. The formula is as follows:

PWR = GWR x 4,200 m^2/fed. x 0.78 (arable rate)

where,

PWR : Project water requirements (m^3/day/fed.)

The GWR and PWR are explained in Table H-2-9.

e) Initial Water Requirements

For the initial period including one to five years, a lower irrigation efficiency was applied in consideration of immature water management system during this period, as discussed before.

Table H-2-10 Project Water Requirement

Crop Type	Crop	Area (Fed.)	Ratio	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total (ms/ year)
No. 1	Rice	27,951	0.254					0.08	1.12	2.67	2.67	2.31	0.53			
	Berseem	27,951	0.254	1.09	1.37	1.24	0.13						0.81	1.30	1.12	
	Soybeans	27,951	0.254				0.10	0.99	2.31	2.18	1.09					
	Sugar Beet	27,951	0.254	0.94	1.30	1.35	0.94	0.23				0.08	0.33	0.58	0.71	
	Sorghum	27,951	0.254						0.64	1.68	2.44	1.22	0.05			
	Vegetable (Winter)	27,951	0.254	1.14	1.27	0.84	0.15						0.10	0.53	0.89	
No. 2	Rice	8,715	0.079					0.02	0.35	0.83	0.83	0.72	0.17			
	Berseem	8,715	0.079	0.34	0.43	0.39	0.04						0.25	0.40	0.35	
	Soybeans	8,715	0.079				0.03	0.31	0.72	0.68	0.34					
	Sugar Beet	8,715	0.079	0.29	0.40	0.42	0.29	0.07				0.02	0.10	0.18	0.22	
	Vegetable (Winter)	8,715	0.079	0.36	0.40	0.26	0.05						0.03	0.17	0.28	
	Sorghum	4,358	0.040						0.10	0.26	0.38	0.19	0.01			
	Vegetable (Summer)	4,358	0.040					0.06	0.25	0.36	0.37	0.01				
	Total	22,000	2.00	4.2	5.2	4.5	1.7	1.8	5.5	8.7	8.1	4.6	2.4	3.2	3.6	
Effective Rainfall				0.3	0.3	0.2	0.1	0	0	0	0	0	0.1	0.2	0.3	
Net Water Requirement (NWR)	(mm/day)			3.9	4.9	4.3	1.6	1.8	5.5	8.7	8.1	4.6	2.3	3.0	3.3	
Gross Water Requirement (GWR)	(mm/day)			6.1	7.7	6.7	2.5	2.8	8.6	13.6	12.7	7.2	3.6	4.7	5.2	
Project Water Requirement (PWR)	(m^3/day/fed.)			20.0	25.2	21.9	8.2	9.2	28.2	44.6	41.6	23.6	11.8	15.4	17.0	8117 m^3/fed/year

Note: 1) Gross Water Requirement (mm/day) = Net Water Requirement ÷ (Irrigation Efficienty : 0.64)
2) Gross Water Requirement (m^3/day/Fed.) = G.W.R. (mm/day) x 4,200 m^2 x (Arable Ratio: 0.78)
3) Leaching requirement is not provable on July.

Admittedly, these values are larger than the values required for growing crops. However, since these requirements are given for only the initial four to five years and the growing is extended by the stepped project implementation over several years, the lack of water will appear at only the final year of implementation. This lack can be covered by modifying the cropping plan.

(4) Summary and Discussion

The peak project water requirement is 44.6 m^3/day/feddan which appear on July, and the amount is 8,117 m^3/year/feddan, as shown in Table H-2-9. The unit duty of water for mains and secondary canal is 1.032 liters/sec/feddan in the rotation system, explained as follows:

$$\frac{44.6 \times 2}{86,400} = 0.001032\ m^3/sec/feddan = 1.032\ liter\ /sec/feddan$$

Lack of water supply appears when this 44.6 m^3/day/feddan is compared with the regulated intake water volume, 40 m^3/day/feddan as follows:

	Volume of Water	
	Peak (m^3/day/fed.)	Year (m^3/year/fed.)
Regulated intake water	40.0	8,000
Planned requirement	44.6	8,117
Lack of water	Δ4.6 (10.3%)	Δ117 (1.4%)

Note: Δ shows lack of water.

There will be three countermeasures to meet water supply cut :

i) Reduction of Cropping Area
For summer crops, the arable area of 85,800 feddan will have to be reduced to 76,963 feddan since peak season water supply shall be cut by 10.3%.
In case the annual water requirement is restricted, the arable area will be 84,599 feddan while without reduction it would be 85,800 feddan.

ii) Change of Irrigation Method
Adoption of sprinkler or drip irrigation system which would improve field application efficiency to 85% instead of 75%.
In this case, peak season water supply regulation would necessitate sprinkler or drip irrigation in 84% of the total arable area; when only annual water requirement is restricted, 12% of the total arable area would need to be irrigated by sprinkler or drip system.

iii) Reuse of irrigation water
When the 900 ppm saline water is irrigated to the land, drainage water will contain 2500 ppm salinity. If this drainage water is used mixing with the water from El Salam canal for irrigation water, the density of the salinity is as follows:

Mixing ratio 900 ppm: 2500 ppm	Density of Salinity ppm
0.9 : 0.1	1060
0.8 : 0.2	1220
0.7 : 0.3	1380
0.6 : 0.4	1540
0.5 : 0.5	1700

According to the Diagnosis and Improvement of Saline and Alkali soils, Agr. Handbook (USA), density of salinity in the irrigation water is defined as follows:

mmhos/cm	ppm		Grade
under 0.25	(under 160)	-	Low
0.25 - 0.75	(160 - 500)	-	Medium
0.75 - 2.25	(500 - 1400)	-	High
over 0.75	(over 1400)	-	Very high

A crop which has high salinity tolerance like cotton should be introduced when this mixing water (under 1400 ppm) is used for irrigation.

2-3 Rotation Irrigation

There are two methods in rotation irrigation. One is where water is alternatively supplied to every part within a field, and another is that water is intermittently supplied to each irrigation block, through one main canal. The former can save labor requirements and the latter can ease water management and maintenance of the main and secondary canals.

These methods have been adopted in Egyptian agriculture, and these were also adopted in this project.
The intermittent operation will be carried out with a single rotation, i.e., 4 days on and 4 days off for paddy fields, based on the small cross section of the canals.
Irrigation method in field lots will be determined by the irrigation intervals and the scale of one rotation irrigation.
The irrigagion interval will be 8 days, i.e. 4 days on and 4 days off, in summer peak. Monthly irrigation intervals are shown in Table H-2-10.

The scale of a rotation block must be determined to ease the water management at each diversion point at all the canals. Five cases of rotation irrigation can be considered as follows:

Case 1	Farm Households	5 feddan
Case 2	2 Field Blocks	50 feddan
Case 3	8 Field Blocks	400 feddan
Case 4	1 Secondary Canal	2,000 feddan
Case 5	3 Secondary Canals	8,000 feddan

Fig. H-2-3 shows the location of diversion points. The scale of a rotation block is determined to simplify water control by selecting the suitable diversion point.

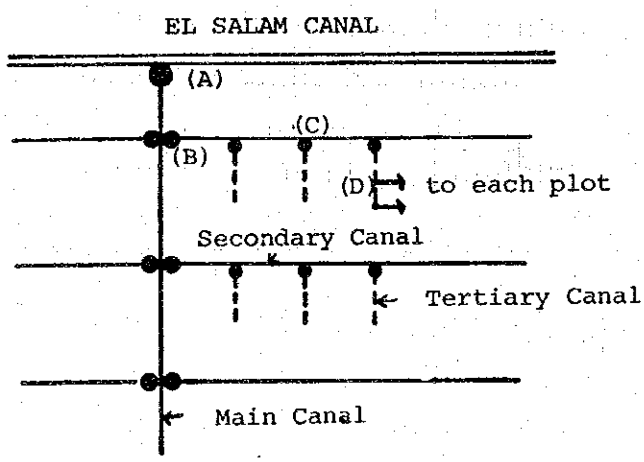


Fig. H-2-3 Diversion Point

In Case 1 and 2, the flow rates required for the tertiary canal are changed much, and thus, impose careful control of the water diversion at (C) point, that is, from the secondary canal to the tertiary canal. In Cases 3 and 4, the diversion control, from Secondary canal to each tertiary canal, are done once in 8 days. In Case 5, the water management at (B), (C) and (D) points are relatively easy because of the once in 8 days control.

In this plan, however, the scale of one satellite village is approximately 2,000 feddan, and thus Case 5 is not suitable from the viewpoints of farm management and cooperative organization.

In the cases of 3 and 4, there are no difference in the water management. However, a smaller area usually suggests more efficient water management where joint cultivation system is introduced. In this plan, therefore, one rotation block is determined to be 400 feddan of Case 3 in Fig. H-2-4.

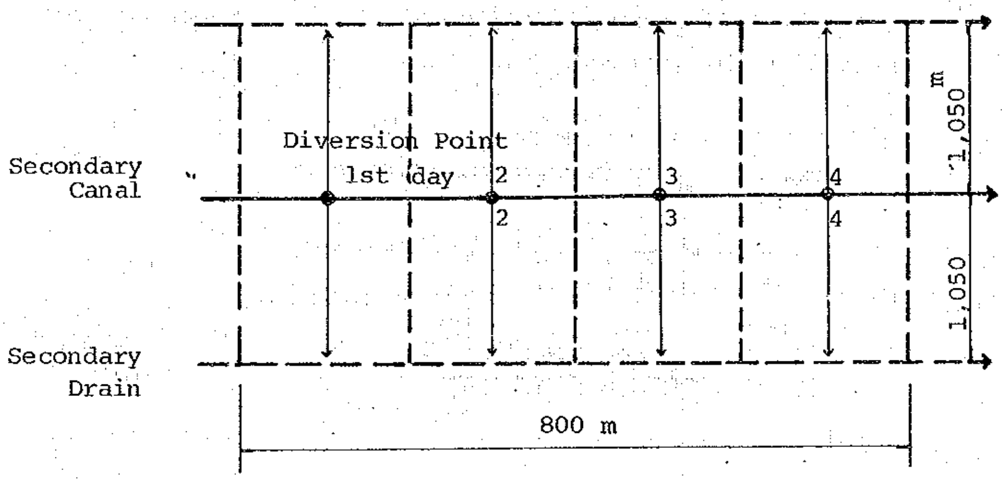


Fig. H-2-4 Rotation System of Irrigation

This irrigation method in Case 3 will be suitable especially at an initial development stage when farmers are not familiar with water management and its organization is not stable. However, when the farm management, marketing, and the farmers organization are stable, the following problems may appear.

(1) Farmers who aim at higher productivity will desire a particular irrigation method for their own farm management system. For this purpose, water supply from main and secondary canals must be controlled so that water-intake is always possible at field plots.

(2) If spray or drip irrigation system is introduced, and intermittent operations at the main and secondary canals are applied, the capacity of the facilities for these irrigation systems will be required to be twice as much as that normally required. The construction cost will therefore be higher.

In order to avoid these problems, water can be always supplied to field plots. For this purpose, it is necessary that water management comprehensively covers the distribution system from water sources to field lots. Also, the structure of the diversion facilities must be modified.

Table H-2-11 Monthly Irrigation Interval

Crops	(PSa) D	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
	mm												
Berseem	39	11	9	10								9	11
Soybeans	70				29	20	9	8	24				
Sorghum	77						35	12	10	18			
Sugar beet	70	21	15	14	21							27	27
Vegetables (Winter)	50	14	13	19									18
" (Summer)	50						10	6	9				
Irrigation interval		←	10 days	→		←	8 days	→		←	10 days	→	

Note: (1) Irrigation interval = Readily available soil water (PSa)/ET crop.(See Table H-2-12)

Table H-2-12 Readily available soil waters

Item / Crop	Berseem	Soybean	Sorghum	Sugar beet	Vegetable
Available Soil Water (Sa)	200 mm/m	200	200	200	200
Fractions of Available Soil Water (P)	0.35	0.5	0.55	0.5	0.45
Readily Available Soil Water (P.Sa)	70 mm	100	110	100	90
Corection for ET erop	0.7	0.7	0.7	0.7	0.7
Rooting Depth	0.8 m	1.0	1.0	1.0	0.8
Readily Available Soil Water (P.Sa)D	39 mm	70	77	70	50

A P P E N D I X - H

H-1 ETo Calculation by Blaney Criddle Method

Station: Port Said Lat. 31°16'N Long. 32°17'E Alt. 1.0 m

Function Items	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.
U'	4.9	5.2	6.0	5.6	5.0	4.6	4.4	3.9	3.9	4.1	4.0	4.4
Temperature: T mean (°C)	14.6	15.6	17.2	19.2	22.2	25.0	26.9	27.2	26.6	24.6	20.8	16.2
P	0.24	0.25	0.27	0.29	0.31	0.32	0.31	0.30	0.28	0.26	0.24	0.23
P (0.46T + 8) = f	3.53	3.79	4.30	4.88	5.65	6.24	6.32	6.15	5.67	5.02	4.22	3.55
Humidity: RH min. (%)	37 M	31 M	24 M	24 M	29 M	31 M	42 M	43 M	40 M	34 M	37 M	38 M
Wind Speed: U day (m/sec) (H=2.0m Daytime Wind) U' x 1.13	5.5 H	5.9 H	6.8 H	6.3 H	5.7 H	5.2 H	5.0 H	4.4 L	4.4 L	4.6 L	4.5 L	5.0 H
Sunshine heavy (hr)	7.1	8.1	8.3	9.2	10.9	12.0	11.9	11.5	10.5	9.3	8.0	6.7
n/N (%)	69 L/M	73 M/H	69 L/M	71 M/H	80 M/H	85 M/H	85 M/H	87 M/H	85 M/H	81 M/H	75 M/H	66 L/M
ETo = c{P(0.46T + 8)} (mm/day)	3.4	4.3	5.0	6.4	7.5	8.4	8.7	7.4	6.8	5.8	4.5	3.5

H-2 ETo Calculation by Radiation Method

Station: Port Said Lat. 31°16'N Long. 32°17'E Alt. 1.0 m

Function Items	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.
Temperature: T mean (°C)	14.6	15.6	17.2	19.2	22.2	25.0	26.9	27.2	26.6	24.6	20.8	16.2
Humidity: RH mean (%)	67	63	59	59	60	61	67	67	65	63	65	67
Humidity: RH min. (%)	37	31	24	24	29	31	42	43	40	34	37	38
U'	4.9	5.2	6.0	5.6	5.0	4.6	4.4	3.9	3.9	4.1	4.0	4.4
Ra (mm/day)	8.5	10.4	12.9	15.1	16.5	17.0	16.8	15.6	13.7	11.4	9.2	8.0
n (hr)	7.1	8.1	8.3	9.2	10.9	12.0	11.9	11.5	10.5	9.3	8.0	6.7
N (hr)	10.3	11.1	12.0	12.9	13.7	14.1	14.0	13.2	12.4	11.5	10.6	10.2
n/N	0.69	0.73	0.69	0.71	0.80	0.85	0.85	0.87	0.85	0.81	0.75	0.66
Rs = (0.25 + 0.5 n/N)Ra	5.06	6.40	7.62	9.14	10.73	11.48	11.34	10.69	9.25	7.47	5.75	4.64
W	0.62	0.63	0.65	0.68	0.71	0.74	0.76	0.76	0.76	0.74	0.70	0.64
WRs (mm/day)	3.14	4.03	4.99	6.22	7.62	8.50	8.62	8.12	7.03	5.53	4.03	2.97
RH (medium)	III	III	III	III	III	III	II	II	III	III	III	III
U (2 m high daytime) (Ux1.13 m/sec)	5.5	5.9	6.8	6.3	5.7	5.2	5.0	4.4	4.4	4.6	4.5	5.0
ETo = c(WRs) (mm/day)	2.9	3.8	4.8	6.0	7.2	8.2	8.5	7.2	6.2	4.9	3.6	2.8

H-3 ETo Calculation by Modified Penman Method

Station: Port Said Lat. 31°16'N Long. 32°17'E Alt. = 1.0 m

Function Items	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.
U	4.9	5.2	6.0	5.6	5.0	4.6	4.4	3.9	3.9	4.1	4.0	4.4
U'	4.2	4.4	5.1	4.8	4.3	3.9	3.7	3.3	3.3	3.5	3.4	3.7
Temperature: T mean (°C)	14.6	15.6	17.2	19.2	22.2	25.0	26.9	27.2	26.6	24.6	20.8	16.2
Humidity: RH mean (%)	67	63	59	59	60	61	67	67	65	63	65	67
ea (mbar)	16.7	17.7	19.6	22.3	26.7	31.7	35.5	36.1	34.9	30.9	24.6	18.4
ed: ea x RH mean/100 (mbar)	11.2	11.2	11.6	13.2	16.0	19.3	23.8	24.2	22.7	19.5	16.0	12.3
ea-ed	5.5	6.5	8.0	9.1	10.7	12.4	11.7	11.9	12.2	11.4	8.6	6.1
Wind Speed: U2 (km/day)	363	380	441	415	372	337	320	285	285	302	294	320
f(u) = {0.27 (1 + U/100)}	1.25	1.30	1.46	1.39	1.27	1.18	1.13	1.04	1.04	1.09	1.06	1.12
(1-W)	0.39	0.36	0.35	0.33	0.29	0.26	0.24	0.24	0.24	0.26	0.31	0.36
W	0.62	0.63	0.65	0.68	0.71	0.74	0.76	0.76	0.76	0.74	0.70	0.64
Ra (mm/day)	8.5	10.4	12.9	15.1	16.5	17.0	16.3	15.6	13.7	11.4	9.2	8.0
n (hr)	7.1	8.1	8.3	9.2	10.9	12.0	11.9	11.5	10.5	9.3	8.0	6.7
N (hr)	10.3	11.1	12.0	12.9	13.7	14.1	14.0	13.2	12.4	11.5	10.6	10.2
n/N (mm/day)	0.69	0.73	0.69	0m71	0.80	0.85	0.85	0.87	0.85	0.81	0.75	0.66
RS = (0.25 + 0.50 n/N)Ra	5.06	6.40	7.68	9.14	10.73	11.48	11.34	10.69	9.25	7.47	5.75	4.64
RnS (1 - α)RS	3.83	4.78	5.81	6.80	8.09	8.67	8.57	7.96	6.99	5.59	4.32	3.44
f(T)	13.6	13.8	14.0	14.4	15.0	15.7	16.1	16.1	16.0	15.6	14.8	13.8
f(ed)	0.19	0.19	0.19	0.18	0.16	0.14	0.12	0.12	0.13	0.14	0.16	0.19
f(n/N)	0.72	0.76	0.72	0.74	0.82	0.87	0.87	0.88	0.87	0.83	0.78	0.70
Rnl	1.86	1.99	1.92	1.92	1.97	1.91	1.68	1.70	1.81	1.81	1.85	1.84
Rn: Rns - Rnl	1.97	2.79	3.89	4.88	6.12	6.76	6.89	6.26	5.18	3.78	2.47	1.60
c	0.87	0.92	0.96	1.02	1.06	1.08	1.08	1.07	1.04	0.99	0.92	0.87
ETo = c{W•Rn+(1-W)f(u)•(ea-ed)} (mm/day)	3.4	4.4	6.4	7.6	8.8	9.5	9.1	8.3	7.3	6.0	4.2	3.0

H-4-(1) Kc of Each Month for Rice

Month		Cropping Order							Average	
		1st	2nd	3rd	4th	5th	6th	7th	10 days	Month
May	First									
	Middle									
	Last									
June	First	0	0	0	0				0	
	Middle	0.51	0	0	0				0.13	0.17
	Last	1.04	0.51	0	0				0.39	
July	First	1.07	1.04	0.51	0				0.66	
	Middle	1.10	1.07	1.04	0.51				0.93	0.89
	Last	1.14	1.10	1.07	1.04				1.09	
Aug.	First	1.17	1.14	1.10	1.07				1.12	
	Middle	1.20	1.17	1.14	1.10				1.15	1.15
	Last	1.20	1.20	1.17	1.14				1.18	
Sep.	First	1.19	1.20	1.20	1.17				1.19	
	Middle	1.10	1.19	1.20	1.20				1.17	1.08
	Last	0	1.10	1.18	1.20				0.87	
Oct.	First	0	0	1.10	1.19				0.57	
	Middle	0	0	0	1.10				0.28	0.28
	Last	0	0	0	0				0	

Note: The last decades irrigation water is not estimated.

H-4-(2) Kc of Each Month for Berseem

Month		Cropping Order							Average	
		1st	2nd	3rd	4th	5th	6th	7th	10 days	Month
Oct.	First	0.62	0	0					0.21	
	Middle	0.75	0.62	0					0.46	0.47
	Last	0.89	0.75	0.62					0.75	
Nov.	First	1.00	0.89	0.75					0.88	
	Middle	1.05	1.00	0.89					0.98	0.96
	Last	1.05	1.05	1.00					1.03	
Dec.	First	1.05	1.05	1.05					1.05	
	Middle	1.05	1.05	1.05					1.05	1.05
	Last	1.05	1.05	1.05					1.05	
Jan.	First	1.05	1.05	1.05					1.05	
	Middle	1.05	1.05	1.05					1.05	1.05
	Last	1.05	1.05	1.05					1.05	
Feb.	First	1.05	1.05	1.05					1.05	
	Middle	1.05	1.05	1.05					1.05	1.05
	Last	1.05	1.05	1.05					1.05	
Mar.	First	1.05	1.05	1.05					1.05	
	Middle	0.53	1.05	1.05					0.88	0.82
	Last	0	0.53	1.05					0.53	
Apr.	First	0	0	0.53					0.18	
	Middle	0	0	0					0	0.06
	Last	0	0	0					0	

H-4-(3) Kc of Each Month for Soybeans

Month		Cropping Order							Average	
		1st	2nd	3rd	4th	5th	6th	7th	10 days	Month
Apr.	First	0	0	0	0				0	
	Middle	0.16	0	0	0				0.04	0.06
	Last	0.38	0.16	0	0				0.14	
May	First	0.52	0.38	0.16	0				0.27	
	Middle	0.79	0.52	0.38	0.16				0.46	0.47
	Last	1.02	0.79	0.52	0.38				0.68	
June	First	1.05	1.02	0.79	0.52				0.85	
	Middle	1.05	1.05	1.02	0.74				0.98	0.96
	Last	1.05	1.05	1.05	1.02				1/04	
July	First	1.02	1.05	1.05	1.05				1.04	
	Middle	0.81	1.02	1.05	1.05				0.98	0.96
	Last	0.57	0.81	1.02	1.05				0.86	
Aug.	First	0	0.57	0.81	1.02				0.60	
	Middle	0	0	0.57	0.81				0.35	0.36
	Last	0	0	0	0.57				0.14	

H-4-(4)Kc of Each Month for Sugar Beet

Month		Cropping Order 1st	2nd	3rd	4th	5th	6th	7th	Average 10 days	Month
Sep.	First	0	0	0	0	0	0	0	0	
	Middle	0.21	0	0	0	0	0	0	0.03	0.04
	Last	0.42	0.21	0	0	0	0	0	0.09	
Oct.	First	0.42	0.42	0.21	0	0	0	0	0.15	
	Middle	0.42	0.42	0.42	0.21	0	0	0	0.21	0.21
	Last	0.48	0.42	0.42	0.42	0.21	0	0	0.28	
Nov.	First	0.59	0.48	0.42	0.42	0.42	0.21	0	0.36	
	Middle	0.71	0.59	0.48	0.42	0.42	0.42	0.21	0.47	0.46
	Last	0.80	0.71	0.59	0.48	0.42	0.42	0.42	0.55	
Dec.	First	1.05	0.80	0.71	0.59	0.48	0.42	0.42	0.64	
	Middle	1.10	1.05	0.80	0.71	0.59	0.48	0.42	0.74	0.74
	Last	1.10	1.10	1.05	0.80	0.71	0.59	0.48	0.38	
Jan.	First	1.10	1.10	1.10	1.05	0.80	0.71	0.59	0.92	
	Middle	1.10	1.10	1.10	1.10	1.05	0.80	0.71	0.99	0.99
	Last	1.10	1.10	1.10	1.10	1.10	1.05	0.80	1.05	
Feb.	First	1.10	1.10	1.10	1.10	1.10	1.10	1.05	1.09	
	Middle	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10
	Last	1.09	1.10	1.10	1.10	1.10	1.10	1.10	1.10	
Mar.	First	1.03	1.09	1.10	1.10	1.10	1.10	1.10	1.09	
	Middle	0.49	1.03	1.09	1.10	1.10	1.10	1.10	1.00	0.98
	Last	0	0.48	1.03	1.09	1.10	1.10	1.10	0.84	
Apr.	First	0	0	0.49	1.03	1.09	1.10	1.10	0.69	
	Middle	0	0	0	0.49	1.03	1.09	1.10	0.53	0.53
	Last	0	0	0	0	0.49	1.03	1.09	0.37	
May	First	0	0	0	0	0	0.49	1.03	0.22	
	Middle	0	0	0	0	0	0	0.49	0.07	0.10
	Last	0	0	0	0	0	0	0	0	

H-4-(5) Kc of Each Month for Sorghum

Month		Cropping Order							Average	
		1st	2nd	3rd	4th	5th	6th	7th	10 days	Month
June	First	0.36	0	0					0.12	
	Middle	0.36	0.36	0					0.24	0.26
	Last	0.50	0.36	0.36					0.41	
July	First	0.78	0.50	0.36					0.55	
	Middle	1.02	0.78	0.50					0.77	0.76
	Last	1.05	1.02	0.78					0.95	
Aug.	First	1.05	1.05	1.02					1.04	
	Middle	1.03	1.05	1.05					1.04	1.02
	Last	0.89	1.03	1.05					0.99	
Sept.	First	0.72	0.89	1.03					0.88	
	Middle	0.30	0.72	0.89					0.64	0.62
	Last	0	0.30	0.72					0.34	
Oct.	First	0	0	0.30					0.10	
	Middle	0	0	0					0	0.03
	Last	0	0	0					0	

H-4-(6) Kc of Each Month for Vegetables (Average)

(1) Winter Vegetables

Crop \ Month	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May
Tomato (15%)	0.32	0.52	0.81	1.10	1.13	1.00	0.26	0
	0.05	0.08	0.12	0.17	0.17	0.15	0.04	0
Onion (15%)	0	0.36	0.85	1.00	1.00	0.93	0.27	0
	0	0.05	0.13	0.15	0.15	0.14	0.04	0
Cabbage (5%)	0	0.33	0.69	0.98	0.64	0	0	0
	0	0.02	0.03	0.05	0.03	0	0	0
Beans (30%)	0	0.36	0.88	1.10	0.99	0.62	0	0
	0	0.11	0.26	0.33	0.30	0.19	0	0
Peas (20%)	0	0.34	0.80	1.09	8.89	0.08	0	0
	0	0.07	0.16	0.22	0.18	0.02	0	0
Spinach (15%)	0	0.33	0.70	0.96	0.76	0.05	0	0
	0	0.05	0.11	0.14	0.11	0.01	0	0
Average	0.05	0.38	0.81	1.06	0.94	0.51	0.08	0

(2) Summer Vegetables

Crop \ Month	May	June	July	Aug.	Sept.
Tomato (20%)	0.27	0.76	1.10	0.74	0.04
	0.05	0.15	0.22	0.15	0.01
Corn (50%)	0.08	0.48	0.98	0.79	0.04
	0.04	0.24	0.49	0.40	0.02
French Beans (10%)	0.30	0.88	1.10	0.69	0.02
	0.03	0.09	0.11	0.07	0
Okura (20%)	0.26	0.61	1.04	0.67	0
	0.05	0.12	0.21	0.13	0
Average	0.17	0.60	1.03	0.75	0.03

Note: Kc of Vegetable are adopted average of each crop.

Kc of Vegetables (Tomate)

Month		Cropping Order							Average	
		1 st.	2 st.	3 st.	4 st.	5 st.	6 st.	7 st.	10 days	Month
Oct.	First	0.48	0	0					0.16	0.32
	Middle	0.48	0.48	0					0.32	
	Last	0.48	0.48	0.48					0.48	
Nov.	First	0.48	0.48	0.48					0.48	0.52
	Middle	0.55	0.48	0.48					0.50	
	Last	0.68	0.55	0.48					0.57	
Dec.	First	0.81	0.68	0.55					0.68	0.81
	Middle	0.94	0.81	0.68					0.81	
	Last	1.07	0.94	0.81					0.94	
Jan.	First	1.13	1.07	0.94					1.05	1.10
	Middle	1.13	1.13	1.07					1.11	
	Last	1.13	1.13	1.13					1.13	
Fev.	First	1.13	1.13	1.13					1.13	1.13
	Middle	1.13	1.13	1.13					1.13	
	Last	1.13	1.13	1.13					1.13	
Mar.	First	1.05	1.13	1.13					1.10	1.00
	Middle	0.88	1.05	1.13					1.02	
	Last	0.72	0.88	1.05					0.88	
Apr.	First	0	0.72	0.88					0.53	0.26
	Middle	0	0	0.72					0.24	
	Last	0	0	0					0	
May	First									
	Middle									
	Last									
June	First									
	Middle									
	Last									
July	First									
	Middle									
	Last									

H-4-(8) **Vegetable (Onion)**

Month		Cropping Order							Average	
		1 st.	2 st.	3 st.	4 st.	5 st.	6 st.	7 st.	10 days	Month
Oct.	First									
	Middle									
	Last									
Nov.	First	0.49	0	0					0.16	
	Middle	0.52	0.49	0					0.34	0.36
	Last	0.70	0.52	0.49					0.57	
Dec.	First	0.90	0.70	0.52					0.71	
	Middle	1.00	0.90	0.70					0.87	0.85
	Last	1.00	1.00	0.90					0.97	
Jan.	First	1.00	1.00	1.00					1.00	
	Middle	1.00	1.00	1.00					1.00	1.00
	Last	1.00	1.00	1.00					1.00	
Fev.	First	1.00	1.00	1.00					1.00	
	Middle	1.00	1.00	1.00					1.00	1.00
	Last	1.00	1.00	1.00					1.00	
Mar.	First	0.94	0.99	1.00					0.98	
	Middle	0.88	0.94	0.99					0.94	0.93
	Last	0.81	0.88	0.94					0.88	
Apr.	First	0	0.81	0.88					0.56	
	Middle	0	0	0.81					0.27	0.27
	Last	0	0	0					0	
May	First									
	Middle									
	Last									
June	First									
	Middle									
	Last									
July	First									
	Middle									
	Last									

H-4-(9) **Vegetable (Cabbege)**

Month		Cropping Order							Average	
		1 st.	2 st.	3 st.	4 st.	5 st.	6 st.	7 st.	10 days	Month
Oct.	First									
	Middle									
	Last									
Nov.	First	0.49	0	0					0.16	
	Middle	0.49	0.49	0					0.33	0.33
	Last	0.51	0.49	0.49					0.50	
Dec.	First	0.67	0.51	0.49					0.57	
	Middle	0.84	0.67	0.51					0.67	0.69
	Last	0.97	0.84	0.67					0.83	
Jan.	First	1.00	0.97	0.84					0.94	
	Middle	1.00	1.00	0.97					0.99	0.98
	Last	1.00	1.00	1.00					1.00	
Fev.	First	0.93	1.00	1.00					0.98	
	Middle	0	0.93	1.00					0.64	0.64
	Last	0	0	0.93					0.31	
Mar.	First									
	Middle									
	Last									
Apr.	First									
	Middle									
	Last									
May	First									
	Middle									
	Last									
June	First									
	Middle									
	Last									
July	First									
	Middle									
	Last									

H-4-(10) **Vegetable (Beans)**

Month		Cropping Order							Average	
		1 st.	2 st.	3 st.	4 st.	5 st.	6 st.	7 st.	10 days	Month
Oct.	First									
	Middle									
	Last									
Nov.	First	0.49	0	0					0.16	
	Middle	0.52	0.49	0					0.34	0.36
	Last	0.70	0.52	0.49					0.57	
Dec.	First	0.90	0.70	0.52					0.71	
	Middle	1.08	0.90	0.70					0.89	0.88
	Last	1.10	1.08	0.90					1.03	
Jan.	First	1.10	1.10	1.08					1.09	
	Middle	1.10	1.10	1.10					1.10	1.10
	Last	1.10	1.10	1.10					1.10	
Fev.	First	1.10	1.10	1.10					1.10	
	Middle	0.90	1.10	1.10					1.03	0.99
	Last	0.49	0.90	1.10					0.83	
Mar.	First	0	0.49	0.90					0.46	
	Middle	0	0	0.49					0.16	0.62
	Last	0	0	0					0	
Apr.	First									
	Middle									
	Last									
May	First									
	Middle									
	Last									
June	First									
	Middle									
	Last									
July	First									
	Middle									
	Last									

H-4-(11) **Vegetable (Peas)**

Month		Cropping Order							Average	
		1 st.	2 st.	3 st.	4 st.	5 st.	6 st.	7 st.	10 days	Month
Oct.	First									
	Middle									
	Last									
Nov.	First	0.49	0	0					0.16	
	Middle	0.49	0.49	0					0.33	0.34
	Last	0.59	0.49	0.49					0.52	
Dec.	First	0.80	0.59	0.49					0.63	
	Middle	1.00	0.80	0.59					0.80	0.80
	Last	1.10	1.00	0.80					0.97	
Jan.	First	1.10	1.10	1.00					1.07	
	Middle	1.10	1.10	1.10					1.10	1.09
	Last	1.10	1.10	1.10					1.10	
Fev.	First	1.07	1.10	1.10					1.09	
	Middle	0.76	1.07	1.10					0.98	0.89
	Last	0	0.76	1.07					0.61	
Mar.	First		0	0.76					0.25	
	Middle			0					0	0.08
	Last			0					0	
Apr.	First									
	Middle									
	Last									
May	First									
	Middle									
	Last									
June	First									
	Middle									
	Last									
July	First									
	Middle									
	Last									

H-4-(12) **Vegetable (Spinach)**

Month		Cropping Order							Average	
		1 st.	2 st.	3 st.	4 st.	5 st.	6 st.	7 st.	10 days	Month
Oct.	First									
	Middle									
	Last									
Nov.	First	0.49	0	0					0.16	
	Middle	0.49	0.49	0					0.33	0.33
	Last	0.56	0.49	0.49					0.51	
Dec.	First	0.70	0.56	0.49					0.58	
	Middle	0.84	0.70	0.56					0.70	0.70
	Last	0.96	0.84	0.70					0.83	
Jan.	First	0.98	0.96	0.84					0.93	
	Middle	0.98	0.98	0.96					0.97	0.96
	Last	0.98	0.98	0.98					0.98	
Fev.	First	0.98	0.98	0.98					0.98	
	Middle	0.47	0.98	0.98					0.81	0.76
	Last	0	0.47	0.98					0.48	
Mar.	First	0	0	0.47					0.16	
	Middle	0	0	0					0	0.05
	Last	0	0	0					0	
Apr.	First									
	Middle									
	Last									
May	First									
	Middle									
	Last									
June	First									
	Middle									
	Last									
July	First									
	Middle									
	Last									

H-4-(13) **Vegetable** (Tomate)

Month		Cropping Order							Average	
		1 st.	2 st.	3 st.	4 st.	5 st.	6 st.	7 st.	10 days	Month
May	First	0.38	0	0					0.13	
	Middle	0.38	0.38	0					0.25	0.27
	Last	0.51	0.38	0.38					0.42	
June	First	0.76	0.51	0.38					0.55	
	Middle	1.01	0.76	0.51					0.76	0.76
	Last	1.13	1.01	0.76					0.97	
July	First	1.13	1.13	1.01					1.09	
	Middle	1.13	1.13	1.13					1.13	1.10
	Last	1.10	1.13	1.13					1.09	
Aug.	First	0.89	1.10	1.13					1.04	
	Middle	0.35	0.89	1.10					0.78	0.74
	Last	0	0.35	0.89					0.41	
Sep.	First	0	0	0.35					0.12	
	Middle	0	0	0					0	0.04
	Last	0	0	0					0	
	First									
	Middle									
	Last									
	First									
	Middle									
	Last									
	First									
	Middle									
	Last									
	First									
	Middle									
	Last									
	First									
	Middle									
	Last									

H-4-(14) **Vegetable (Corn)**

Month		Cropping Order							Average	
		1 st.	2 st.	3 st.	4 st.	5 st.	6 st.	7 st.	10 days	Month
May	First	0	0	0					0	0.08
	Middle	0.19	0	0					0.06	
	Last	0.38	0.19	0					0.19	
June	First	0.41	0.38	0.19					0.33	0.48
	Middle	0.62	0.41	0.38					0.47	
	Last	0.86	0.62	0.41					0.63	
July	First	1.07	0.86	0.62					0.85	0.98
	Middle	1.10	1.07	0.86					1.01	
	Last	1.10	1.10	1.07					1.09	
Aug.	First	1.04	1.10	1.10					1.08	0.79
	Middle	0.36	1.04	1.10					0.83	
	Last	0	0.36	1.04					0.47	
Sep.	First	0	0	0.36					0.12	0.04
	Middle	0	0	0					0	
	Last	0	0	0					0	
	First									
	Middle									
	Last									
	First									
	Middle									
	Last									
	First									
	Middle									
	Last									
	First									
	Middle									
	Last									
	First									
	Middle									
	Last									

H-4-(15) **Vegetable (French Bean)**

Month		Cropping Order							Average	
		1 st.	2 st.	3 st.	4 st.	5 st.	6 st.	7 st.	10 days	Month
May	First	0.38	0	0					0.13	0.30
	Middle	0.42	0.38	0					0.27	
	Last	0.67	0.42	0.38					0.49	
June	First	0.96	0.67	0.42					0.68	0.88
	Middle	1.10	0.96	0.67					0.91	
	Last	1.10	1.10	0.96					1.05	
July	First	1.10	1.10	1.10					1.10	1.10
	Middle	1.10	1.10	1.10					1.10	
	Last	1.10	1.10	1.10					1.10	
Aug.	First	0.83	1.10	1.10					1.01	0.69
	Middle	0.21	0.83	1.10					0.71	
	Last	0	0.21	0.83					0 35	
Sep.	First	0	0	0.21					0 07	0.02
	Middle	0	0	0					0	
	Last	0	0	0					0	
	First									
	Middle									
	Last									
	First									
	Middle									
	Last									
	First									
	Middle									
	Last									
	First									
	Middle									
	Last									
	First									
	Middle									
	Last									

H-4-(16) **Vegetable (Okura)**

Month		Cropping Order							Average	
		1 st.	2 st.	3 st.	4 st.	5 st.	6 st.	7 st.	10 days	Month
May	First	0.38	0	0					0.13	
	Middle	0.38	0.38	0					0.25	0.26
	Last	0.41	0.38	0.38					0.39	
June	First	0.59	0.41	0.38					0.46	
	Middle	0.79	0.59	0.41					0.60	0.61
	Last	1.05	0.70	0.59					0.78	
July	First	1.10	1.05	0.70					0.95	
	Middle	1.10	1.10	1.05					1.08	1.04
	Last	1.08	1.10	1.10					1.09	
Aug.	First	0.92	1.08	1.10					1.03	
	Middle	0	0.92	1.08					0.67	0.67
	Last	0	0	0.92					0.31	
Sep.	First									
	Middle									
	Last									
	First									
	Middle									
	Last									
	First									
	Middle									
	Last									
	First									
	Middle									
	Last									
	First									
	Middle									
	Last									
	First									
	Middle									
	Last									

H-5-(1) Crop Coefficient

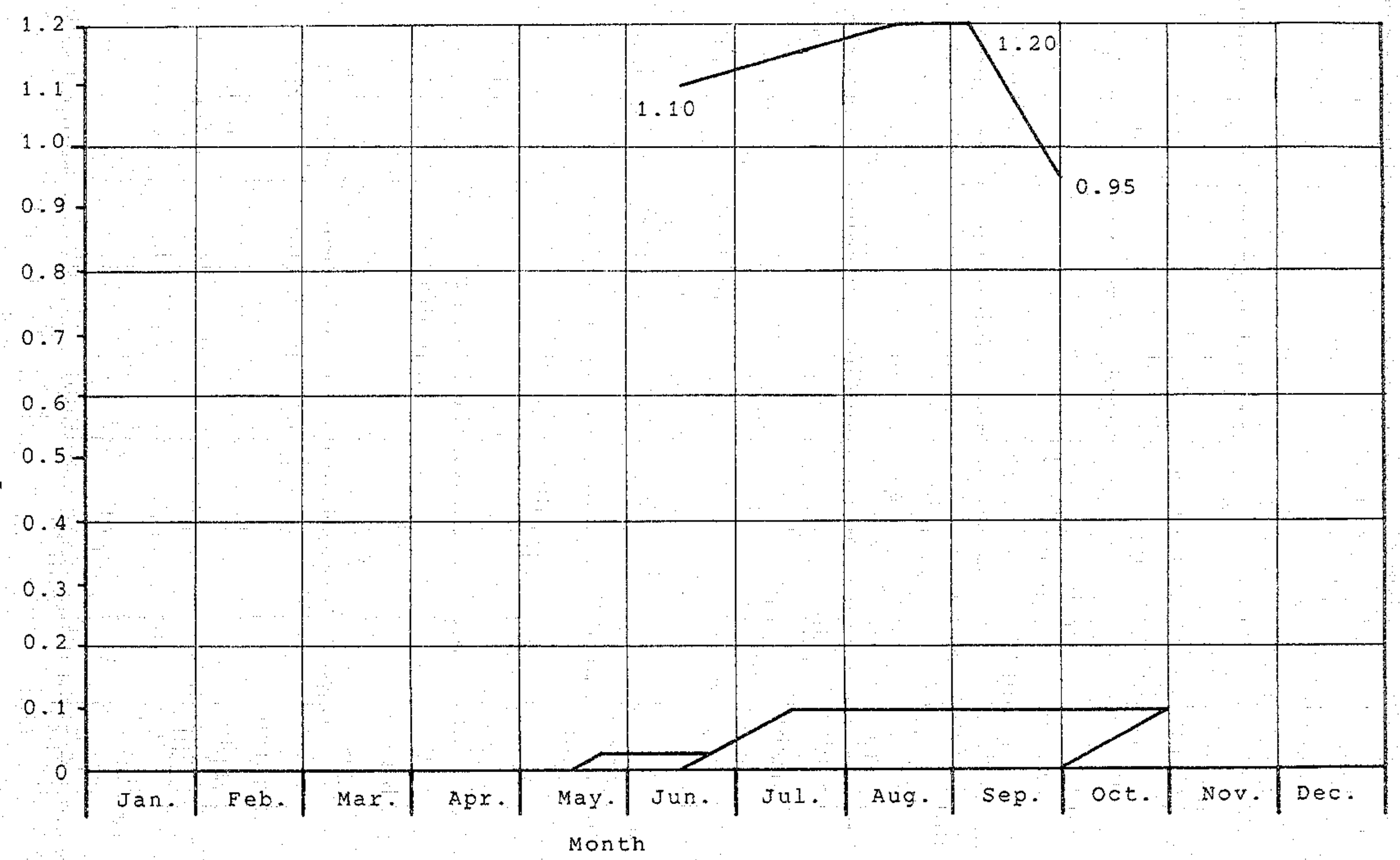
Crop: Rice

ETo = 8.4, 8.7, 7.4

RH_{min} = 34 ～ 42 %

Wind Speed (m/s) = 3.9 ～ 4.4

		days
Initial		
Crop development	60	
Mid Season	20	
Late Season	25	
	Total	105

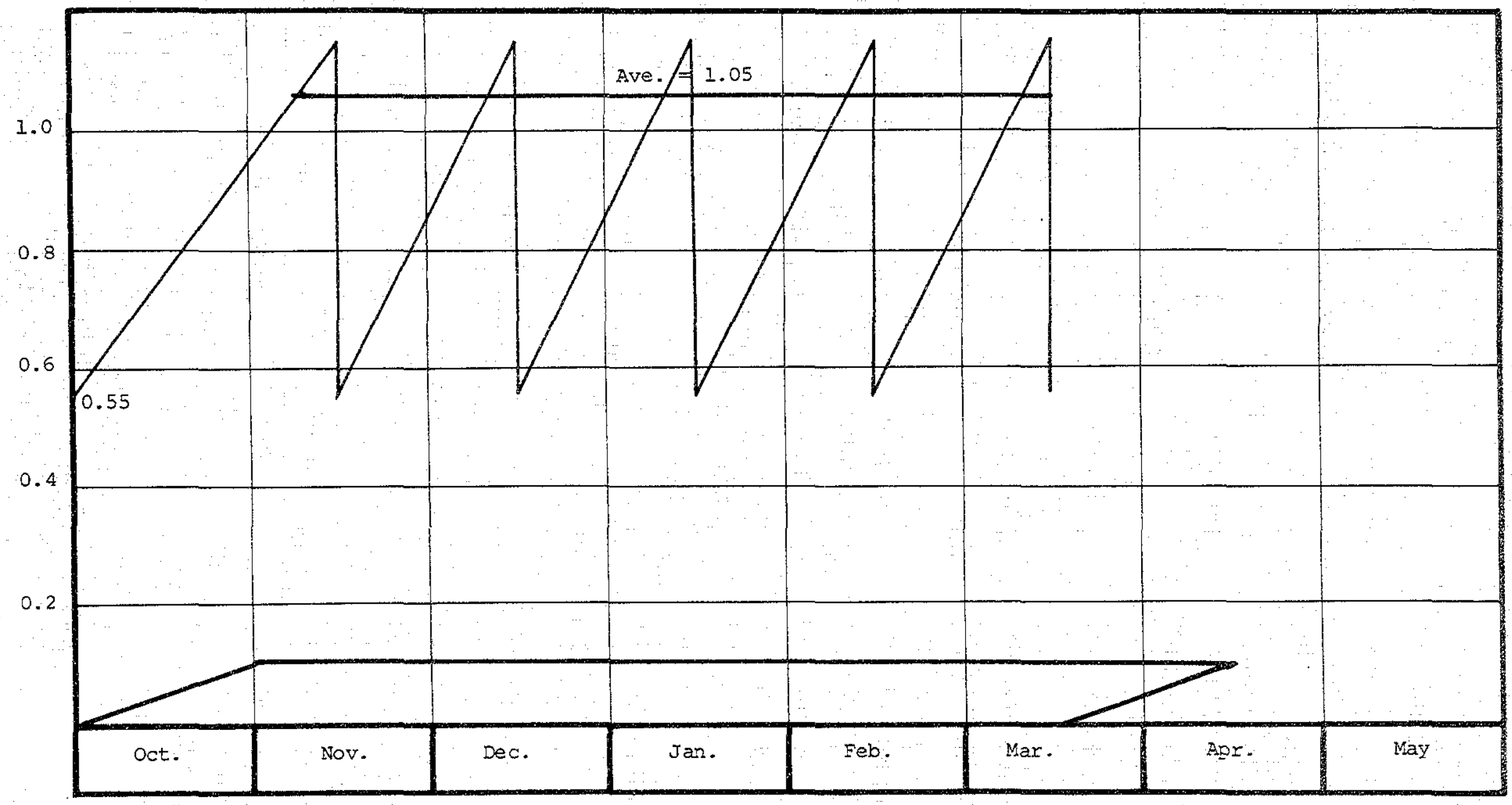


H-5-(2) Crop Coefficient

Berseem

Eto =
RHmin =
Wind Speed = 4.0-6.0
(m/s) (4.9)

Initial	days
Crop development	
Mid Season	
Late Season	
Total	165

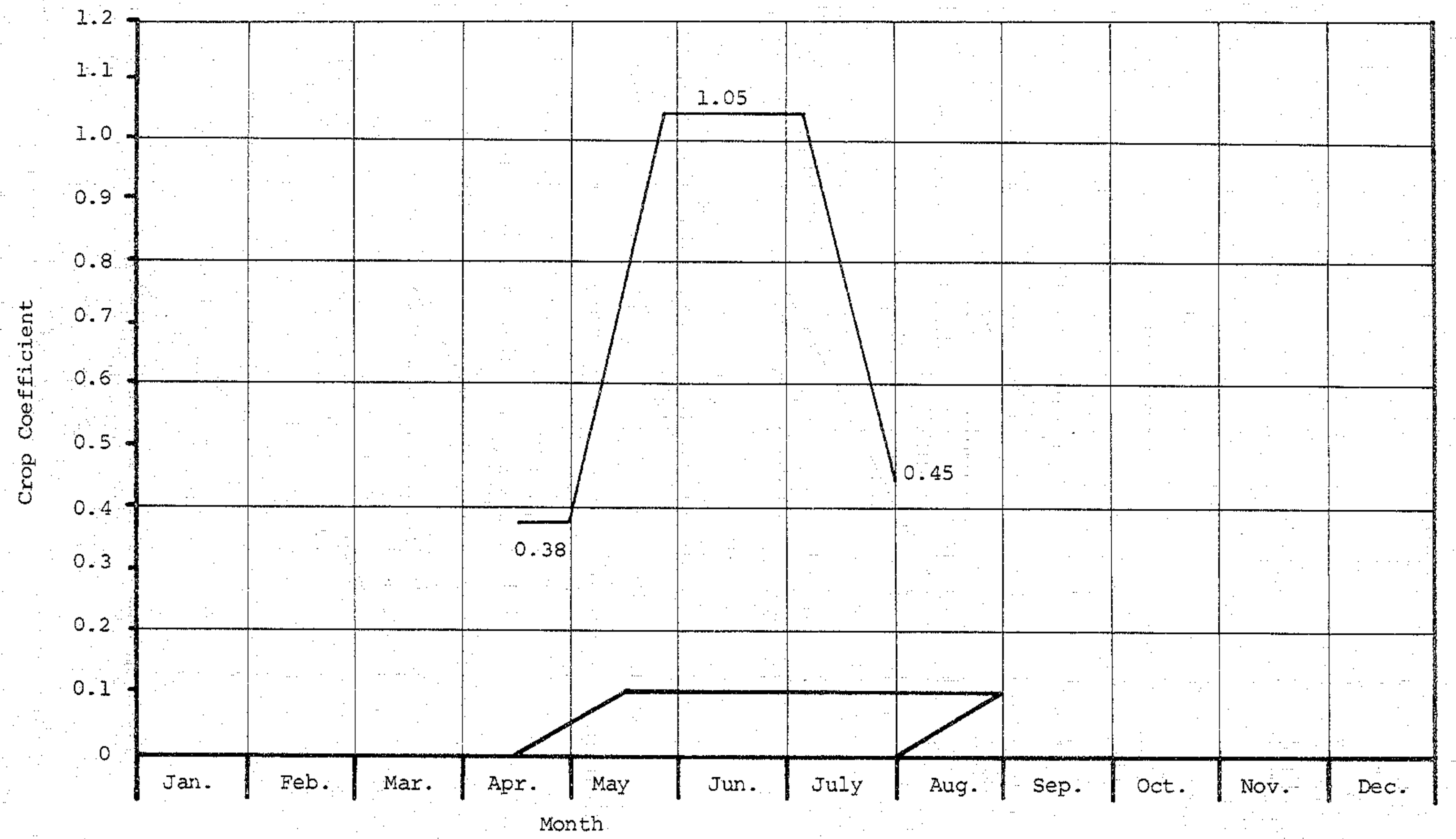


H-5-(3) Crop Coefficient

Crop: Soybeans

ETo = 6.4, 7.5, 8.4
RH min = 29 - 42%
Wind Speed (m/s) = 7.0 - 6.2

Initial	15 days
Crop development	25
Mid Season	40
Late Season	25
Total	105

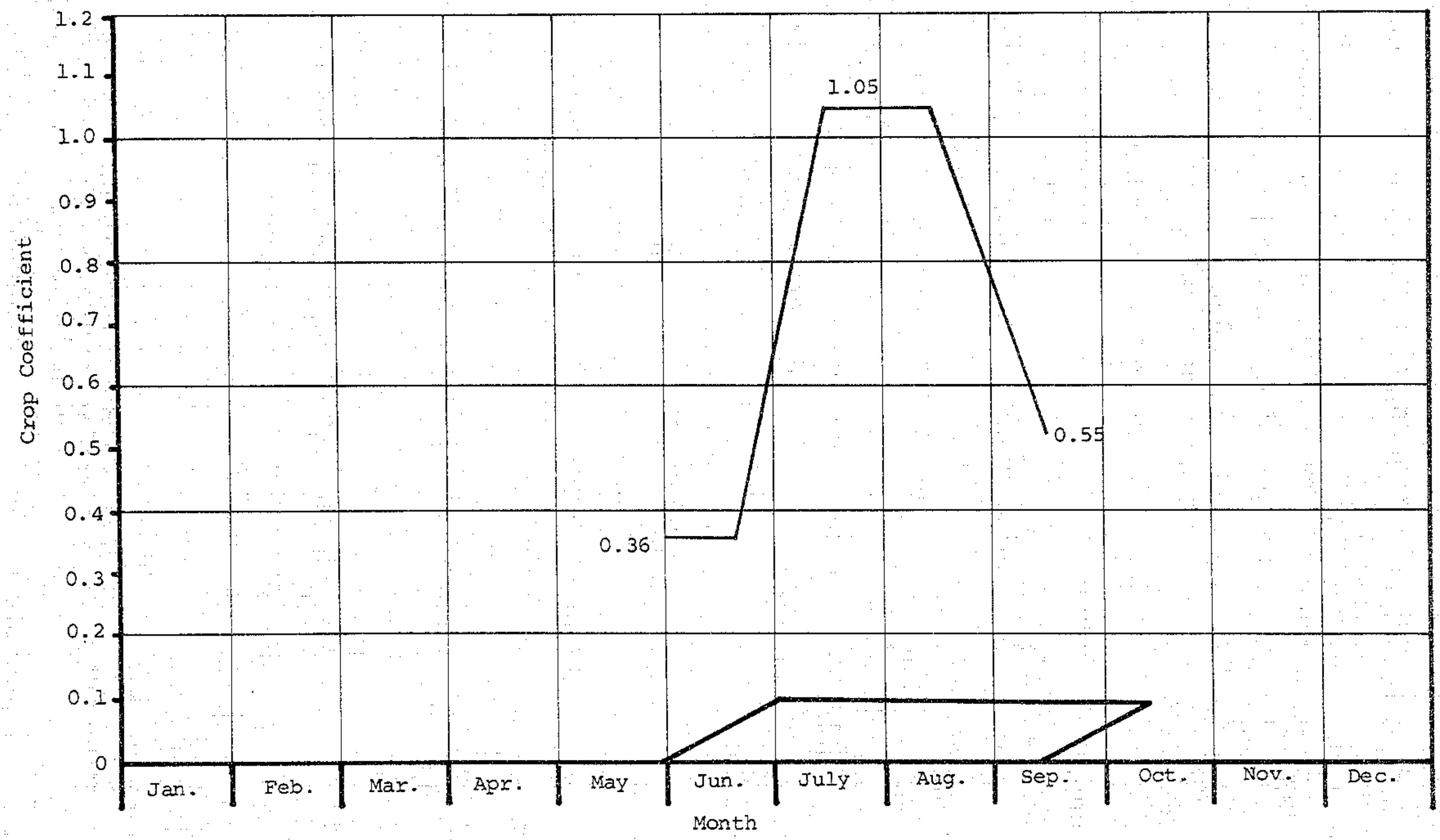


H-5-(4) Crop Coefficient

Crop: Sorghum

ETo = 8.4, 8.7
RH min = 29 - 42%
Wind Speed= 5.4 - 7.0
(m/s)

Initial	20 days
Crop development	25
Mid Season	30
Late Season	30
Total	105

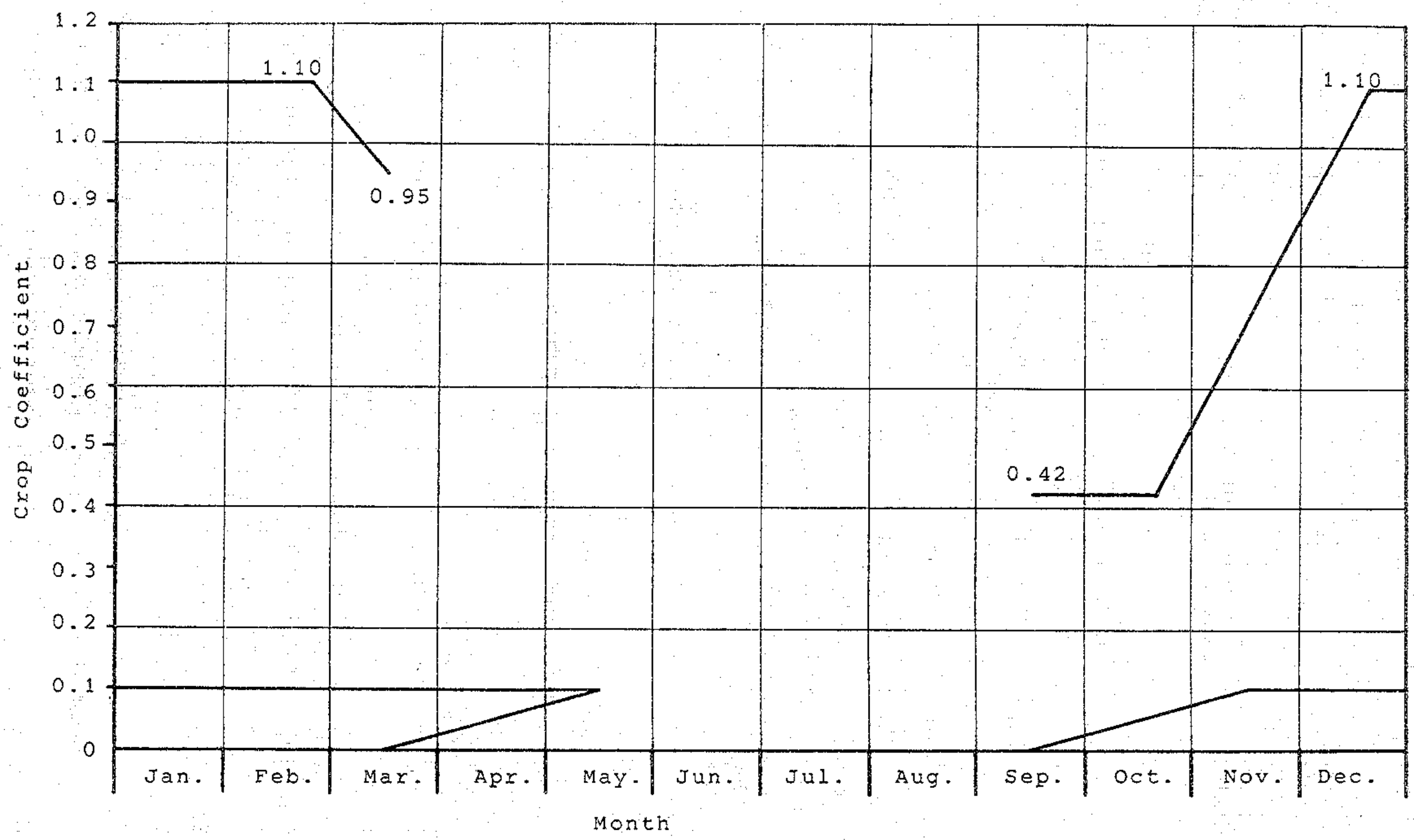


H-5-(5) Crop Coefficient

Crop: Sugar Beet

ETo = 6.8, 5.8, 4.5
RH min = 31 ～ 38%
Wind Speed (m/s) = 5.7 ～ 8.4

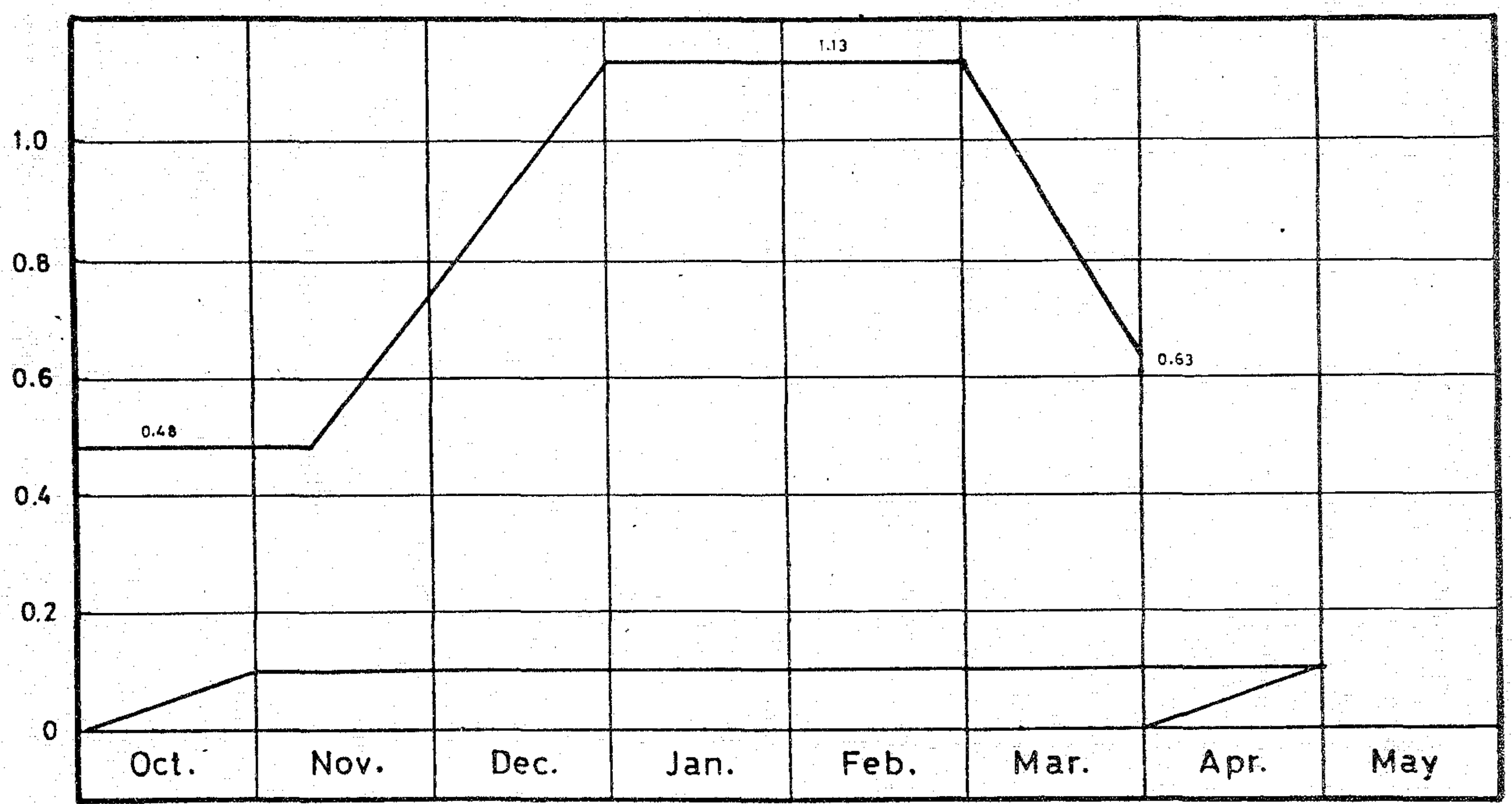
Initial	35	days
Crop development	60	
Mid Season	65	
Late Season	20	
Total	180	



H-5-(6) **Vegetables (Tomato)**

ETo = 5.8, 4.5, 3.5
RH_{min} = 24 ~ 38%
Wind Speed (m/s) = 5.6 ~ 8.4 m/s

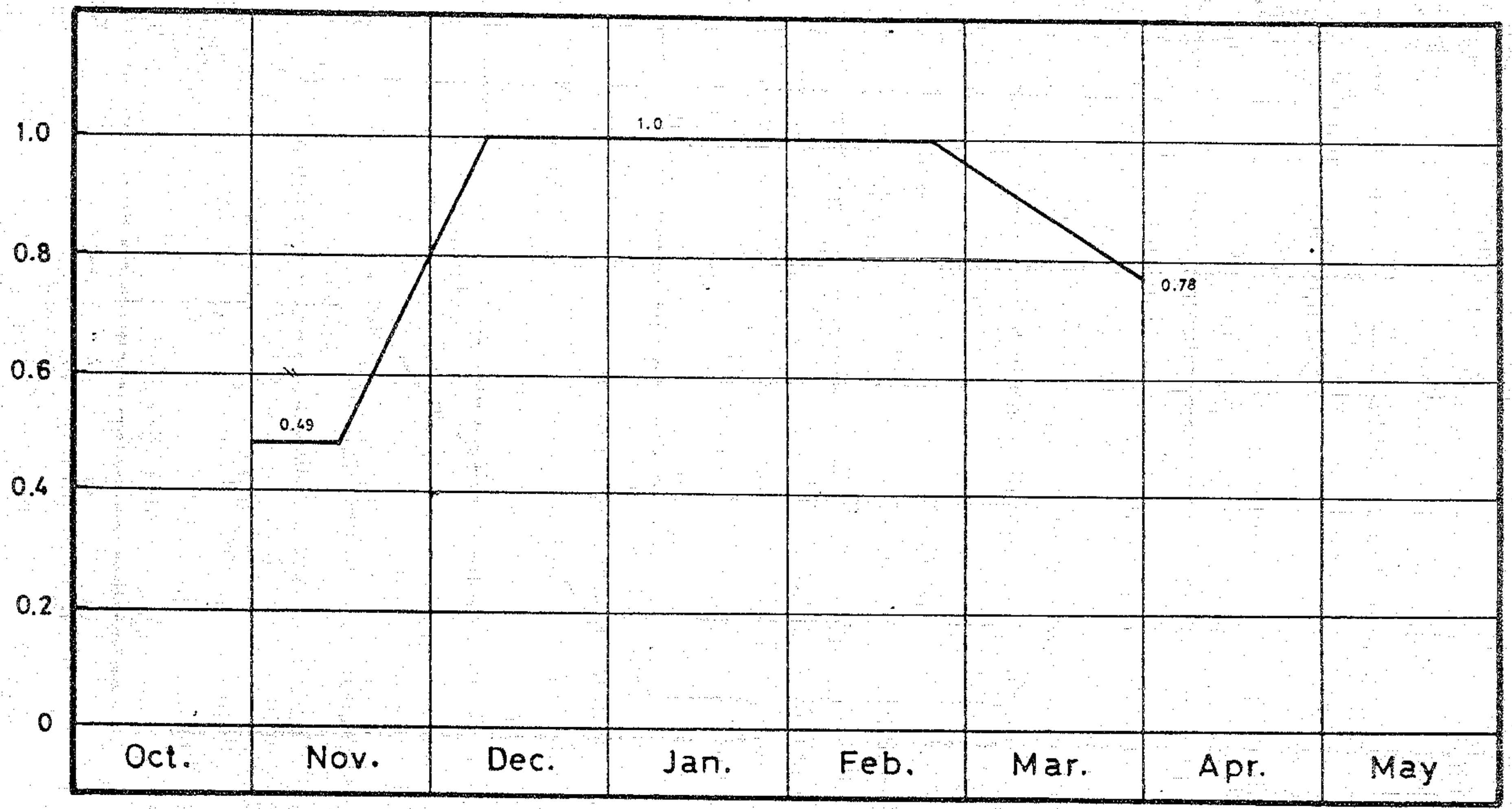
Initial	35	40	days
Crop development	45	50	
Mid Season	70	75	
Late Season	30	30	
Total	180	195	



H-5-(7) **Vegetables (Onion)**

ETo =
RH_{min} =
Wind Speed = (m/s)

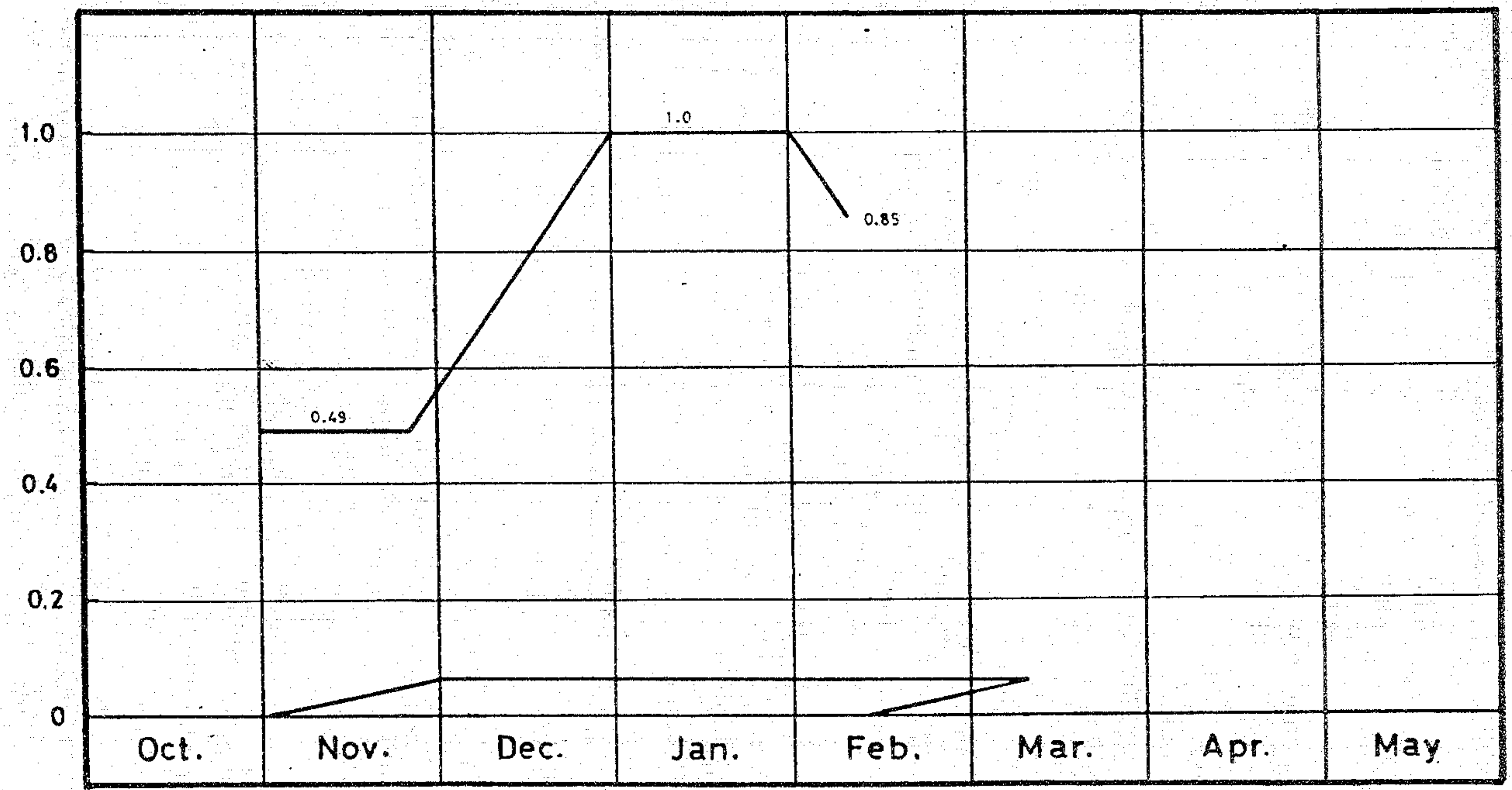
Initial	20	15	days
Crop development	35	25	
Mid Season	110	75	
Late Season	45	35	
Total	210	150	



H-5-(8) **Vegetables (Cabbege)**

Eto =
RHmin =
Wind Speed =
(m/s)

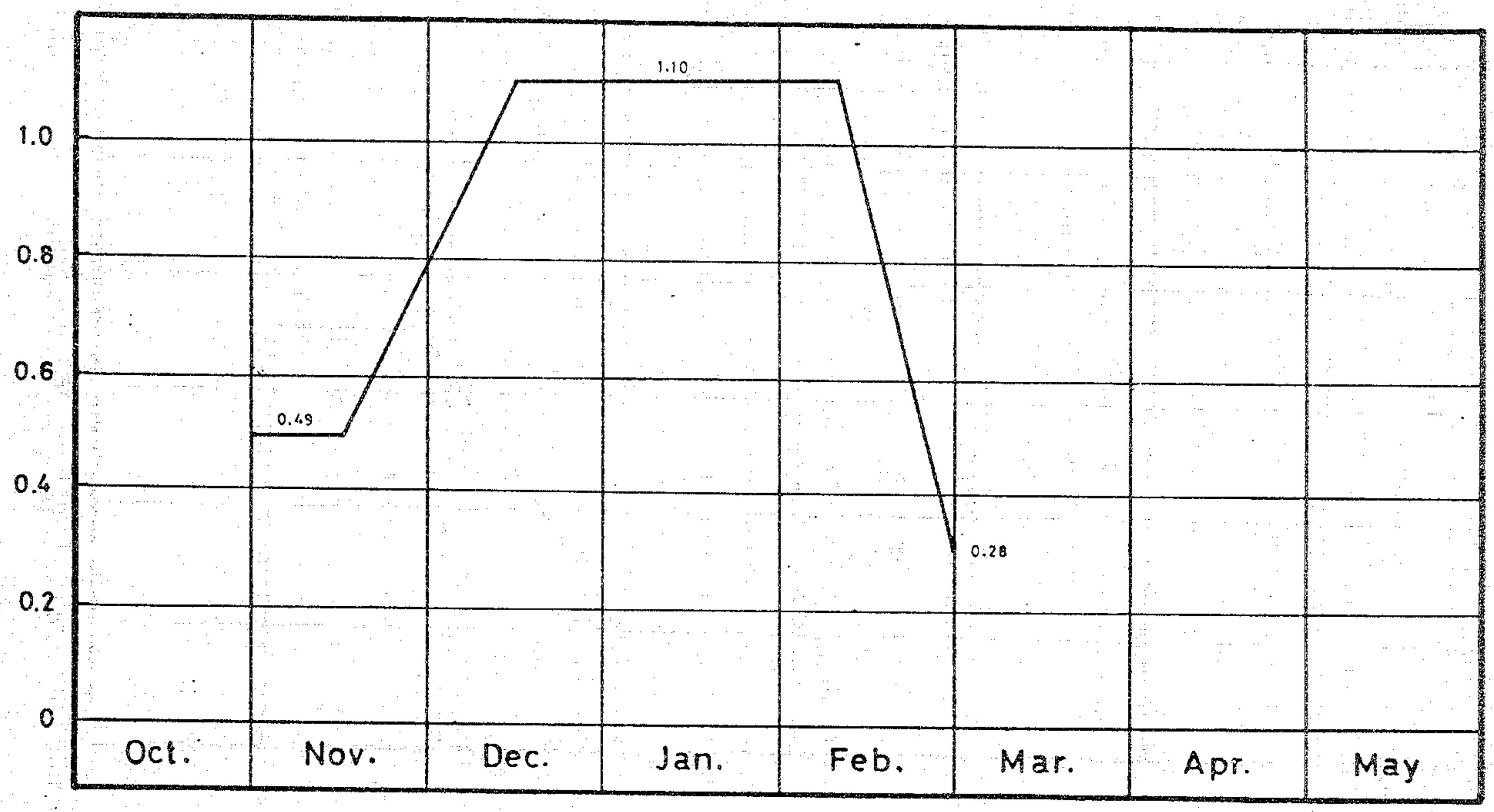
Initial	25	25	days
Crop development	35	35	
Mid Season	25	30	
Late Season	10	10	
Total	95	100	



H-5-(9) **Vegetables (Beans)**

ETo =
RH_{min} =
Wind Speed = (m/s)

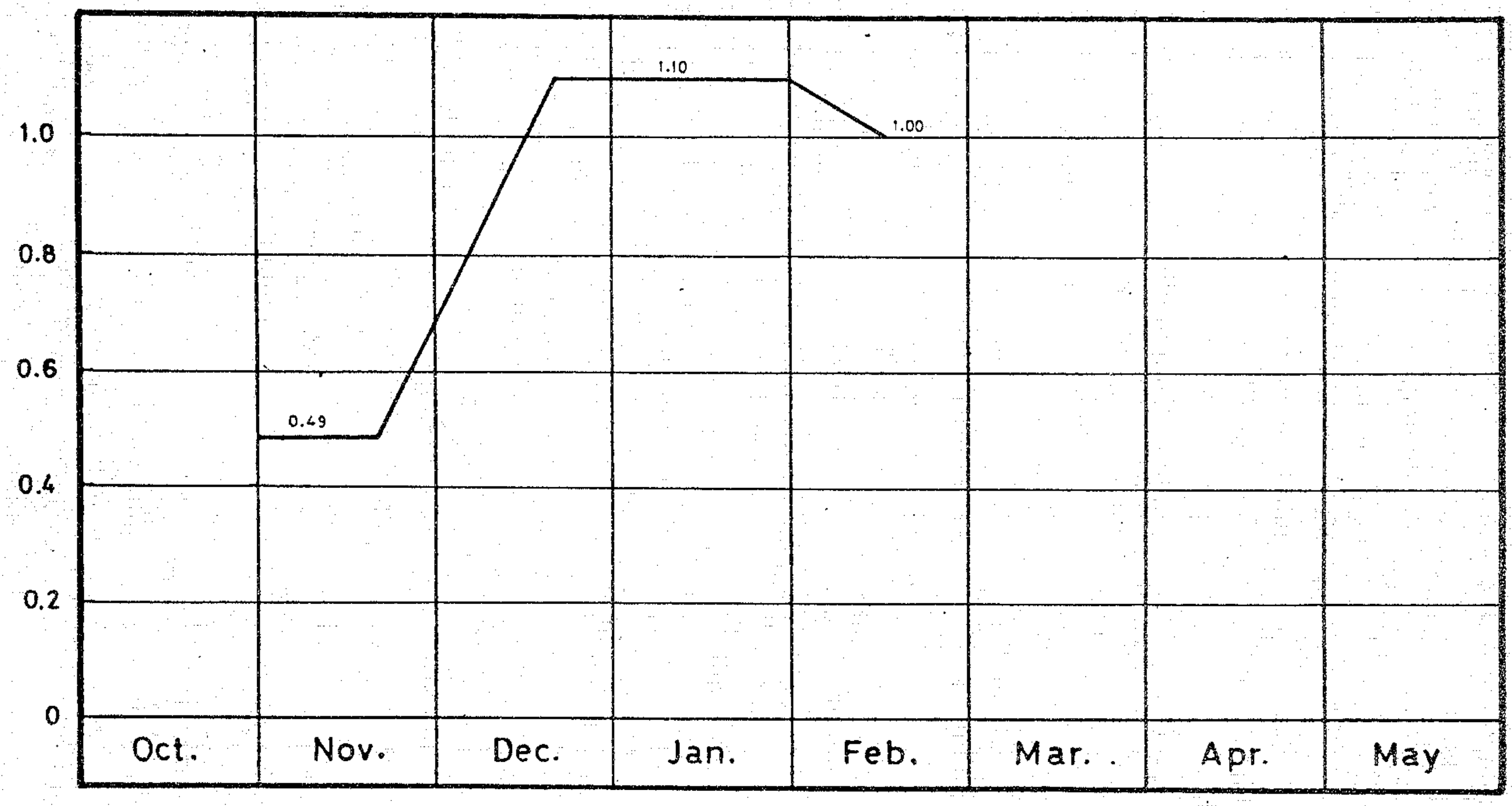
Initial	15	15	days
Crop development	25	30	
Mid Season	50	55	
Late Season	20	20	
Total	110	120	



H-5-(10) **Vegetables (Peas)**

Elo =
RH_{min} =
Wind Speed =
(m/s)

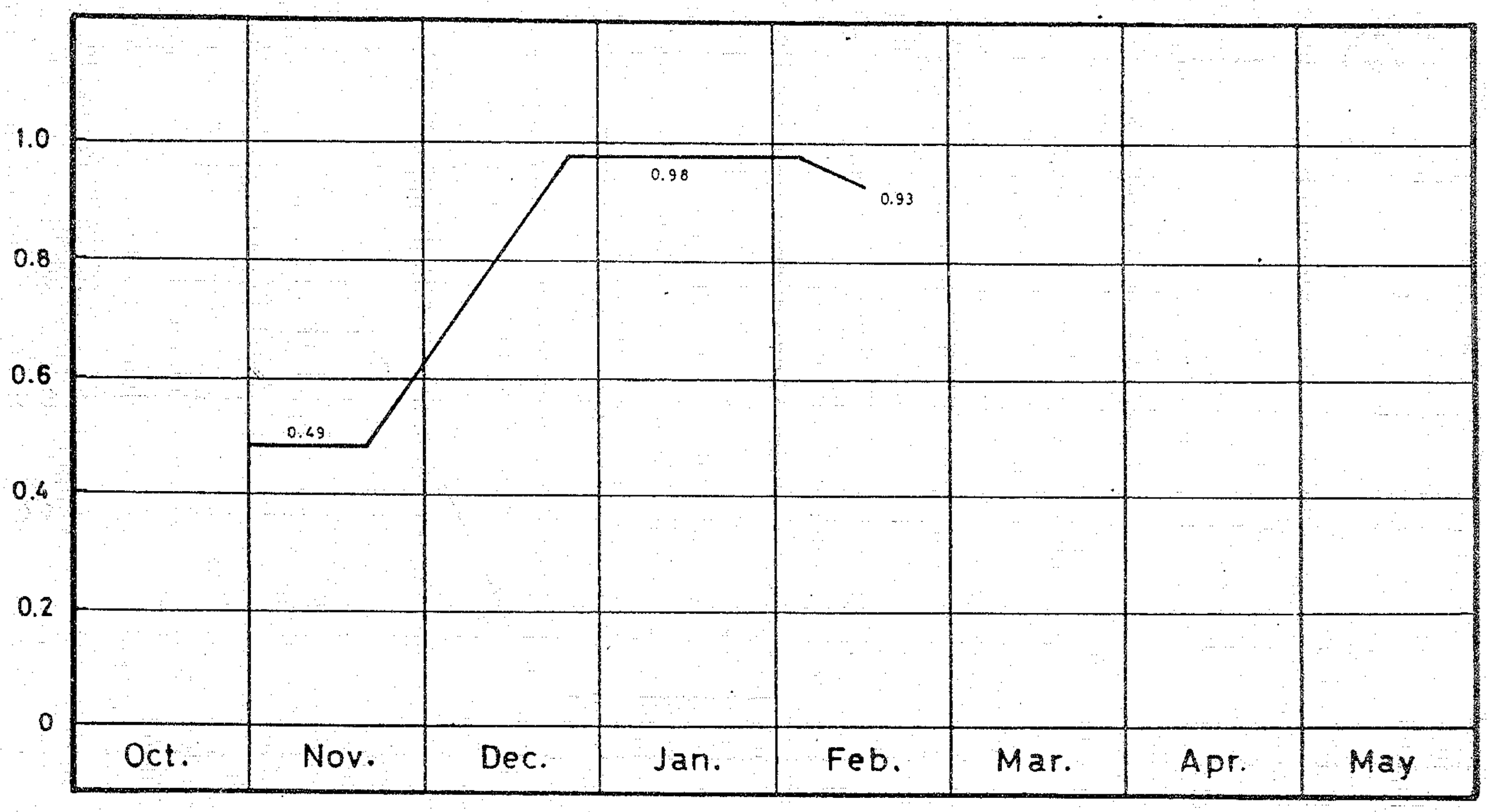
Initial	20	20	days
Crop development	25	30	
Mid Season	35	40	
Late Season	15	15	
Total	95	105	



H-5-(11) Vegetables (Spinach)

ETo =
RHmin =
Wind Speed (m/s) =

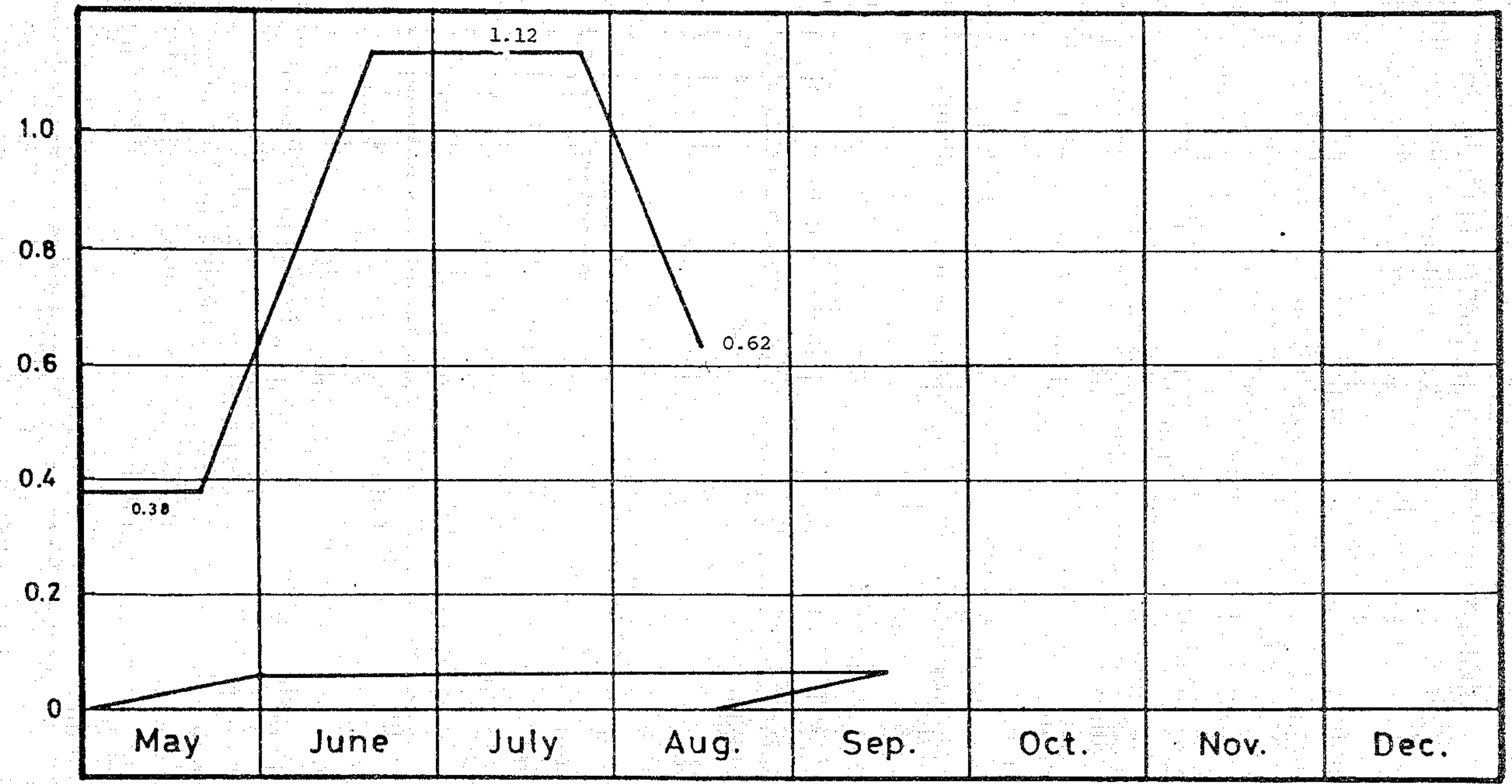
Initial	20	20	days
Crop development	30	35	
Mid Season	40	40	
Late Season	10	10	
Total	100	105	



H-5-(12) **Vegetable** (Tomate)

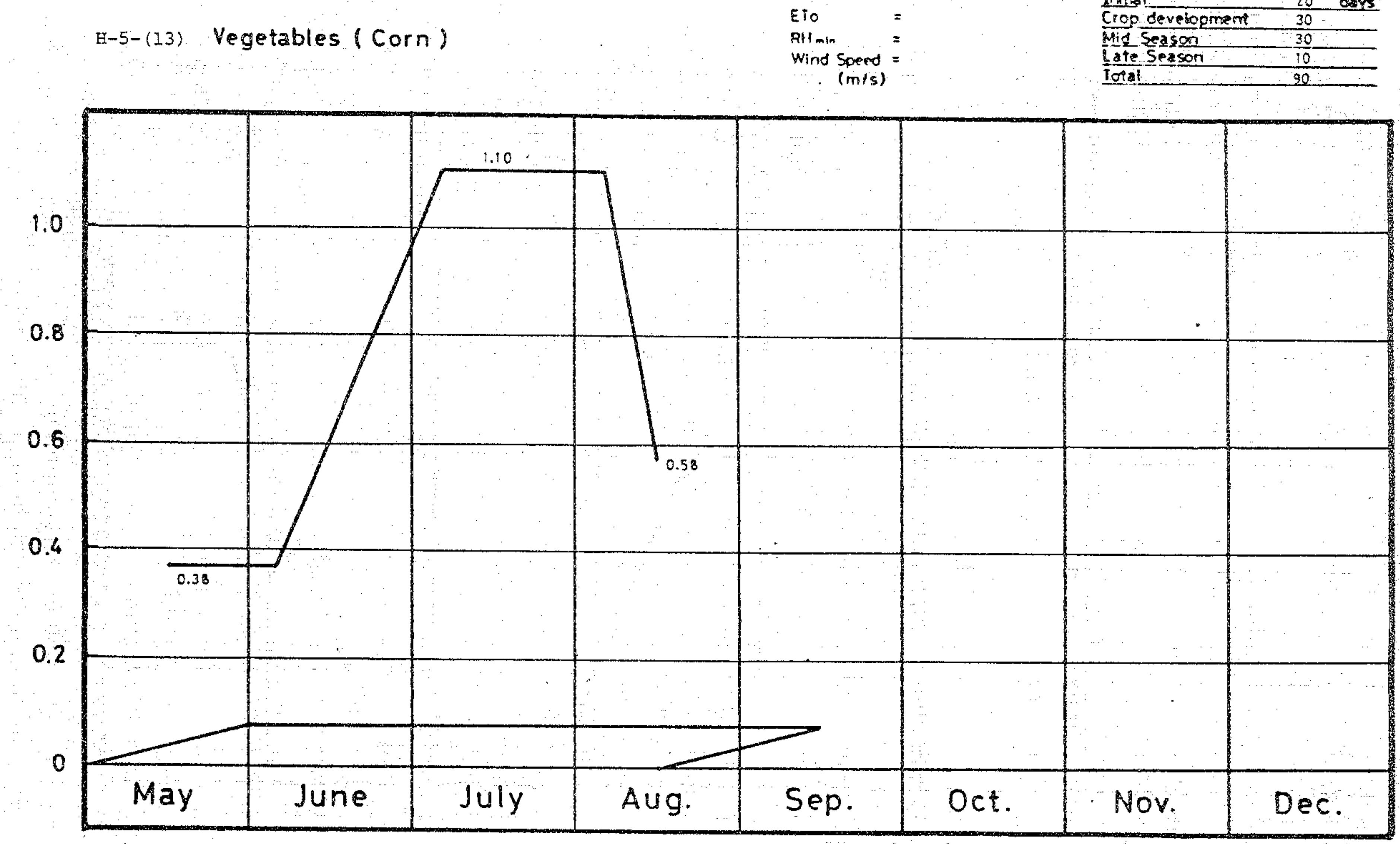
ETo =
RH_{min} =
Wind Speed = (m/s)

Initial	30	20	days
Crop development	40	30	
Mid Season	45	35	
Late Season	30	20	
Total	145	105	



H-5-(13) Vegetables (Corn)

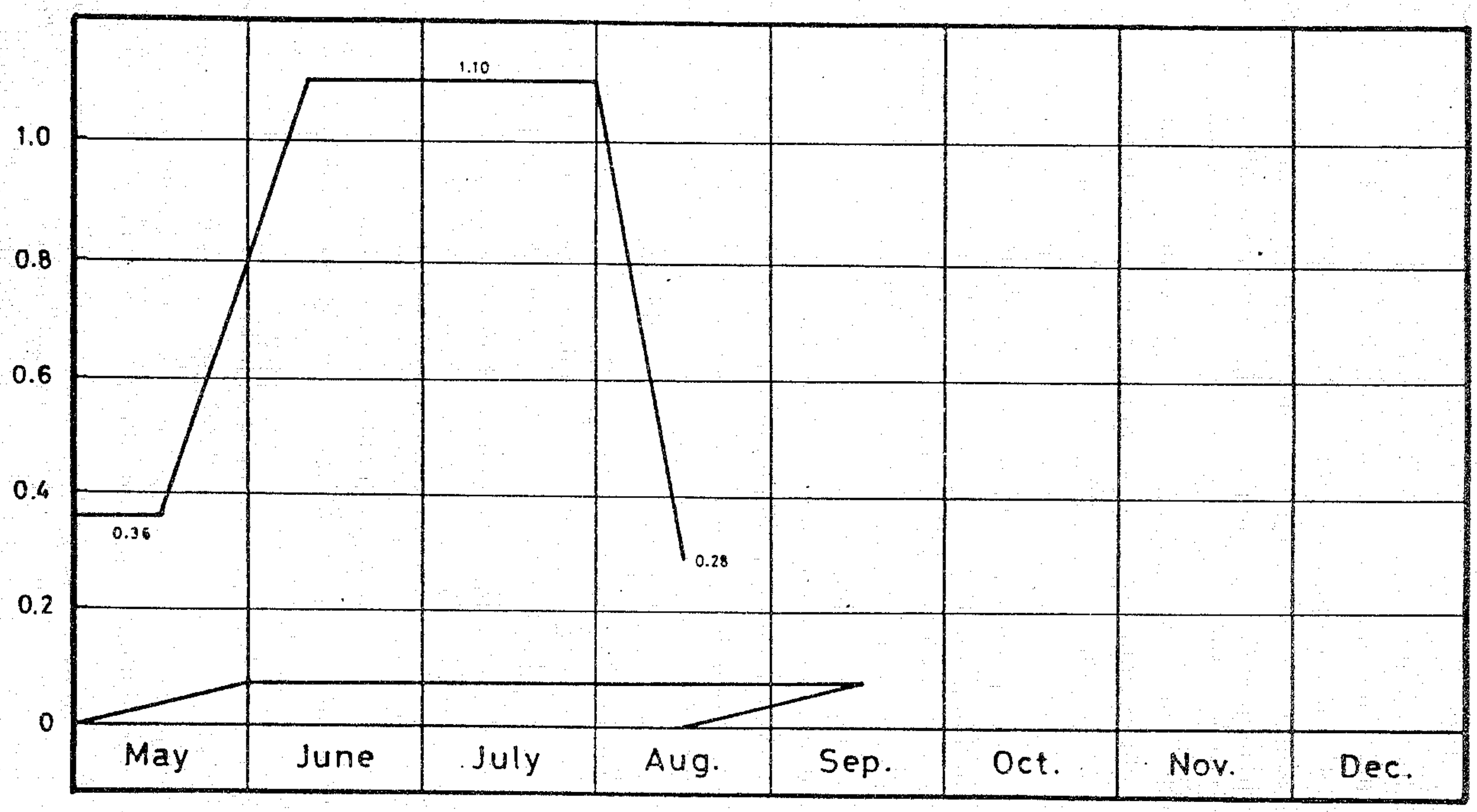
Initial	20	days
Crop development	30	
Mid Season	30	
Late Season	10	
Total	90	



H-5-(14) Vegetables (French Bean)

Eto =
RH_{min} =
Wind Speed = (m/s)

Initial	15	15	days
Crop development	25	25	
Mid Season	50	50	
Late Season	20	15	
Total	110	105	



H-5-(15) Vegetables (Okura)

ETo =
RH_{min} =
Wind Speed = (m/s)

Initial	30	25	days
Crop development	40	30	
Mid Season	40	30	
Late Season	20	15	
Total	130	105