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PRACTICAL-PERIOD RAPORT

The irrigation-project Bebedouro
- Seepage-losses
- Irrigation-efficiency on field-level

computador RN OK!

by
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1: INTRODUCTION

This report forms the reflextion of that wich I, concrete on research, have done during the period april-september 1986 at CPATSA, Centro de Pesquisa Agropecuária do Tropico Semi-Árido (Center of Agricultural and cattle-breeding research in the semi-arid tropics), subdivision of EMBRAPA, Empresa Brasileira de Pesquisa Agropecuária (Brasilian institution of agricultural and cattle-breeding research) in scope of my study at the Agricultural University, Wageningen, the Netherlands, as period of practice.

This report consist of three parts:
A general part about the irrigation-project Bebedouro, in which the research has taken place. Followed by the research: one part on water-distribution and water-transport efficiency at secondary level and a second part on irrigation-management of furrow-irrigation at field-level.

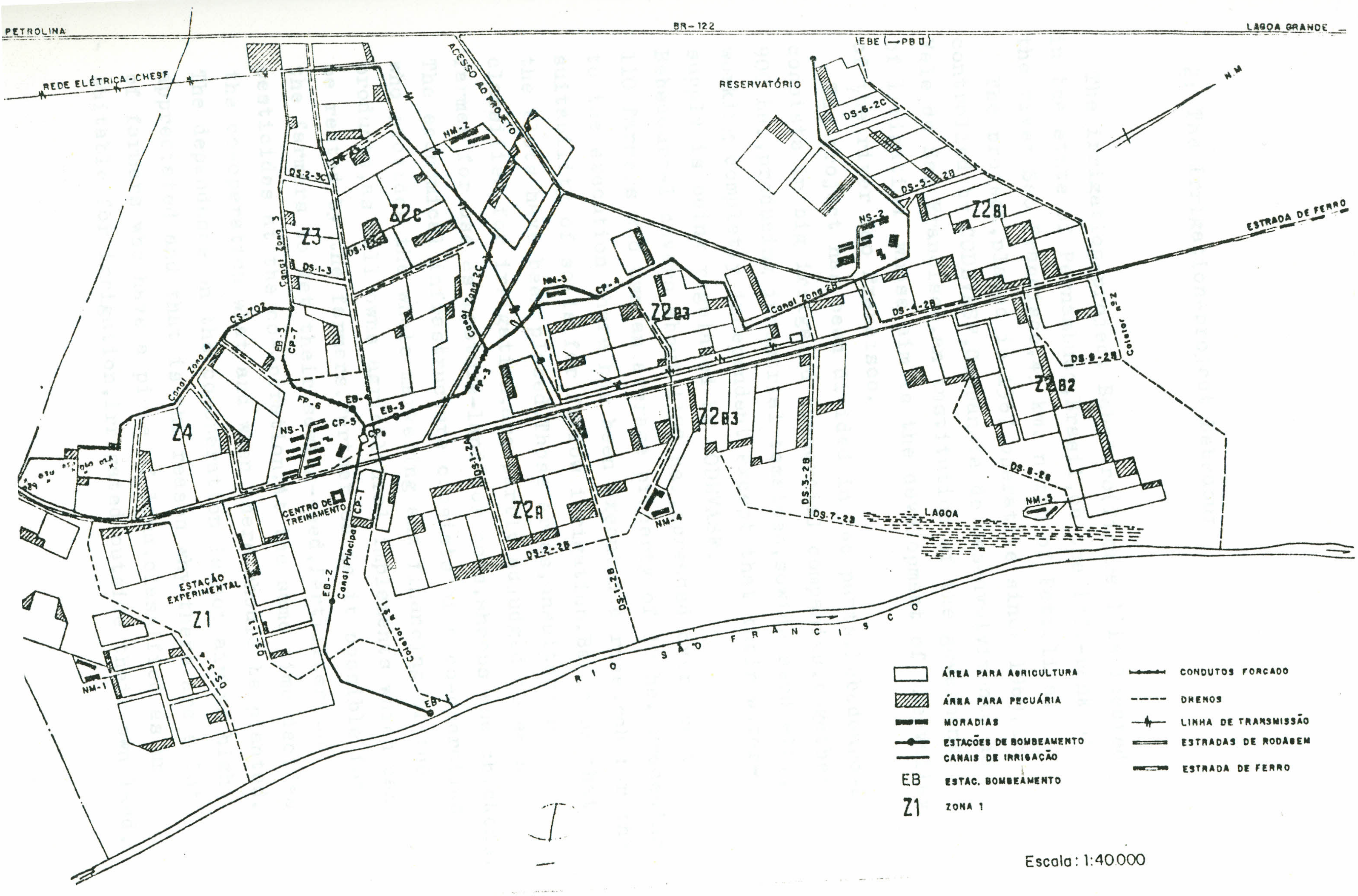


Figure 1: Irrigation-project Bebedouro-1

2: The Irrigation-project Bebedouro

The irrigation-project Bebedoro(figure 1)is located in the state of Pernambuco,Brasil,on the left-bank of the river Sao Francisco,45 km. north of Petrolina.

The project,placed in 1967,operative since 1969,is controlled by CODEVASF,Companhia de Desenvolvimento de Valė de Sao Francisco,an institution of the goverment of irrigation whose aim is the development of the valley of the river Sao Francisco.

The project has been divided in two parts.Bebedouro-2 consists in big irrigated commercial companies,together 900 ha.,producing industrial tomatoes,sowing seed etc., working completly independent,except that their water-supply is being regulated by CODEVASF.
Bebedouro-1 covers about 1100 ha.,spreaded over about 110 farmers who own an average property of 10 ha..Preceding to the execution there has been executed a research for the suitability of soils for furrow irrigation.Based on that the plots have been placed.Those areas,unsuitabile classified for irrigation,are partly adjudged to each farmer for use as pasture-land for cows,sheeps and chickens. The economical infrastructure consists of a co-operation, who provides the whole marketing and financing of the products,as well owns agricultural implements which can be rented by the farmers.Further on is it possible for the farmers to get their sowing-seed,fertilizer and pesticides at the co-operation.At the same time decides the co-operation what and when there should be planted. The dependence on the co-operation is not always high appreciated and that is the reason why there are a lot of farmers who have a piece of land,classified as unsuitable for irrigation,irrigated outside their own land,

because by doing so they only depend on CODEVASF and not on the co-operation.

The crops which are cultivated througout the year, are the regional kind like tomatoes,onions,melons,graphs, bananas,beans and corn.

The project has been divided in zones,each with a relative independent working irrigation- and drainage systeem.Each zone is regulated by a "canaleiro",an operator in service of CODEVASF.

The climate is semi-arid with an average yeartemperature of approxily 30°C and a rainamount about 400 mm.,which fallspreponderating in the months january,february and march.

The soil is classified as being a lato-soil(oxi-soil) with a high zand content of 70-80% until 90 cm. depth through wich the moisture ability is small and the rooting depth is reduced.

3.1: RESEARCH 1; PLAN AND JUSTIFICATION

The plan of this first part was to examine how the water-distribution in Bebedouro-1 occured and what were the possible problems present in a zone.At the same time some measurements would be taken in the primair/secundair kanal-systeem to see how much water was being lost by seepage and inefficiency of the distribution-systeem because this two water-losses contribute to the drainage problems in this project.The inefficiency of the distribution-systeem that was caused by the delay time which arised from the fact thet the operator of the gates,on his bike, slower was than the progressing time of the water,appeared to be practical inpossible to examine because this took place at 7 o'clock in the morning,therefore before it was possible to arrive at the field.

3.2: MATERIALS AND METHODS

The water-distribution systeem became clear through information of the technical staff of CODEVASF,conversations with the operator("canaleiro")and with some farmers.

As field of research for determination of the seepage-losses was chosen zone 2-B(see figure 1 and figure 3) that is located on the primair kanal Cp4.During several days the discharges were measered in ten different sections.

These discharges,which are necessary for the calculation of the water-losses through seepage,are calculated by making use of the formula:

$$Q = A \times R^{2/3} \times S^{\frac{1}{2}} \times N^{-1}, \qquad (1)$$

in which

Q = discharge in m^3/s

A = wet section in m^2

R = hydralic radius in m

S = slope of the canal in m/m

N = manning factor

The factor S in (1) is determined by means of a levelling instrument.

The factor N in (1) is determined by means of a velocity meter,while all the other factors were known.

The seepage-losses are calculated through the continuity-equation:

$$V = Q1 - Q2,$$

in which

V = losses between the sections 1 and 2 in m^3/s.

Further the losses per km. t.m.o.

$$V_1 = V/1,$$

in which

V_1= losses per km. in m^3/s

1 = distance between the sections 1 ans 2 in km.

3.3: RESULTS

The primary canal- and distribution systeem

The primary canal, trapezoid constructed out of concrete plates with a mixture of betums for the seams, has a total length of 10680 m.. The water is pomped out of the river on the highest point of the project by means of three little pomps of 1800 m^3/h each and two big pomps of each 3450 m^3/h on capacity. There are, further on, 4 other pomping-stations, which take care of the distribution of the water over the different zones and two reservoirs, which fill a threefold function; shortening of the delay-time, caused by the daily filling of the canals, to obtain more flexibility in the distribution of varied waterquantity and as reserve. The systeem operates from Monday until Sunday and from 5 o'clock in the morning until 5 o'clock in the afternoon. On Saterday only Bebedouro-2 is irrigating, eventual is it possible for the farmers to bring in a request to obtain water on Saterday. The pomps start to work at 5 o'clock in the morning in order to have filled the canals between seven and eight o'clock. The secondary gates close between four and five o'clock in the afternoon, after which the pomps continue to work until the both reservoirs are completly full. On Monday they begin to work earlier, because one company use water on Sunday out of the second reservoir, through which it is almost empty on Monday morning.

The capacity of the pomps is being considered sufficient. That of the reservoirs too small, through which more ability is asked of the operating-crew and the efficienty is lowered through the delay in time between the request for more/less water and the realization of this request.

The delivered discharge into the secondary canal is stabilized by an upstream-control,a so called "giraudet weir",through which it is possible to measure discharges by means of $Q = R \times C_d \times C_v \times 2/3 \times (2/3 \times g)^{\frac{1}{2}} \times b \times h_1^{1,5}$ (see figure 2).However,because this structure is to be choked very easily and there is no measure-equipment present to measure h_1,is measuring of discharges with this structure inpossible.

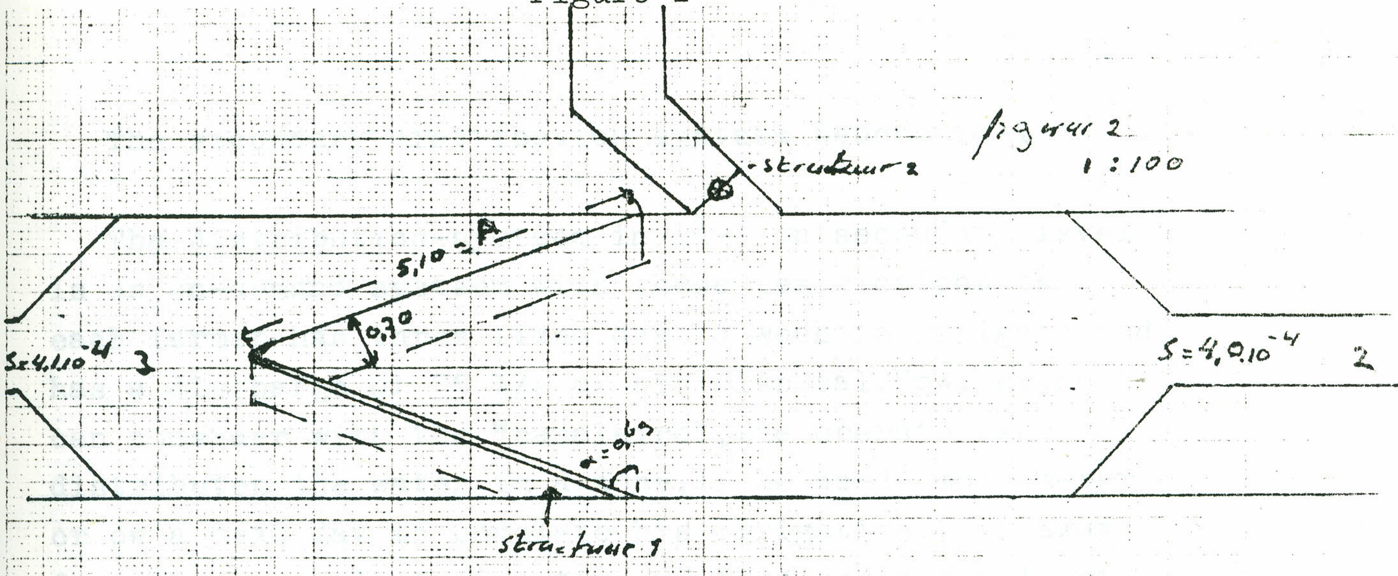
The inlet gate self is an orifice-type structure(see figure 2)and is,because of lacking of the gauge-data for fixing of the factor C_e (in the formula $Q = C_e \times A \times (2 \times g \times (h_2-h_1))^{\frac{1}{2}}$),as also the lacking of the measurement-instruments for measuring A,h_1 and h_2,not suitable for using as a measurement-structure.

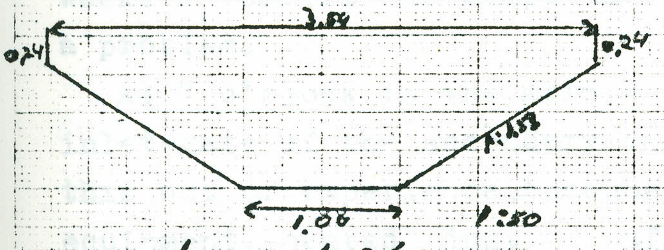
The distribution works in the primary canal for the distribution of the water over the different zones are also of the orifice-type and as well unsuitable as measurement-equipment.The distribution-structure consists in general of two orifices;one for the primary headcanal and the other one for the primary zonecanal.The operator opens the zone-inlet completly and regulates the quantity of the water in his zone by opening or closing the other gate.

Zones,which are linked directly on one of the pomping-stations,are regulated directly by these stations.A problem in these zones is that the pomp has a minimal capacity, which in some times is larger than the necessary capacity. The operator then talks with the farmers of the concerning zone to see if it is possible to delay the irrigation until the next day.

The waterquantity in the primary headcanal that runs until the second reservoir,is regulated by means of the level of this reservoir,the headpomps and the intermediate pompingstations,from the office of CODEVASF in the middle of the project by using walky-talkies.

Figure 2





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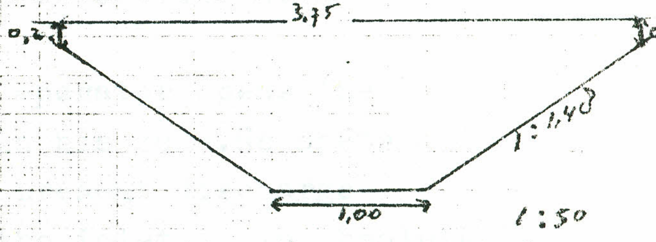

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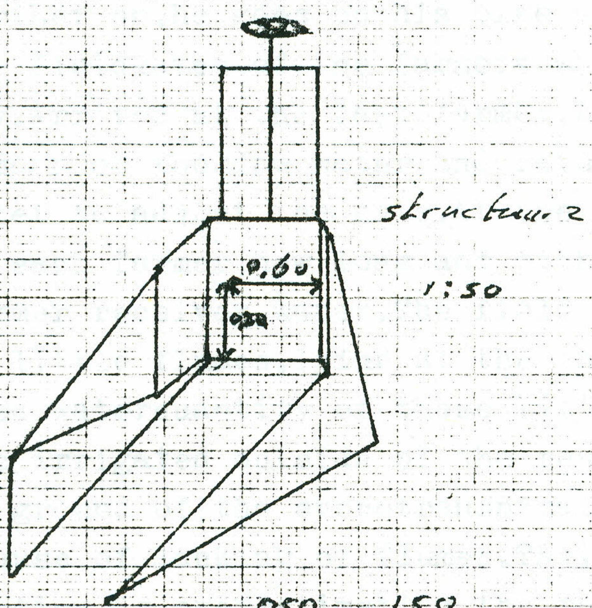

„Structuur 1 : $Q = R\, C_d\, C_v\, \frac{2}{3} \left(\frac{2}{3} g\right)^{0,50} \cdot b \cdot h_1^{1,50}$ $b = 2A + L$

"gieaudet weir

$R = 0,90$ voor

45° a 70°, $L \simeq 0,4$ m ; $\alpha = 69°$, $L \simeq 0,2$m

„Structuur 2 $Q = C_e \cdot A \cdot \sqrt{2 g h_1}$

"Orifice

$C_e = 0,61$?

The secondary distribution systeem Bebedouro-1

The distribution-systeem in Bd-1 on secondary level is an on-demand systeem with these restrictions that each farmer has three fixed days a week to irrigate and has a discharge of 35 l/s at his disposal.However,he can consider with the "canaleiro",the operator,who distributes the water in a zone,if he needs more water or on a next day to complete his irrigation.Look away from the transplantation-time of tomatoes,a couple of weeks a year,is the compliance with these request not a problem.

At 7 o'clock in the morning,the operator opens the inlet-gate of the secondary canal in his zone.He opens this out of experience,because the present discharge-equipment,located just after the inlet,is in absolute useless state.Further on,he goes on his bike along his canal to open the fieldgates of the farmers,who will irrigate that day.Arrived at the last farmer,he looks if there is too much or too few water and returns to the secondary inlet to adjust the gate.At the same time he notes down of each farmer,how long and with which discharge the farmer receives water.The field-discharge is measured with little flumes,lying at the entrance of each farm.The used waterquantity of those little pieces of land,which are irrigated outside of the real farm, is calculated on ground of the evopotranspiration time a cropfactor,because of lacking of flumes.They told me that this calculation is overestimeting the real used waterquantity,through which it is unattractive for the farmers to irrigate those pieces.Yet,it is obious that the independence is even more attractive.

The problems in a zone are:
First:that the farmers are willing to take more water than they really need,what can cause drainage problems.This is being countered through asking a higher waterprice by CODEVASF.
Second: through the absolute useless state of the discharge-measurementequipment,a constant headorifice outlet in the secondary canal,is it inpossible for the operator to work efficiently and there is not control on too huge losses through seepage.
Third: the farmers,whose piece of land is located at the tail-end of the canal,get their correct amount of water after the delay-time,caused by cycling of the operator.
Fourth: the noted discharges are probable higher than the real delivered discharges.This.because the notation of the discharges of each farmer happens early in the morning,before the operator has completed his regulations. And most of the time,he adjusts his inlet-gate first too high,in order to check the last farmer first and then he adjusts the secondary inlet-gate to its proper position.

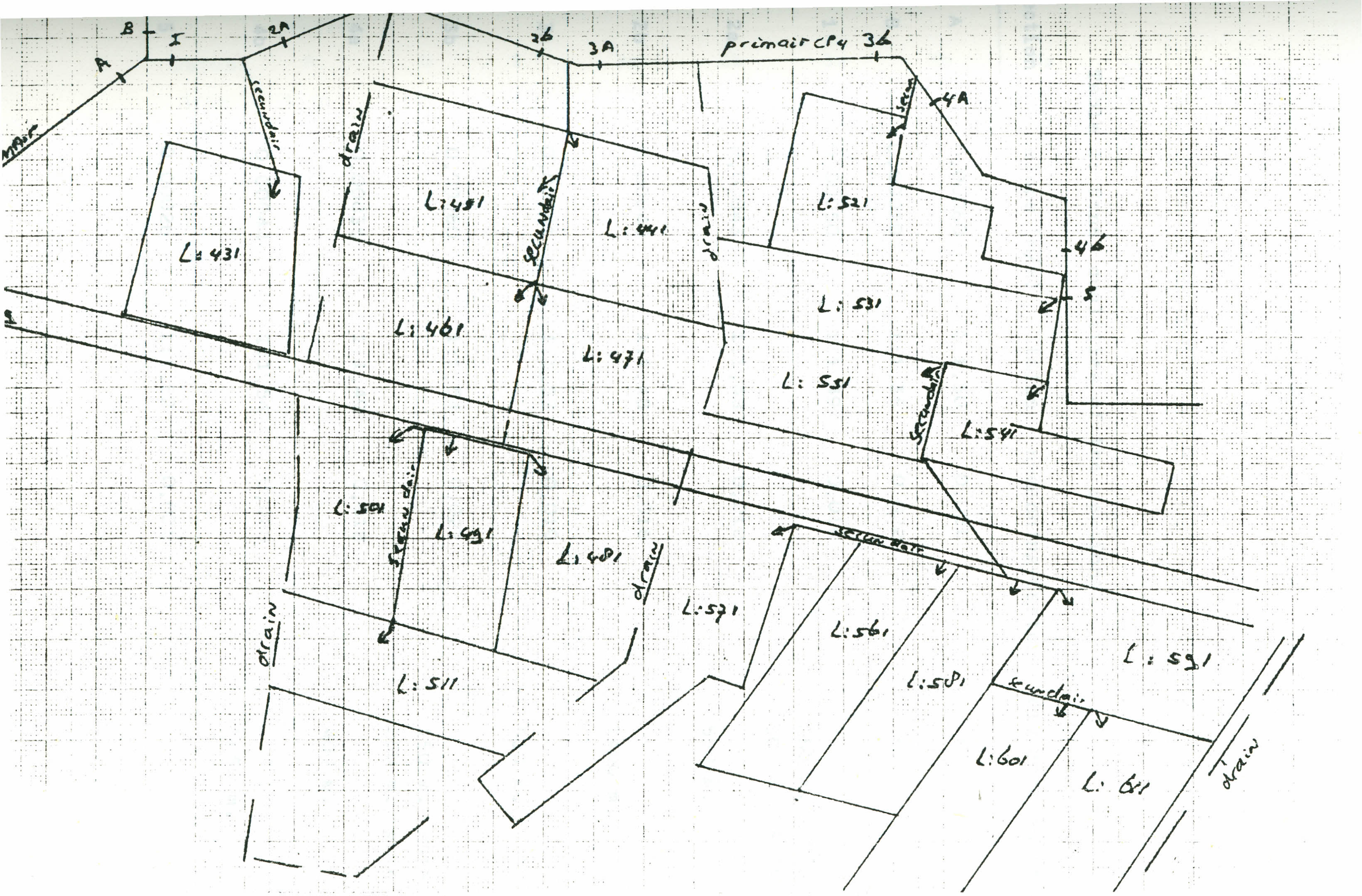

Figure 3: zone 2-B , scale 1:10.000

Table 1: Canal qualities of the sections

ection	slope (m/m)	talus	n=manning-factor	distance enter sections
A	0,00060	1:1,50	0,021	-
B	0,00018	1:1,35	0,022	-
1	0,00050	1:1,49	0,018	
				250 m. gate closed 500 m. gate open
2a	0,00043	1:1,48	0,018	
				550 m.
2b	0,00040	1:1,48	0,018	
				1400 m.
3a	0,00041	1:1,53	0,019	
				550 m.
3b	0,00060	1:1,54	0,022	
				150 m. gate closed 250 m. gate open
4a	0,00035	1:1,49	0,018	
				400 m.
4b	0,00044	1:1,54	0,020	
				1850 m.
5	0,00026	1:1,52	0,021	

	section																	
Datum	A	B	1		2a		2b		3a		3b		4a		4b		5	
18/08	1715	443	1269		1194		1165		927		882		803		778		497	Q_i
				75		29		238		45		79		25		281		V
				33		-		209		-		52		-		222		I
				84		53		21		81		108		62		32		V_l
				93		95		91		91		88		92		89		E
19/08	1650	296	1358		1300		1249		1078		1024		1015		972		694	Q_i
				58		51		171		54		9		43		277		V
				15		-		117		-		-		-		212		I
				86		93		39		98		60		107		35		V_l
				94		93		77		91		94		89		87		E
04/09	1510	215	1275		1266		1216		1045		1003		993		973		763	Q_i
				9		50		171		42		10		20		210		V
				-		-		138		-		-		-		68		I
				36		90		24		76		67		50		77		V_l
				97		93		86		93		93		95		63		E
05/09	1635	375	1251		1171		1146		920		887		811		774		621	Q_i
				80		25		226		33		76		37		153		V
				41		-		165		-		52		-		109		I
				78		46		44		61		96		92		24		V_l
				94		96		80		93		89		89		84		E
08/09	1652	443	1209		1137		1117		879		851		843		808		520	Q_i
				72		20		238		28		11		35		288		V
				33		-		205		-		-		-		238		I
				78		37		24		52		73		87		27		V_l
				93		97		90		94		91		90		91		E

Q_i = Volume, measured in section i in l/s

V = Losses between two sections in l/s

I = Irrigation in l/s

V_i = Lossses per km. in l/s per km.

E = Efficiency in %

3.4: CONCLUSIONS

The structure,a constant head orifice outlet,present in each secondary canal,ought to be restored to facilitate the task of the operator,to deliver the discharges asked by the farmers sooner and to make it possible to measure the amount of water in the secondary canal.

An average manning-factor (N) of 0,020 for a with concrete plates clothed canal (normaly a manning-factor of o,014) is far too high.In order to get a higher capacity the canals,as well the upstream-control structures,which because of their construction,silt up very quickly,ought to be cleaned more frequently.

The average transport-efficiency,calculated by means of

$E = (1 - V_1/Q_i) \times 100$,

in which

E = transport-efficiency in %
V_1 = seepage-losses in l/s,lost between two sections per km. canallength
Q_i = discharge in l/s of the upstream section

$E_{\text{primary canal}} = 93\ \%$
$E_{\text{secondary canal}} = 84\ \%$

It deserves the recommondation to execute a research towards the fluctuations of the delivered discharges and at the same time to check if the exactly measured amount corresponds with the amount ,calculated by the operator.Because this amount is calculated by measuring only twice a day the field-discharges and multiplies the average of these two with the duration of the irrigation.

3.5: LITERATURE

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4.1: RESEARCH 2: PLAN

The plan of this research was to discover if it is possible to prevent the apperent salt- and drainage problems in the project Bebedouro-1 by means of good watermanagement.Some farmers would be regulary followed during one planting season in their irrigation-management. Also would there be taken groundsamples in the fields to check the salt- and moisture percentage.Some correlations would be carried out to see if there existed a relation between the way of irrigating and the salt-content in the soil,as well between the way of irrigating and the efficiency on fieldlevel.By doing so,it could be possible to suggest a better way of irrigating towards the farmer.

4.2: WORKING METHOD AND JUSTIFICATION

To find a coherence between irrigation-management and salt-percentage,five farmers have been selected, based on facts of 1985 in which appeared that they had salt problems.Just because of these problems,the farmers had left uncultived that piece of land,where that specified groundsample had been taken.But with the expectation that the adjacent piece of land would as well contain a high salt-content,I decided to direct the research at those pieces of land.By each farmer,several points were spreaded over the fields,where I tryed to take ground-samples each week to determine the salt- and moisture percentage.

At the same time,I tryed to collect irrigation performences as much as possible.What,because the farmers were irrigating often at the same time and other organizing problems has,unfortunately,not succeded completly.After a while,it appeared that following five farmers was far too much.So I had to decide to eonfine the research to three farmers,through which it became easier but took away the possiblities to correlate factors such as : slope of the fields,furrow-length etc. with the irrigation efficiency of the different farmers.

Unfortunately,it was inpossible to change the way of irrigating throughout the season,because the results of the laboratory of soils were only known after 8 à 10 weeks.

Afterwards,only correlations between irrigation-management and irrigation-efficiency have been made, because the founded salt-percentages were very low and didn't change during the season nor differed between the farmers.

4.3: MATERIALS AND METHODS

Soil- and plantdata

Percentage of moisture and electrical conductivity (EC): These were determined of disturbed soilsamples,taken at 0-30,30-60,60-90 cm. beneath surface at 20 cm. distance from the furrow at the points,indicated in figure 4.On two points;point 22,point 24,was the sublayer in such a stony way that at those points some soilsamples are lacking.The electrical conductivity of the moisture-abstraction at 25 °C of disturbed soilsamples has been determined in the soil-laboratory.

The rooting depth of the crops has been based on earlier published papers on rooting depth of these crops in the project Bebedouro.

The crop-coefficient,kc',a coefficient necessary on determining the actual evopotranspiration,has been choosen out of earlier publications,because it appeared that the crop-coefficients ,such as given in the FAO paper 24 (Doornebos,Pruitt) were not directly emploing in combination with the evoporation,such as measured with a class-A evaporationpan here in the project.

The hydralic conductivity,k, was determined in the field,while making use of the augerhole-method,where

$$k = c \times (h_n - h_1)/(t_n - t_1) \qquad \text{(m/day)}$$

and the inverse augerhole-method,where

$$k = 1{,}15 \times r \times (\log(h_1 + \tfrac{1}{2}r) - \log(h_n + \tfrac{1}{2}r))/t_n - t_1 = 1{,}15 \times r \times \tan\alpha \qquad \text{(cm/s)}$$

Not all points were measured,because the sublayer at some points was too stony or because,while drilling,the walls became smeared in such a way that the measured hydralic conductivity was not longer reliable.

The bulk density, wilting point(15 atm.), field capacity (1/3 atm.) and texture:
These were all determined on disturbed soilsamples in the soil-laboratory and averaged on the present drill-points in the field.

Irrigation-data

The irrigation-performance was checked by taking 9 soilsamples in the furrow at 1/4,2/4,3/4 of the furrow-length on depth;0-20,20-40,40-60 cm beneath surface before irrigation,as well 9 soilsamples after irrigation.These values were averaged upon a value (D3),of which I pressume that it represents the maximal moisture-increase in the moisture profile.The advance-time was noted at 1/4,2/4, 3/4 of the furrow-length,as well were noted data necessary for the calculation of inlet-discharge(main d'eau) and the outstream-discharge(run-off).Soilsamples,taking 10. 30,100 cm aside of the furrow to check the lateral moisture profile,only gave the result that the inaccuracy in determining the percentage of moisture in soilsamples was quiet large (9%).This inaccuracy is caused,because it is inpossible to take the samples on exact the same spot.

The main d'eau was checked every 15 min. by means of measuring the difference in height between the furrow and a straight plank with a water-level on it.And by measuring the difference in height between the water-level in the canal and the same straight plank.Afterwards appeared that the water-level was inaccuracy during a certain time and through that have these irrigation-data not been just used.The main d'eau was calculated by means of $Q = 60.000 \times 0{,}54 \times 3{,}14 \times r^2 \times (2 \times g \times h)^{\frac{1}{2}}$. (3)
in which

Q = main d'eau in l/min.
r = radius siphon in m.
h = difference in height between furrow and w.l. canal in m.
g = gravitation acceleration = 9,8 m/s^2

The run-off discharge was measured with the help of a WSC-flume.However,the calibration table to converse the measured heights into discharges,appeared to be not correct.Under field circumstances,thus a short furrow, covered with plastic,a siphon of which the discharges were known and by successievely measuring the heights in the flume,I have executed an own calibration.

R = advance ratio number,is the ratio of the advance-time and the total irrigation-time.According to literature a ratio of 1:4 is the optimum for the best performance in furrow irrigation.

The advance-curve shows the way of the water through the furrow as a function of time and corresponds with the equation:

$$L = b \times t^a \qquad (4)$$

in which
L = advance-length in m.
t = advance-time in min.
b,a = constants

The constants a and b are to obtain by puting L against t on two-sides log paper,whereby b is being represented by the value at t = 1 min. and a is being represented by the slope of the grafic.

The infiltration

The infiltration-discharge curve represents the infiltration-discharge as a function of time and corresponds with the equation:

$$I = k \times t^{n} \qquad (5)$$

in which

I = infiltration-discharge in l/min/furrowlength

t = averaged infiltration-time in min.

k,n = constants

The constants k,n are to obtain by puting I against t on two-side log-paper,whereby k is being represented by the value at t = 1 min and n is being represented by the slope of the grafic.n has always a value between 0 and -1.

Out of (5) the infiltration-velocity is deduced:

$$i = k \times l^{-1} \times B^{-1} \times t^{n} \qquad (6)$$

in which

i = infiltration-velocity in mm/min.

l = furrow length in m.

B = furrow width in m.

The cumulative infiltration-depth is then the intergration of this (6) function and well:

$$D(B) = k \times l^{-1} \times B^{-1} \times (n+1)^{-1} \times t^{(n+1)} \qquad (7)$$

in which

$D(B)$ = cumulative infiltration in mm.

To obtain the averaged infiltration-depth (D2),you fill in the averaged infiltration-time in equation (7).

At the same time,you get an averaged infiltration-depth by means of:

$$D1 = V_i - V_r/l \times B \qquad (8)$$

in which

$D1$ = averaged infiltration in mm.

V_i = main d'eau in l.

V_r = run-off volume in l.

Theoretical,are D1 and D2 equal but through inaccuracy during measuring,is there always a difference between these two values.

Starting from the average of these two values,it seems to me that this averaged value is only functional in case the furrow-width is small(f.e. smaller than 80 cm.) or the time of irrigation is quiet large,because only in these cases the amount of infiltrated water can spread well-balanced over the furrow-width,so that this infiltration value is in direct relation with the actual evopotranspiration-values.

For determining the water-balanses,I had to know,how much water had infiltrated in the point,where the soil-samples for determining the moisture-percentage were taken. For that,I assume that the infiltrated water spreads itself in a half-eliptic way with the amount of water, measured by means of the soilsamples before and after irrigation in the middle of the furrow(D3),as the half-longitudinal of the elips.And that the area of the half-elips corresponds with the calculated averaged infiltration depth out of formulae (7) and (8),is the averaged value of D1 and D2,multiplies with the furrow width,as such:

$$\tfrac{1}{2} \times 3{,}14 \times S \times D3 = B \times \overline{D1D2} \qquad (9)$$

in which

S = half width-axle of the elips,in other words, the one-side lateral spreading in m.

D3 = the half length-axle of the elips = the maximal moisture-increase in the infiltration pattern in mm.

and the eliptic figure:

$$x^2/S^2 + y^2/D3^2 = 1 \qquad (10)$$

in which

x = the distance to the middle of the furrow in m.

y = the infiltration-depth at x in mm.

x is the distance to the middle of the furrow and in my case,the soilsamples were taken 20 cm from the middle.With this value filled in (10),I have calculated y,of which I assume it is the infiltration-depth.

With this,it is possible to calculate an adjusted cumulative infiltration-curve and well:

$$y = k' \times t^{(n + 1)} \qquad (11)$$

in which

y = cum. infiltration-depth in mm.

n = constant out of the infiltration-curve

k' = constant = $y/T_i^{(n + 1)}$

in which

T_i = averaged infiltration-time

Efficiencies

E = percentage run-off: is the ratio of the cumulative amount of run-off and the total amount of irrigation-water

DU = distribution-efficiency in procents: is the ratio of the minimal infiltration-depth and the averaged infiltration-depth along the furrow.

P = percentage percolation: is the ratio of the amount of percolation and the total amount of infiltrated water.

O = an overall-efficiency: is the product of E,DU and P and well:

$$O = \frac{(100 - E)}{100} \times \frac{DU}{100} \times \frac{(100 - P)}{100} \times 100 = \qquad \% \qquad (12)$$

The waterbalances

The irrigation-gift was calculated by (11),gives the value y.For data,which are lacking,was used an average of the other data.The evopotranspiration-losses were calculated according to

$$E_a = kc' \times E_t \qquad (13)$$

in which

E_a = actual evopotranspiration in mm/day
kc' = crop co-efficient
E_t = evaporation,here in the project Bd.,measured with a class-A evaporation-pan.

The moisture percentage for each layer is the average of the moisture percentage of the present drilling points.

The effective rainfall is the measured amount of rainfall multiplied with a factor 0,75 (FAO-paper 25).

4.4: RESULTS

The average salt percentage:
EC (Augostino) = 0,74 mmhos/cm.
EC (Ivanildo) = 0,76 mmhos/cm.
EC (Messias) = 1,03 mmhos/cm.
(see figure 10)

These values are the average values of the found salt-percentage in the layer 0-90cm. during the period 8 april-15 july,so during the whole growing season of the crops.The values are,according to the USDA handbook 60,in the class in which the salt effects on the production of the crops are negligible.

The average advance-curve:
Augostino: $L_g = 10,9\ t^{0,66}$ (t in min.)
Ivanildo; $L_g = 11,7\ t^{0,58}$ (t in min.)
Messias: $L_g = 7,8\ t^{0,71}$ (t in min.)
(see figure 11)

The differences between these curves are presumable caused by the state of weed-growing in the furrow and to a lesser extent by the slope of the fields.The data,however,are insufficient to say something about it with enough certainty.

The average infiltration-curve:
Ivanildo: $I_g = 109\ t^{-0,43}$ l/min/furrow-length
Augostino: $I_g = 171\ t^{-0.48}$ l/min/furrow-length
Messias: $I_g = 106\ t^{-0.49}$ l/min/furrow-length
(see figure 12)

The average cumulative infiltration-curve:

Augostino: $y_g = 4,0\ t^{0,52}$ mm. (t in min.)

Ivanildo: $y_g = 2,8\ t^{0,57}$ mm. (t in min.)

Messias: $y_g = 2,8\ t^{0,51}$ mm. (t in min.)

(see figure 12)

Efficiency

The average run-off (E) was:

Augostino: $(E_g) = 21\%$

Ivanildo: $(E_g) = 25\%$

Messias: $(E_g) = 25\%$

The average distribution efficiency (DU) was:

Augostino: $(DU_g) = 81\%$

Ivanildo: $(DU_g) = 77\%$

Messias: $(DU_g) = 82\%$

The average percolation (P) was:

Augostino: $(P_g) = 27\% = 0,9$ mm/day

Ivanildo: $(P_g) = 44\% = 1.3$ mm/day

Messias: $(P_g) = 43\% = 1,7$ mm/day

The average percolation-losses of Augostino are lower because his practiced irrigation-interval was longer compared to that of the other farmers.

The average overall-efficiency (O) was:

Augostino: $(O_g) = 46\%$

Ivanildo: $(O_g) = 32\%$

Messias: $(O_g) = 36\%$

The relative high overall-efficiency of Augostino was mainly caused by his relative low percolation-losses.

Correlations

The following relations appeared to show good correlations:

Between "b" (constant in the advance-curve function: $L = b\ t^a$) and the initial moisture percentage "H" and well:

$b = 0,89\ H + 0,21$ (see figure 13)

In other words, if the initial moisture percentage just before irrigation is higher, then the water will flow faster through the furrow.

Between "E" (run-off percentage) and "R" (ratio advance-number) and well:

$E = 43,9 \log R + 32,9$ (see figure 14)

In other words, if R approach to zero, than the percentage run-off will also approach to zero. If you want to reduce the run-off losses then you have to reduce the run-off period or enlarge the advance-time. To obtain a run-off percentage of 10%, you need a R smaller than o,30.

Between "DU" (moisture-distribution efficiency) and "R" (ratio advance-number) and well:

$DU = 31,7 \log R + 87,1$ (see figure 15)

Here, the relation is the other way around, to obtain a good distribution along the furrow, a high DU-value, you need a high R-value, so a long irrigation-period and/of a short advance-time. For a distribution-percentage of better than 90%, you need a R-value of 1,23 or more.

Between "P" (percentage percolation) and "R" (ratio advance-number) and well:

$P = 18,1\ R + 19$ (see figure 16)

Just as the relation between run-off losses and R,you get more percolation if R is higher.But you get,even if R is reduced to zero,a percolation-loss of 19%.

And between "O" (overall efficiency) and "R" (ratio advance-number) and well:

$$O = 2{,}05\ R \log^2 R - 1{,}40 \log^2 R + 3{,}11\ R \log R - 14{,}00 \log R - 10{,}61\ R + 47{,}76$$ (see figure 17)

This relation shows a grafic,which shows for a R-value 0 till 0,20 a rising leg and for a R-value 0,20 to ∞ a falling leg.The maximum value for "O" is 50% with a R-value of 0,20.A maximum value of 50% is quiet low and is mainly due to the high percolation-losses,which inplies that the soils are not suitable enough for furrow irrigation.

4.5: CONCLUSION

The moisture percentage

The initial moisture percentage,just before irrigation, was in all cases,exept in the case of Ivanildo,crop watermelon,much too high.This shall be the main cause for the large percolation losses (average 38%) of these farmers. The big problem,however,is that the level of field-capacity is very low,through which it is for the farmers very difficult to guess when the irrigation should be taken place.A little test,executed with soil samples (depth 0-20 cm.)with different moisture percentages to see if it possible,by means of moisture prints on journal-paper,to give an indication for the farmers,appeared to give a not good enough result.There were cleary visible moisture-prints from 10% moisture-percentage,while an appearance of about 8% would be suitable.

The salt-content

Due to the excess of irrigation-water of good kwality (EC: 0,08 mmhos/cm) stayed the salt-content probably very low.Also the raising of the pheartic-level up to 60-90 cm below surface,caused by the excess of percolation, didn't influence the salt-content of the investigated fields.Yet,there are clearly visible salt-problems in this project.Presumeble,this salt is from a goegenetic nature and are the problems not caused directly through irrigation.Even so,through the excess of percolation-water,it could be possible that the raising ground-water has brought up salt-accumulations from deep layers.

The water-management

The main d'eau

The maximal non-erosive main d'eau is according to the formule: $Q_{max} = 0,63 : s$ (in l/min,in which s = slope in %).
The furrow-slope of Messias and Ivanildo was 0,9% and that of Augostino was 0,4%.
So the maximal main d'eau could have been:
Q_{max} (Ivanildo,Messias) = 42 l/min.
Q_{max} (Augostino) = 94,5 l/min.
There was irrigated by Ivanildo&Messias with a main d'eau of Q_g = 39,5 l/min average and by Augostino with a main d'eau of Q_g = 47,5 l/min.
Since there were not found any good correlations between main d'eau (Q) and efficiency or between main d'eau (Q) and advance-time (T_a) and the fact that it is inpossible for farmers to know exactly their main d'eau,it is very difficult and useless to recommend one.If the farmer thinks that there should be more water on the field then he asks for more water and irrigates with more than one siphon rather than enlarging the time of irrigation. Esteemed the correlations.this seems to me the right way of acting.

The time of irrigation

Esteemed the correlations between efficiency and the ratio advance-number (R),it is to recommend to apply a R-value of 0,20.By doing so,one obtains:

$R = 0{,}20$

A distribution-efficiency (DU) = 65%
A run-off (E) = 2%
A percolation (P) = 23%
A overall-efficiency (O) = 50%

Certainly,seeing the problems in this project,which are caused by the excess of water to be drained,the abovementioned R is recommended,although the distribution along the furrow will be quiet bad.

With an average advance-curve of:

$$L = 10{,}1\ t^{0{,}65}\ \text{m/min.}$$

and an average furrow-length of about 90 meter,one gets an average advance-time of 29min..A R-value of 0,20 gives a total irrigation-time of 35min.These 6 min is approximaly the recession-time,so it is to recommend to stop the irrigation when the water has reached the end of the furrow. Suppose an average infiltration-time (T_i) of 30 min. and an average infiltration-curve of:

$$y_g = 3{,}2\ t^{0{,}53}\ \text{mm/min.}$$

then there will infiltrate,with this T_i,about 19,4 mm. of which 4,5 mm will be lost through percolation,so ± 15 mm. is the effective irrigation-gift.With an evopotranspiration of 6-9 mm/day multiplies with the crop-coefficient,kc' 0,44 for tomato and water-melon,the actual evopotranspiration will be 2,6-4 mm/day.So an irrigation-interval of 5 till 6 days will be enough.

4.6: LITERATURE

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4.7: CONTENTS SUPPLEMENTS

Figure 4: Lay-out of the fields, drilling points

scale 1:2.000

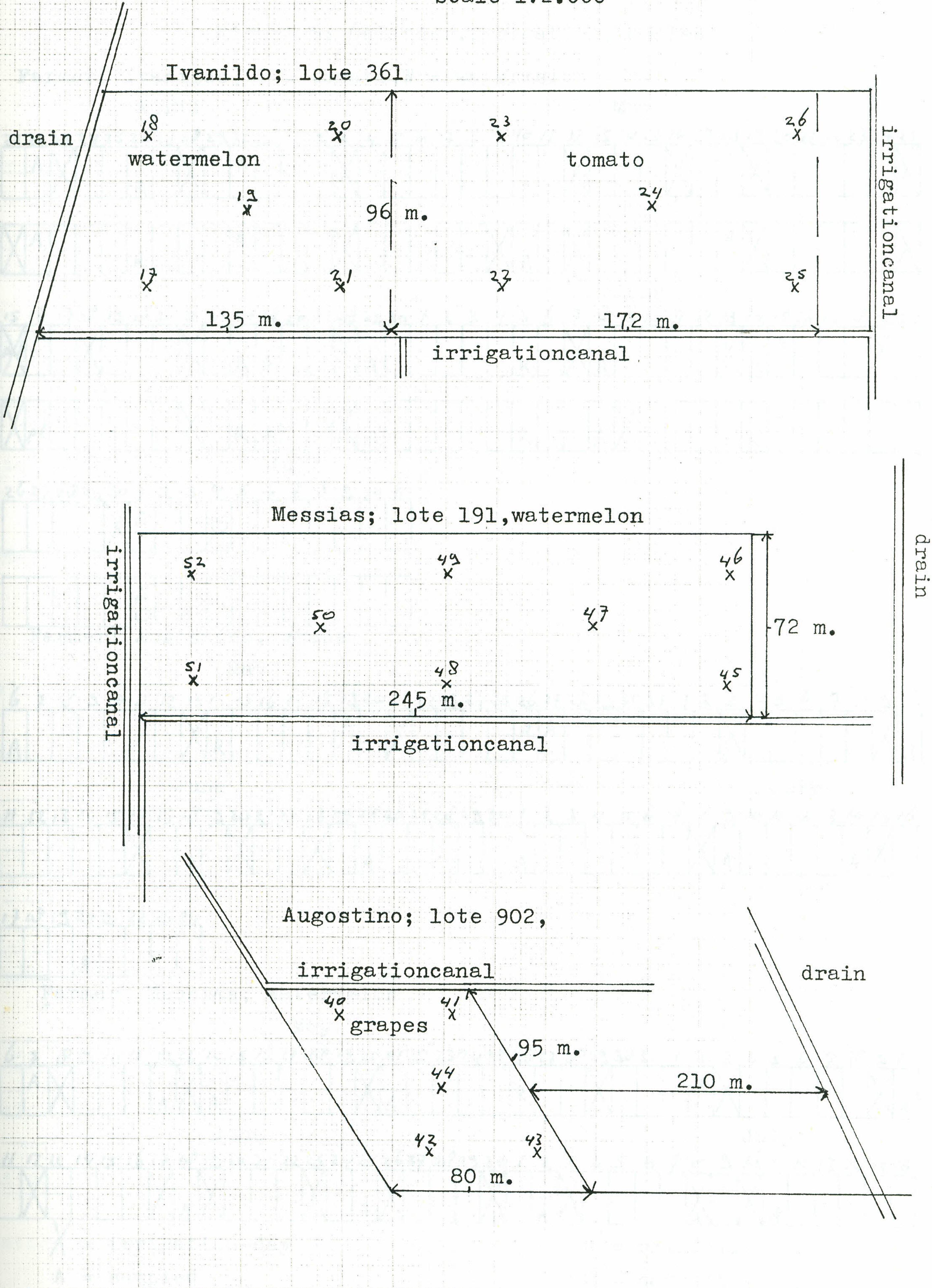


Figure 5: Calender,irrigation,sampled

Farmer: Ivanildo, T = tomato,W = watermelon

April May

	21	22	23	24	25	26	27	28	29	30	31	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
T		A	X			R		X		A				X							A		X				X		A	X						X
W	X	A				R				A				X						X	A		X						A	X						X

June

	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
T	X Al			X				X		R	A			X	A						R		X	A					X	R	A				X	
W	X	pl						X		R	A			X	A						R			A	X					R	A					

July

	26	27	28	29	30	1	2	3	4	5	6	7	8	9	10	11
T					X	A			O							
W						A O										

Farmer: Augostino, grapes

May

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	1	2	3	4	5	6	7	8	9	10
A							X	R					A		X					R	A							X						X	A

June July

11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
					X		A		X			X		A						A							X	A					A	X	

17	18	19	20	21	22	23	24
			A				

Farmer: Messias, watermelon

May

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	1	2	3	4	5	6	7	8	9	10
	A	X				A	X	R						X	A					R			X				A	X						X	A

June July

11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
	X					X	A	X				X		A	X				X A		A	X					X A		X	A					

X = irrigation-day

A = sampled

pl = planting

R = rainfall

O = harvest

Table 3: General facts

farmer	crop	sowing-date	harvest	sowing-seed kg/ha	productivity kg/ha
ivanildo	watermelon	16/04/'86	07/07/'86	1,1	7515,4
ivanildo	tomato	15/04/'86	04/07/'86	0,27	23289,5
Augostino	grapes	-	-	-	-
Messias	watermelon	25/04/'86	18/07/'86	1,1	8812,5

farmer	area ha.	furrow slope %	plant distance m.	furrow length m.	furrow width m.
ivanildo	1,30	0,89	0,70	96	3,00
ivanildo	1,65	0,96	0,80	96	1,10
Augostino	0,75	0,40	3,00	95	2,00&1,40
Messias	1,76	0,90	0,80	72	3,75

farmer	irrigation interval days	fertilizer kg/ha	rooting-depth cm.	crop-factor kc'
ivanildo	7	62,formula 21, urea	60 - 75	0,44
ivanildo	5	163,formula	30 - 60	0,44
Augostino	8	-	90 -150	0,39
Messias	5	185,formula 57,urea	60-75	0,44

Table 4: Soil-data

Ivanildo, point 17 until 21

depth (cm)		0-30	30-60	60-90
texture in %	sand	82	74	66
	silt	12	12	12
	clay	6	14	22
bulk density (g/cm^3)		1,53	1,57	1,55
fieldcapacity in %		10,10	11,84	13,75
wiltingpoint in %		4,86	5,97	7,45
moisture-capacity (mm)		24,1	27,6	29,3

Ivanildo, point 22 until 26

depth (cm)		0-30	30-60	60-90
texture in %	sand	79	72	68
	silt	11	13	10
	clay	10	15	22
bulk density (g/cm^3)		1,53	1,51	1,49
fieldcapacity in %		8,78	14,11	17,86
wiltingpoint in %		4,72	8,03	10,19
moisture-capacity (mm)		18,6	27,5	34,3

Table 4: Soil-data

Augustino, point 40 until 44

depth (cm)		0-30	30-60	60-90
texture in %	sand	79	78	71
	silt	7	6	6
	clay	14	16	23
bulk density (g/cm^3)		1,48	1,57	1,54
fieldcapacity in %		5,46	10,60	14,75
wiltingpoint in %		3,11	5,73	7,92
moisture-capacity (mm)		10,4	22,9	31,6

Messias,point 45 until 52

depth (cm)		0-30	30-60	60-90
texture in %	sand	87	82	73
	silt	7	7	8
	clay	6	11	19
bulk density (g/cm^3)		1,55	1,55	1,55
fieldcapacity in %		5,32	8,00	11,78
wiltingpoint in %		2,54	3,86	5,60
moisture-capacity (mm)		12,9	19,2	28,7

Table 5: Irrigation-data

DATA	COLONO	Q	dh	Ø	Vi	Vr	Vinf	Ta	To	Ti	R	L
20.05.86	Messias	45,3	10,6	3,5	951,3	133,5	817,8	14	21	22	1: 0,5	$9,2\ t^{0,79}$
29.05.86	Messias	38,1	9,5	4,0	1646,7	244,0	1402,7	31	47	37	1: 0,52	$7.5\ t^{0,66}$
03.06.86	Messias	28,4	7,8	3,0	2086,7	99,6	1987,1	58	73	44	1: 0,26	$5,5\ t^{0,64}$
26.06.86	Messias	31,6	11,2	2,9	2292,0	658,2	1633,8	20	70	65	1: 2,50	$8,8\ t^{0,70}$
30.06.86	Messias	43,2	18,0	3,0	3134,4	1062,9	2071,5	16	62	57	1: 2,88	$9,6\ t^{0,72}$
03.07.86	Messias	40,7	7,8	3,6	2502,8	1293,0	1209,8	17	61	57	1: 2,59	$8,2\ t^{0,74}$
10.07.86	Messias	20,1	6,5	3,0	915,9	148,2	767,7	32	46	25	1: 0,4	$5,5\ t^{0,74}$
13.05.86	Agostinho	45,0	17,0	2x2,2	3285,0	1449,0	1836,0	29	73	65	1: 1,52	- -
21.05.86	Agostinho	63,8	15,2	3X2,2	2623,4	699,0	1923,4	27	42	32	1: 0,55	$12,0\ t^{0,64}$
08.07.86	Agostinho	44,9	8,7	2;3;2,9	2514,4	261,0	2253,4	36	56	44	1: 0,56	$14,0\ t^{0,53}$
15.07.86	Agostinho	36,2	4,5	2,5;3,0	3185,6	167,6	3018,0	73	88	62	1: 0,29	$9,1\ t^{0,58}$
09.05.86	Ivanildo	49,7	6,0	2x3,0	3185,6	197,4	3232,2	54	69	47	1: 0,28	- -
23.05.86	Ivanildo	78,5	15,0	2x3,0	3532,5	633,1	2899,4	31	45	34	1: 0,45	$9,6\ t^{0,68}$
28.05.86	Ivanildo	29,0	8,2	3,0	987,0	152,4	834,6	26	34	30	1: 0,31	$13\ t^{0,62}$
12.06.86	Ivanildo	27,0	7,0	3,0	1026,0	303,6	722,4	23	38	31	1: 0,65	$11\ t^{0,69}$
25.06.86	Ivanildo	43,0	18,0	3,0	2408,0	839,4	1568,6	31	56	47	1: 0,80	$10\ t^{0,67}$

Q = main d'eau (l/min)
dh = pressure height siphon (cm)
Ø = diameter siphon (cm)
T_a = advance-time (min)
T_o = irrigation-time (min)
T_i = average infiltration-time (min)
R = ratio advance-number
L = advance-curve (m/min)
I = infiltration-curve (l/min/furrow)
D(B) = cumulative infiltration-curve on furrow-width (mm/min)
D(S) = adjusted cum. infiltration-curve (mm/min)
D1 = infiltrated water according to formule 8 (mm)
D2 = infiltrated water according to formule 7 (mm)
D3 = measured moisture-difference in the furrow (mm)
y = infiltrated water according to formule 11 (mm)
S = lateral moisture-spreading (cm)

I	D (B)	D'(S)	D 1	D 2	D 3	y	S	H	H - VP	E	DU	P	O
$97\ t^{-0,54}$	$0,8\ t^{0,46}$	$3,4\ t^{0,46}$	3,0	3,3	15,6	14,2	48	9,8	+ 3,1	14	95	20	65
$150\ t^{0,42}$	$1,0\ t^{0,59}$	$2,6\ t^{0,58}$	5,2	8,1	22,0	21,1	72	9,1	+ 2,5	15	78	36	42
$94\ t^{-0,40}$	$0,6\ t^{0,60}$	$2,2\ t^{0,60}$	7,4	5,8	21,7	20,9	72	9,2	+ 2,6	5	58	32	37
$70\ t^{-0,40}$	$0,4\ t^{0,60}$	$2,0\ t^{0,60}$	6,0	4,9	26,3	24,1	49	9,2	+ 2,6	29	93	63	24
$200\ t^{-0,64}$	$2,1\ t^{0,36}$	$4,8\ t^{0,36}$	7,7	9,0	21,1	20,8	94	9,5	+ 2,8	44	95	72	18
$77\ t^{-0,61}$	$0,7\ t^{0,39}$	$3,8\ t^{0,39}$	4,5	3,4	20,4	18,4	46	9,5	+ 2,8	52	94	66	20
$56\ t^{-0,42}$	$0,4\ t^{0,58}$	$1,0\ t^{0,58}$	2,8	2,6	6,9	6,7	93	9,2	+ 2,6	16	58	12	43
$277\ t^{-0,81}$	-	-	11,4	-	33,5	28,2	37	10,9	+ 2,9	44	98	39	34
$153\ t^{0,52}$	$2,0\ t^{0,48}$	$5,7\ t^{0,48}$	11,9	10,6	39,6	30,3	31	11.2	+ 3,2	27	78	21	45
$180\ t^{-0,48}$	$1,1\ t^{0,52}$	$2,8\ t^{0,52}$	7,0	7,9	20,8	20,1	77	11,3	+ 3,3	10	80	7	67
$180\ t^{-0,45}$	$1,0\ t^{0,55}$	$3,4\ t^{0,55}$	9,3	9,7	35,5	33,3	58	11,4	+ 3,4	5	67	28	46
$135\ t^{-0,35}$	$0,72t^{0,65}$	$1,8\ t^{0,65}$	11,2	8,8	22,1	21,8	86	11,9	+ 0,9	15	63	51	26
$205\ t^{-0,48}$	$3,7\ t^{0,52}$	$5,6\ t^{0,52}$	27,5	23,2	37,3	35,4	48	12,2	+ 0,8	18	76	35	41
$65\ t^{-0,40}$	$1,4\ t^{0,60}$	$2,4\ t^{0,60}$	7,9	9,9	18,6	16,6	30	14,3	+ 2,7	16	77	35	42
$40\ t^{-0,41}$	$0,7\ t^{0,59}$	$1,1\ t^{0,59}$	6,8	5,2	8,3	7,9	51	11,9	+ 0,5	51	82	0	40
$100\ t^{-0,50}$	$1,9\ t^{0,50}$	$3,0\ t^{0,50}$	14,8	13,1	22,0	20,7	44	12,1	+ 0,7	35	87	43	32

H = moisture-content in weightpercentage (%)
H-VP= Moisture-difference H and fieldcapacity (%)
E = percentage run-off (%)
DU = percentage moisture-spreading along the furrow (%)
P = percentage percolation (%)
O = percentage overall-efficiency (%)
Vi = delivered water-amount (l)
Vr = run-off (l)
Vinf= Vi - Vr (l)

Table 6: Waterbalance, Ivanildo

Ivanildo, tomato

DATA	08.05		15.05		22.05		30.05		10.06		18.06.		01.07	
I		21,8		+20,5		+52,0		+20,5		+28,4		51,5		194,7
E (044)		-19,5		-23,4		-22,2		-32,8		-24,9		-36,3		
V (0-30)	65,0	+ 8,3	56,7	+ 6,7	50,0	-12,0	62,0	+11,1	50,9	+ 5,3	45,6	- 3,8	49,4	
V (30-60)	66,0	+ 4,6	61,4	- 4,9	66,3	- 6,6	72,9	+ 8,1	64,8	- 4,5	69,3	+10,7	58,6	
V (0-60)	131,0	+ 2,9	118,1	+ 1,8	116,3	-18,6	134,9	+19,2	115,7	+ 0,8	114,9	+ 6,9	108,0	
V (60-90)	80,6	+ 9,9	70,7	- 5,9	75,9	- 2,3	78,2	+10,8	67,4	- 4,2	71,6	- 0,3	71,9	
Rainfall		+ 2,0				+14,0				+ 0,2		+ 0,3		
P (0-60)		+17,2		- 1,1*		+25,2		+ 6,9		+ 4,3		+22,4		76,1
P (60-90)		+ 9,9		- 5,9*		- 2,3		+10,8		- 4,2		- 0,3		
P_t		+27,1		- 7,0*		+22,9		+17,7		+ 0,1		+22,1		

Ivanildo, watermelon

I		+21,8		+34,4				+42,0		+21,0		+42,0		
E 0,44		-19,5		-23,4		-22,2		-32,8		-24,9		-36,3		
V (0-30)	53,3	+ 3,5	49,8	- 3,0	52,8	+13,3	39,5	-15,8	55,3	+20,1	35,2	- 1,2	36,4	
V (30-60)	59,4	+ 3,4	56,0	- 1,2	57,2	+ 6,6	50,6	- 5,3	55,9	- 3,9	59,8	+10,0	49,8	
V (0-60)	112,7	+ 6,9	105,8	- 4,2	110,0	+19,9	90,1	-21,1	111,2	+16,2	95,0	+ 8,8	86,2	
V (60-90)	61,0	+ 0,2	60,8	- 3,5	64,3	+ 2,2	62,1	- 5,2	67,3	- 4,3	71,6	+ 8,9	62,7	
Rainfall		+ 1,7				+14				+ 0,2		+ 0,3		
P (0-60)		+10,9		+ 6,8		+12,7		-11,9*		+12,5		+14,8		
P (60-90)		+ 0,2		- 3,5		+ 2,2		- 5,2		- 4,3		+ 8,9		
P_t		+11,1		+ 3,3		+14,9				+ 8,3		+23,7		
								-17,1*						

I = irrigation-gift in mm

E (kc') = Evaporation in mm

V = Moisture-content in mm

P = Percolation

Figure 6: Soil moisture-percentage (0-60)
Ivanildo,tomato

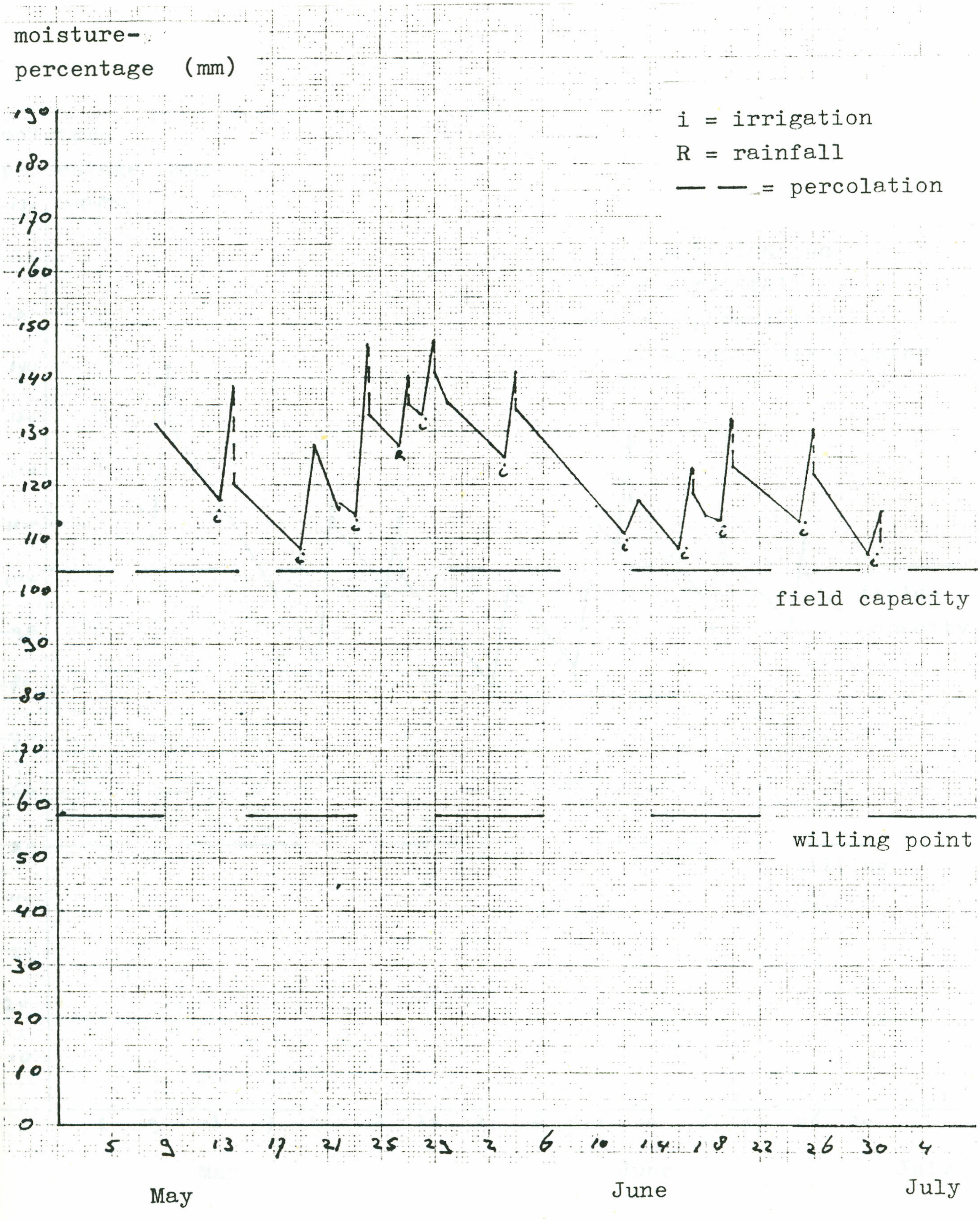
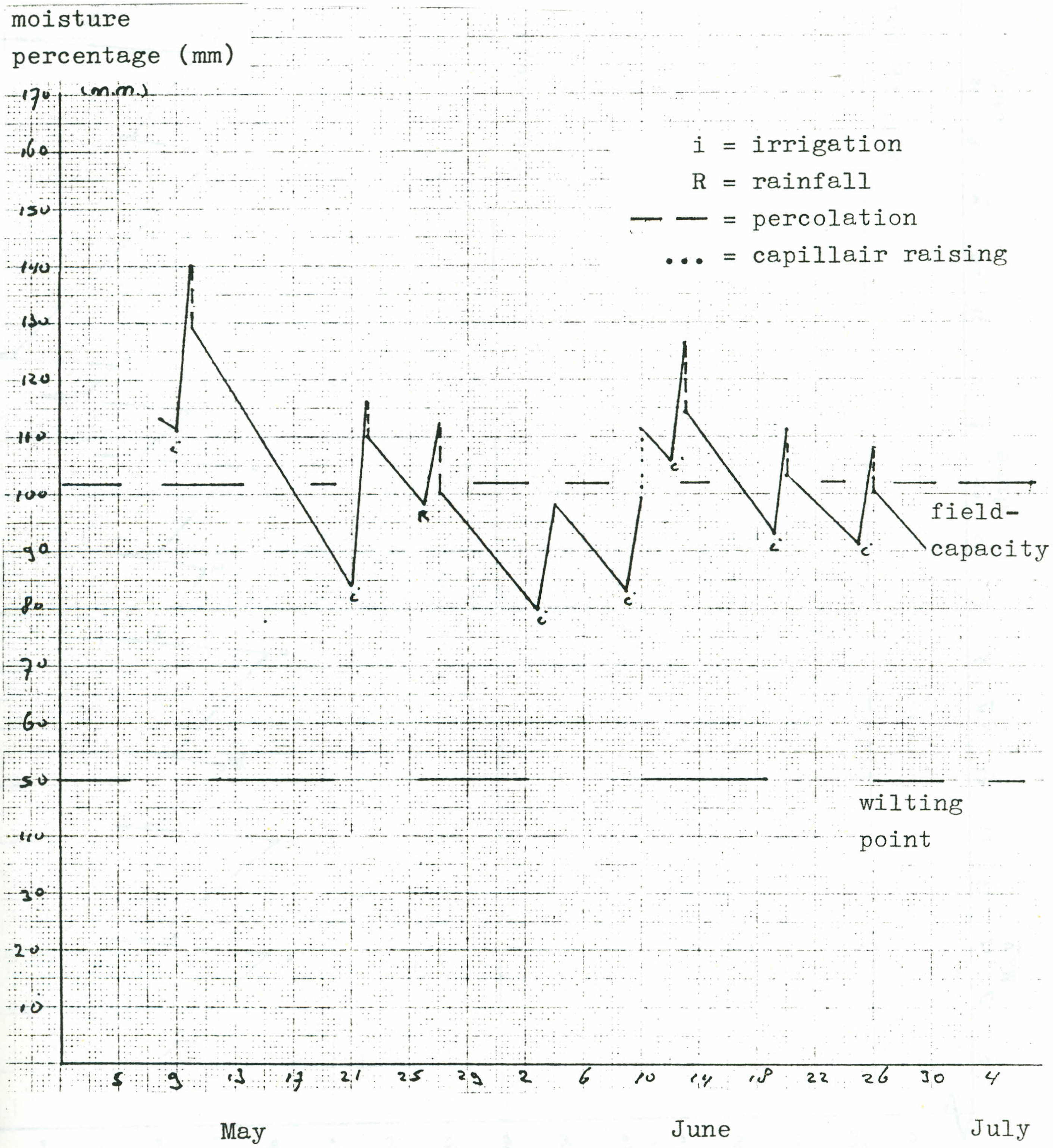


Figure 7: Soil moisture-percentage (0-60 cm.)
Ivanildo,watermelon



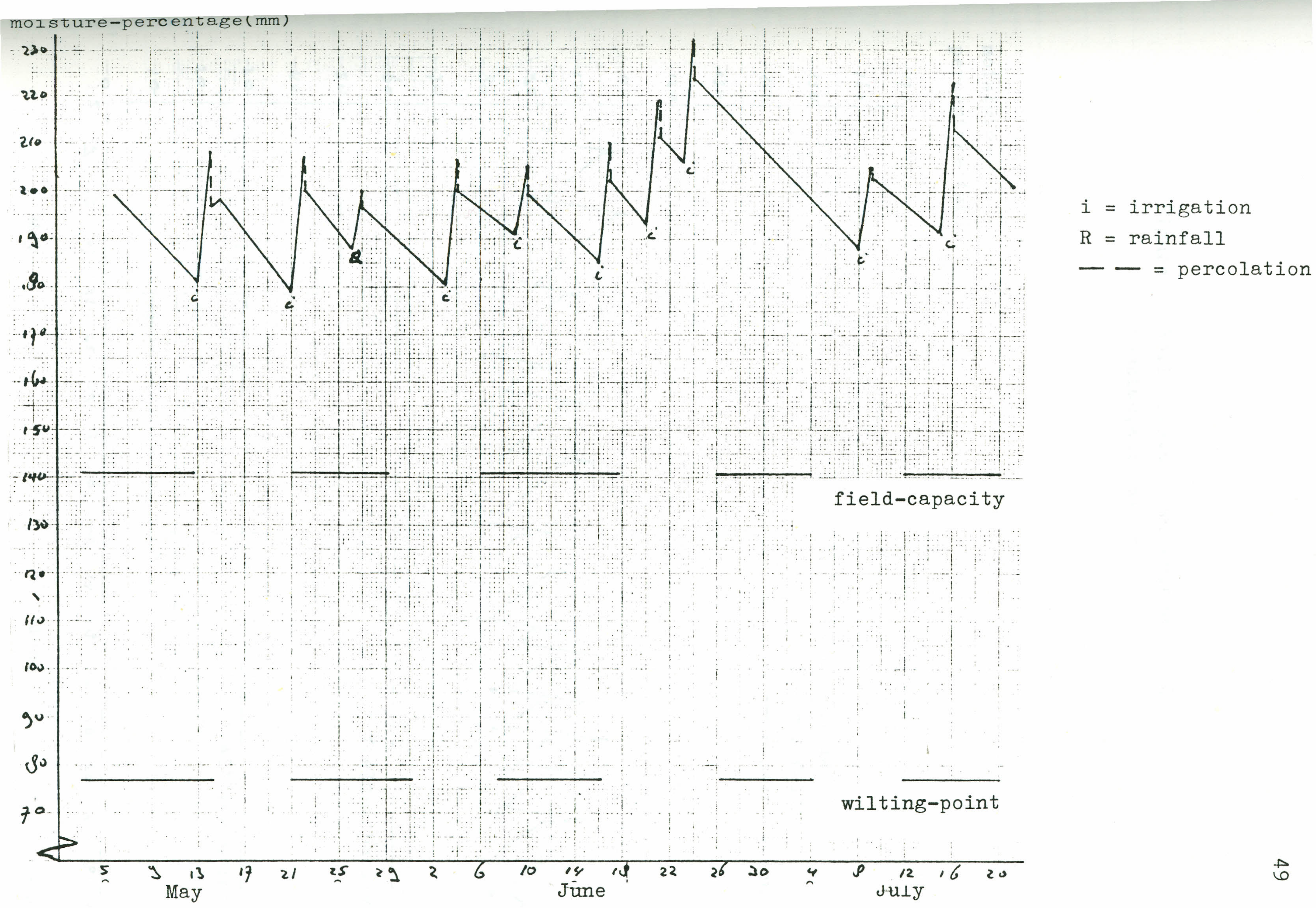
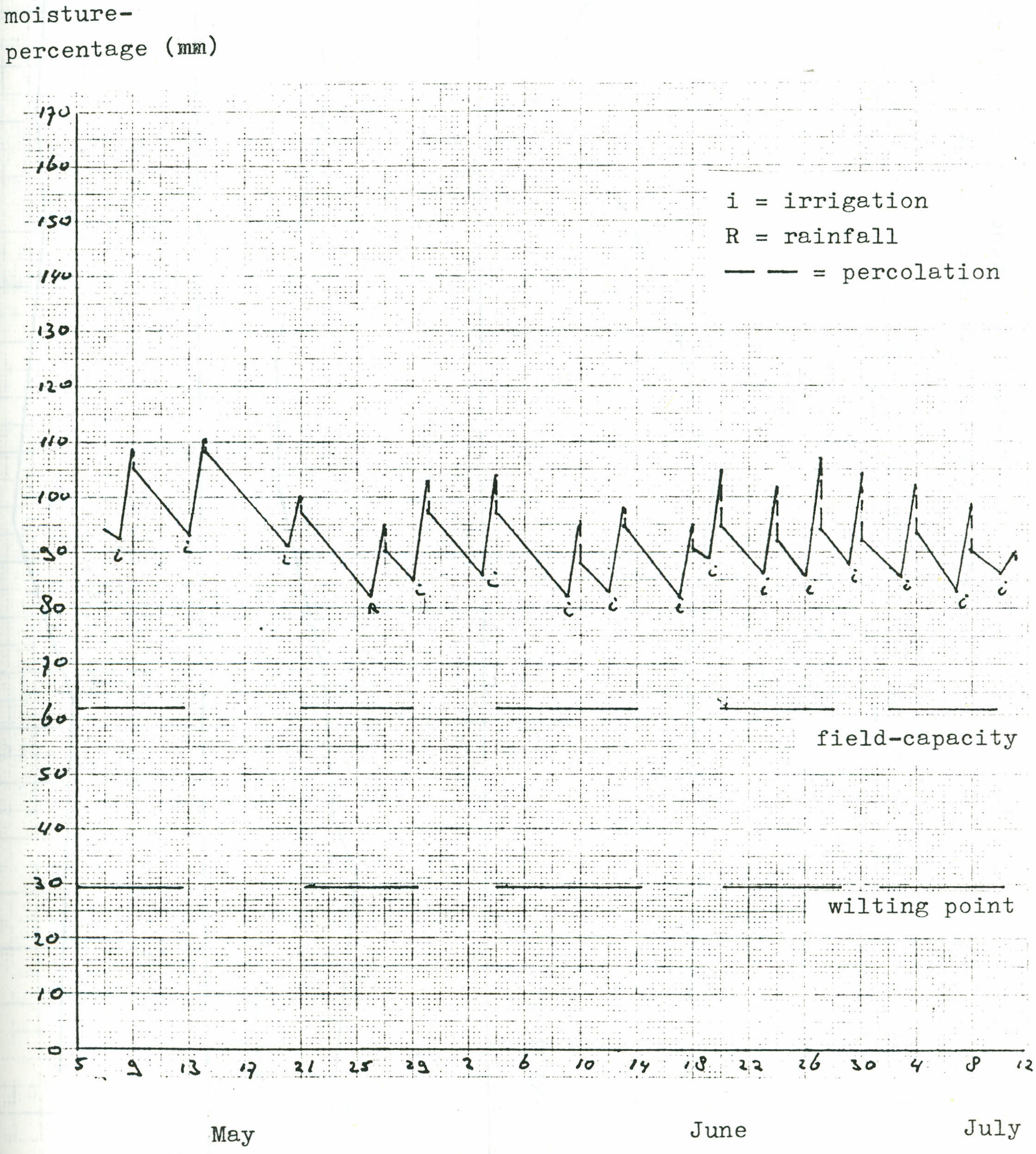

moisture-percentage(mm)
230
220
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
5
9
13
17
21
25
29
2
6
10
14
18
22
26
30
4
8
12
16
20
May
June
July
field-capacity
wilting-point
i
R
i = irrigation
R = rainfall
— — = percolation

Figure 9: Soil moisture-percentage (0-60)
Messias,watermelon



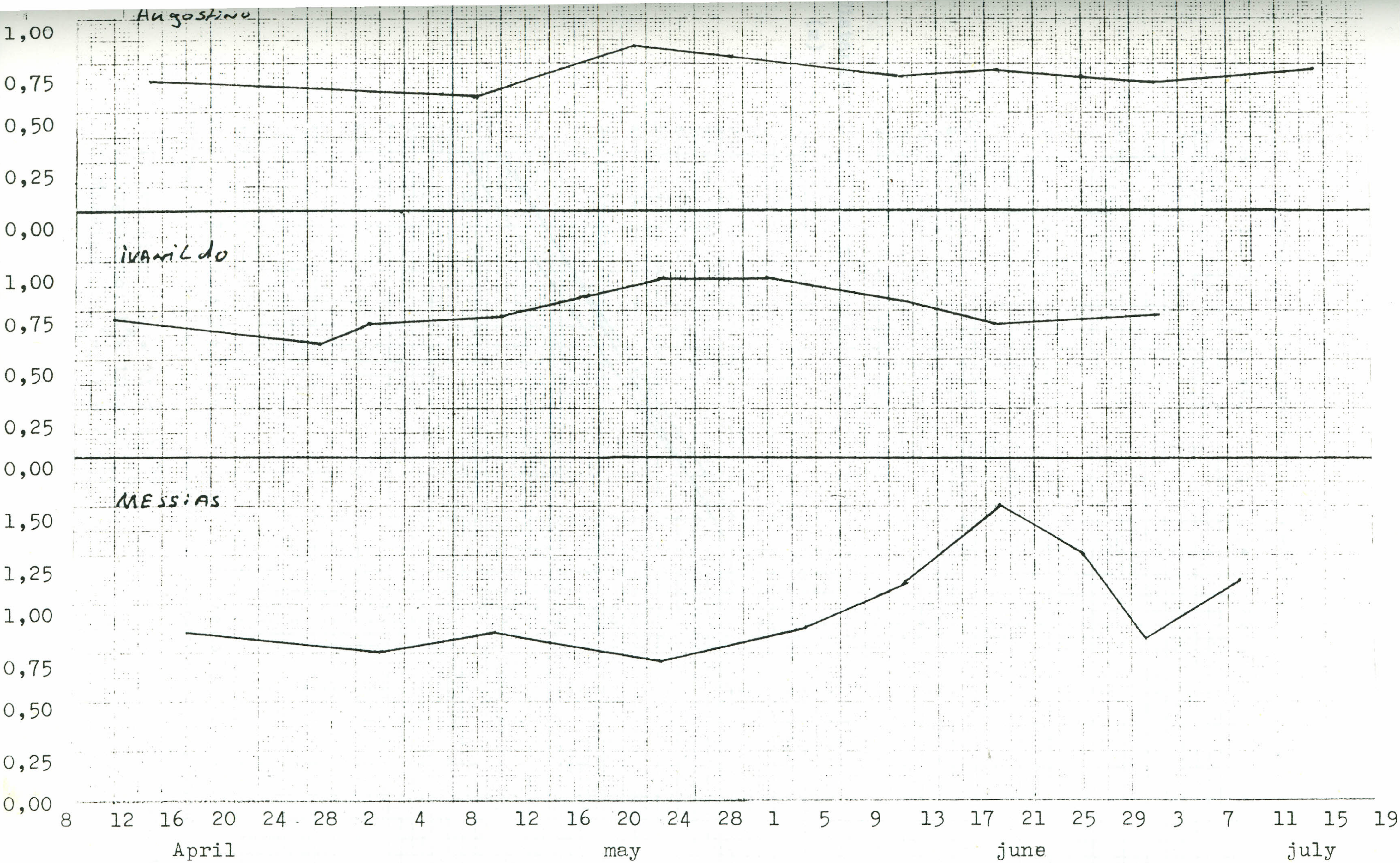
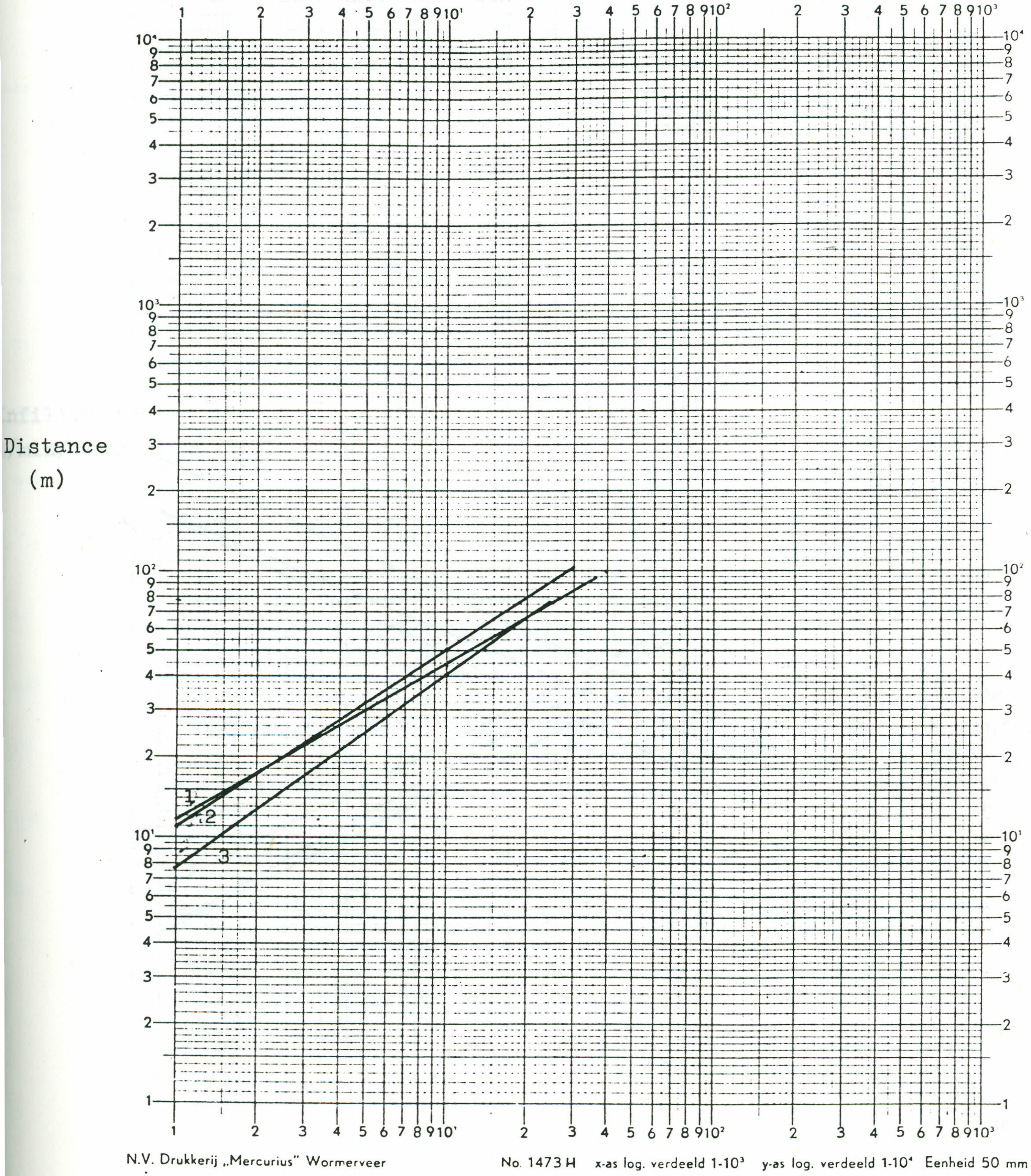


Figure 10: Average salt-percentage
Electrical conductivity (EC) in mmhos/cm.

Figure 11: Average adavance-curve

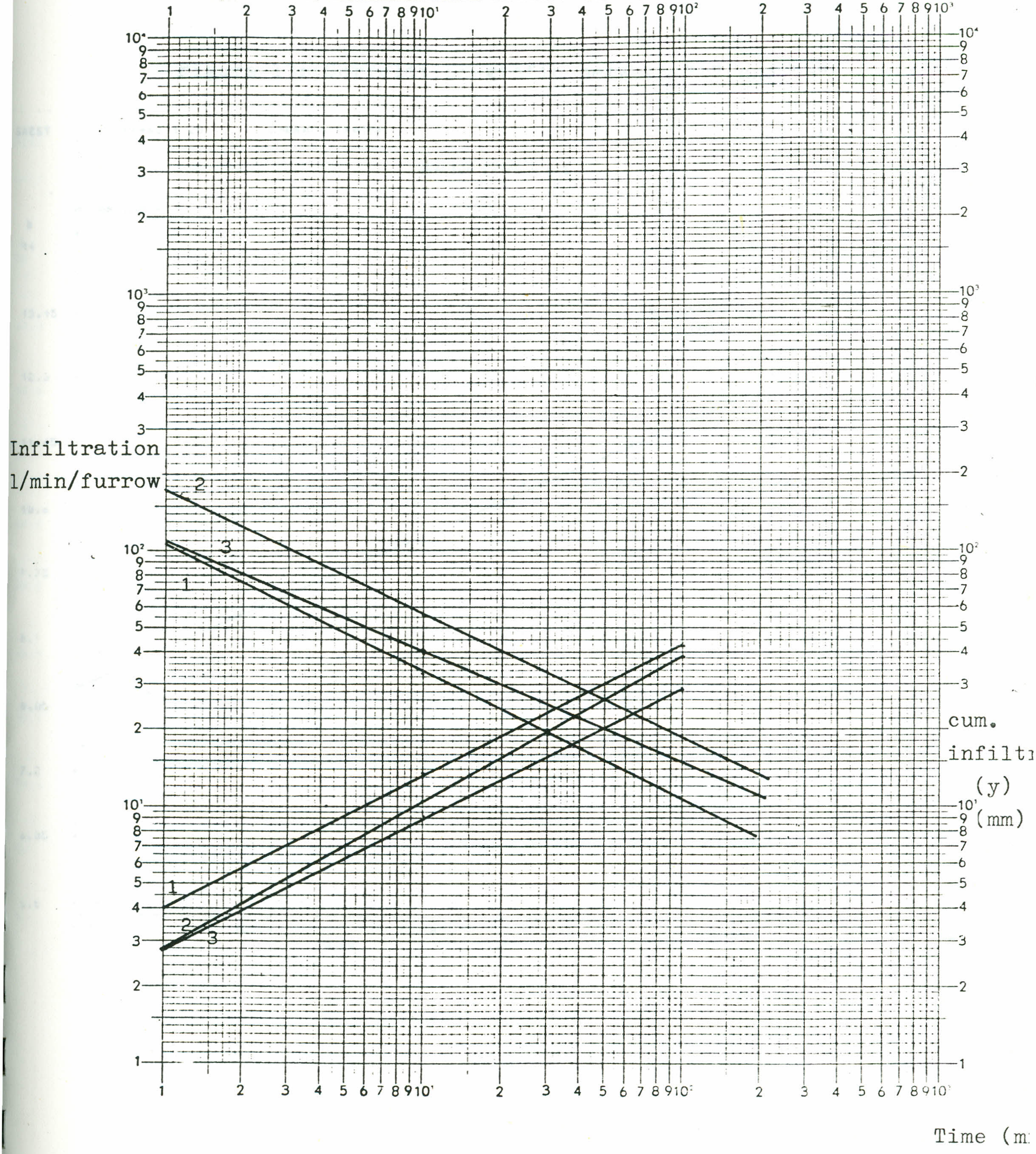


1: Ivanildo ; $L_g = 11,7\ t^{0,58}$

2: Augostino; $L_g = 10,9\ t^{0,66}$

3: Messias ; $L_g = 7,8\ t^{0,71}$

Figure 12: Average Infiltration



(1) : Messias, $I_g = 106\ t^{-0,49}$ (1): Augostino, $y_g = 4,0\ t^{0,52}$

(2) : Augostino, $I_g = 171\ t^{-0,48}$ (2): Ivanildo, $y_g = 2,8\ t^{0,57}$

(3) : Ivanildo, $I_g = 109\ t^{-0,43}$ (3): Messias, $y_g = 2,8\ t^{0,51}$

Figure 13: Correlation-grafic between "b" and "H"

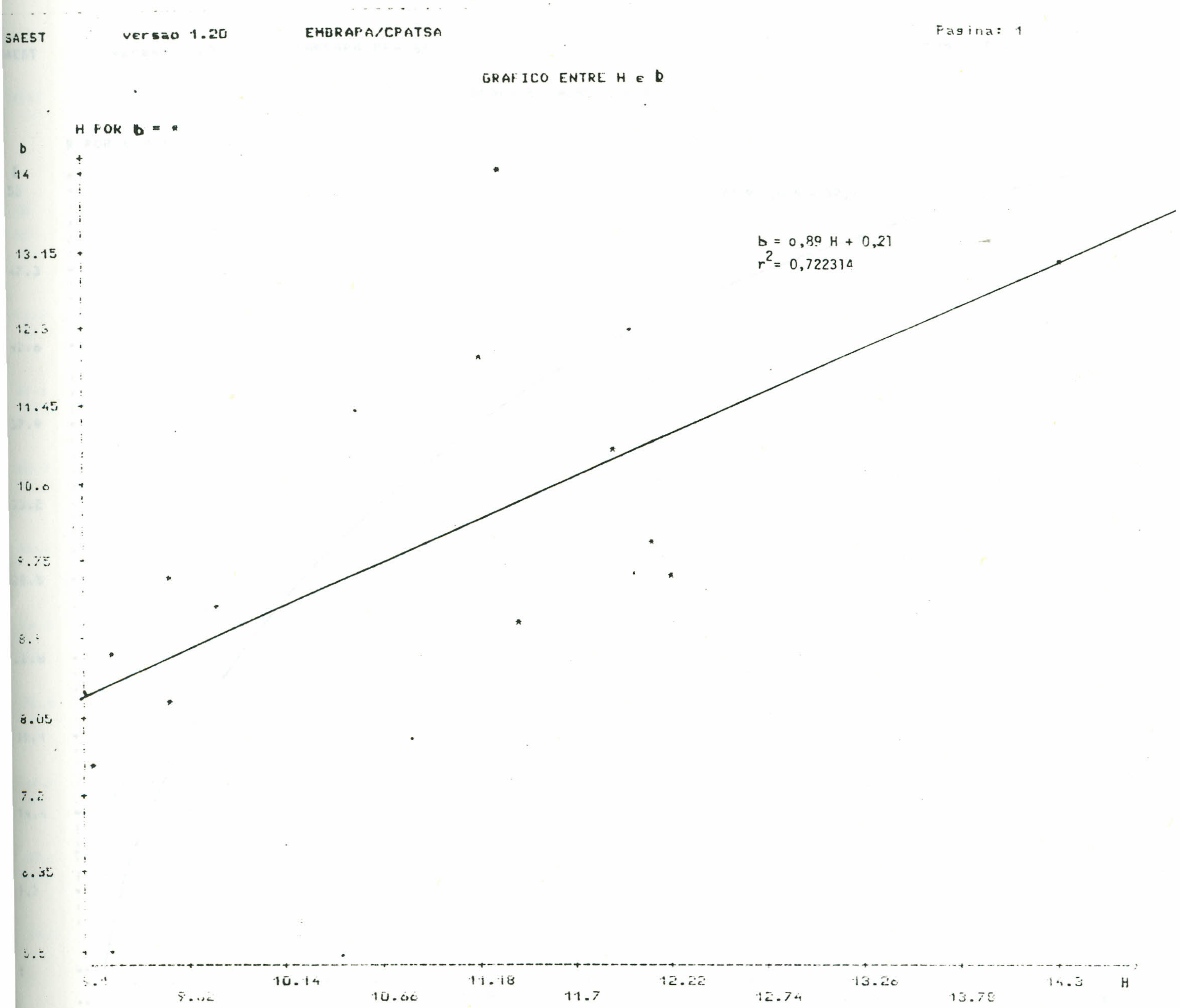

SAEST versao 1.20 EMBRAPA/CPATSA Pagina: 1

GRAFICO ENTRE H e b

H FOR b = *

Figure 14: Correlation-grafic between "E" and "R"

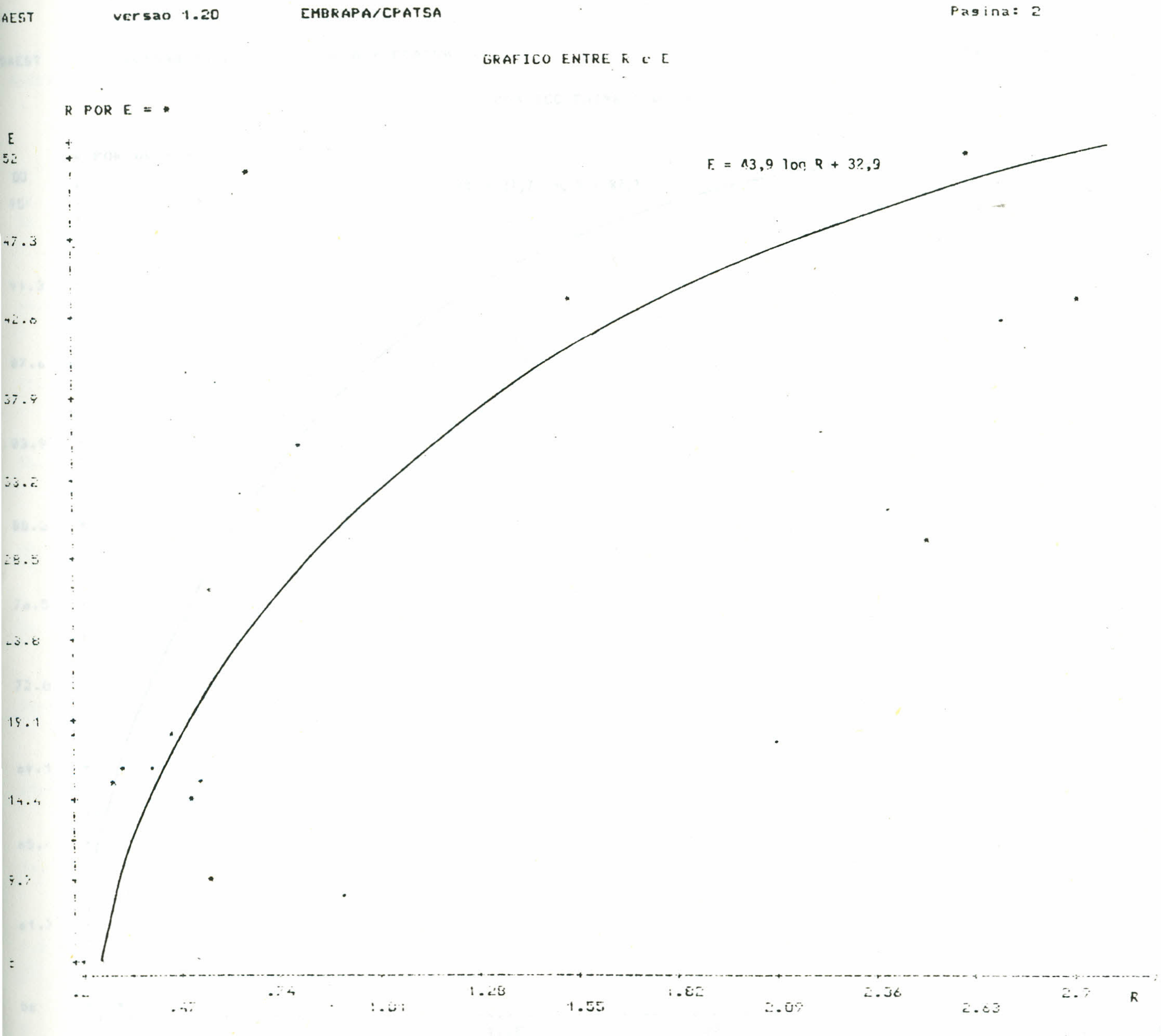


Figure 15: Correaltion-grafic between "DU" and "R"

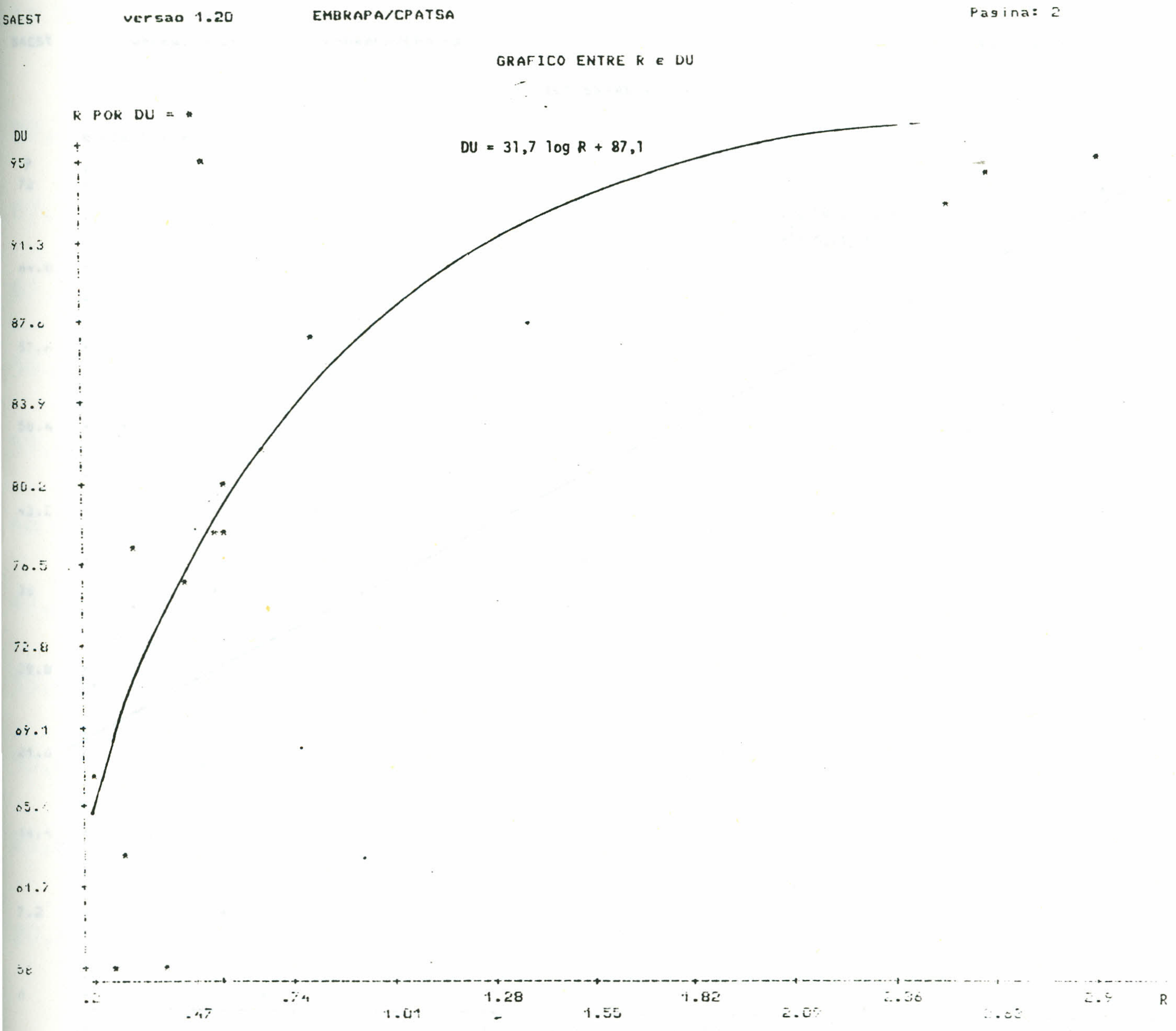


Figure 16: Correlation-grafic between "P" and "R"

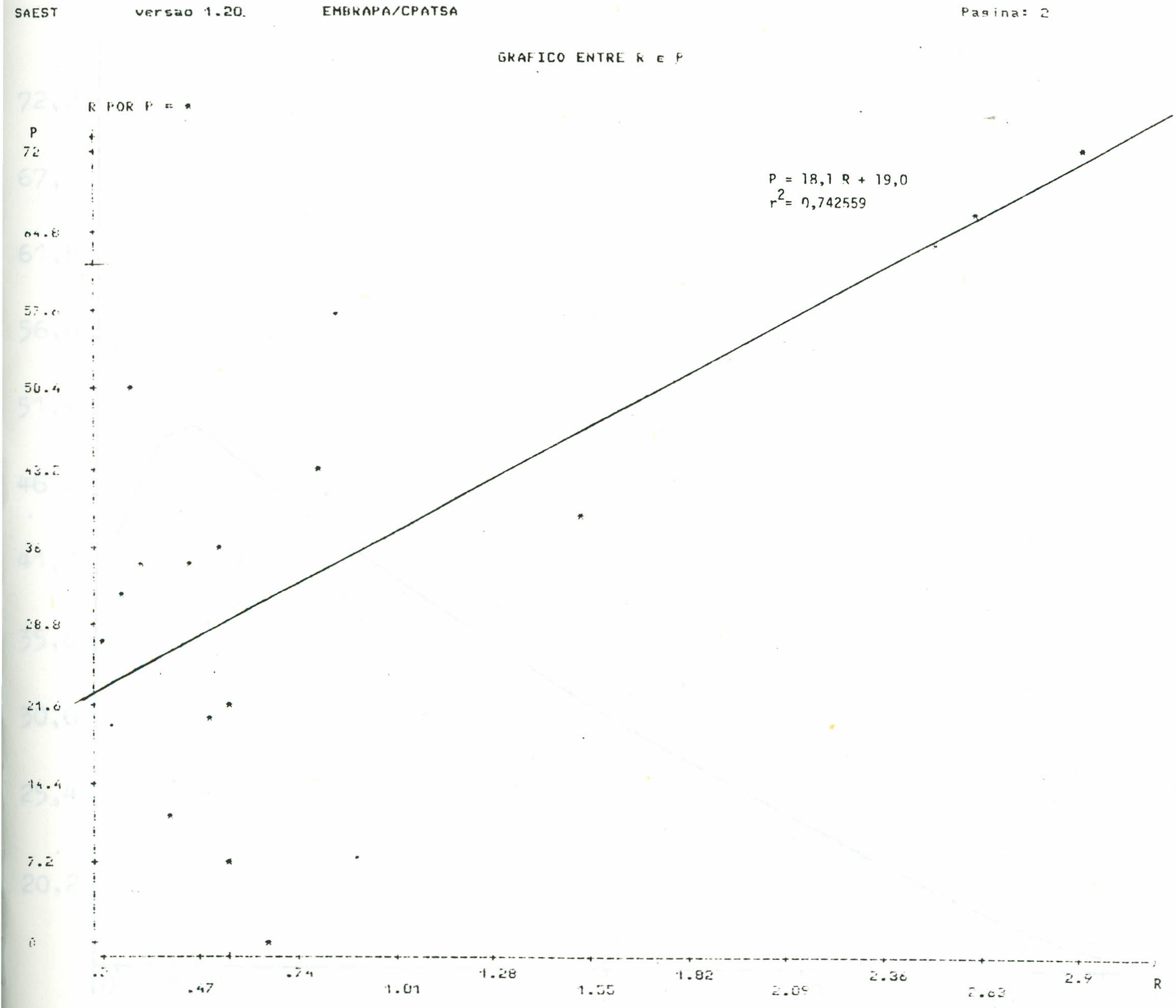
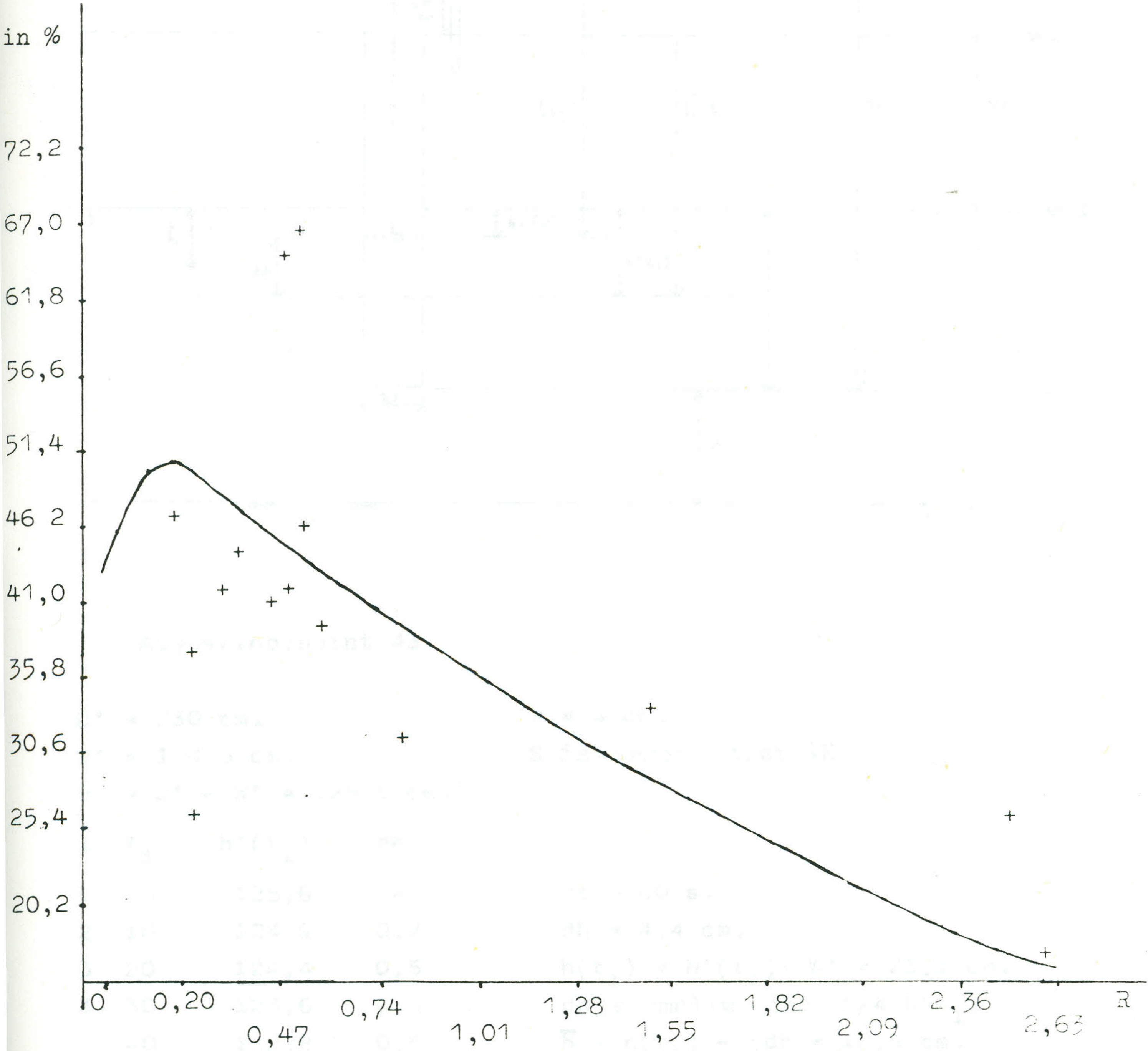
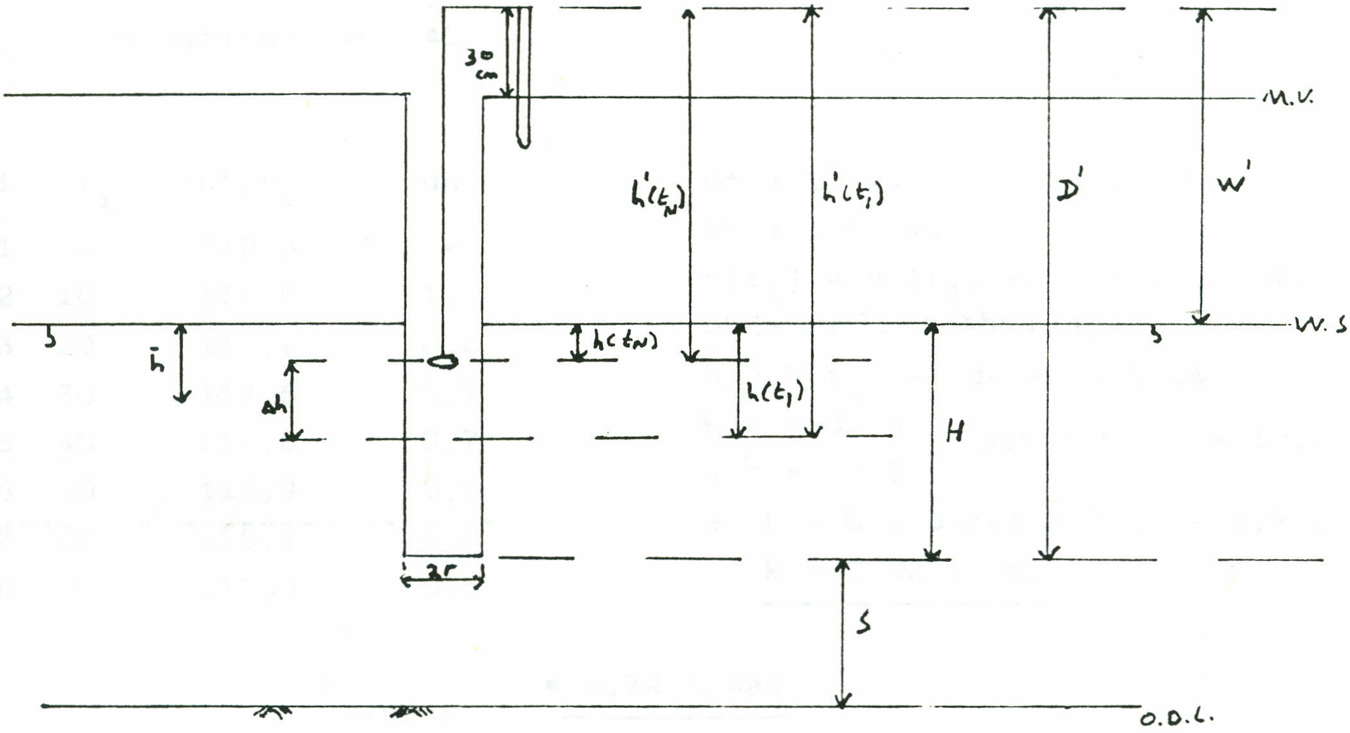


Figure 17: Correlation-grafic between "O" and "R"



Calculation hydralic conductivity , "k".



Augostino;point 43

D' = 230 cm.

W' = 104,5 cm.

H = D' - W' = 125,5 cm.

r = 4 cm.

S is larger than ½H

i	t_i	$h'(t_i)$	dh
1	0	125,6	-
2	10	124,9	0,7
3	20	124,4	0,5
4	30	123,6	0,8
5	40	122,8	0,8
6	50	122,0	0,8
7	60	121,2	0,8
8	70	120,8	0,4

dt = 60 s.

dh = 4,4 cm.

$h(t_1) = h'(t_1) - W' = 21,1$ cm.

dh is smaller than 1/4 $h(t_1)$

$\bar{h} = h(t_1) - \frac{1}{2}dh = 18,9$ cm.

$H/r = 31,4$

$\bar{h}/r = 4,7$ } gives a C = 9,0

en k = C x dh/dt = 9,0 x 4,4/60 =

k = 0,66 m/dag .

Augostino; point 43

i	t_i	$h'(t_i)$	dh
1	0	119,8	-
2	10	118,8	1,0
3	20	118,2	0,6
4	30	117,5	0,7
5	40	116,8	0,7
6	50	115,9	0,9
7	60	115,1	0,8
8	70	115,0	0,1

dt = 50 s.

dh = 3,9 cm.

$h(t_1) = h'(t_1) - W' = 15,3$ cm.

dh is smaller than $1/4\ h(t_1)$

$\bar{h} = h(t_1) - ½dh = 13,3$ cm.

$H/r = 31,4$ gives a C = 10,5

$\bar{h}/r = 3,3$

en $k = C \times dh/dt = 10,5 \times 3,9/50 =$

$k = 0,82$ m/dag.

$k_{average} = 0,74$ m/dag

Augostino; point 40

D' = 240 cm.

W' = 101,2 cm.

H = D' - W' = 138,8 cm.

r = 4 cm.

S is larger than ½H

i	t_i	$h'(t_i)$	dh
1	0	121,8	-
2	10	119,1	2,7
3	20	117,0	2,1
4	30	115,1	1,9
5	40	113,5	1,6

dt = 20 s.

dh = 4,8 cm.

$h(t_1) = h'(t_1) - W' = 20,6$ cm.

dh is smaller than $1/4\ h(t_1)$

$\bar{h} = h(t_1) - ½dh = 18,2$ cm.

$H/r = 34,7$ gives a C = 9,0

$\bar{h}/r = 4,5$

en $k = C \times dh/dt = 9,0 \times 4,8/20 =$

$k = 2,16$ m/dag

Augostino; point 40

i	t_i	$h'(t_i)$	dh
1	0	121,3	-
2	10	119,3	2,0
3	20	117,4	1,9
4	30	115,5	1,9
5	40	114,0	1,5

$dt = 20$ s.

$dh = 3,9$ cm.

$h(t_1) = h'(t_1) - W' = 20,1$ cm.

dh is smaller than $1/4\ h(t_1)$

$\bar{h} = h(t_1) - \frac{1}{2}dh = 18,1$ cm.

$\left.\begin{array}{l} H/r = 34,7 \\ \bar{h}/r = 4,5 \end{array}\right\}$ gives a $C = 9,0$

en $k = C \times dh/dt = 9,0 \times 3,9/20 =$

$k = 1,76$ m/dag.

$k_{\text{average}} = 2,0$ m/dag

Messias; point 46

$D' = 218$ cm.; $W' = 114$ cm.

$H = D' - W' = 104$ cm.

$r = 4$ cm. ; S is larger than $\frac{1}{2}H$

i	t_i	$h'(t_i)$	dh
1	0	143,0	-
2	10	141,8	1,2
3	20	139,7	2,1
4	30	138,0	1,7
5	40	135,8	2,2
6	50	134,0	1,8

$dt = 40$ s.

$dh = 7,2$ cm.

$h(t_1) = h'(t_1) - W' = 29,0$ cm.

dh is smaller than $1/4\ h(t_1)$

$\bar{h} = h(t_1) - \frac{1}{2}dh = 25,4$ cm.

$\left.\begin{array}{l} H/r = 26,0 \\ \bar{h}/r = 6,3 \end{array}\right\}$ gives a $C = 8,0$

en $k = C \times dh/dt = 8,0 \times 7,2/40 =$

$k = 1,44$ m/dag

Messias;point 48 , inverse augerhole method

D' = 211 cm.

r = 4 cm.

i	t	h'(t_i)	h(t_i)	h(t_i) + r/2
1	1	83,4	127,6	129,6
2	5	88,0	123,0	125,0
3	10	92,1	118,9	120,9
4	40	102,0	109,0	111,0
5	60	107,9	103,1	105,1
6	80	112,6	98,4	100,4
7	100	116,5	94,5	96,5

Zet h(t_i) + r/2 op semi-log papier uit tegen t_i ter verkrijging van α.

en k = 1,15 x r x tanα =

1,15 x 4 x 0,0011 = 0,0056 cm/s. =

4,4 m/dag.

Messias;point 48

i	t	h'(t_i)	h(t_i)	h(t_1) +r/2
1	10	56,6	154,4	156,4
2	20	62,1	148,9	150,9
3	40	73,3	137,7	139,7
4	60	81,0	130,0	132,0
5	80	88,5	122,5	124,5
6	100	100,0	111,0	113,0

k = 1,15 x r x tanα =

1,15 x 4 x0,0013 = 0,0059 cm/s =

5,2 m/dag.

$k_{average}$ = 4,8 m/dag

Messias;point52 ,inverse augerhole method

D' = 193 cm.
r = 4 cm.

i	t_i	$h'(t_i)$	$h(t_i)$	$h(t_i) + r/2$
1	1	86,0	107,0	109,0
2	20	96,1	96,9	98,9
3	40	104,9	88,1	90,1
4	60	110,7	82,3	84,3
5	80	114,6	78,4	80,4
6	100	118,9	74,1	76,1

Zet $h(t_i) + r/2$ op semi-log papier uit tegen t_i ter verkrijging van en $k = 1{,}15 \times r \times \tan\alpha =$

$1{,}15 \times 4 \times 0{,}0014 \times 36 \times 24 = \underline{5{,}6 \text{ m/dag}}$

Messias;Point52

i	t_i	$h'(t_i)$	$h(t_i)$	$h(t_i) + r/2$
1	1	52,0	141,0	143,0
2	20	67,4	125,6	127,6
3	40	80,3	112,7	114,7
4	60	90,5	102,5	104,5
5	80	98,6	94,4	96,4
6	100	105,0	88,0	90,0
7	120	109,7	83,3	85,3

Zet $h(t_i) + r/2$ op semi-log papier uit tegen t_i ter verkrijging van en $k = 1{,}15 \times r \times \tan\alpha =$

$1{,}15 \times 4 \times 2{,}1/10 \times 1/120 \times 36 \times 24 = \underline{6{,}9 \text{ m/dag}}$

$k_{average} = \underline{6{,}2 \text{ m/dag.}}$

Ivanildo;point24

D' = 157 cm.
W' = 74 cm.
H = D' - W' = 83 cm.

r = 4 cm.
S is larger 1/2 H

i	t_i	$h'(t_i)$	dh
1	0	116,5	-
2	10	112,5	4,0
3	20	108,6	3,9
4	30	106,2	2,4
5	40	104,1	2,1
6	50	102,0	2,1

dt = 30 s.
dh = 10,3 cm.
$h(t_1) = h'(t_1) - W' = 42,5$ cm.
dh is smaller 1/4 $h(t_1)$
$\bar{h} = h(t_1) - 1/2\ dh = 37,4$ cm.
$H/r = 20,7$
$\bar{h}/r = 9,3$ } gives a C = 7,0
en k = C x dh/dt = 7,0 x 10,3/30 =
k = 2,4 m/dag.

Ivanildo;point24

i	t_i	$h'(t_i)$	dh
1	0	100,5	-
2	10	97,0	3,5
3	20	94,6	2,4
4	30	92,1	2,5
5	40	90,4	1,7

dt = 20 s.
dh = 5,9 cm.
$h(t_1) = h'(t_1) - W' = 26,5$ cm.
dh smaller 1/4 $h(t_1)$
$\bar{h} = h(t_1) - 1/2\ dh = 23,5$ cm.
$H/r = 20,7$
$\bar{h}/r = 5,9$ } gives a C = 9,3
en k = C x dh/dt = 9,3 x 5,9/20 =
k = 2,7 m/dag.

$k_{average}$ = 2,5 m/dag.

Ivanildo;point 20/21 , inverse augerhole method

D' = 209 cm.
r = 4 cm.

i	t_i	$h'(t_i)$	$h(t_i)$	$h(t_i) + r/2$
1	10	56,3	152,7	154,7
2	20	62,2	146,8	148,8
3	40	73,4	135,6	137,6
4	60	79,8	129,2	131,2
5	80	88,6	120,4	122,4
6	100	100,0	109,0	111,0

en $k = 1{,}15 \times r \times \dfrac{\log (h_1 + r/2) - \log(h_n + r/2)}{t_n - t_1}$

$= 1{,}15 \times 4 \times \log \dfrac{154{,}7}{111{,}0} : 90 = 0{,}0712$ cm/s.

$= \underline{6{,}1 \text{ m/dag.}}$