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SMR/402 - 32

COLLEGE ON SOIL PHYSICS
9 - 27 October 1989

"Water Balance Studies"

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WATER BALANCE STUDIES

SUMMARY OF LECTURE NOTES

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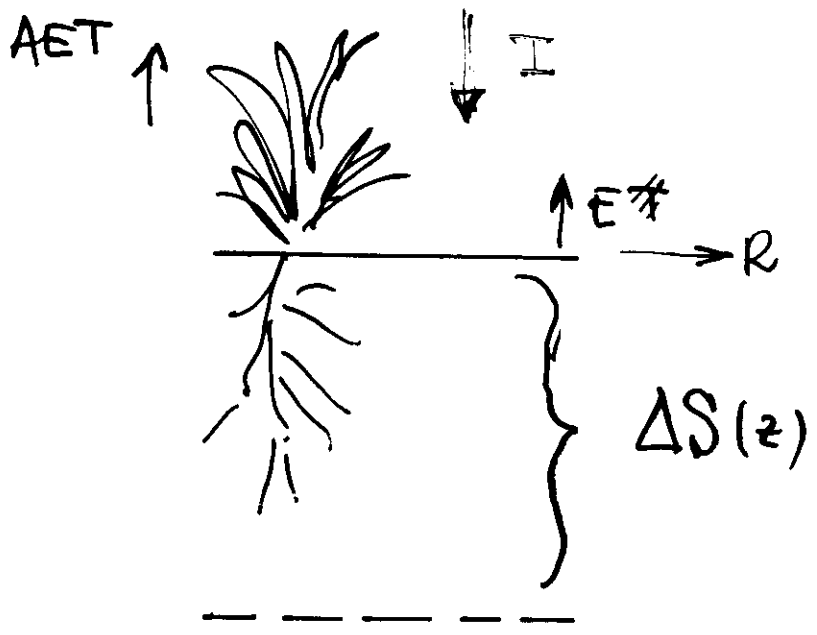
ICTP - Trieste - Oct 24, 1989.

SOIL WATER BALANCE

FOR A GIVEN SOIL LAYER
WITH OR WITHOUT VEGETATION



FROM MEASUREMENTS OF { RAINFALL I, RUNOFF R, ΔS }

- DETERMINE - AET OR E
  - DRAINAGE

LEACHING BEYOND ROOT ZONE OR REPLENISMENT AQUIFER

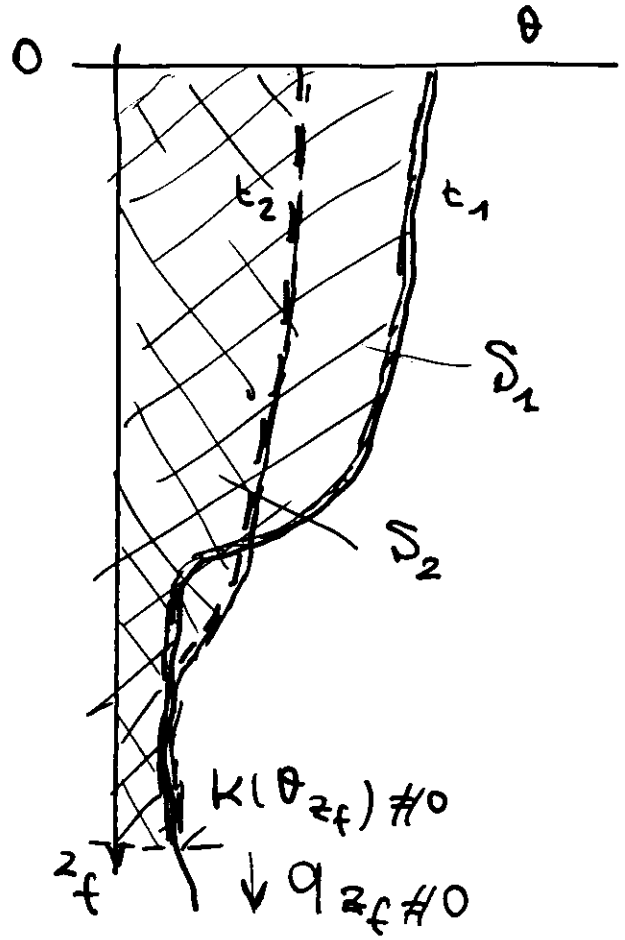
(DEPENDING THICKNESS OF SOIL LAYER)

IN TERM OF FIELD STUDIES

2METHODS OF ESTIMATION S.W.B.

METHOD 1 D ≠0

* SOIL WATER CONTENT MEASUREMENTS ARE DONE TO A DEPTH SUCH THAT THE SOIL REMAINS ALWAYS AT A LOW WATER CONTENT BELOW z_f



$\Rightarrow q_{z_f} \neq 0 \quad \forall t$

BETWEEN $0 - z_f$

$$AET = (S_1 - S_2) + I$$

* REQUIRES ONLY NEUTRON PROBE MEASUREMENT
* IS THE MOST ACCURATE TECHNIQUE IF ASSUMPTION SATISFIED

METHOD . WELL ADAPTED TO ARID - SEMI ARID
. NOT FEASIBLE IN HUMID - SUB. HUMID OR IF WATER TABLE

EXAMPLE 1.

CHARACTERIZATION OF THE EFFECT OF ORGANIC AMENDMENT (DRY MANURE - 10T/ha EVERY 2 YEARS) ON WATER CONSUMPTION AND CROP PRODUCTION OF MILLET & PEANUT

FOR A DEGRADATED SAND OF NORTH - SENEGAL

RESEARCH DONE WITH L. CISSE, SENEGALESE INST. OF AGRIC. RESEARCH, WITHIN THE FRAME OF A TECHNICAL ASSISTANCE PROGRAMME BETWEEN AIEA / SENEGAL

RESULTS PUBLISHED IN "AGRONOMIE", 1988.

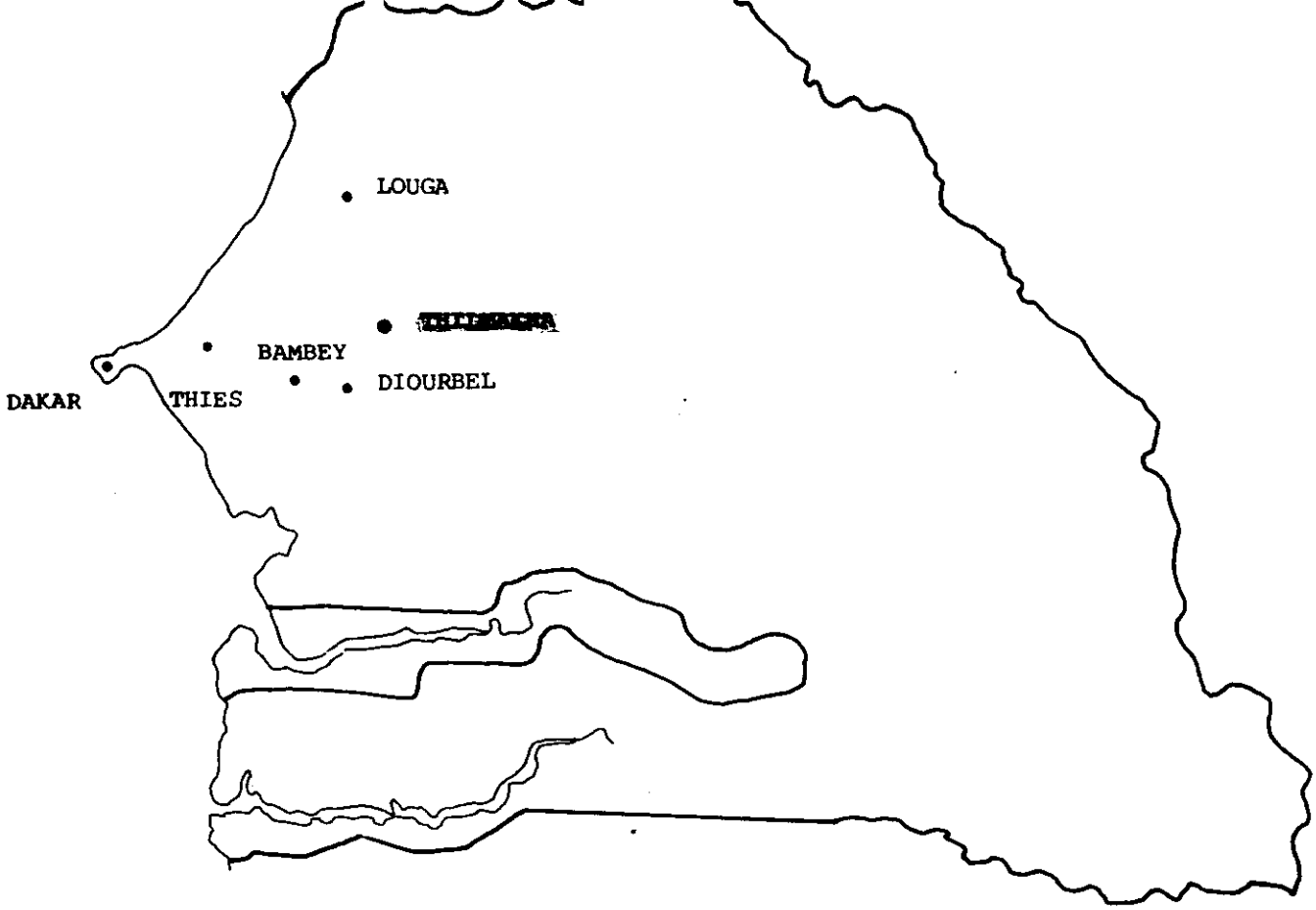


FIGURE 1.a : LIEU D'IMPLANTATION DE L'EXPERIMENTATION AGRONOMIQUE (THILMAKHA)

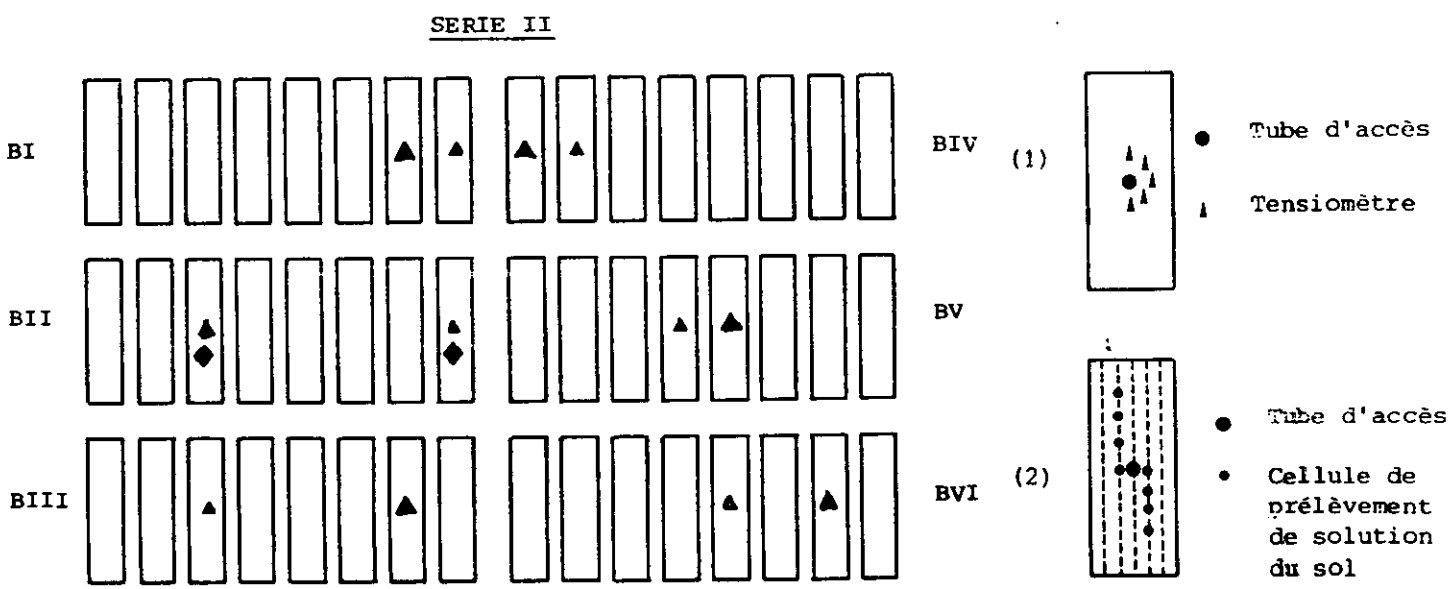
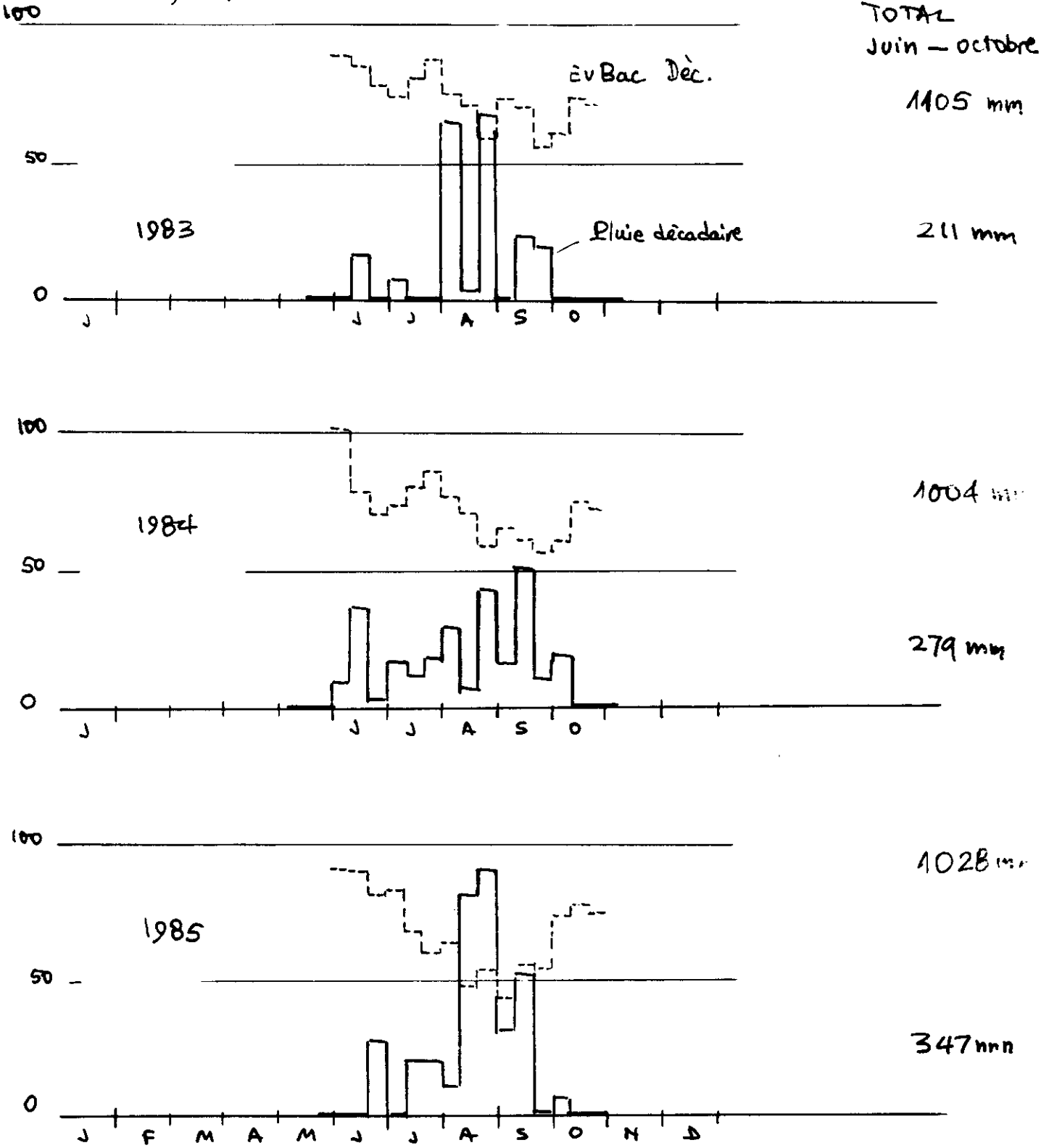


FIGURE 1.b : SCHEMA DU DISPOSITIF EXPERIMENTAL (SERIE II) - DISTRIBUTION DES TRAITEMENTS

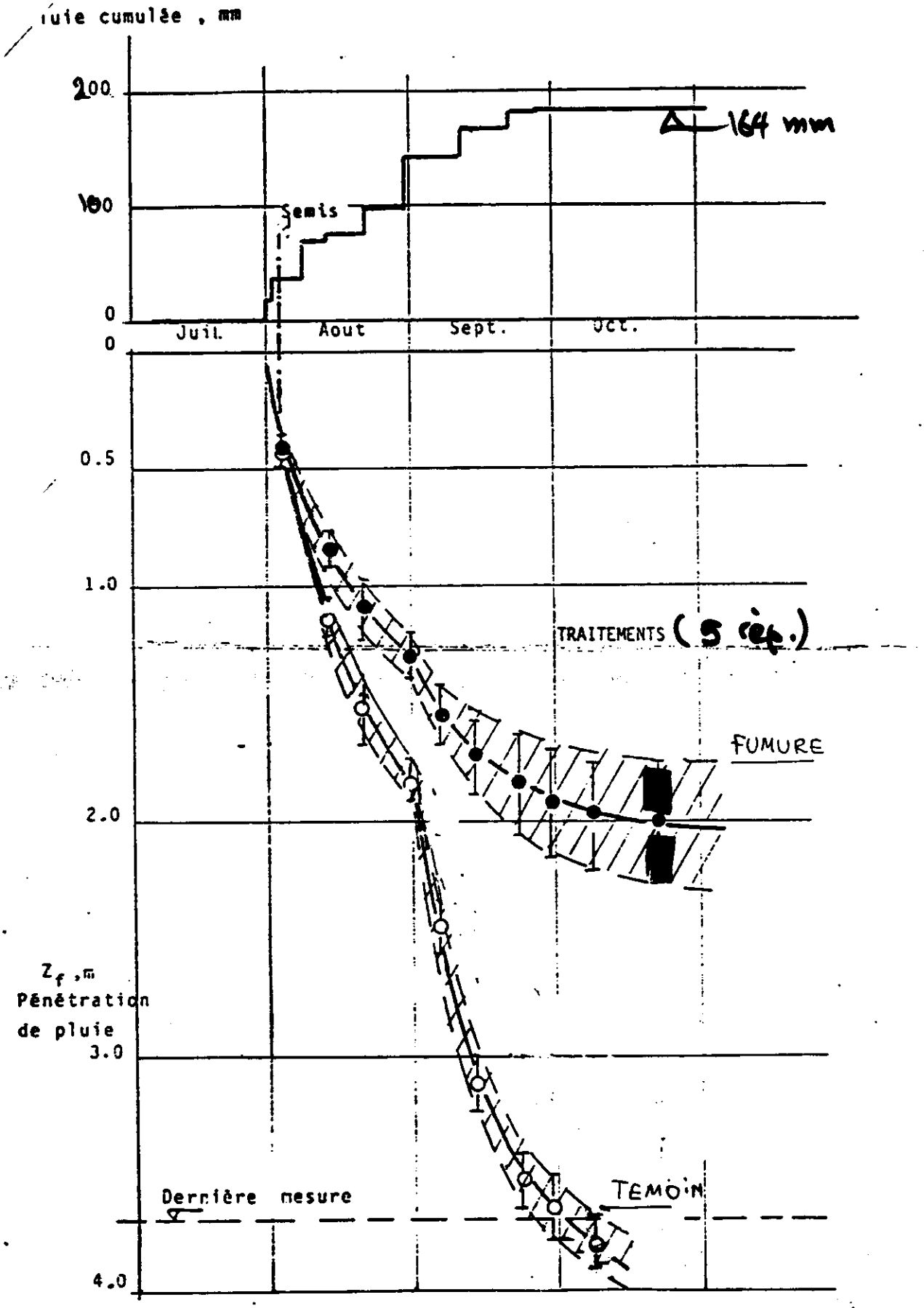
▲ T1
▲ To
◇ Site de caractérisation hydrodynamique
(1) Disposition du tube d'accès et des tensiomètres
(2) Disposition des cellules de prélèvement de solution du sol



CARACTERISTIQUES CLIMATIQUES

- THILMAKHA -

FIGURE 1


Pluie cumulée , mm
200
100
0
164 mm
Semis
Juil.
Aout
Sept.
Oct.
0
0.5
1.0
TRAITEMENTS (5 rép.)
FUMURE
2.0
Z_f ,m
Pénétration
de pluie
3.0
Dernière mesure
TEMOIN
4.0

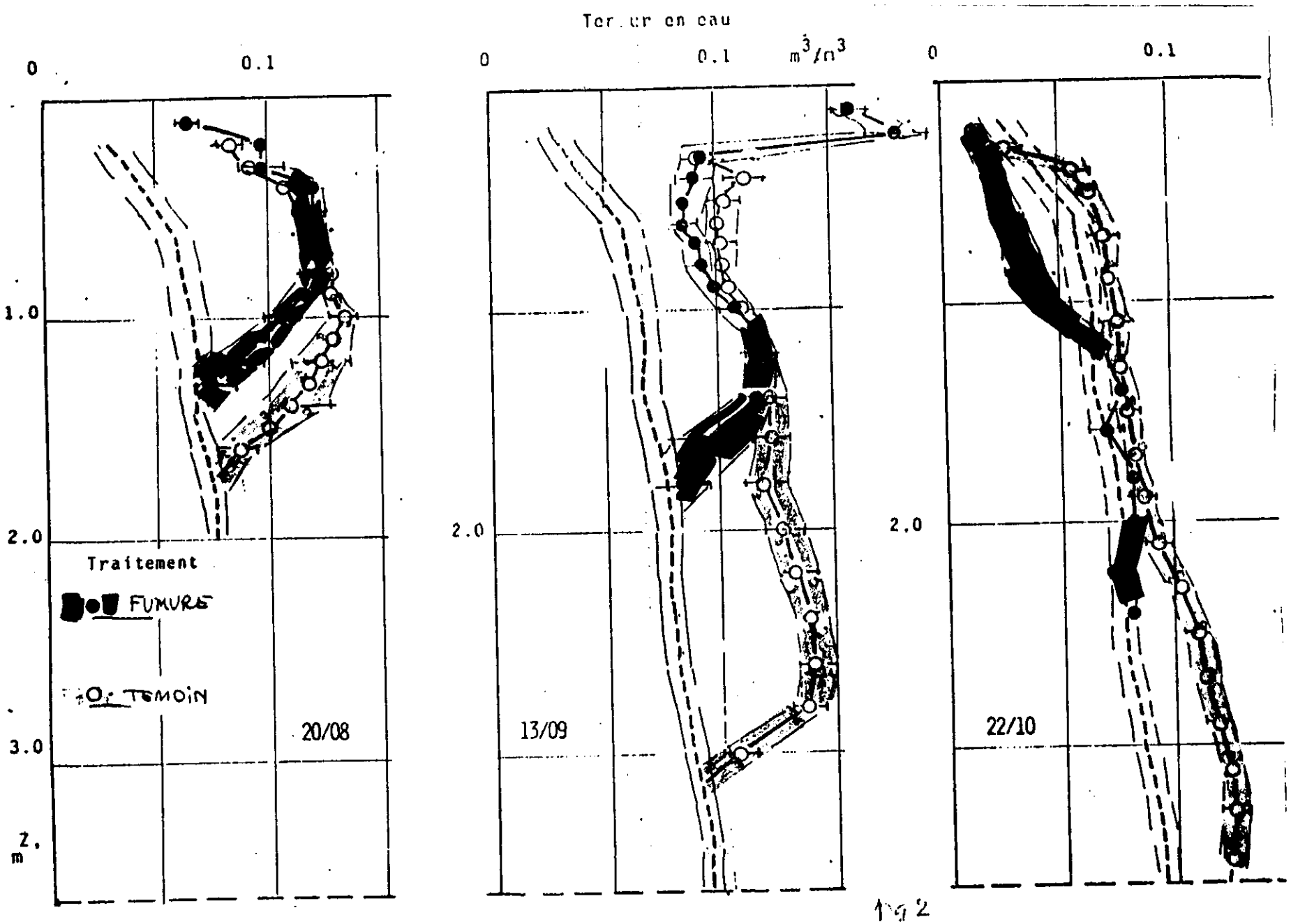
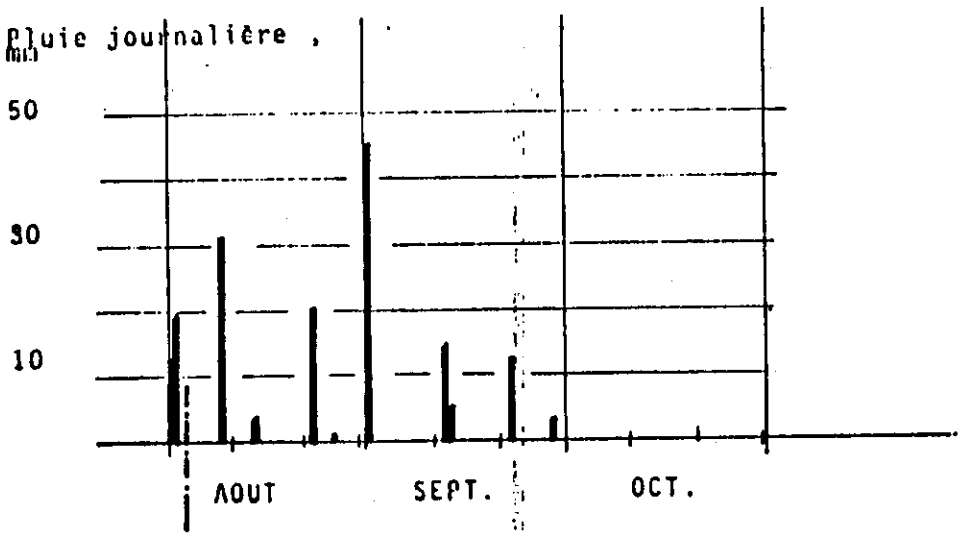
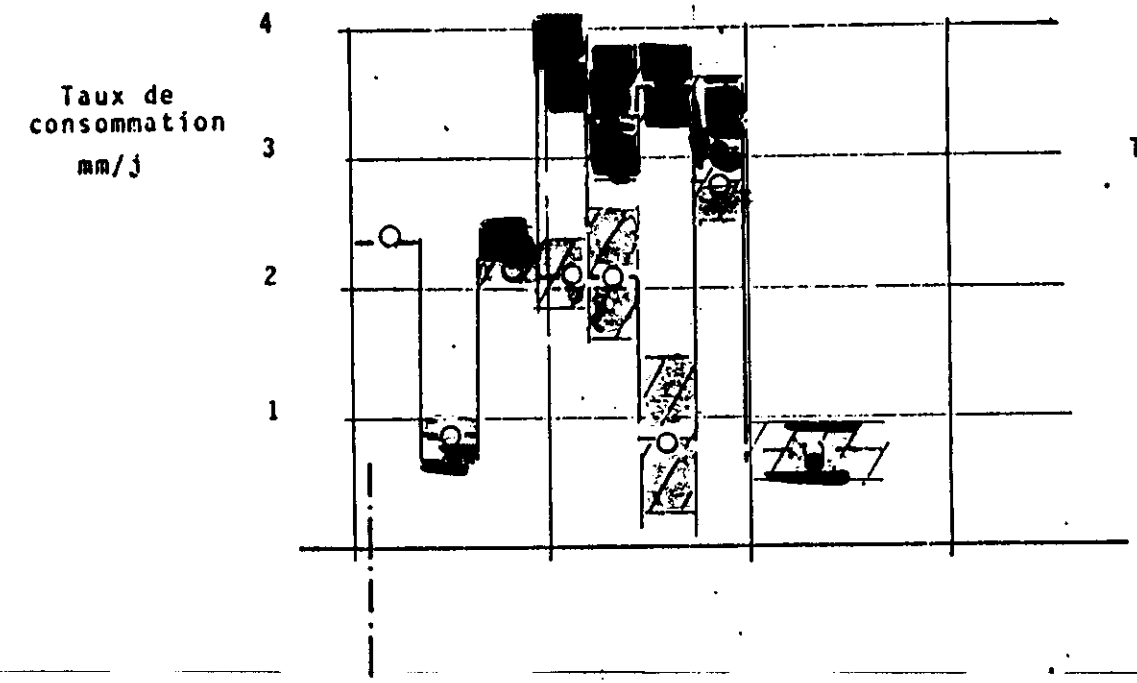

Teneur en eau
0
0.1
m³/m³
0
0.1
0
0.1
1.0
2.0
3.0
m
Z.
2.0
2.0
Traitement
FUMURE
TEMOIN
20/08
13/09
22/10

Fig 2





ARACHIDE

Pluie totale 164 mm

Rendements kg/ha

Traitement	PAILLE	GRAINES
FUMURE	2700	640
TEMOIN	500	140

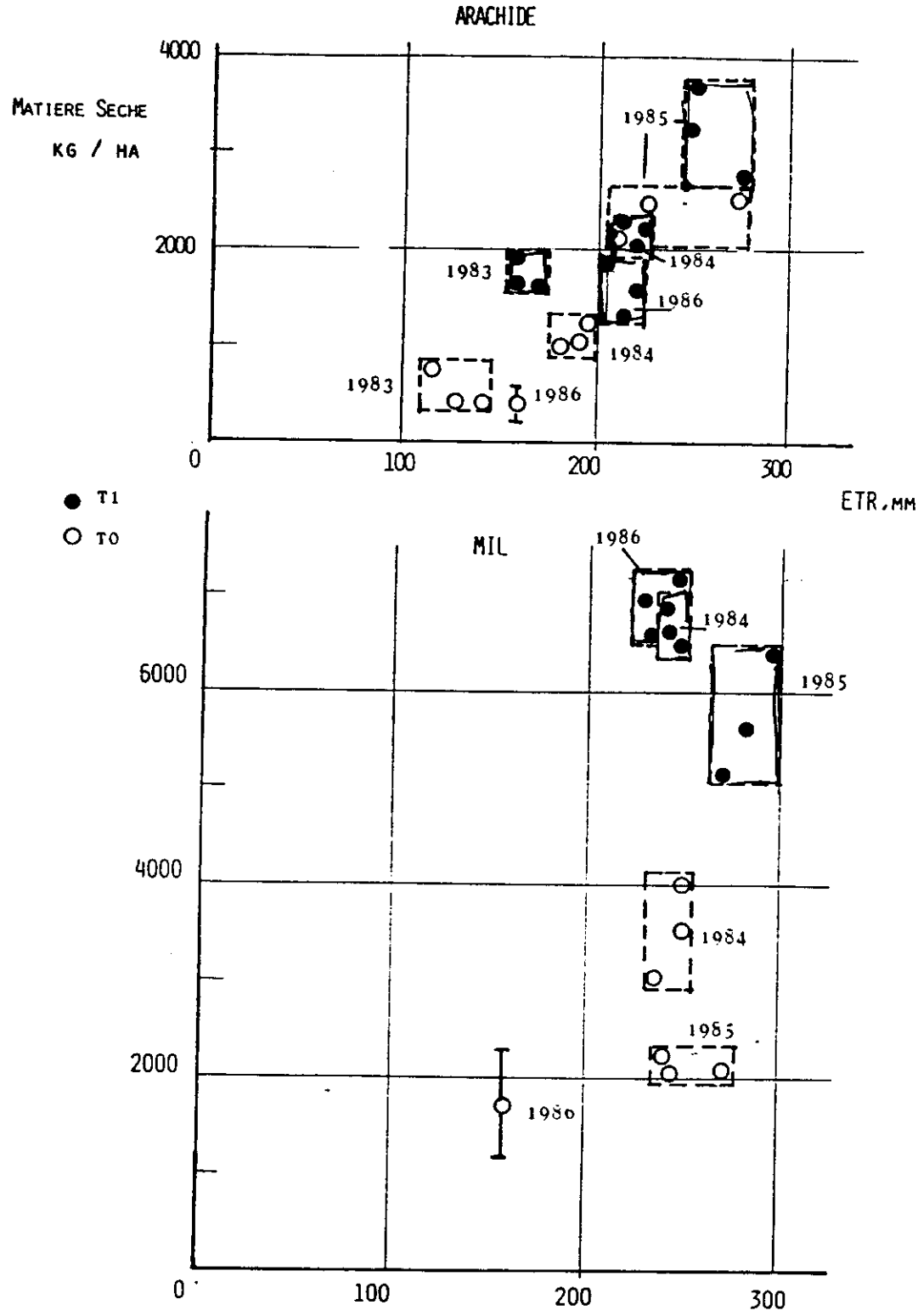
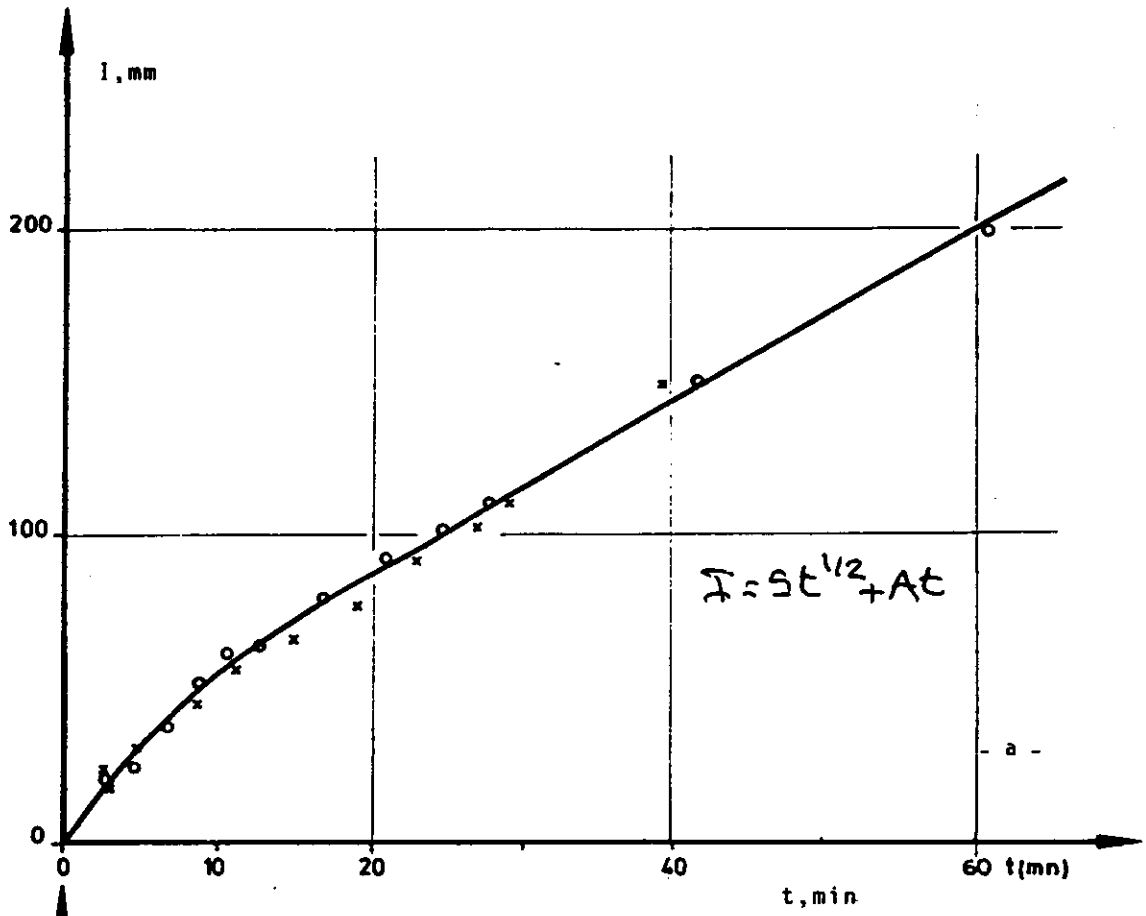

ARACHIDE
MATIERE SECHE
KG / HA
4000
2000
0
100
200
300
1985
1984
1983
1986
1984
1983
1986
T1
T0
ETR, MM
MIL
1986
1984
1985
6000
4000
2000
0
100
200
300
1984
1985
1986

Fig 8


I, mm
200
100
0
0
10
20
40
60 t(mn)
t, min
$I = St^{1/2} + At$
- a -

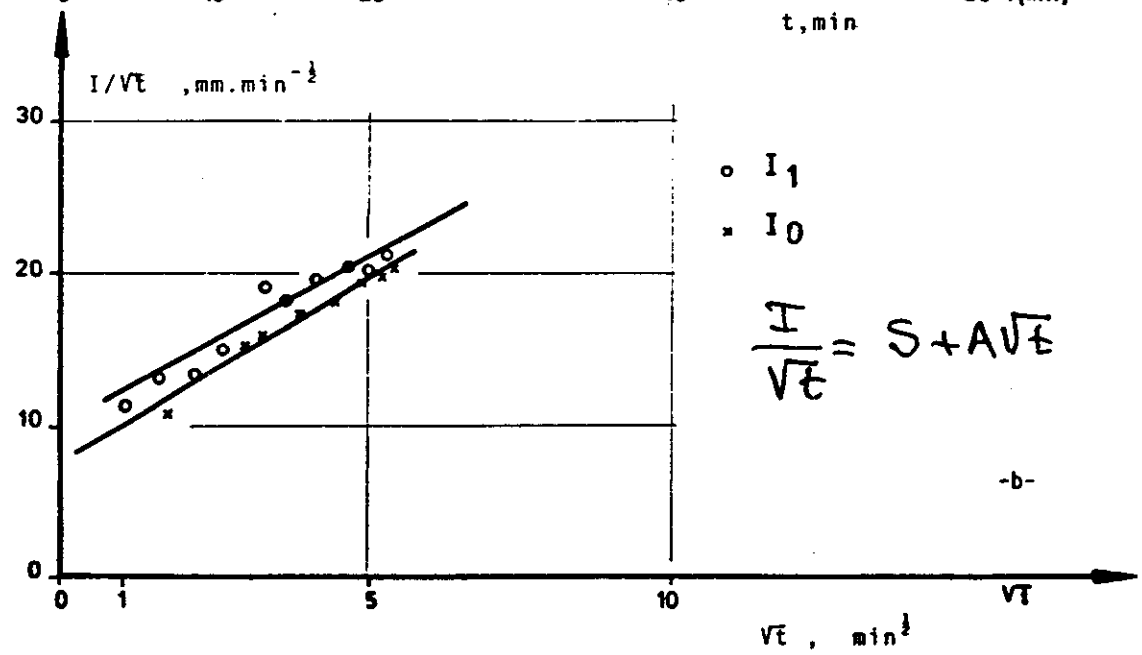

I/√t , mm.min$^{-\frac{1}{2}}$
30
20
10
0
0
1
5
10
√t
√t , min$^{\frac{1}{2}}$
o I_1
x I_0
$\frac{I}{\sqrt{t}} = S + A\sqrt{t}$
-b-

fig 4

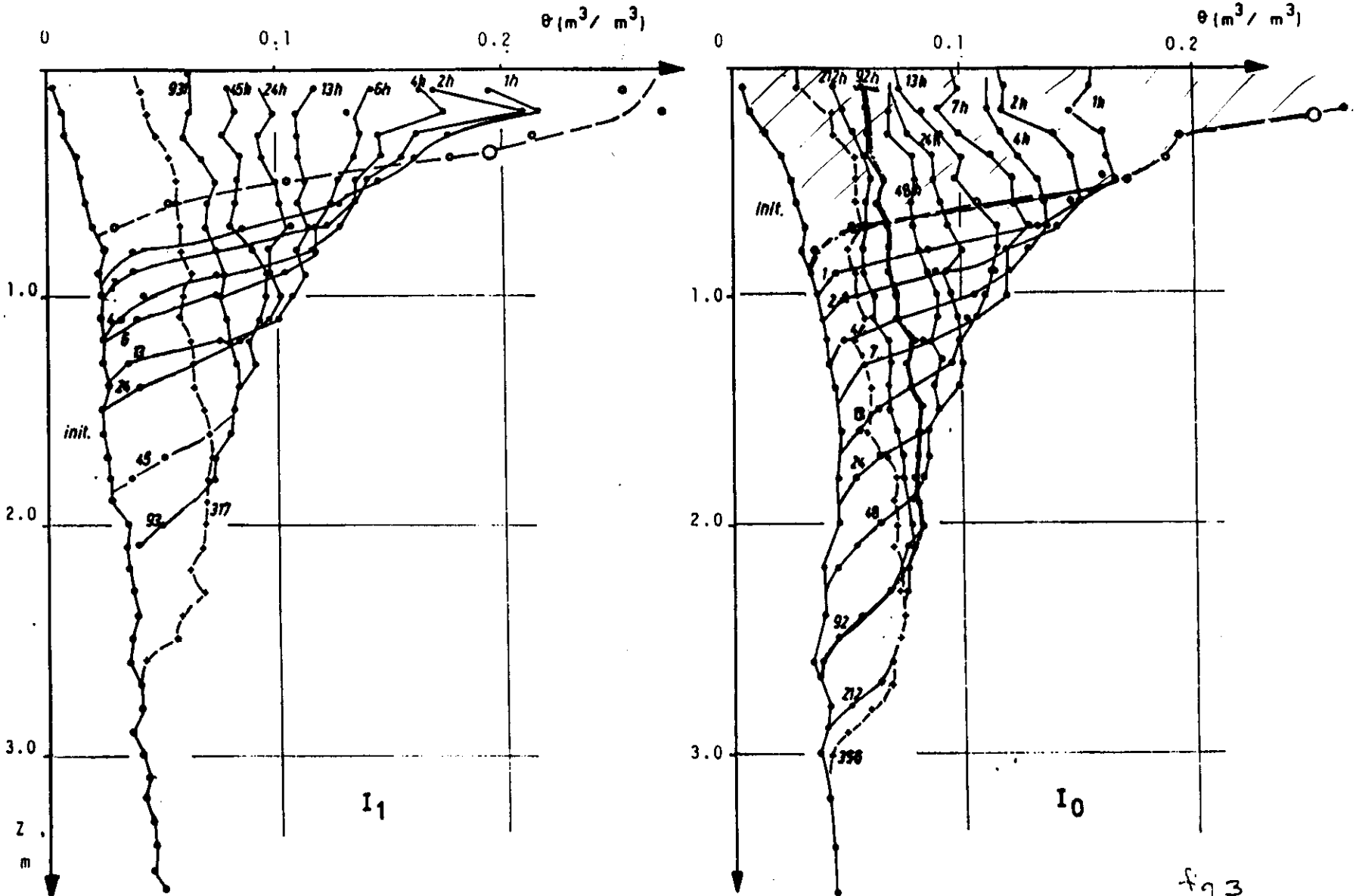
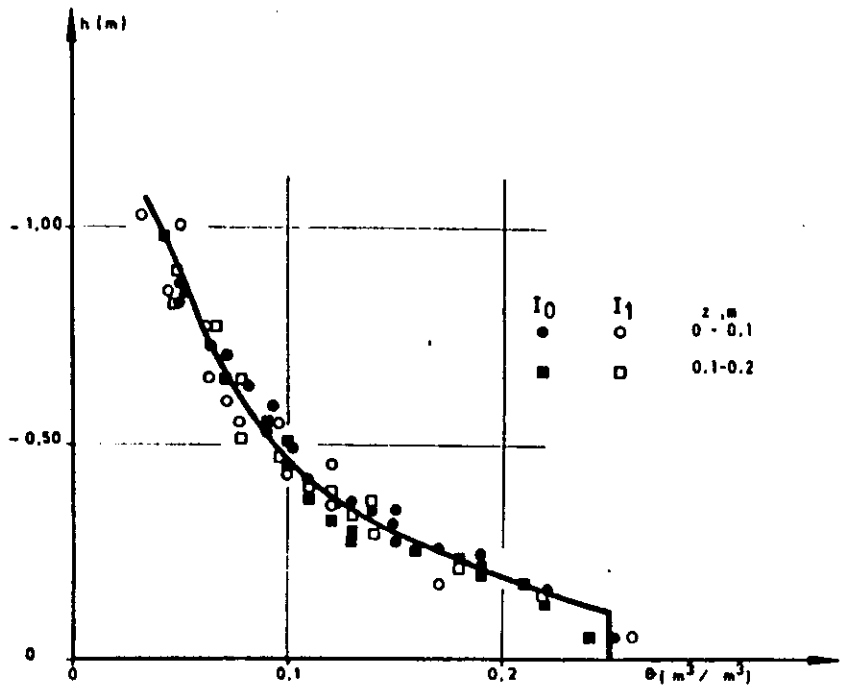
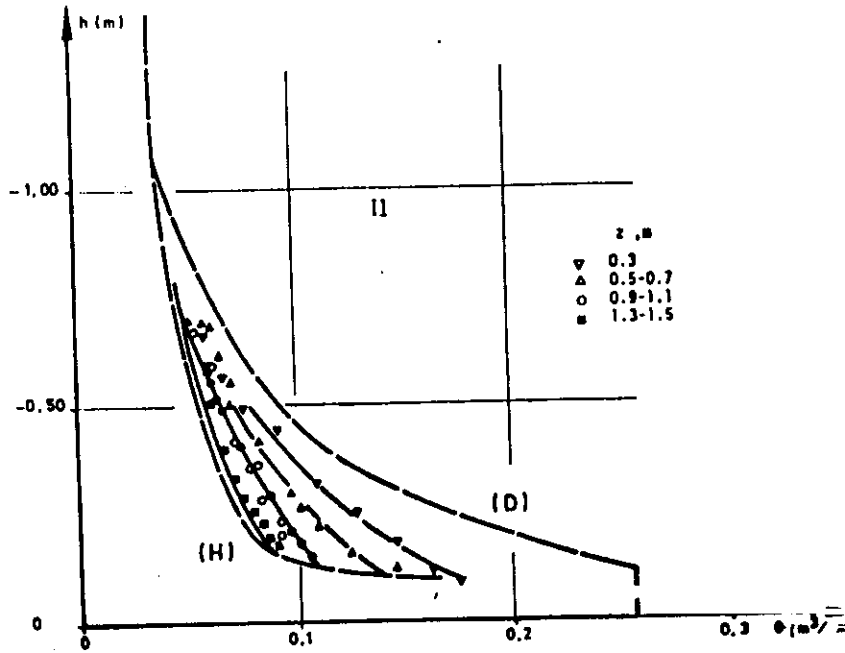
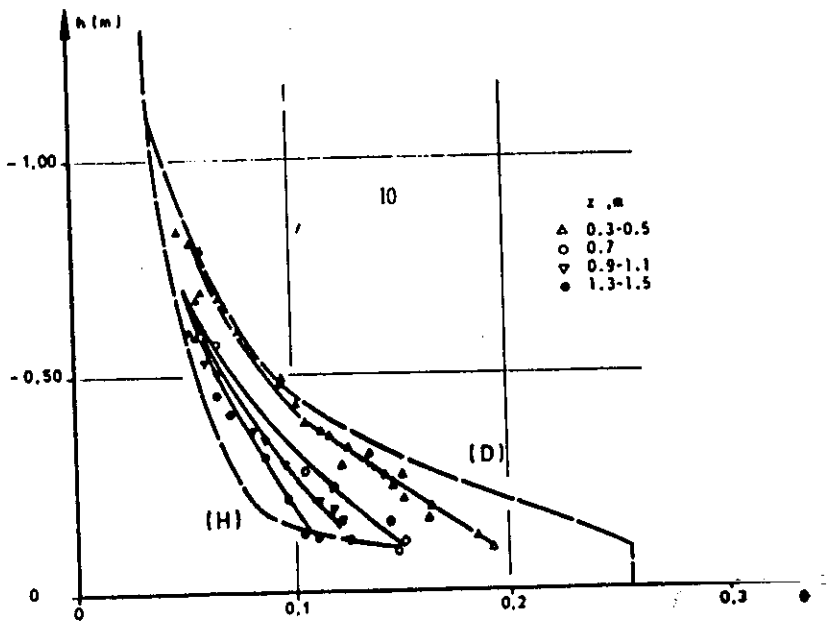


fig 3

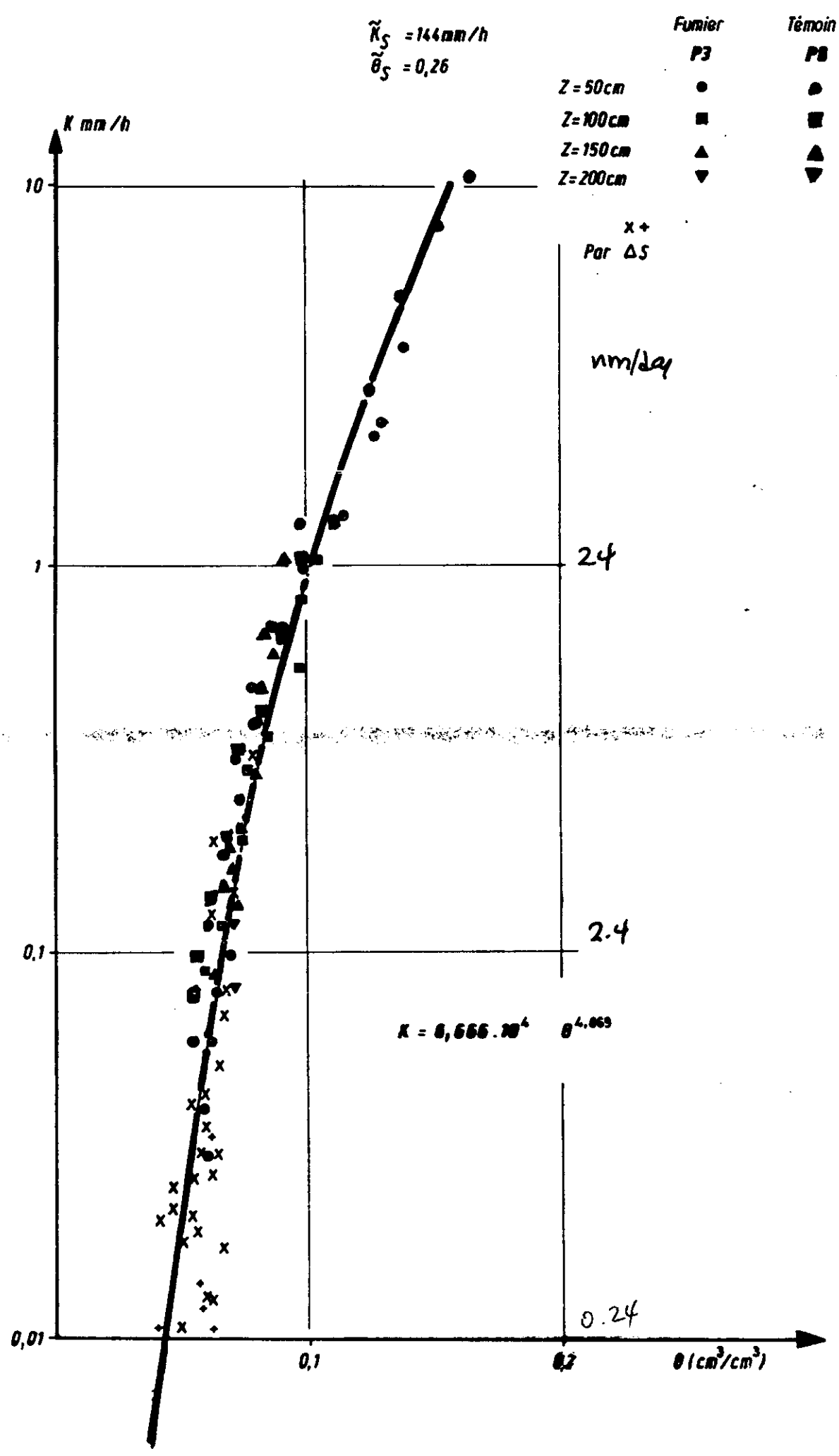

h (m)
-1,00
-0,50
0
0
0,1
0,2
θ(m³/ m³)
I0
I1
z ,m
0 - 0,1
0.1-0.2

7a


h (m)
-1,00
-0,50
0
0
0,1
0,2
0,3
I1
z ,m
0.3
0.5-0.7
0.9-1.1
1.3-1.5
(D)
(H)


h (m)
-1,00
-0,50
0
0
0,1
0,2
0,3
I0
z ,m
0.3-0.5
0.7
0.9-1.1
1.3-1.5
(D)
(H)

-80-


$\tilde{K}_S$ = 144 mm/h
$\tilde{\theta}_S$ = 0,26
Fumier
Témoin
P3
P8
Z = 50cm
Z = 100cm
Z = 150cm
Z = 200cm
K mm/h
10
1
0,1
0,01
0,1
0,2
θ (cm³/cm³)
x +
Par ΔS
nm/day
24
2.4
0.24
K = 8,666 . 10⁴ θ^4,869

0
20
100
T (m)
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θ (ω/ω)
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T_{1000}

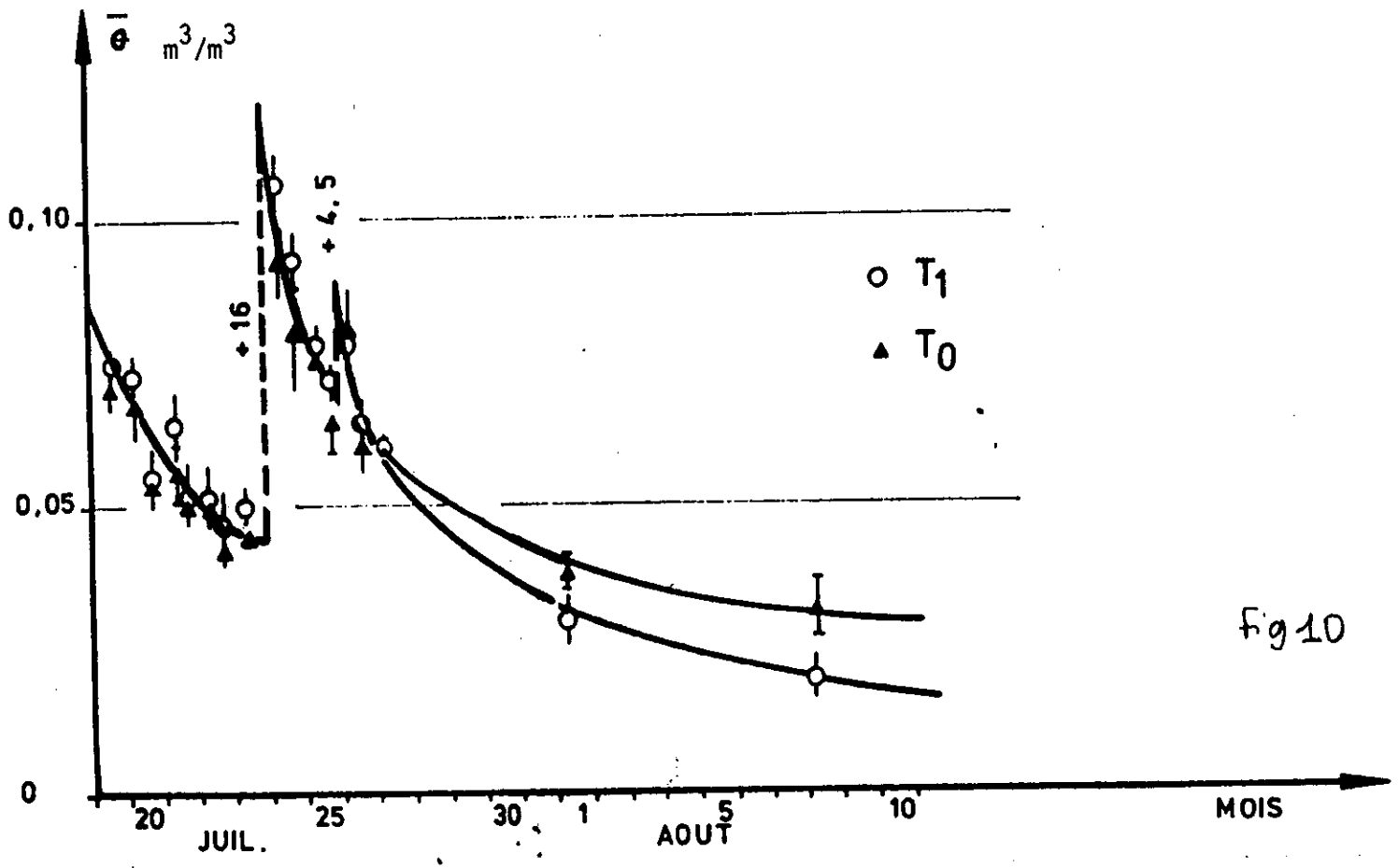

$\overline{\theta}$ m³/m³
0,10
0,05
0
+16
+4,5
T1
T0
20
JUIL.
25
30
1
AOUT
5
10
MOIS

Fig 10

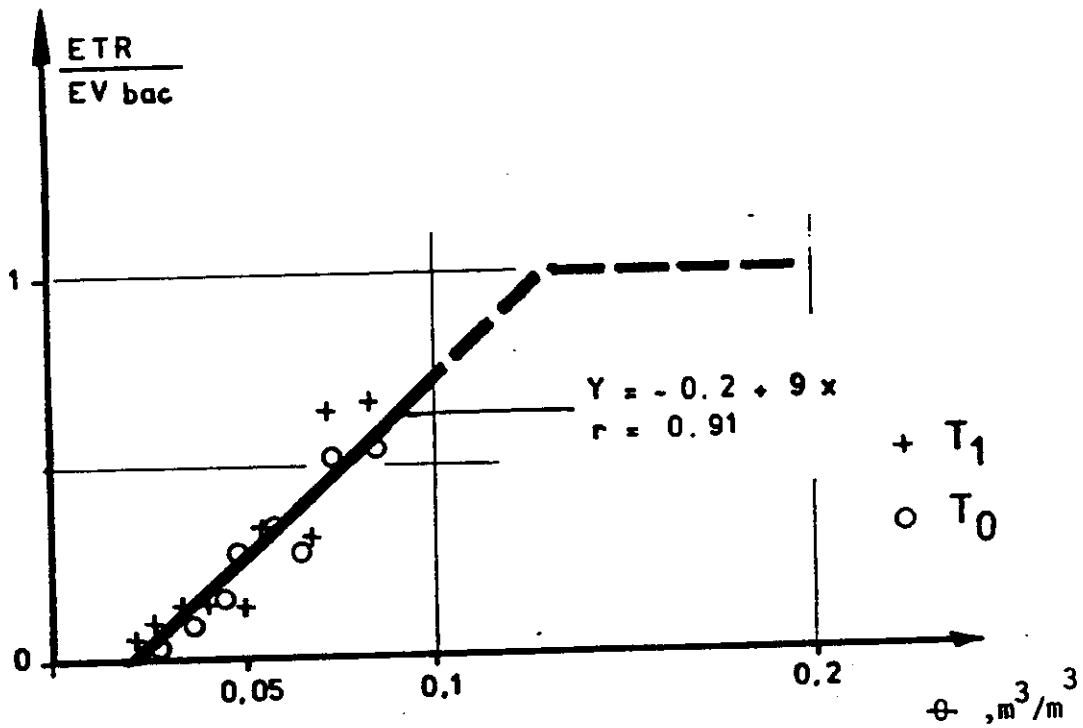


fig 12

EXAMPLE 2 -

EFFECT OF SHORT DISTANCE SOIL VARIABILITY (ACCUMULATION OF CLAY CONTENT IN THE SOIL PROFILE) ON

- WATER INFILTRATION
- DRAINAGE AND NUTRIENT LOSSES

SAME COLLABORATION AS IN EXAMPLE 1, BUT EXPERIMENTATION DONE IN BAMBEY, CENTRAL SENEGAL.

UNDER CROP

(IAEA - ISRA - IMG)

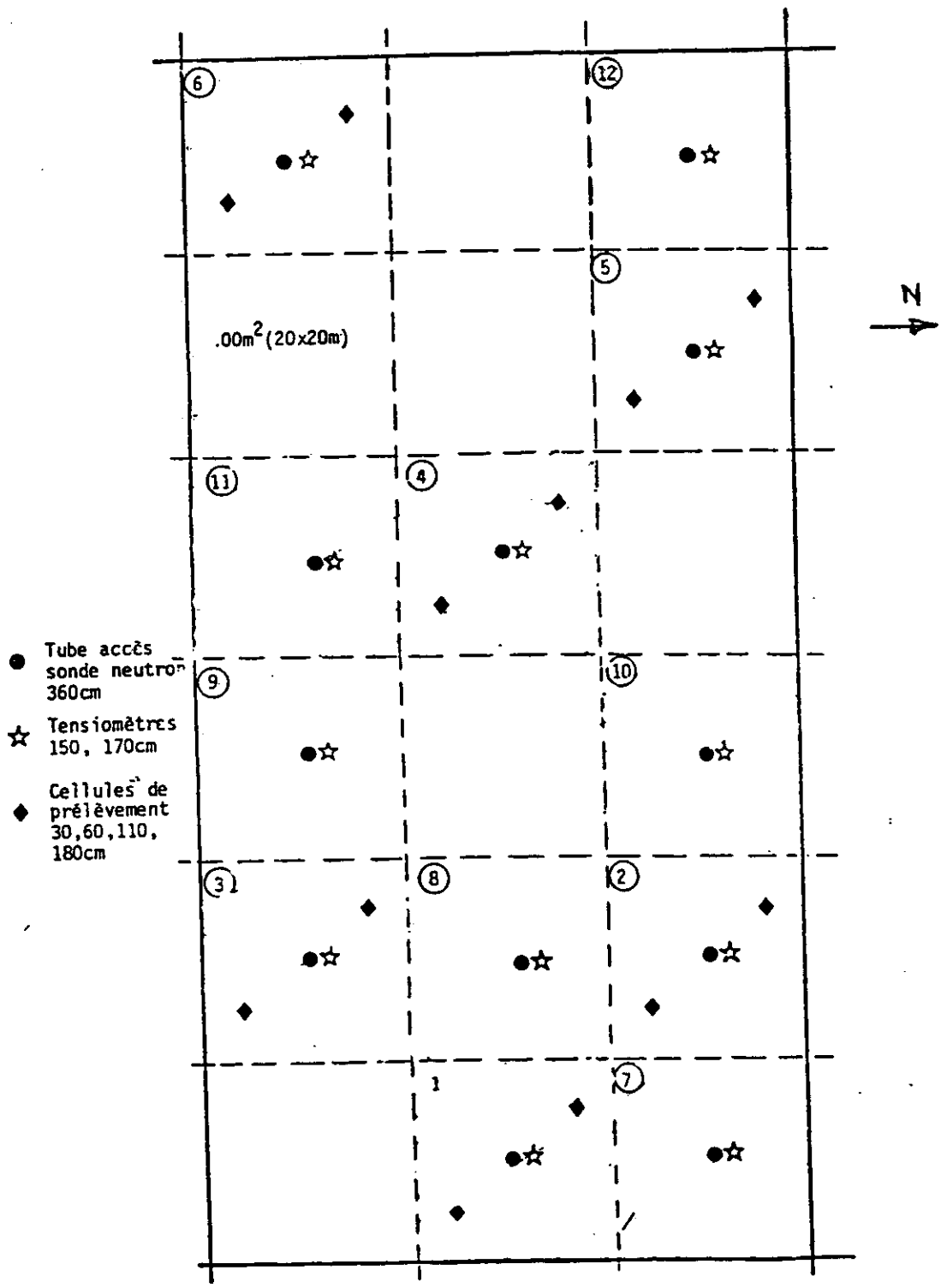
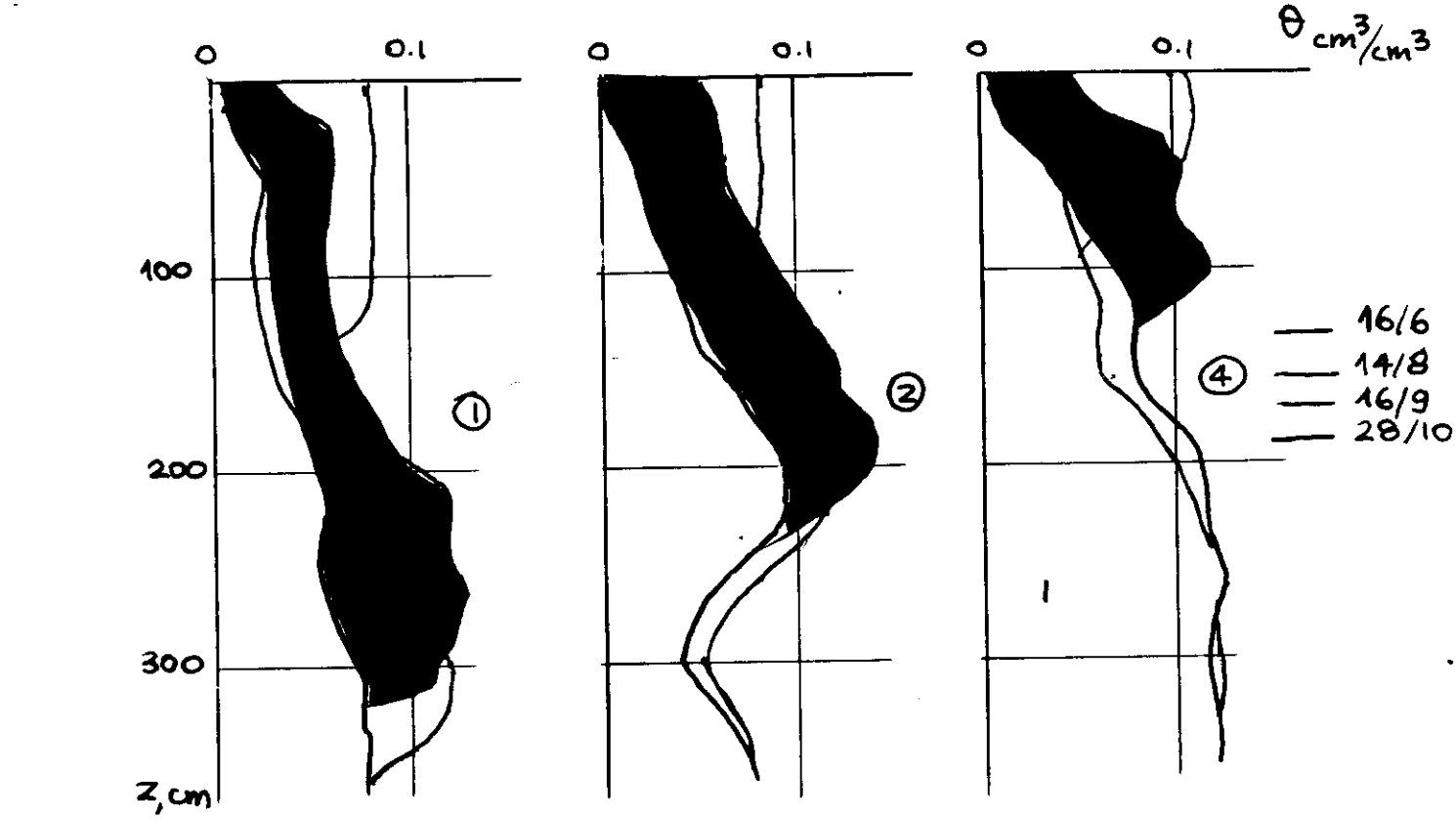
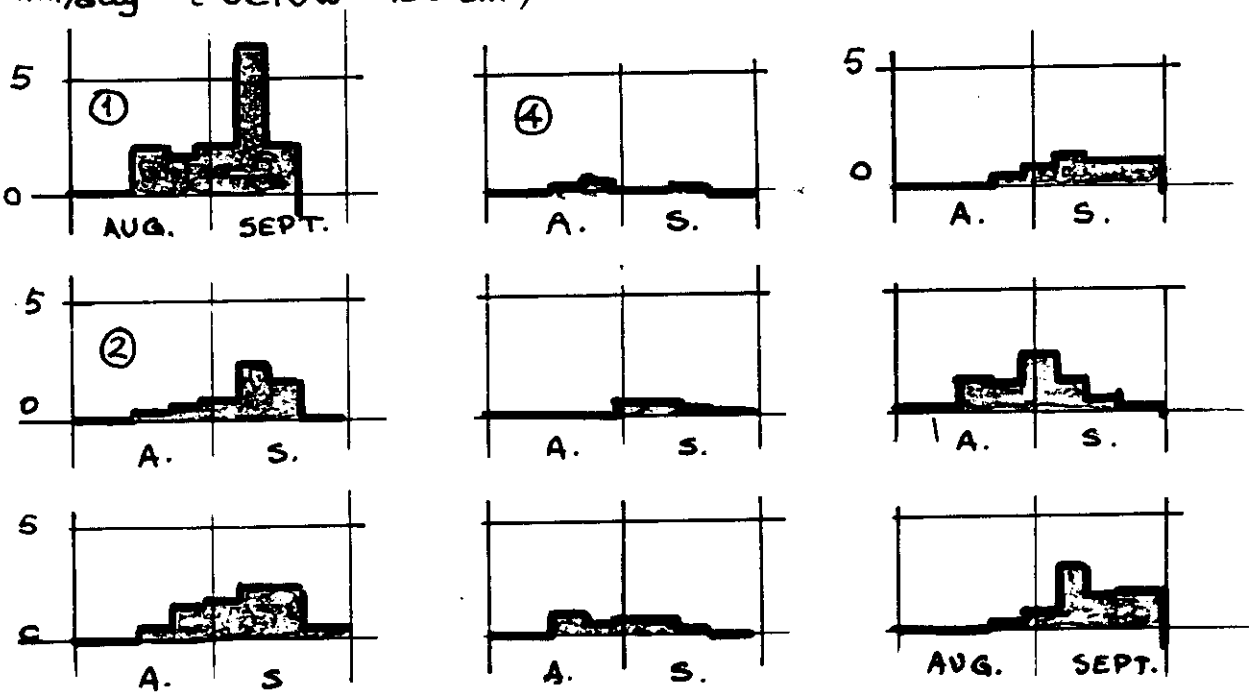


Figure 1 - BAMBEY - Suivi sous mil - 1980



mm/day (below 150 cm)



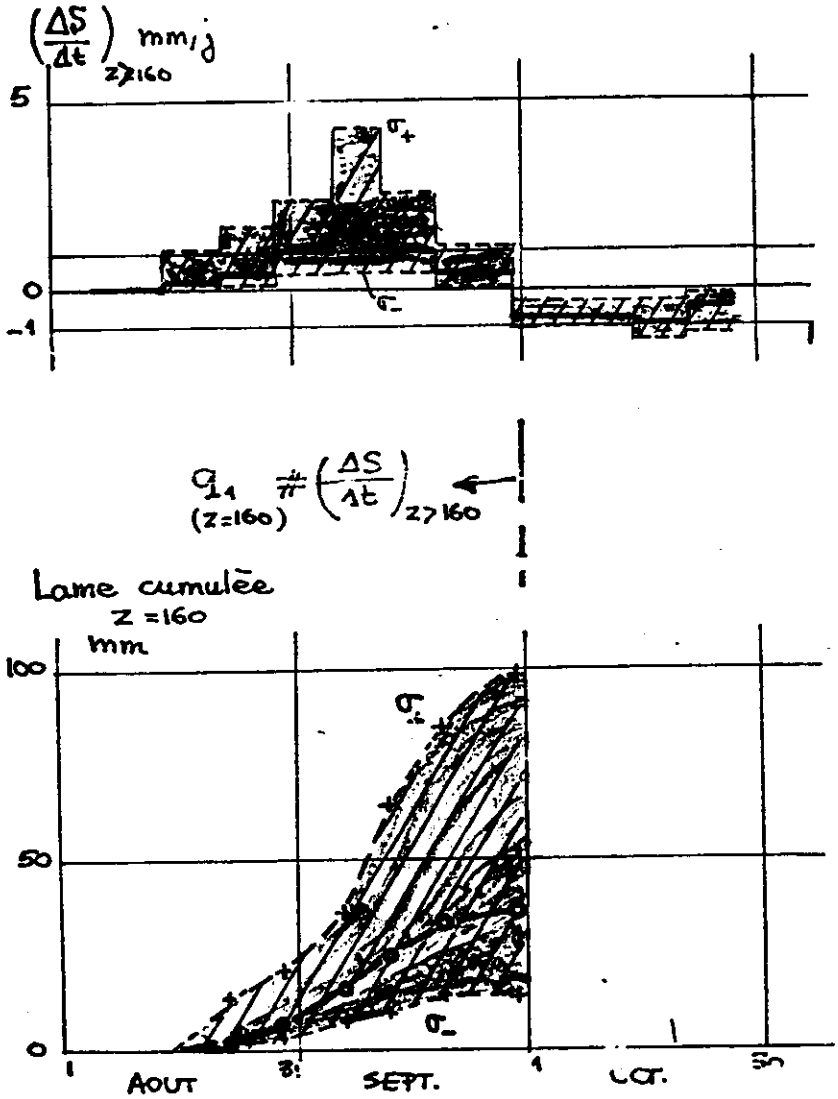


Figure 9 - Valeurs moyennes taux de variation de stock et lame percolée à 160 cm sous mil.

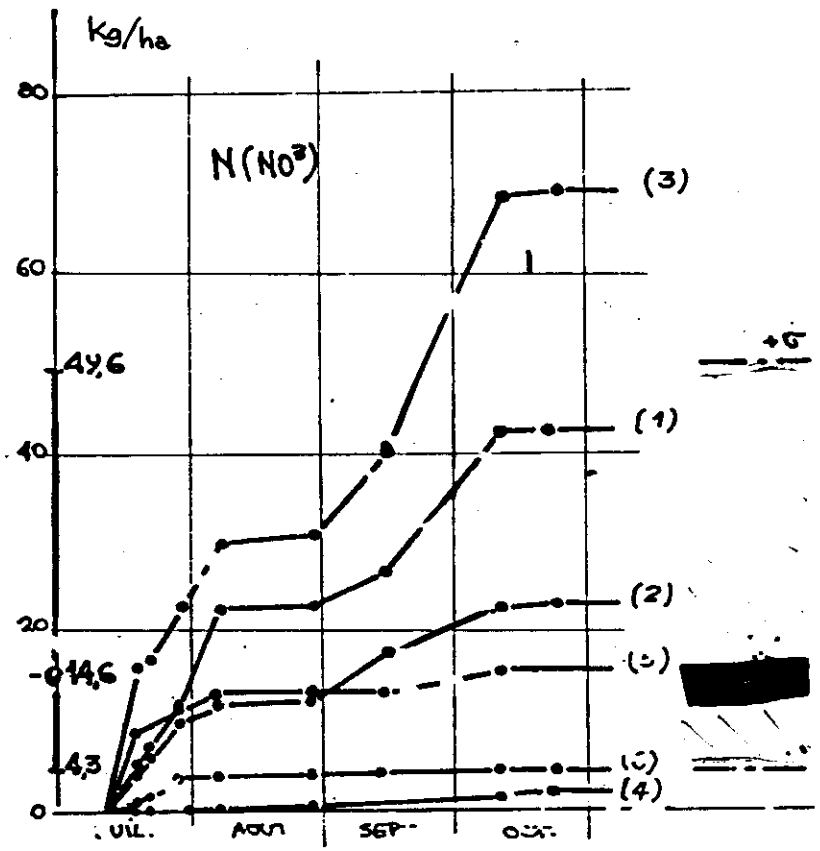


Fig. 8 - Estimation of cumulative nitrogen losses under peanut from 6 independent sites of measurments (neutron moisture meter, tensiometers, solute concentration cells) at a depth of 110 cm under a one hectare field of sandy soil at BAMBEY, Senegal
(from VACHAUD et al, 1982)

METHOD 2 , CONTROL OF FLUX AT Z_i

* ACCESS TUBES ARE NOT LONG ENOUGH

OR

* MARKED DRAINAGE (OR CAPILLARY RISE) AT z_f

→ REQUIRES NEUTRON PROBE + TENSIOMETERS

2 DIFFERENT "FLUX CONTROLLED" POSSIBILITIES

2.i : ZERO FLUX METHOD

- x BARE SOIL OR SHALLOW ROOT SYSTEM
- x NO RAINFALL DURING PERIOD MEASUREMENT
- x NO NEED FOR $K(\theta)$

2.ii - DARCY'S ESTIMATION OF q

x NO LIMIT OF APPLICABILITY BUT REQUIRES $K(\theta)$ ON SITE OF MEASUREMENT

x VERY SENSITIVE TO ERRORS ON θ FOR VERY WET SOILS.

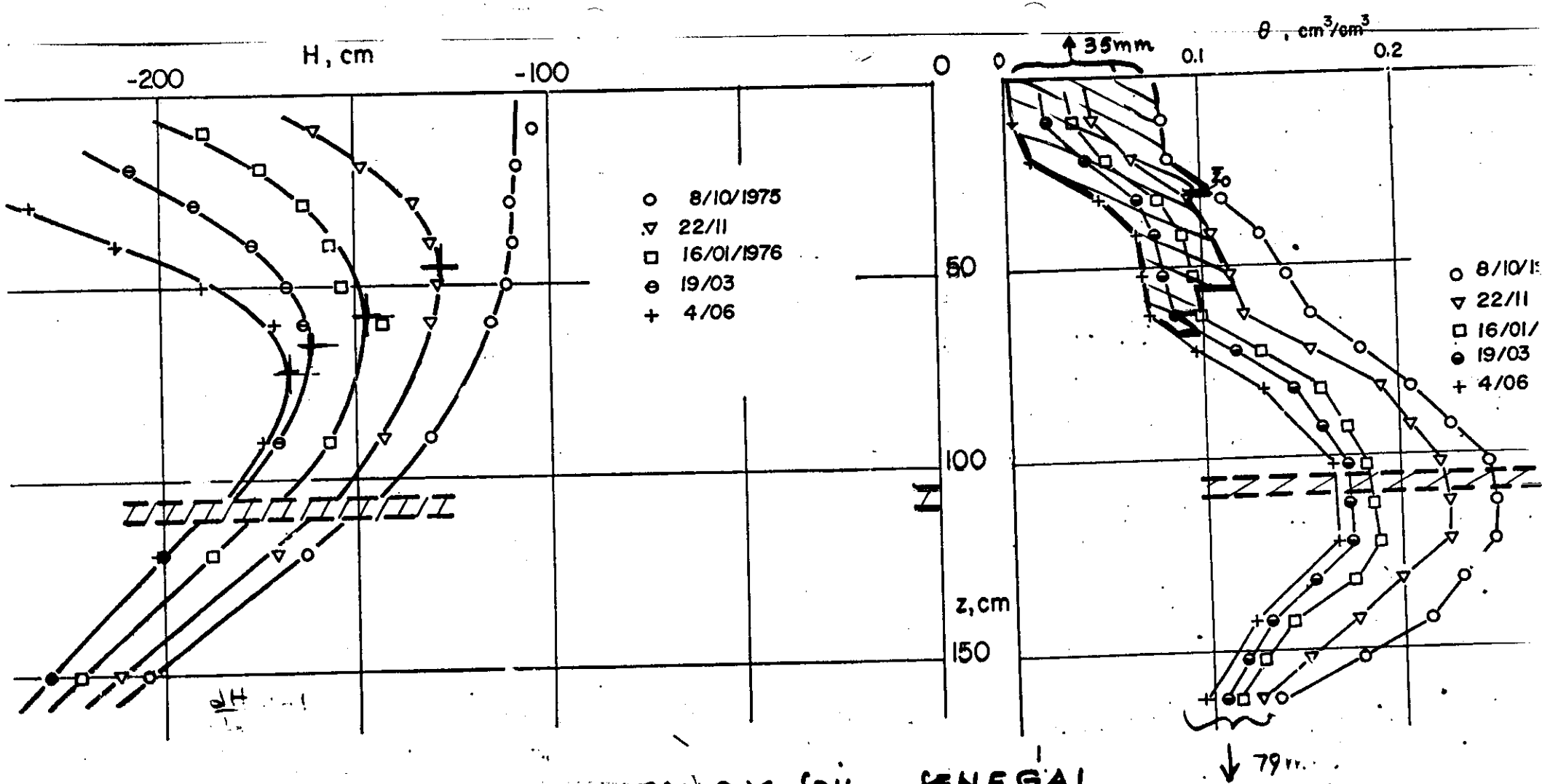
x OFTEN INAPPLICABLE

EXAMPLE 3

ESTIMATION OF SOIL WATER BALANCE OVER ONE YEAR (DRY SEASON) BY ZERO FLUX METHOD - BARE SOIL

BAMBEY, CENTRAL SENEGAL

SAME COLLABORATION AS EX 1. & 2.



SANDY soil - SENEGAL

ETR = 35 mm

35 + 114 mm → D = 79 mm ; $\frac{ETR}{Ev.\,BAC} = \frac{0.014}{}$

Class A pan = 2450 mm

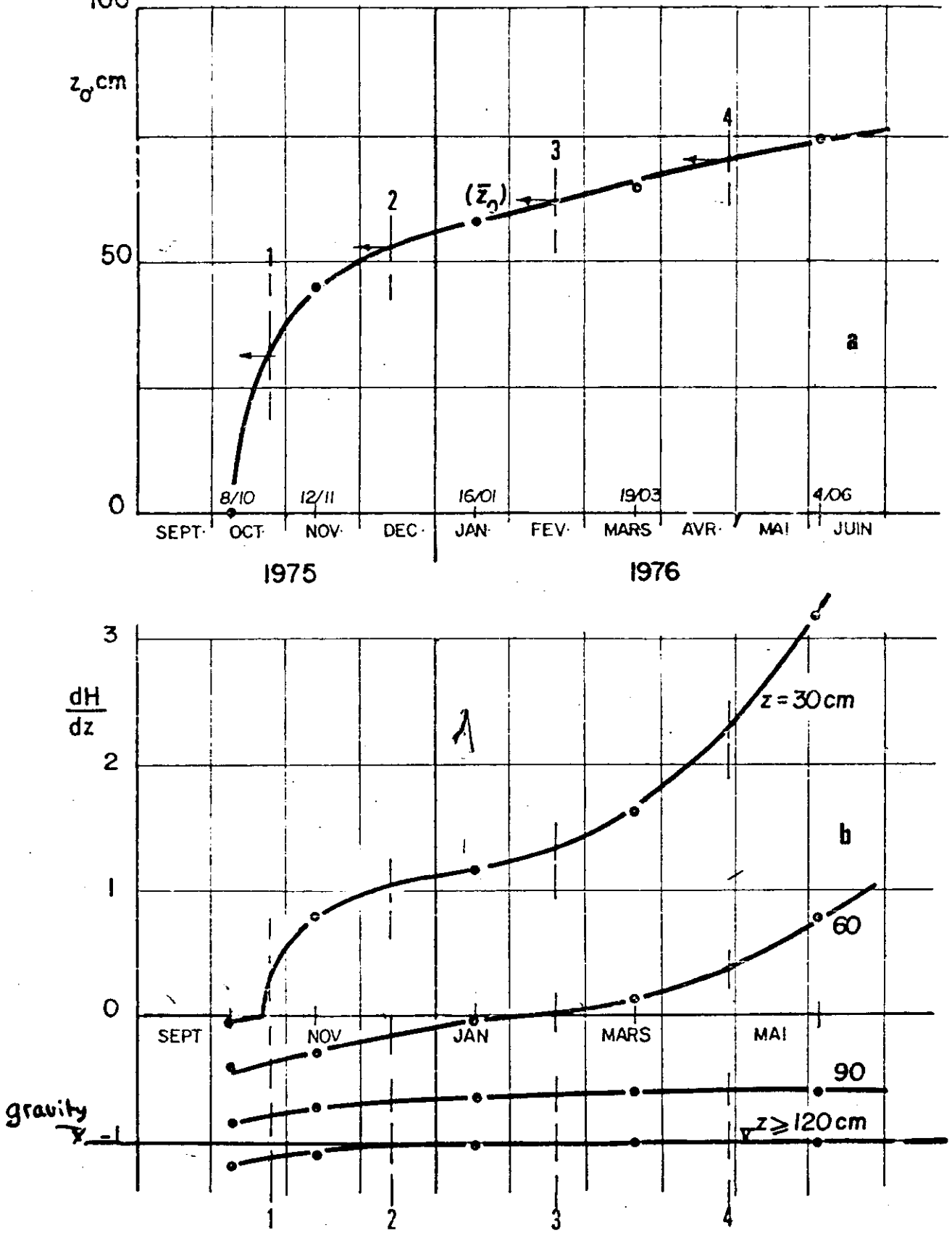


FIGURE 18 - Evolution durant la saison sèche 1975-76 de la profondeur du plan de flux nul (18.a) et du gradient de charge à différents niveaux (18.b) mesurés sur le site B2.
Les temps médians entre deux mesures sont notés (1), (2), (3), et (4) et servent à définir les valeurs moyennes des variables entre deux mesures.

ESTIMATION OF EVAPORATION OF A DRIP IRRIGATED OLIVE TREE ORCHARD BY SOIL WATER FLOW MEASUREMENTS

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AIMS

ESTIMATION OF EVAPOTRANSPIRATION AND DRAINAGE AT THE SCALE OF 1 HA FOR AN OLIVE TREE ORCHARD WITH SPACING 7 x 7 M.

* FROM LOCAL MEASUREMENTS OF SOIL WATER ON SELECTED TREES.

* ACCOUNTING FOR EXISTENCE IN THE NEIGHBOURHOOD EACH TREE OF BOTH A ZONE OF HIGH LEVEL OF EVAPOTRANSPIRATION (IRRIGATION BULB) AND A ZONE OF VERY LOW EVAPORATION.

8 trees instrumented
1 selected a priori
with a posteriori validation

WEIGTHING PROCEDURE

1 - IRRIGATED ZONE

. ACCESS TUBE 1 → 3 M²

. ACCESS TUBE 2 → 9 M²

$$\Delta S_i^* = \frac{\Delta S_1 + 3\,\Delta S_2}{4}$$

$$D_i^* = \ldots\ldots\ldots$$

2 - DRY ZONE

$$\Delta S_{ni}^* = \frac{\Delta S_3 + \Delta S_4}{2}$$

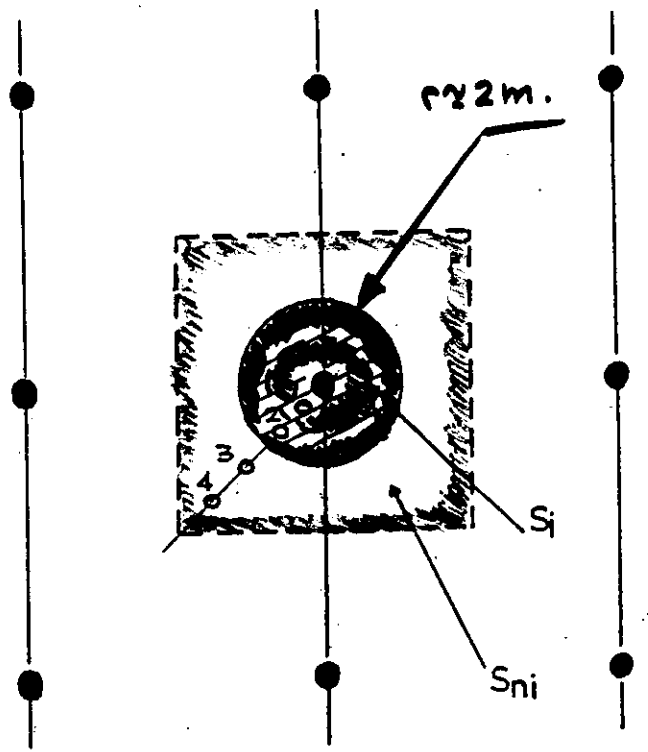
$$D_{ni}^* = \ldots\ldots\ldots$$

3 - TOTAL SURFACE (1/4 IRRIGATED, 3/4 DRY)

$$ETR = P + 1/4\,[I - (\Delta S_i^* + D_i^*)] + 3/4\,(\Delta S_{ni}^* + D_{ni}^*) - R$$

- P: Total rainfall
- I: Total Irrigation (mm)
- R: Total Runoff

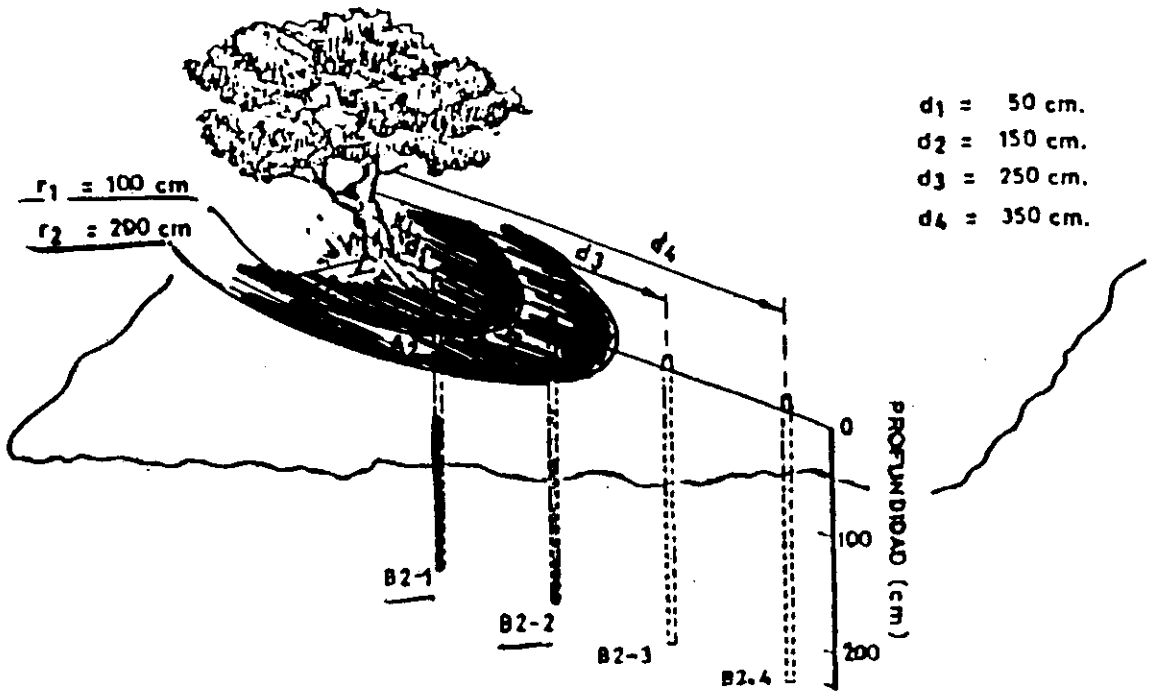
7 x 7 m

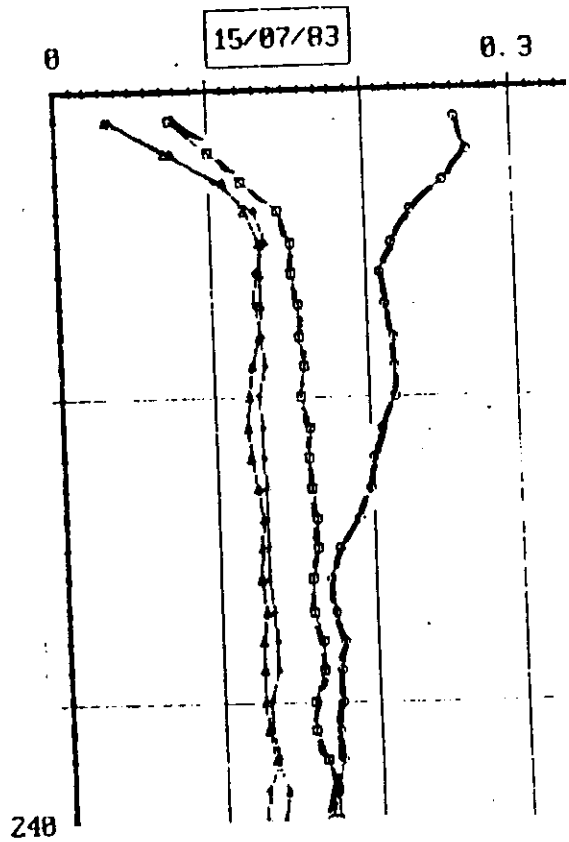


$$\frac{S_i}{S_{ni}} \simeq \frac{1}{4}$$

● Arbol

(3m²)
(9 m²)





B2-1
B2-2
B2-3
B2-4

ESTIMATION OF TERMS OF WATER BALANCE

TIME INTERVAL # 2 WEEKS

I = IRRIGATION DOSE PER TREE
KNOWN FROM DAILY APPLICATION

ΔS^* = WEIGHTED CHANGE OF TOTAL STORAGE (0-2.4 m)

D^* = WEIGHTED DRAINAGE AT 2.4 m, APPLYING DARCY's WITH $K(\theta)$ DETERMINED ON THE SAME SITE.

R = RUNOFF (ONLY DURING WINTER RAIN) ESTIMATED WITH ASSUMPTION, ETR # ETP (WINTER).

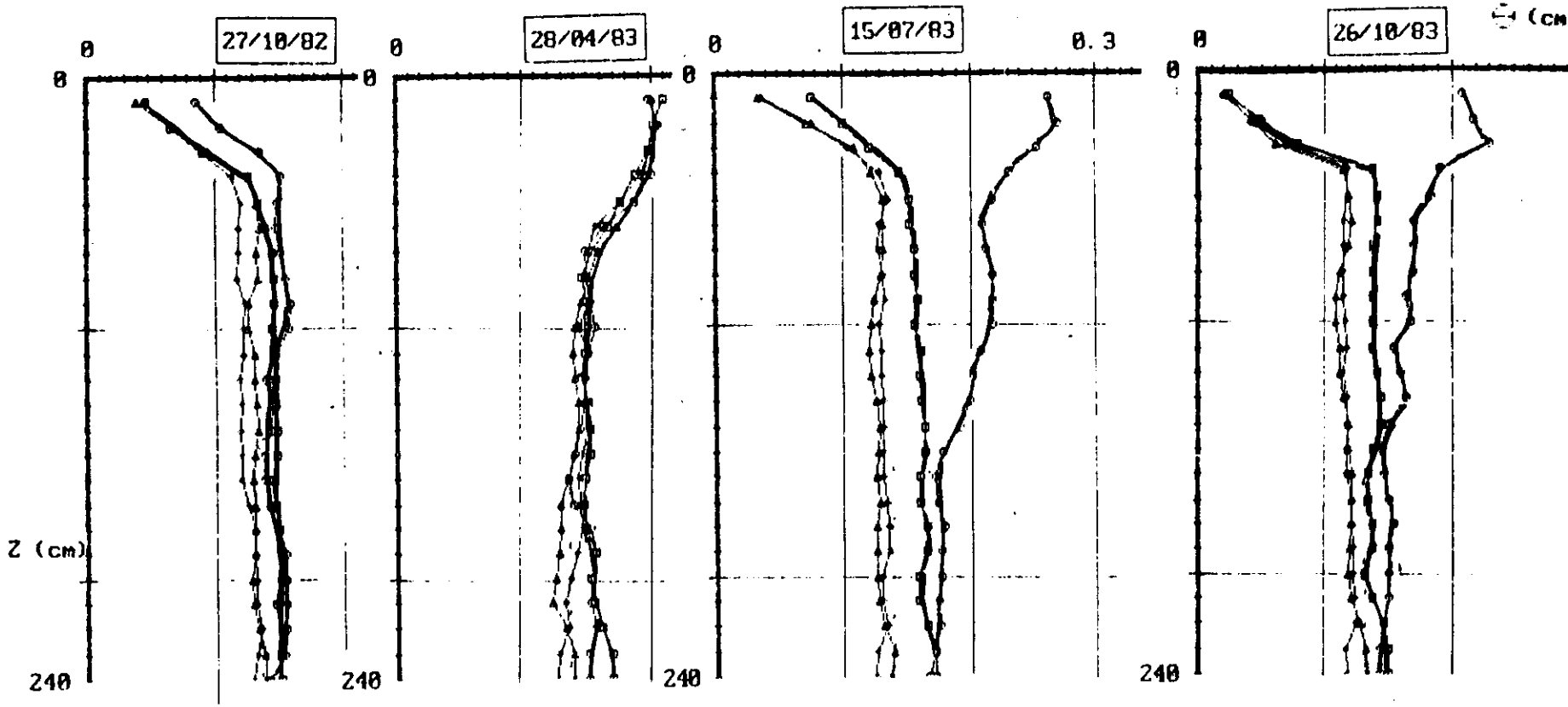
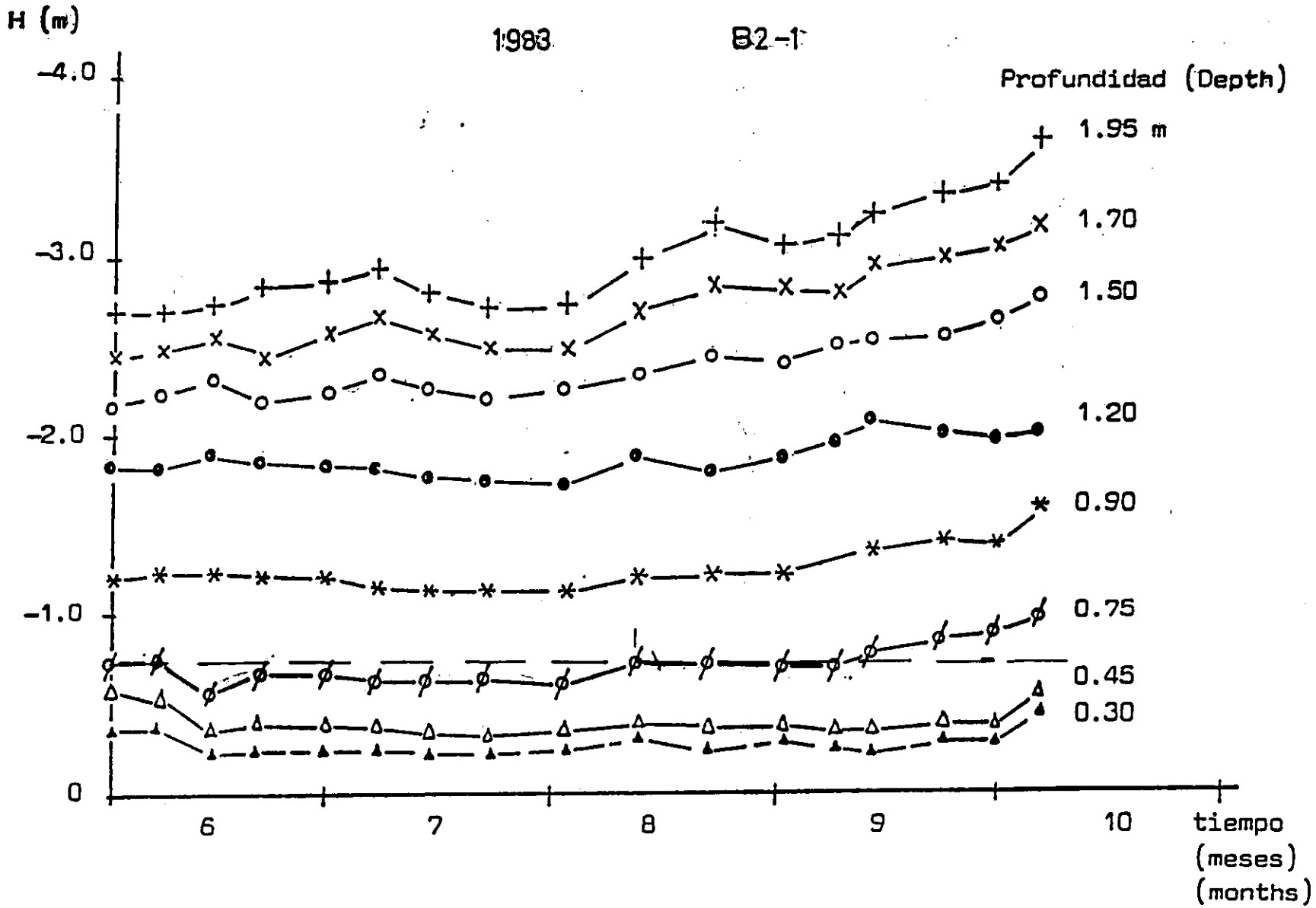


fig4


H (m)
1983
B2-1
Profundidad (Depth)
-4.0
-3.0
-2.0
-1.0
0
1.95 m
1.70
1.50
1.20
0.90
0.75
0.45
0.30
6
7
8
9
10
tiempo
(meses)
(months)

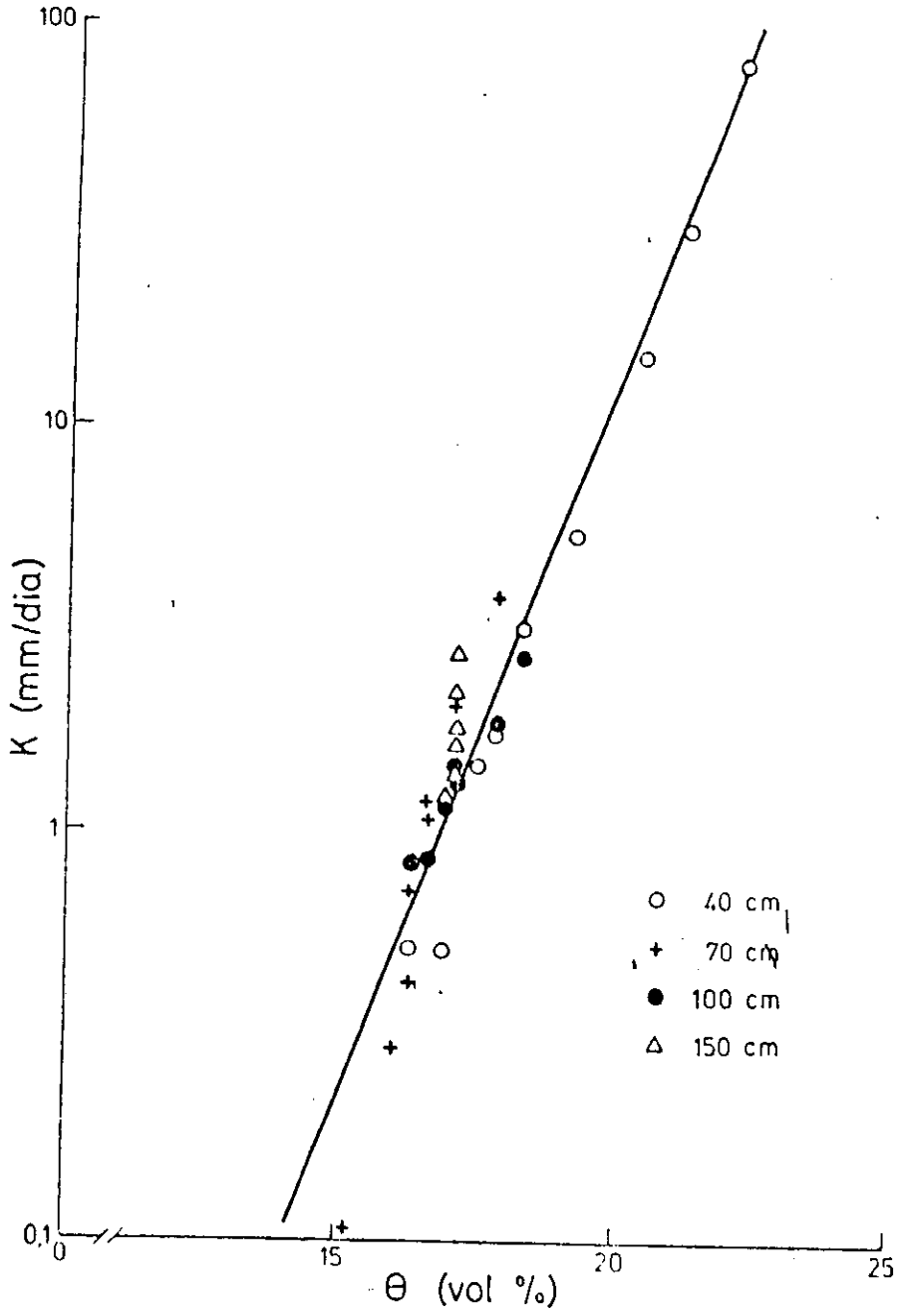
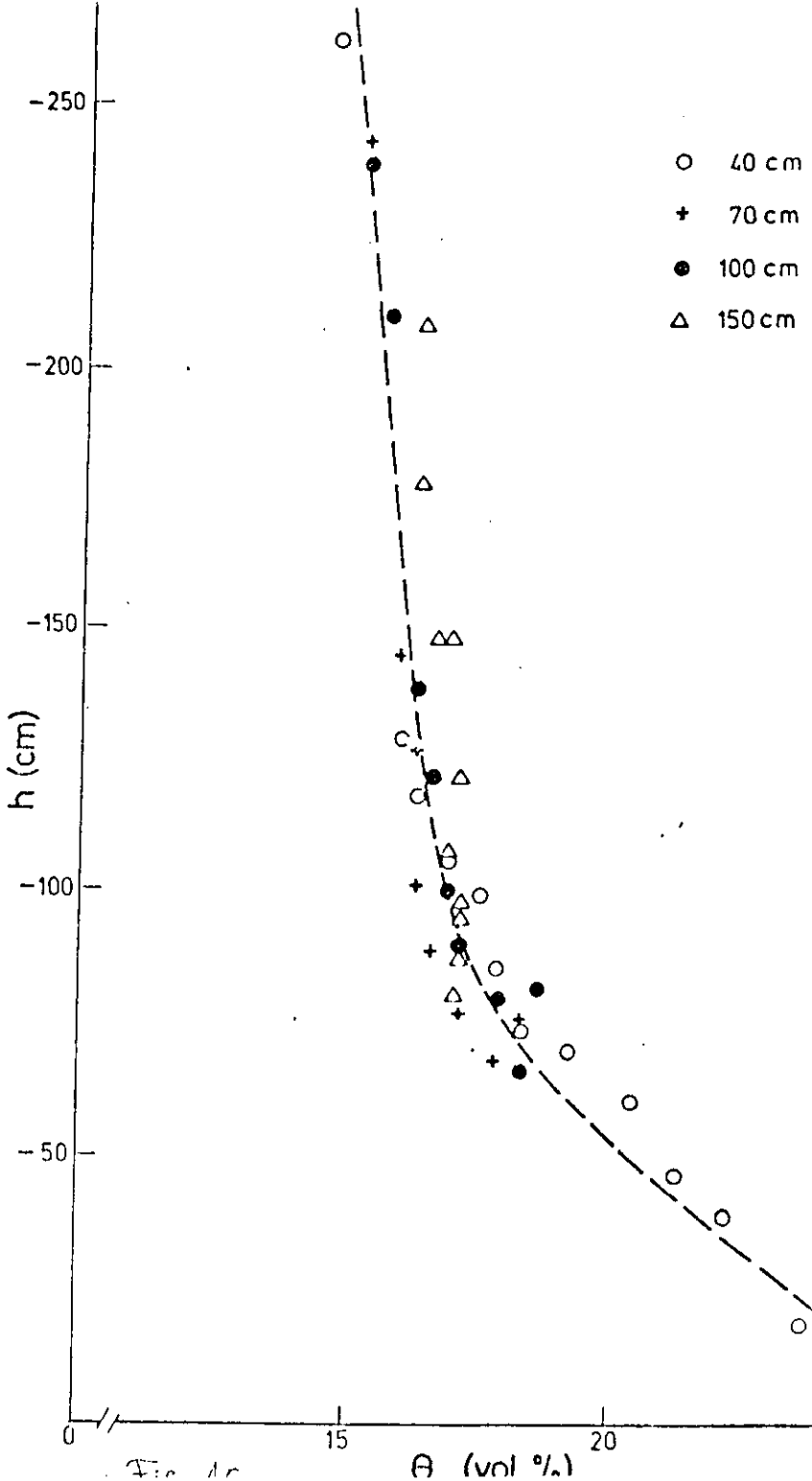
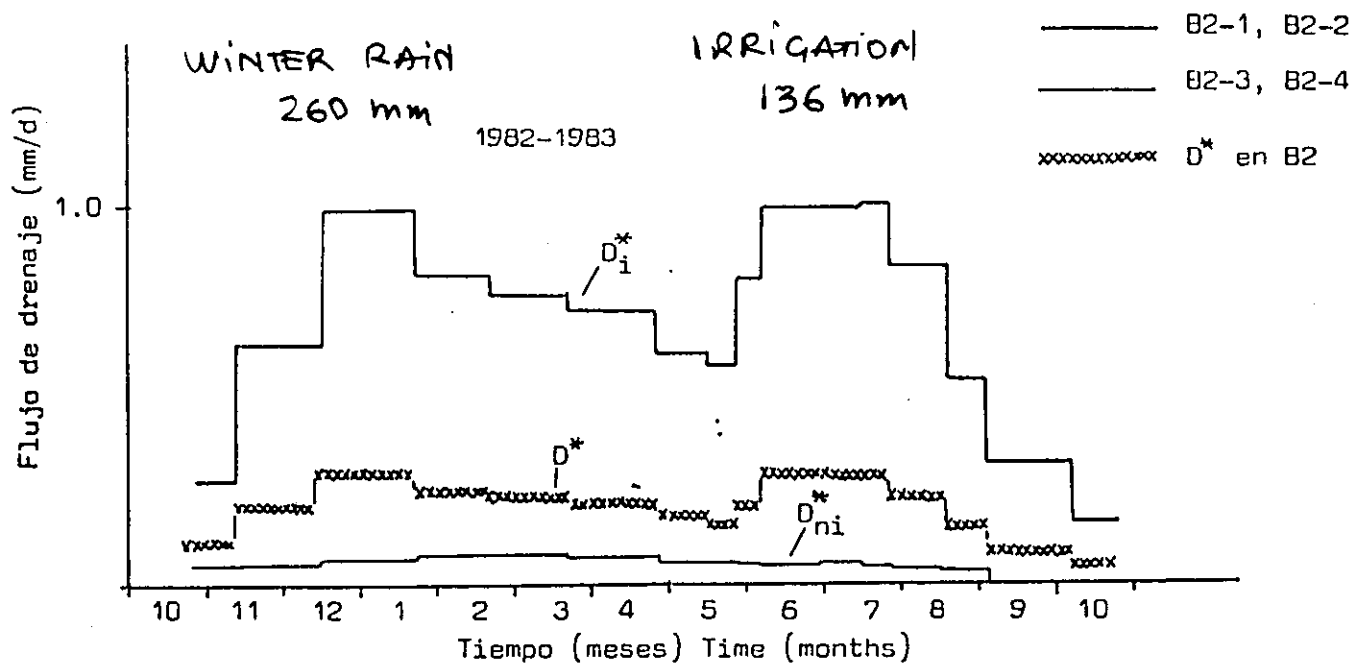

100
10
1
0,1
K (mm/dia)
0
15
20
25
θ (vol %)
40 cm
70 cm
100 cm
150 cm

Fig. 9


-250
-200
-150
-100
-50
h (cm)
0
15
20
θ (vol %)
40 cm
70 cm
100 cm
150 cm


B2-1, B2-2
B2-3, B2-4
D* en B2
WINTER RAIN
260 mm
IRRIGATION
136 mm
1982-1983
Flujo de drenaje (mm/d)
1.0
D_i^*
D*
D_{ni}^*
10 11 12 1 2 3 4 5 6 7 8 9 10
Tiempo (meses) Time (months)

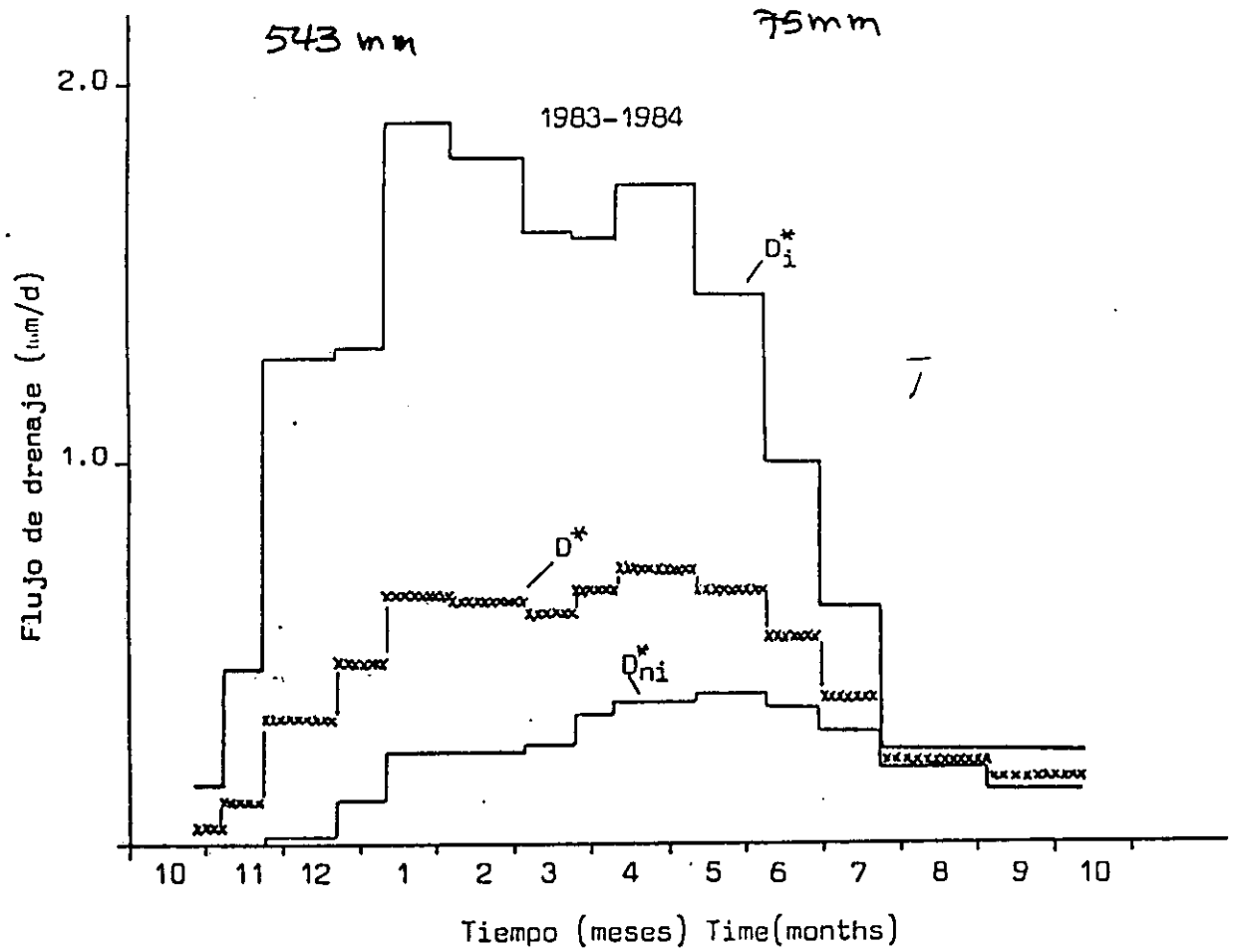

543 mm
75mm
1983-1984
Flujo de drenaje (mm/d)
2.0
1.0
D_i^*
D*
D_{ni}^*
10 11 12 1 2 3 4 5 6 7 8 9 10
Tiempo (meses) Time(months)

Fig. 1

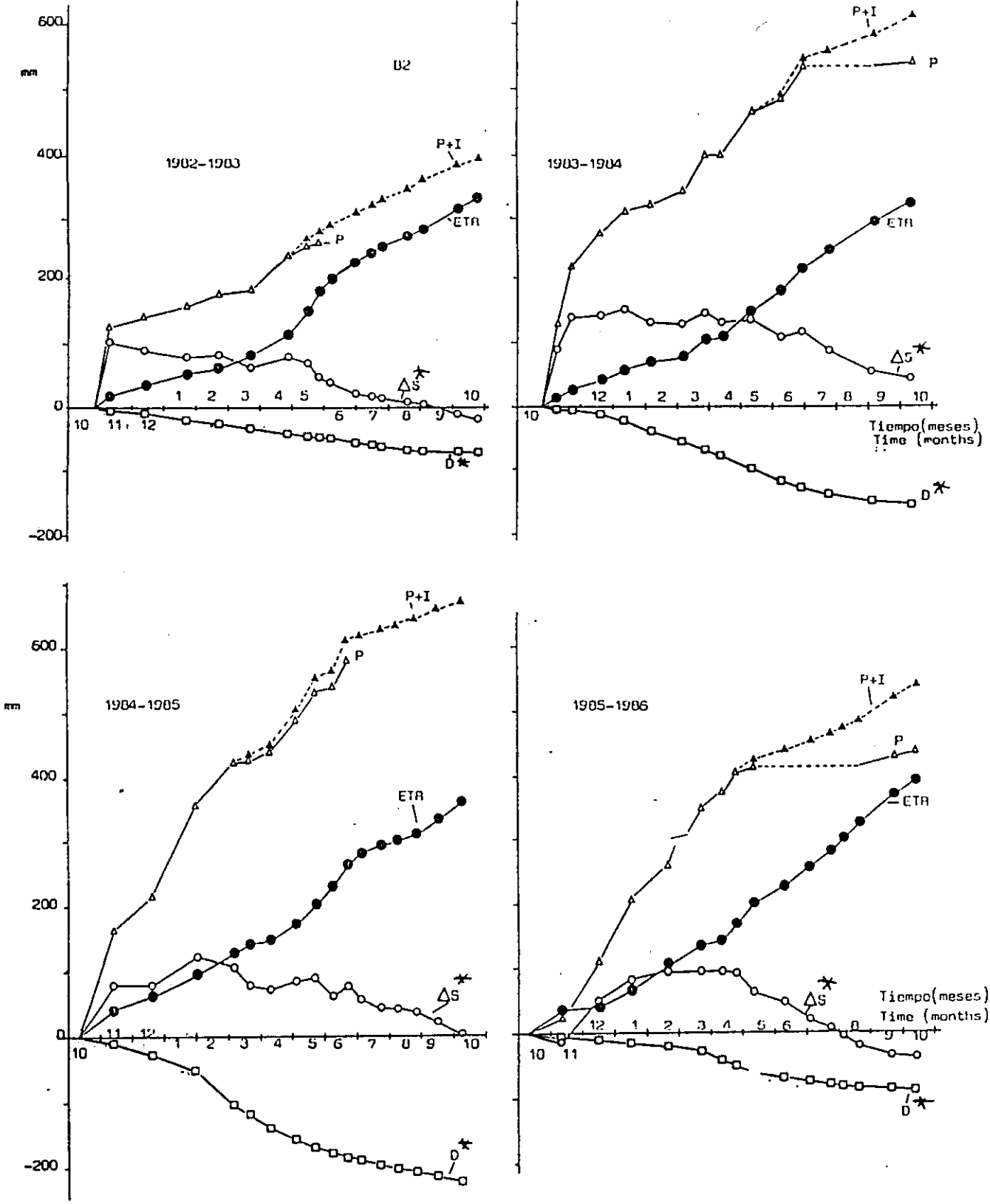
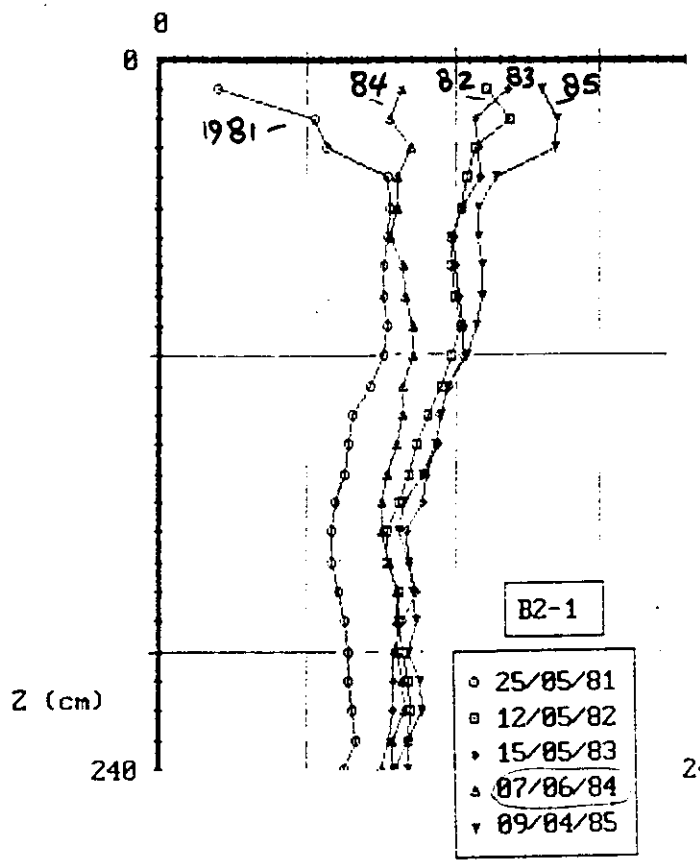
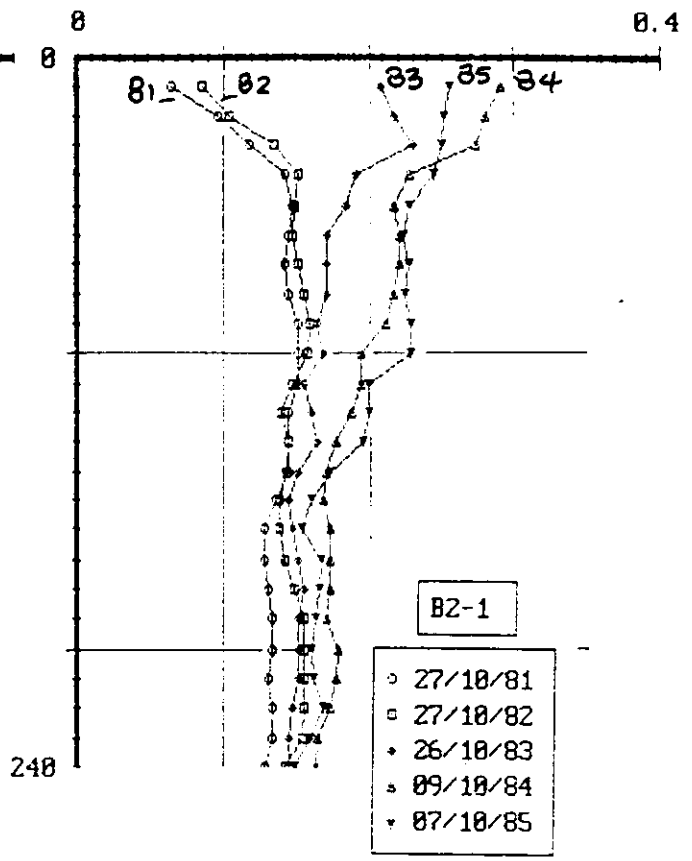

B2
1982-1983
1983-1984
1984-1985
1985-1986
mm
600
400
200
0
-200
P+I
P
ETR
ΔS
D
10 11 12 1 2 3 4 5 6 7 8 9 10
12 1 2 3 4 5 6 7 8 9 10
Tiempo(meses)
Time (months)

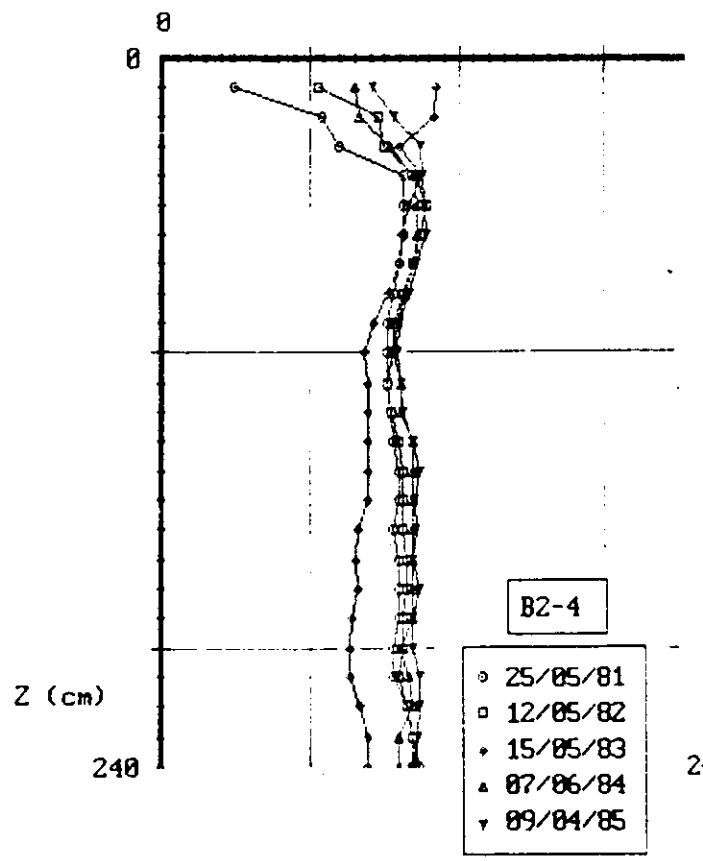
Fig. 3 (2)

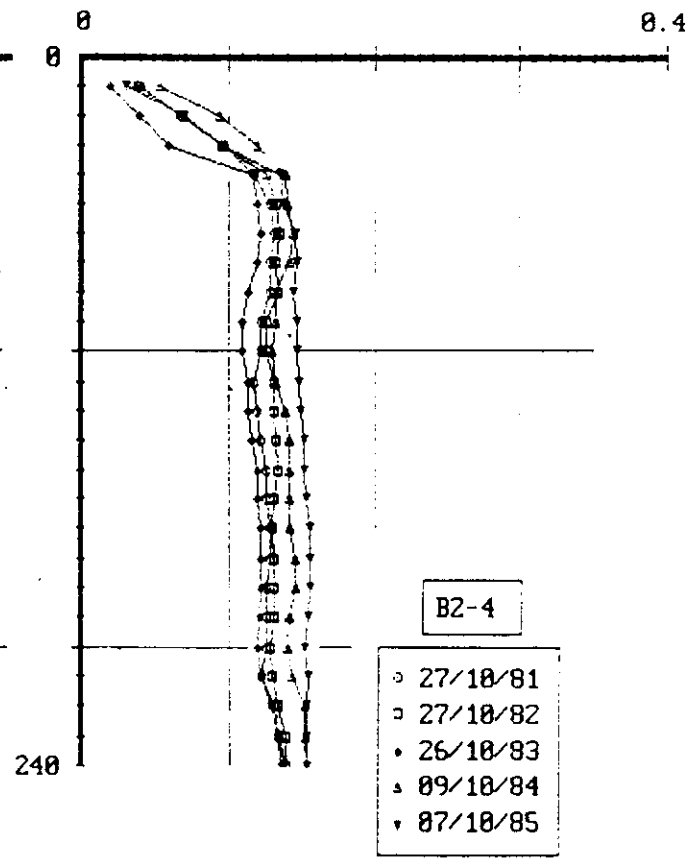


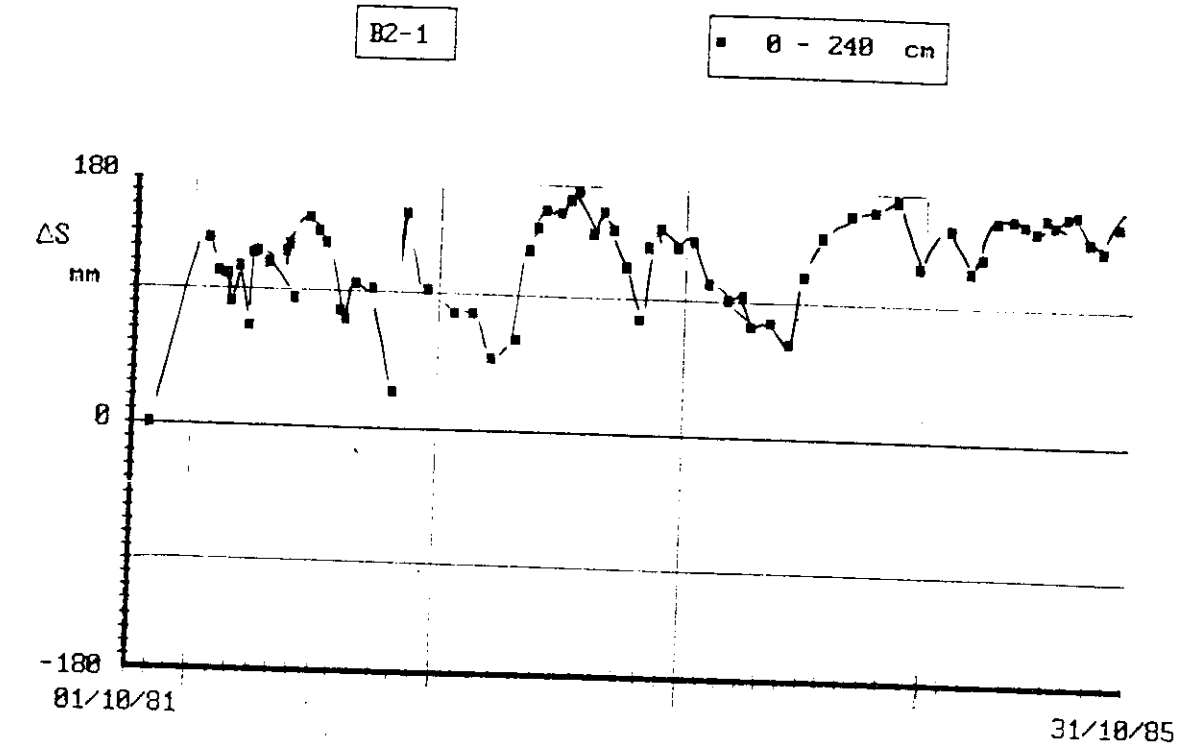


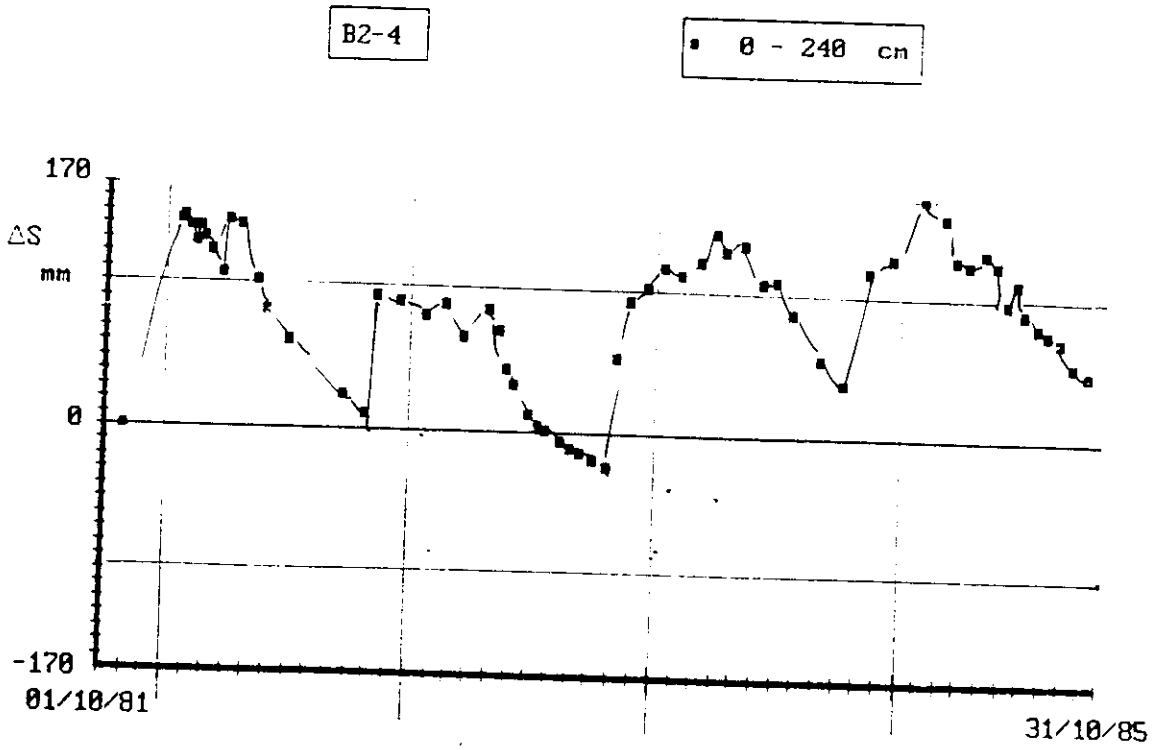
Début irrigation

fin d'irrigation






B2-1
0 - 240 cm
180
ΔS
mm
0
-180
01/10/81
31/10/85


B2-4
0 - 240 cm
170
ΔS
mm
0
-170
01/10/81
31/10/85

Tree spacing 7x7 m. Weighted irrigation : 0.1 EV

Hydrological year	Period	P (mm)	I (mm)	D (mm)	R (mm)	ETR (mm)	ETP (mm)
1982-1983	27/10/82						
	28/04/83	236,9		40,9		114,3	220,3
	28/04/83						
	26/10/83	21,4	135,8	31,8		223,1	745,7
						337.4	965
1983-1984	26/10/83						
	11/05/84	467,7		101,7	81,7	148,0	229,8
	11/05/84						
	09/10/84	74,7	65,1	55,6		174,4	607,1
						322.4	836.9
1984-1985	09/10/84						
	20/03/85	429,7		139,5	69,1	142,2	159,3
	20/03/85						
	07/10/85	154,1	86,7	99,0		218,2	791,3
						460.4	940.6
1985-1986	07/10/85						
	26/4/86	407,4		51,4	95,6	167,7	252,0
	26/4/86						
	14/10/86	30,9	100,5	36,0		225,7	729,7
						392.4	981.7

Total values of precipitation (P), irrigation (I), weighted drainage (D), actual evapotranspiration (ETR), and potential evapotranspiration (ETP), during precipitation and irrigation periods.