# WATER AVAILABILITY OF SOME TYPICAL SOILS OF THE KISII AREA

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## Preface

The research described in this report has been carried out by a post-graduate student as a part of his study for his master degree. The research is a part of the research carried out by the Training Project in Pedology at Kisii, Kenya, which is a project of the Agricultural University of Wageningen, the Netherlands. The amount of available water in typical soils was studied, to support the evaluation of soil maps, made in the project, with regard to the suitability of soils to certain crops. The fieldwork was mainly done in Feb. 1976, the report was completed in Jan. 1978.

## Acknowledgements

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Thanks to Mr. Dokter for letting me use his type-writer.

Wageningen, January 1978.

Summary

In order to get information about the available water, pF-curves, FC, WP and amounts of roots were measured, for some (10) typical soils of the area covered by the Training Project in Pedology, Kisii, Kenya. In the report various elements of water availability studies are discussed, specially with regard to their practical value.
Water content measurements at FC, and at WP gave good values for the total amount of water available to plant roots, stored in the soil. For shallow, gravelly soils (50 cm.) this was app. 75 mm, for 100 cm. deep red clay soils 100 mm, and for 150 cm. deep red clay soils it was 135 mm. Allthough in the deeper soils rootgrowth was strongly reduced below 50 cm, this part of the profile supplied about 50% of the water, available in a soil.

# Chapter I - Introduction

# I. INTRODUCTION

## I.1. The research

With regard to land evaluation it is important to find easy, reliable methods to determine the amount of water a soil can supply to a certain crop. The research described in this report is an attempt to get information about the available water in some typical soils of the 'Kisii area'. Consequently research has been carried out concerning pF-curves, field capacity, wilting point and root growth. The following chapters are dealing with these subjects. In the report the discussion of the methods and results in connection with obtaining valuable data with regard to land evaluation is emphasized. Also the system the 'Kenya Soil Survey Project' uses to estimate the amount of available water is examined.

## I.2. Generalities concerning water availability studies

The amount of water available to plants is a funtion of climate, soil and plant conditions. The climate determines the amount of rain, soil conditions determine the amount of water which is held in the soil (run-off, drainage), available to plants (pF-curve, WP, FC), soil and plant conditions determine the amount of 'available water' in reach of plant roots (rootability, rootgrowth).
Water reaching the soil profile can only partly been used, because some of it is drained away or to heavily bound to the soil. From this amount of 'available' water a certain part cannot be used because it is out of reach of plant roots. To avoid confusion these amounts will consistantly be called 'available moisture' and 'available moisture in reach of the plant roots'. Both amounts are not easily to be quantified. Available moisture is often given as the difference between the amount of water held at 'field capacity' and the amount held at 'permanent wilting point', derived from the pF-curve, applying certain fixed (arbitrary) pF values for FC and WP. Allthough this procedure has proven

to be usefull in classifying soils upon their available moisture, both FC and WP are no constant, intrinsic properties of a certain soil (as will be discussed in the chapters about FC and WP). The part of this available water a plant can actually use, is restricted by rootgrowth and hydraulic features of a soil. Up till now it seems difficult to quantify these properties in such a way that they can be used to measure the available water in reach of the plant roots. Emperical formulae are given to estimate this amount. In the foregoing the classical approach to soil moisture availability is used. (in fact the research discussed in this report is based on this approach.) Modern workers in soil physics use what is called the 'dynamic' approach, describing soil, plant and atmosphere as a continuum in which water continually moves under influence of potential energy gradients. This approach is usefull to give a better understanding of what is happening in a soil, but it is difficult to translate this knowledge into quantative terms for a normal field soil.
'The physical analyses of processes constituting the field water cycle is still in its beginning stages, and is as yet based upon symplifying assumtions, which do not allways represend the complex conditions, which in fact prevail at different locations' (Hillel, 1971).

## I.3. pF

Since Schofield (1935) 'invented' pF and pF-curves it has proven to be a widely used and convenient way to describe the moisture release properties of a certain soil. The pF-curve shows the relation between moisture tension and percentages moisture in a soil. Whereas moisture tension rapidly increases in a dry soil, Schofield introduced the 10-logaritm of the moisture tension in cm. water column, which is called pF. Because the availability of soil moisture to a plant is influenced by its potential, a pF-curve is indispensible in a thorough water availability study. Often the amount of water available to a plant is directly derived from the pF-curve as the amount of water held between FC and WP (using certain fixed pF values for FC and WP).

## I.4. FC

Viehmeyer and Hendrickson (1931) have defined the field capacity as 'the amount of water held in the soil after the excess gravitational water has drained away and after the downward movement of water has materially decreased, which usually takes place within 2-3 days after a rain or irrigation in pervious soils of uniform structure and texture'.

For a long time this water content at which internal drainage is practically zero has been accepted as a characteristic, constant physical property of a certain soil. In recent years, with increasing knowledge and insight about the processes which occur in the soil, one has recognized that in fact the field capacity concept is arbitrary, and field capacity is not an intrinsic physical property. Richards (1960) even states that the field capacity concept may have done more harm than good.

Field capacity is influenced by 'external' factors like depth of the antecedent moisture, presence of impeding layers, rate of evapotranspiration a.o. Moreover there is no universal way to determine the moment 'downward movement of water has materially decreased', and for heavy textured soils this moment may never be reached. On the other hand most soil have a 'sudden' slowing of the downward movement of water within 2 or 3 days after wetting. Therefore, if carefully used and measured, field capacity can still be a valuable property.

Since field capacity is influenced by factors like impeding layers and soildepth, which are not taken into account in a laboratory, using small samples and fixed methods, field capacity should ideally be determined in the field.

Likewise merely using a certain fixed pF value to determine the water content at FC is, though it might be valid for a lot of soils, not a proper way of determining the lower limit of water availability.

## I.5. WP

Wilting point or permanent wilting percentage is based upon the wilting coefficient concept of Briggs and Shantz (1912), and has been defined as (Hendrickson and Viehmeyer, 1945) 'the rootzone soil wetness at which the wilted plant can no longer recover turgidity even when it is placed in a saturated atmosphere for 12 hours'.
It is found that there are considerable ranges in water contents of the soil, at which plants can undergo permanent wilting (Sykes 1965, Furr and Reeve 1945). Therefore the term 'wilting range' is also used, being the range between what is called the 'incipient wilting point' and the permanent wilting point. Incipient wilting point -introduced by Furr and Reeve, 1945- is defined as 'the water content of the soil, at which the lowest pair of true leaves of a particular kind of plant, at a particular stage of growth, wilt and fail to recover in a saturated atmospere.
Wilting takes place when the supply of water is not sufficient for the plant to maintain turgor. The water content at this moment is not only determined by soil properties, but also by properties of the plant (e.g. root growth) and environmental properties (specially those influencing transpiration). There is no unique soil water content or potential at which the uptake of water by the plant is suddenly blocked. Consequently it can be stated that also WP is no intrinsic soil property.
However in many cases the pF 4.2 percentage sufficiently indicates the amount of water which cannot be substracted from a soil by plants.

## I.6. Availible water in reach of the plant roots

'A considerable body of knowledge exists about the distribution of plant roots in soils, but it is inadequate for predictions about the behaviour of plants on soils of different kinds'(Soil Taxonomy, 1975). Allthough the 'body' is there, at present, quantatively relating roosystem and

rootability data to water availability is not yet possible. The utility of the 'available water' depends on rooting characteristics and water retaining and transmitting properties of root and soil.
The rooting characteristics are partly due to plant properties (branching of roots, diameter, rootpressure etc.), and partly the effect of soil properties. The most important ones are water and nutrient content of the soil, the system of pores a plant can use, and the shear strength and compressibility of the soil.'The ability of the plant roots to find space to grow and to force its way into soil is often the most important factor limiting plant growth'(Russell, 1973). It is stated that roots of cereals need pores of at least 0.2 mm. to grow and young primary roots of most trees and herbaceous plants are considerably larger than this. Most roots are larger (often much larger) than pores present in structureless soils. Roots must often force their way into a soil, so they can only grow in soils which are compressible. The compressability of a soil is largely influenced by its water content.
The amount of water leaving the soil by way of the plant is determined by the suction and transmitting properties of the plant, and the water retaining and transmitting properties of the soil. Large 'conductive' roots are said to be over 1 mm. in diameter, whereas roots of less than 0.2 mm. should give rise to a considerable resistance to water movement (Gardner, 1964). Again it is difficult to translate our physical knowledge of water movement near the plant roots into quantative terms. Gardner and Ehlig (1962) found in their experiments that appreciable amounts of water can move several cm. towards the roots, as long as the water content of the soil is not to near the wilting point. Russell (1973) states that a root system of evenly distributed, 0.25 mm. thick roots, 1 cm. apart, should easily be capable of drying most soils to wilting point.
Young roots are the most important part of the root system concerning water intake.

The amount of available water in reach of the plant root is mostly calculated by summerizing the available water over the rootable depth, using certain reductions for the deeper part of the profile.

## I.7. Rating system K.S.S.P. concerning water availability

The final rating of the availability of soil moisture storage as used by the Kenya Soil Survey Project is a combination of the ratings of the soil depth, the average 'PAM value' in the topsoil, and profile hindrances to rootdevelopment. The soil depth is the depth of the rootable zône and the average PAM value (Productive Available Moisture) is the average percentage moisture stored between pF 2.3 and pF 3.7 in the top 50 cm. of the soil. The ratings are as follows :

Soil depth ratings:

| | |
|---|---|
| deeper than 180 cm. | 0 |
| " " 120 cm. | 1 |
| 120 - 80 cm. | 2 |
| 80 - 50 cm. | 3 |
| 50 - 25 cm. | 4 |
| less than 25 cm. | 5 |

Ratings of the average PAM values:

| | |
|---|---|
| more than 15 vol% | 1 |
| 15 - 12 " | 2 |
| 12 - 8 " | 3 |
| 8 - 5 " | 4 |
| less than 5 " | 5 |

Ratings of profile hindrances:

| | | |
|---|---|---|
| none | 1 | (e.g. oxic horizons) |
| slight | 2 | (e.g. oxic argillic transitional horizons) |
| moderate | 3 | (e.g. cambic horizon, distint stratification) |
| strong | 4 | (e.g. pronounced arg. hor. or stratification) |
| very strong | 5 | (e.g. planic and sodic horizons) |

Summerising these ratings for a certain soil leads to the final rating which is interpreted as follows:

| sum: | final rating: | | may be equivalent with: |
|---|---|---|---|
| 2 | 0 | exeptionally high | more than 180 mm. |
| 3-4 | 1 | very high | 180 - 130 mm. |
| 5-6 | 2 | high | 130 - 90 mm. |
| 7-9 | 3 | moderate | 90 - 60 mm. |
| 10-12 | 4 | low | 60 - 35 mm. |
| 13-15 | 5 | very low | less than 35 mm. |

The equivalents are total productive and readily available moisture data.

The PAM value is introduced because of its higher value with regard to production. Allthough the plant is not yet wilting even at pF's higher than 3.7, the reduction of the yield makes it useless to account for the amount of water stored between pF 3.7 and 4.2. The PAM value is directly derived from the pF-curve or calculated as 80% of the percentage water stored between pF 2.3 and 4.2 if no seperate pF 3.7 value is determined. A bit of calculation on the given ratings and equivalent moisture data shows that profile hindrances give a reduction in available water of 10-50%.

# Chapter II - The research

## II. THE RESEARCH

### II.1. Introduction

As mentioned in the first chapter the purpose of the research was to collect information on the availability of water in soils of the Kisii area.
The research was carried out in the first 4 weeks of a dry period, expecting this drought would cause the plants to wilt. 10 sites were selected,

on every site a pit was dug to describe the soil,
pF samples were taken,
FC was measured,
soil samples were taken trice a week to determine the water content of the soil at WP,
the crop was described and observed,
roots were counted.

Besides that, at one site (site 3) the water content of the soil was measured at various times after wetting, to find out after how many time FC is reached.
Analyses were carried out at the laboratory in Kisii.
In the report the research is dealt with under the following headings :

1. determination of pF-curves,
2. " " the field capacity,
3. " " " wilting point,
4. rootstudies.

### II.2. Soils and sites

The most important criteria for selecting observation sites were :

a. typical soils for the area,
b. " crops " " " ,
c. a big chance that plants would wilt,
d. easy to reach (specially with regard to FC observ.)

10 sites were selected,

with 3 different kinds of red soils ( 3 shallow, 3 deep and 3 very deep red soils) and one planosol,
maize and sugarcane as typical crops,
7 sites in South-Nyanza near Ranen and Rongo because of the dryer climate than in Kisii,(map in appendix)
3 sites near Kisii (with pasture) for FC observations

In this chapter a brief description of these 10 sites is given with regard to crop and soil. Full profile descriptions are given in the appendix. The numbers used here are used throughout the report, indicating site and soil numbers.

Site 1. Shallow soil with pasture near Kisii, stone layer (hard and soft) at about 45 cm. Below the stone layer a stiff red clay is found, also occuring at a certain depth at site 2 and 3, which are situated in the same plot as 1.

Site 2. Deep red clay soil with pasture near Kisii. Stiff red clay from 35 cm. downwards. Little roots in stiff red clay, soft rock and stones at 90 cm.

Site 3 Very deep red clay soil with pasture near Kisii. Stiff red clay from 100 cm. downwards, B3 deeper than 150 cm.

Site 4. Shallow soil with maize near Ranen (South-Nyanza), less than 30 cm. deep, gravelly throughout the profile. Plant distance in the row 80 cm. between 2 rows 90 cm. Hight 170 cm.,cobs are beginning to expand, rather many low weeds, basal leaves are drying (at the beginning of the research period).

Site 5. Deep red clay soil with maize near Ranen ( S-N). B3 at 90 cm. Plant distance in the row 65 cm., between 2 rows 90 cm. At the beginning of the research period, the hight is 175 cm., hardly any cobs are formed, all leaves are green and hardle any weeds occur.

Site 6. Very deep red clay soil with maize near Ranen (S-N). B3 deeper than 150 cm. Plant distance in the row 85 cm., between 2 rows 60 cm.,At the beginning of th the research period the hight is 190 cm.,there were no cobs yet and the basal leaves were yellowing. No weeds.

Site 7. Shallow soil with sugarcane near Ranen (S-N). Less than 50 cm. deep, gravel and rotten rock from 25 cm. Plant distance in the row 60 cm., between 2 rows 100 cm. Hight of the plants 350 cm., plants seem somewhat yellower than on lower parts of the plot, where site 8 and 9 are situated.

Site 8. Deep red clay soil with sugarcane near Ranen (S-N). B3 at 90 cm. Plant distances as site 7, hight 375 cm.

Site 9. Very deep red clay soil with sugarcane near Ranen. B3 at 150 cm. Plant distances as site 7, hight 425 cm.

Site 9a. Young sugarcane from a ratoon, less than 50 cm. high, is also observed on a site near to site 7-9, with a soil similar to the soil of site 9.

Site 10. Planosol with sugarcane near Rongo (S-N). Gray loam with an abrupt textural change at 50 to 60 cm., over dark gray heavy clay. Plant distances in the row 70 cm., between 2 rows 110 cm., hight of the plants 300 cm., many weeds.

## II.3. Methods and materials

pF-curves.

Two 100 cc. samples were taken at various depths of each soil, preferably two of each horizon. Water content at various soil suctions, and bulk densities have been determined according to the methods given by Stakman et al (1969). pF 0, 0.4, 1 and 2 on a sand bed, pF 2.3, 2.8 on a bed with kaolinitic clay, and pF 3, 3.6 and 4.2 with pressure membrane apparatuses.

Field capacity.

Before determining the FC at different sites an examination was carried out, to get an impression, about the time it takes before FC is reached after wetting. This has been repeated 3 times. At site 3 a small earth dike (20 cm. high) around an area of approx. 75 to 75 cm. was made, leaving the inner part undisturbed. 200 l. water was added to this area, and soil samples were taken, with an Edelman soil auger, at various depths and times after wetting. The soil was covered with plastic to prevent evaporation. The moisture content of the samples was determined gravimetically.

Field capacities at the different sites were measured in a similar way. A smaller area was used (30x30), and less water (50 l.). Soil samples for moisture determination were taken 24 hours after wetting at various depths, in duplo.

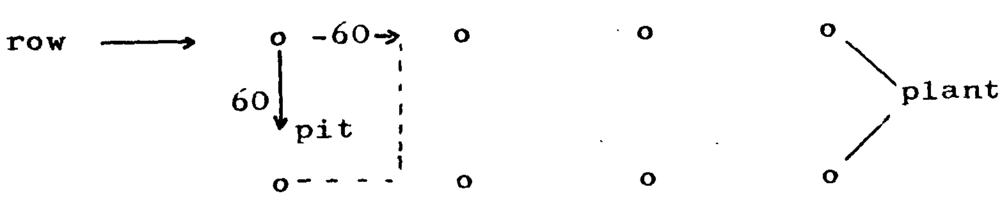
Wilting point.

In order to measure the water content of the soil at which plants started to wilt permanently, soil samples were taken trice a week, at 2 or 4 places per site, at various depths (same depths as pF samples), with an Edelman soil auger. Where the crop was maize 4 augerings were made, 2 near the plant and 2 in the middle of 2 rows, to find out if that would make any noticable difference. Because the rooting system of sugarcane seemed to be more evenly distributed throughout the soil, only 2 augerings were made here, as was done with pasture. The samples were kept (some for over 2 or 3 months) in small plastic bags, and the water content determined gravimetically. About 1300 samples are taken.

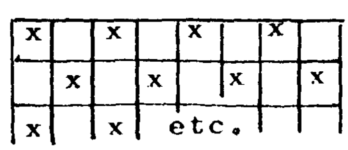
Crop conditions at the beginning of, and during the research period were closely examined, to be able to know when the permanent wilting point was reached.

Root studies.

After digging the pit and straightening the walls, roots were counted (or if many the amount was estimated) per 100cm2, over the rootable depth, and over a distance of 60 cm. from a plant, in 2 directions like this :




To reduce the amount of work squares were counted alternatively as follows :




x = counted square

To devide the wall of the pit in squares, a wooden framework was used (60x140 cm.), devided in squares of 10x10 cm. with the help of ironwire. The roots were counted in different classes, the classes which have been used are 0-½, ½-1, 1-2, and bigger than 2 mm. In the figures showing the results of the root countings (see appendix), the last 2 classes have been taken together, because hardly any roots were bigger than 2 mm.

# Chapter III - Discussion

## III. Discussion

pF-curves:

As can be seen from the figures, pF-curves 3 - 8 have been constructed disgarding the pF 2.3 and pF 2.8 values. This has been done, because of the big difference between the pF 2.8 and pF 3.0 values for these soils. Of course also pF 3.0 or higer pF values might be wrong, but these seem acceptable compared with wilting point data. Even after using this 'trick' pF-curves look strange, specially when compared to each other. Roughly it can be stated that the curves 4-8 look like curves of a sandy soil, which does not have to be strange, because it might be due to special porosity features of these (clay) soils. Also it is possible to figure out a reason for the difference between the soils of the Kisii and Ranen area. However than curve no. 9, resembling the curves of 1-3, is the stumbling block. There certainly is no any reason to expect a big difference between the curves of 8 and 9. Both are red clay soils lying in the same plot, 50 m. apart, with soil no. 9 just being 50 cm. deeper than soil no. 8. Comparing pF-curves 4-8 with no. 10, again it seems strange that they look more 'sandlike' than the curves of the A1 and A21 of the planosol, which have a loamy texture.

The conclusion might be that pF-curves 1,2,3,9 and 10 are most reliable, but of course one never knows.

FC measurements:

In general it can be stated that FC measurements were highly inaccurate, to small wetting area's, to little water and to little samples have been used and taken ( Black, 1965). From the measurements carried out to find the time at which FC is installed, it can be concluded that, as was expected, this happens very fast i.e. 6-8 hours after wetting.

Due to factors stated above and the relatively long time between wetting and sampling (24 hours), FC measurements at the various sites might not be very accurate. Never the less, comparison of the measured FC's and the moisture content at the beginning of the research period (table 1, page 37), shows that most data are not bad at all. Most data are good except for some which are obviously wrong, which is probably due to

lab. inaccurities. The beginning of the research period was also the beginning of the dry period, and specially the water content of the subsoil was expected to be near field capacity.
If FC measurements had a very strange or no result, the water content at the beginning of the research period is taken, to be able to calculate the available water.

WP measurements

As with the FC measurements, few samples were taken at one site, on one day. However samples were taken every 2 or 3 days, and by this the variation in water content of the soil was more or less known, and the 'mean' water content of the soil at wilting point can easily be substracted from the diagrams (page 38-48). Clear wilting signs were only seen with maize (on all sites,i.e. 4-6). It is difficult to state in the field that a plant has wilted permanently. In this experiment the water content a few days after the first wilting of the top and the green leaves, has been taken as the water content at wilting point. Sugarcane at the shallowest site and on the planosol (site 7 and 10) seemed to suffer water stress, at the end of the research period, but no clear wilting signs were seen.

Root studies

As can be seen from the diagrams of site 4-6 (page 51,52), with maize about all roots are found within 100 cm. and most of them even within 50 cm. (on the deep soils of course). In the shallow soil most roots are found in the top 30 cm, coinciding with the depth of soil formation. Sugarcane shows a more gradual decrease in roots (site 7-10, page 53,54), but also here hardly any roots are found below 100 cm, and most of the roots within 50 cm.

Combining results concerning FC and WP leads to table 2 (page 49). Table 2 gives volume percentages moisture available in a soil, and the part (in %) of this amount of moisture that has been used by the plant. The available moisture has been calculated using the pF 4.2 value as the upper limit and the measured FC as the lower limit of availability. Important data of table 2 are repeated in table 3, opposite to the next page, supplemented with amounts of available and used water, per horizon, in mm.

Table 3

| | depth | available moisture vol.% | % used | available moisture mm. | | mm. used | |
|---|---|---|---|---|---|---|---|
| Site no. 1 | 0-25 cm. | 25 | 88 | 63 | | 55 | |
| | 25-45 | 27 | 59 | 54 | | 32 | |
| | 45-95 | 14 | 36 | 70 | | 25 | |
| | 95-100 | 15 | 40 | 8 | | 3 | |
| | | | | | 195 | | 115 |
| Site no. 2 | 0-30 cm. | 25 | 100 | 75 | | 75 | |
| | 30-55 | 25 | 76 | 63 | | 48 | |
| | 55-75 | 25 | 33 | 50 | | 16 | |
| | 75-95 | 15 | 47 | 30 | | 14 | |
| | | | | | 218 | | 153 |
| Site no. 3 | 0-40 cm. | 21 | 76 | 84 | | 64 | |
| | 40-80 | 17 | 65 | 68 | | 44 | |
| | 80-120 | 14 | 21 | 56 | | 12 | |
| | 120-150 | 13 | 8 | 39 | | 3 | |
| | | | | | 247 | | 123 |
| Site no. 4 | 0-20 cm. | 20 | 90 | 40 | | 36 | |
| | 20-40 | 24 | 79 | 48 | | 38 | |
| | | | | | 88 | | 74 |
| Site no. 5 | 0-20 cm. | 22 | 64 | 44 | | 28 | |
| | 20-50 | 20 | 60 | 60 | | 36 | |
| | 50-85 | 15 | 40 | 53 | | 21 | |
| | 85-100 | 18 | 56 | 27 | | 15 | |
| | | | | | 184 | | 100 |
| Site no. 6 | 0-20 cm. | 20 | 95 | 40 | | 38 | |
| | 20-50 | 20 | 60 | 60 | | 36 | |
| | 50-100 | 15 | 47 | 75 | | 35 | |
| | 100-150 | 13 | 23 | 65 | | 15 | |
| | | | | | 240 | | 124 |
| Site no. 7 | 0-20 cm. | 20 | 85 | 40 | | 34 | |
| | 20-50 | 24 | 58 | 72 | | 42 | |
| | | | | | 112 | | 76 |
| Site no. 8 | 0-20 cm. | 19 | 100 | 38 | | 38 | |
| | 20-60 | 19 | 63 | 76 | | 48 | |
| | 60-90 | 17 | 29 | 51 | | 15 | |
| | 90-100 | 15 | 27 | 15 | | 4 | |
| | | | | | 180 | | 95 |
| Site no. 9 | 0-20 cm. | 23 | 78 | 46 | | 36 | |
| | 20-70 | 20 | 70 | 100 | | 70 | |
| | 70-110 | 12 | 42 | 48 | | 20 | |
| | 110-150 | 21 | 10 | 84 | | 8 | |
| | | | | | 278 | | 134 |
| Site no.10 | 0-20 cm. | 19 | 95 | 38 | | 36 | |
| | 20-60 | 22 | 86 | 88 | | 76 | |
| | 60-70 | 12 | - | 12 | | - | |
| | 70-150 | 16 | 0 | 128 | | 0 | |
| | | | | | 266 | | 112 |

From this table it can be seen that maize uses 60-100% of the water stored in the top 50 cm.( approx. 80 roots per 100 cm2), approx. 50% of the water stored from 50-100 cm.(15 roots per 100cm2), and 25% of the water stored below 100 cm.(less than 5 rts/100cm2). At the end of the research period sugarcane had used 60-100% of the water stored in the upper 50 cm of the soil (100rts/100cm2), 30-50% of the water stored between 50 and 100 cm. (30 rts./100 cm2), and 10% of the water stored below 100 cm.(less than 10 roots/100 cm2). 60-100% of the water maize uses is substracted from the upper 50cm, 30-40% from between 50 and 100 cm, and 10% from below 100 cm. 50-100% of the water sugarcane uses is substracted from the top 50 cm, 30-45% from the layer between 50 and 100 cm, and 10% comes from below 100 cm. Thus for both sugarcane and maize it can be said, that almost half of the water which has been used, in the deeper soils, comes from below 50 cm. And although hardly any roots are found below 100 cm, this part of the profile can still supply 10% of the moisture available to plant roots. Total amounts of water, stored in the soil, in reach of plantroots, or used at the end of the res. period are also given in the table.

Rating data of this report with the system the K.S.S.P. uses leads to the following ratings: (see page 10,11)

| | | total rating | final rating | may be equiv. with | measured |
|---|---|---|---|---|---|
| Profile | 1 | 7 | moderate | 90-60 mm. | 115 mm. |
| | 2 | 6 | high | 130-90 | 153 |
| | 3 | 4 | very high | 180-130 | 123 |
| | 4 | 7 | moderate | 90-60 | 74 |
| | 5 | 6 | high | 130-90 | 100 |
| | 6 | 5 | high | 130-90 | 124 |
| | 7 | 7 | moderate | 90-60 | 76 |
| | 8 | 6 | high | 130-90 | 95 |
| | 9 | 5 | high | 130-90 | 134 |
| | 10 | 6 | high | 130-90 | 112 |

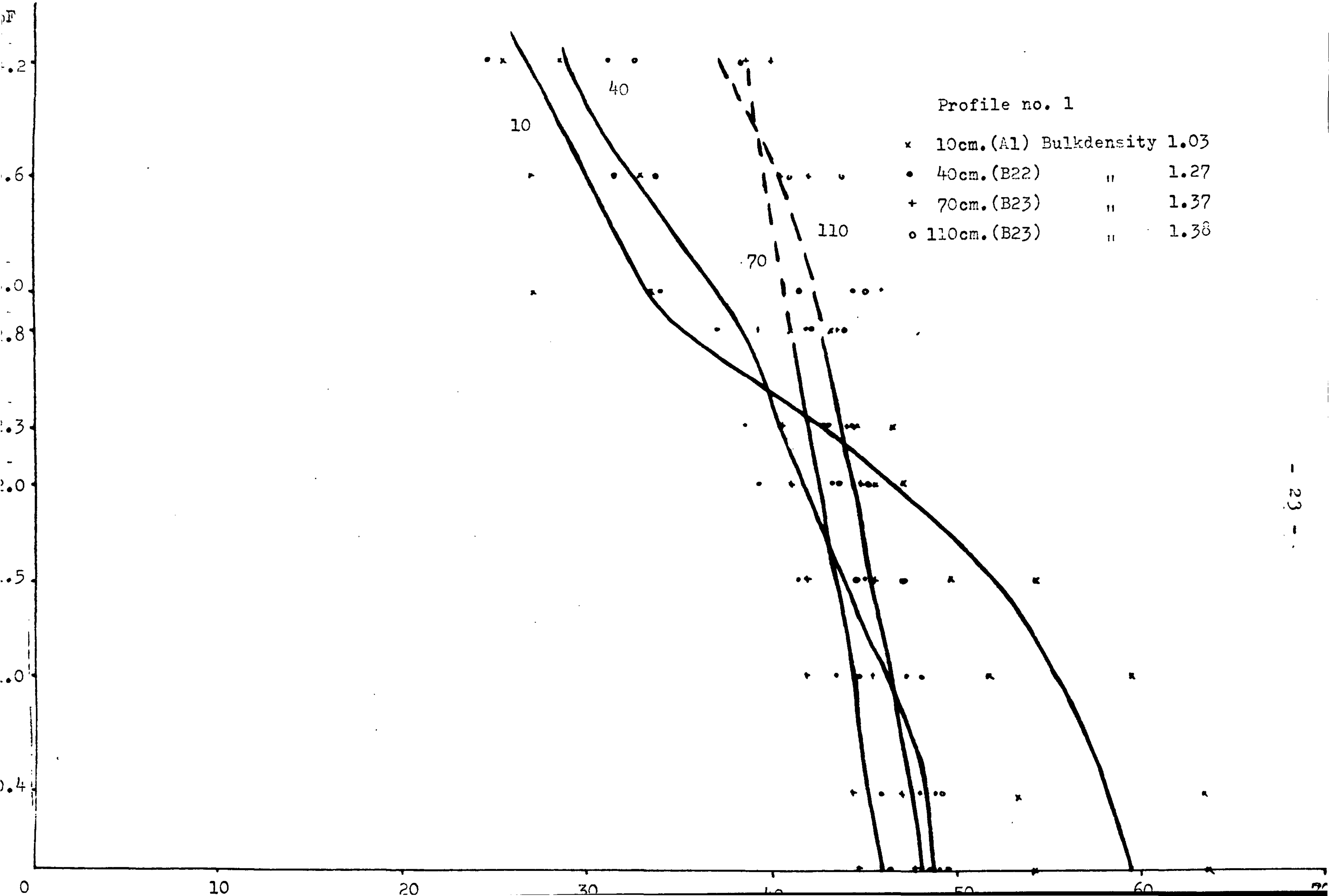
Comparing the equivalent amounts given by the K.S.S.P. and the actual measured amounts, it can be seen that they are quite similar i.e. for soil 4-10.

Ln spite of the 'strange' pF-curves, the research leads to good availability data. Simply taking soil samples after saturation of the soil (by rain or irrigation), and at the time plants start to wilt, seems to be an easy way to get information about the available water in reach of plant roots. To measure pF's rather complicated instruments have to be used, and besides that, the available water data obtained from a pF-curve need certain adaptions to get the amount of water a plant can actually use. These adaptions have to be measured carefully in the field, and checked for every new kind of soil (see introduction, page 7,8).
Thus specially in new area's to get 'quick' information about the amounts of available water the 'gravimetric' method is very usefull, of course this only goes for area's with dry periods in which plants wilt.

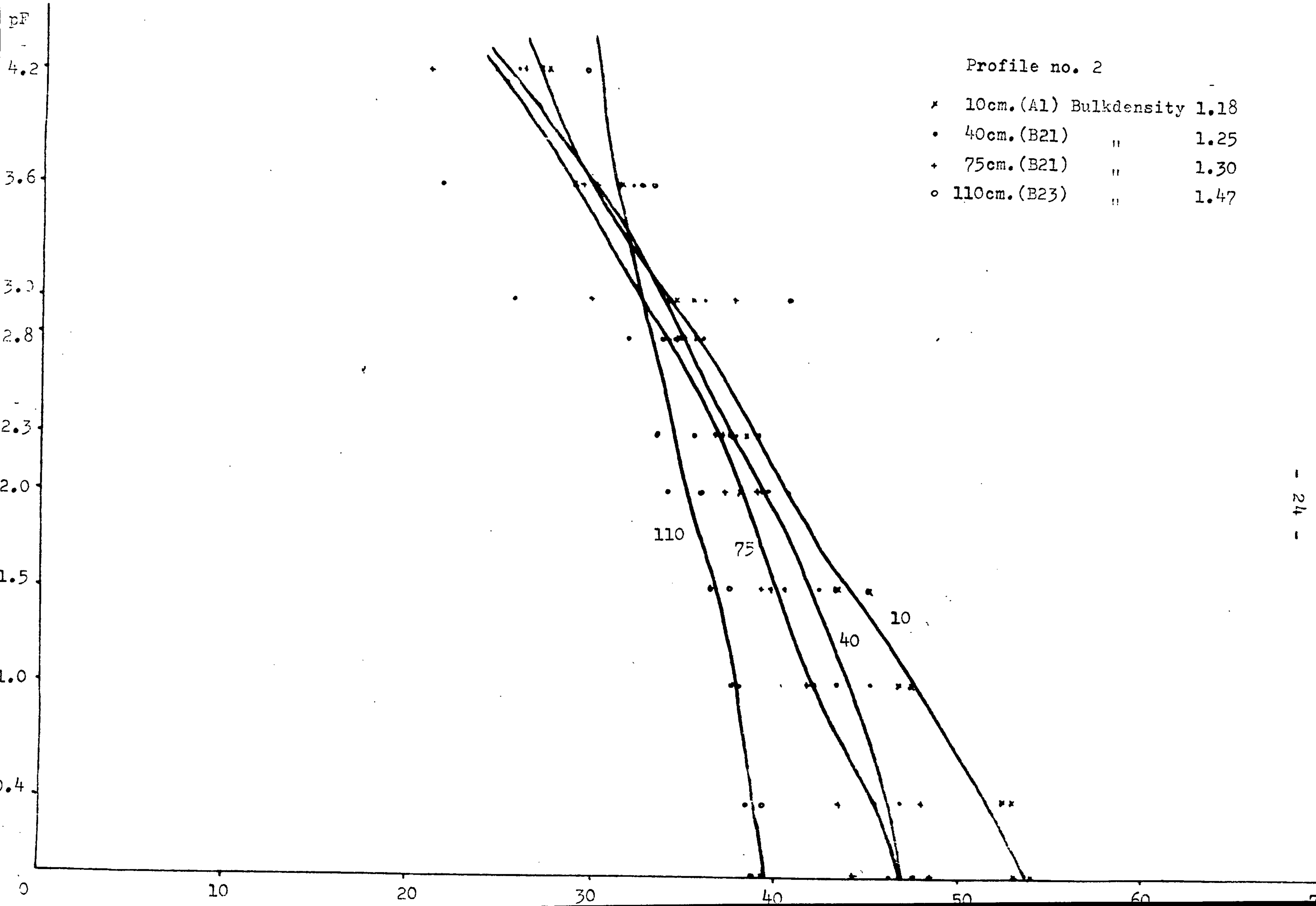
# APPENDIX

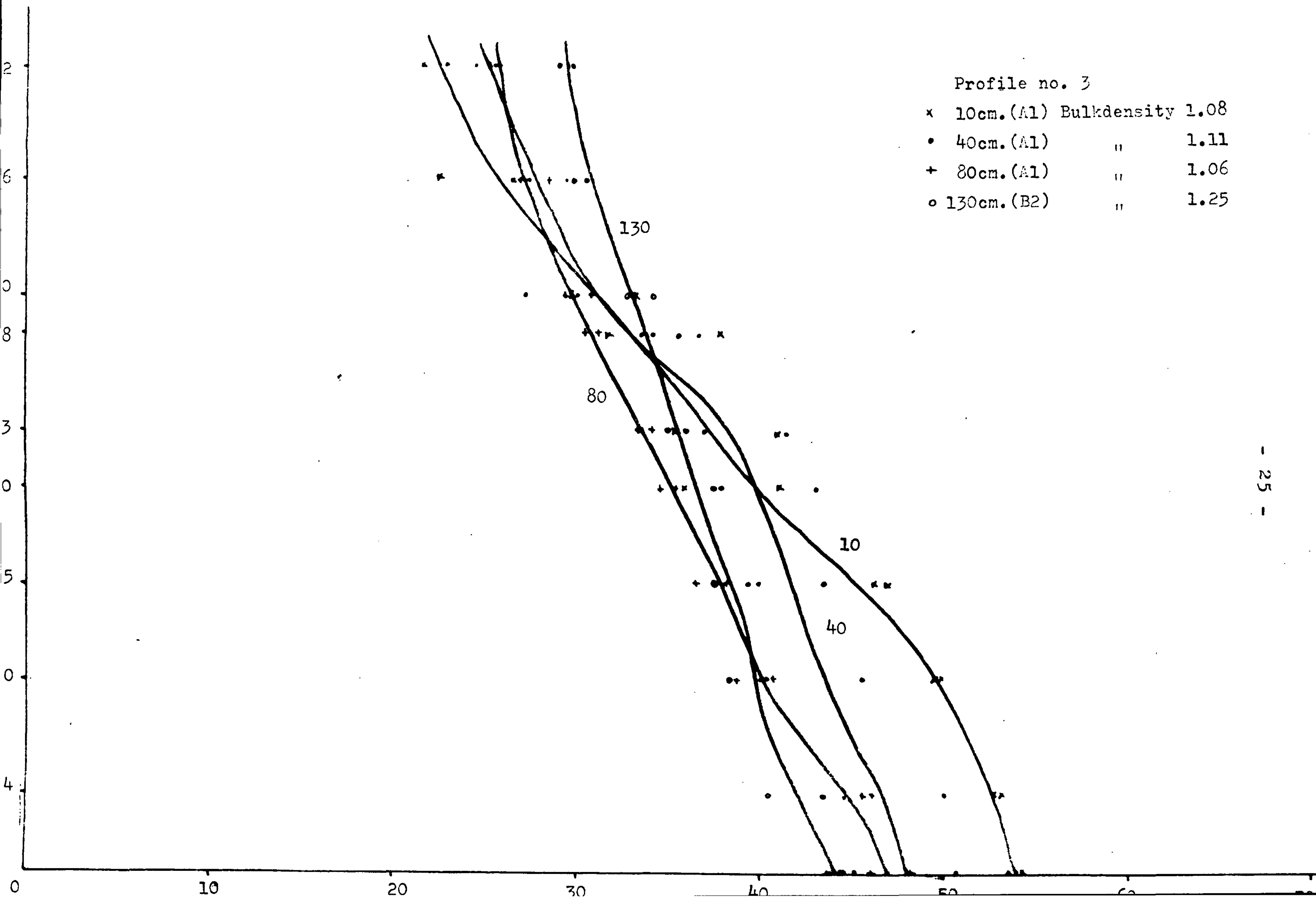
## RESULTS

1. pF-curves and bulkdensities,
   numbers near curves refer to the sampling depth.

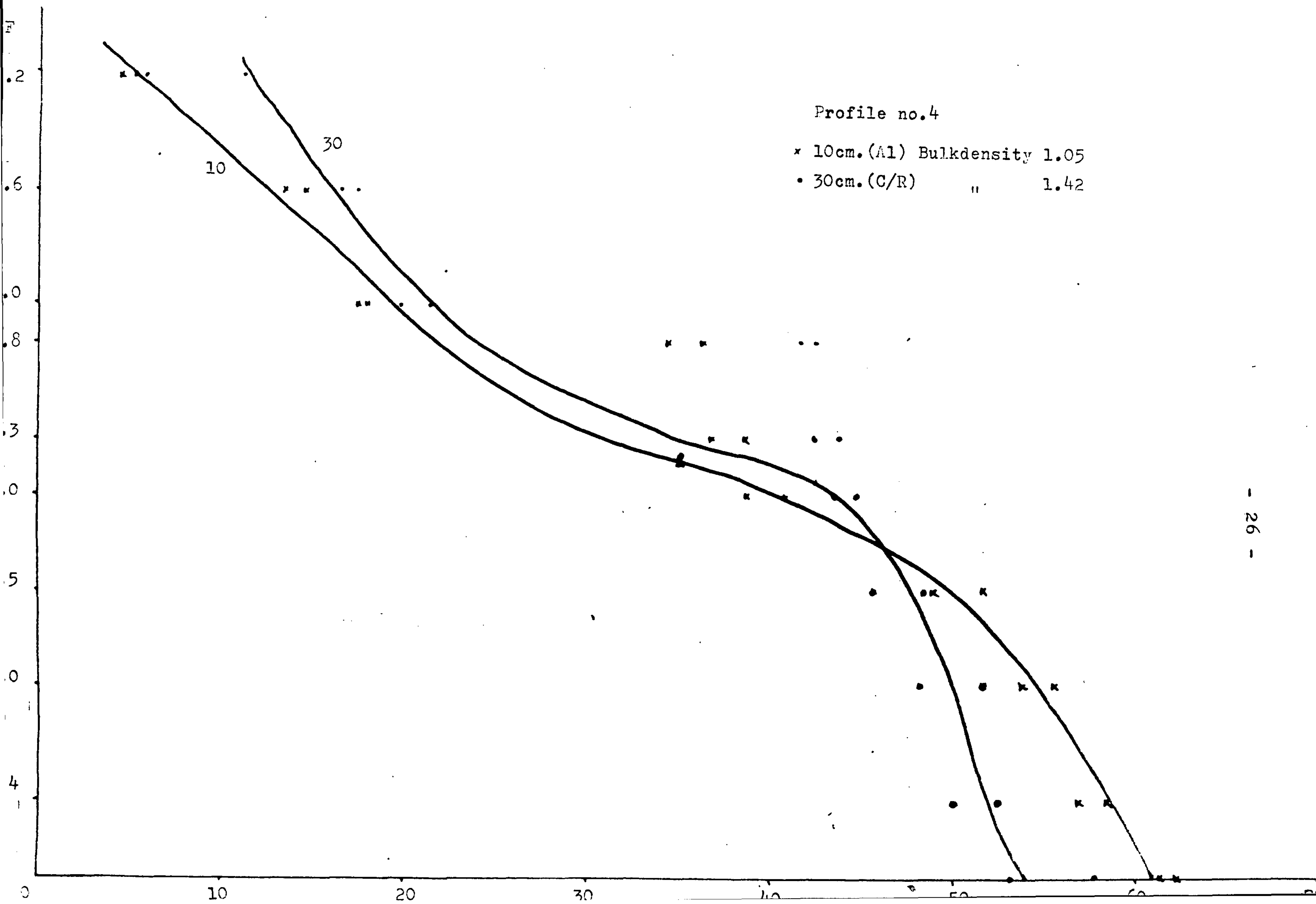


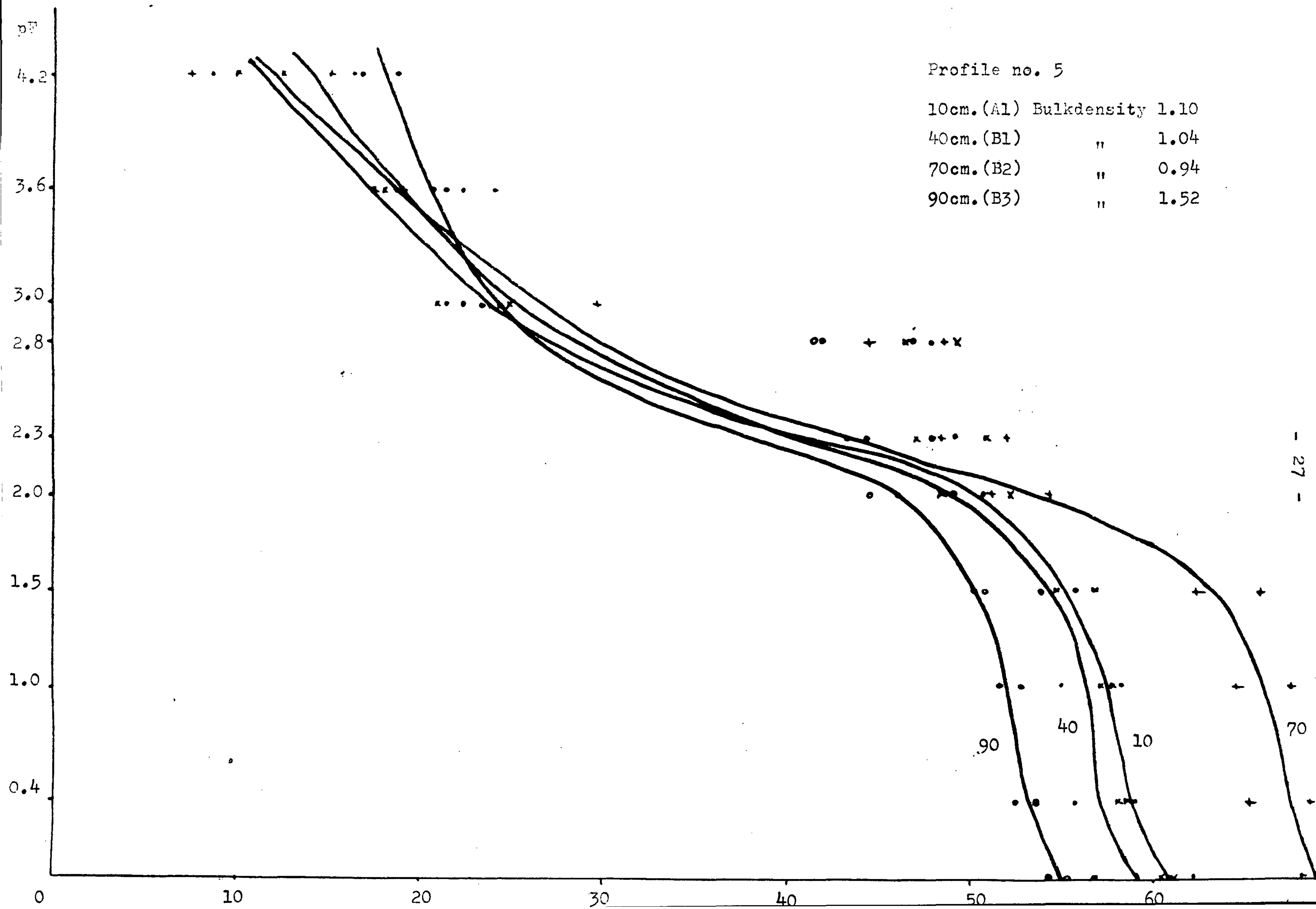
Profile no. 1
x 10cm.(A1) Bulkdensity 1.03
• 40cm.(B22) " 1.27
+ 70cm.(B23) " 1.37
o 110cm.(B23) " 1.38
10
40
70
110
0
10
20
30
60


pF
4.2
3.6
3.0
2.8
2.3
2.0
1.5
1.0
0.4
0
10
20
30
40
50
60
70
Profile no. 2
× 10cm.(A1) Bulkdensity 1.18
• 40cm.(B21) " 1.25
+ 75cm.(B21) " 1.30
o 110cm.(B23) " 1.47
110
75
40
10

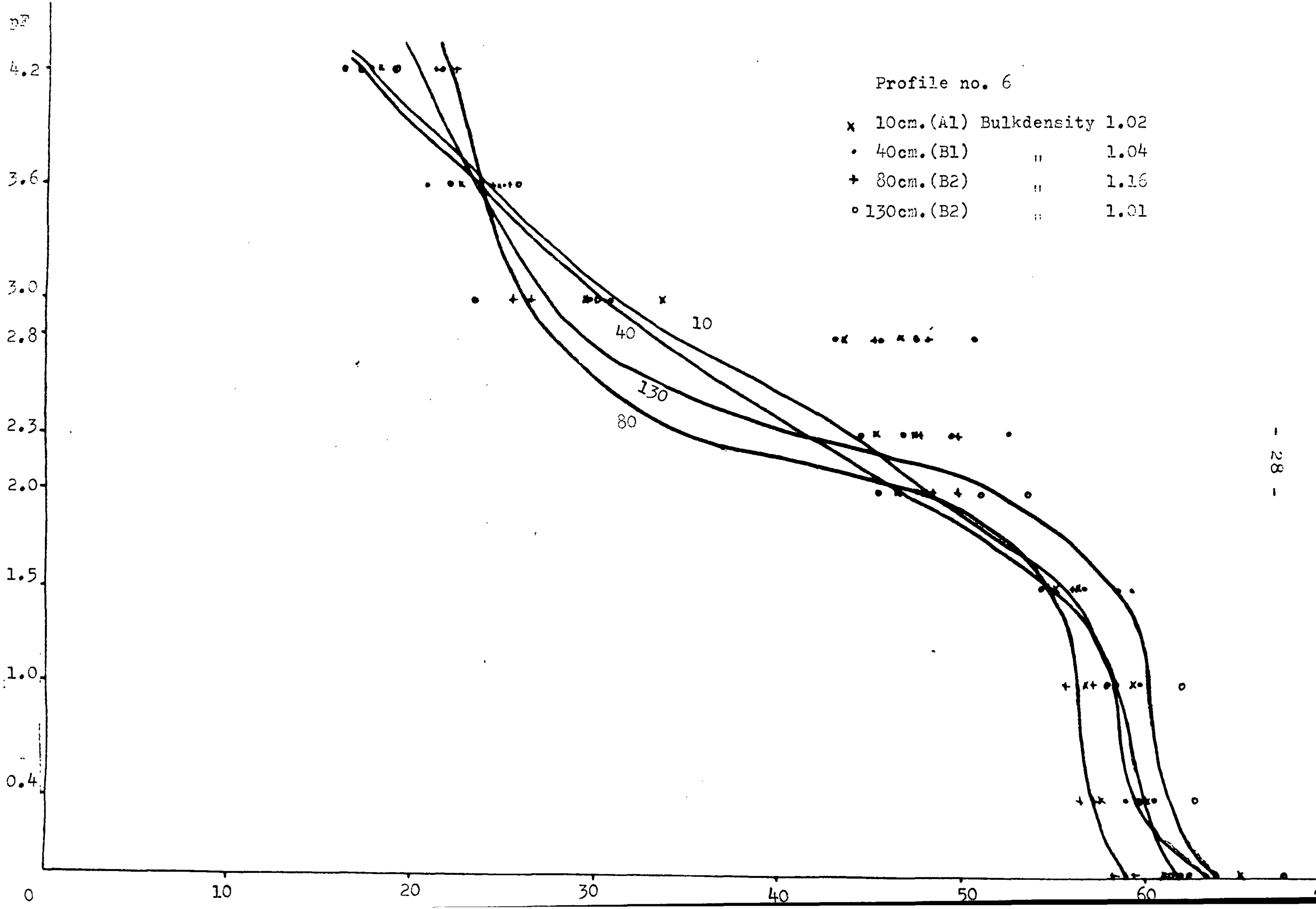

Profile no. 3
× 10cm.(A1) Bulkdensity 1.08
• 40cm.(A1) " 1.11
+ 80cm.(A1) " 1.06
o 130cm.(B2) " 1.25
130
80
10
40
0
10
20
30
40

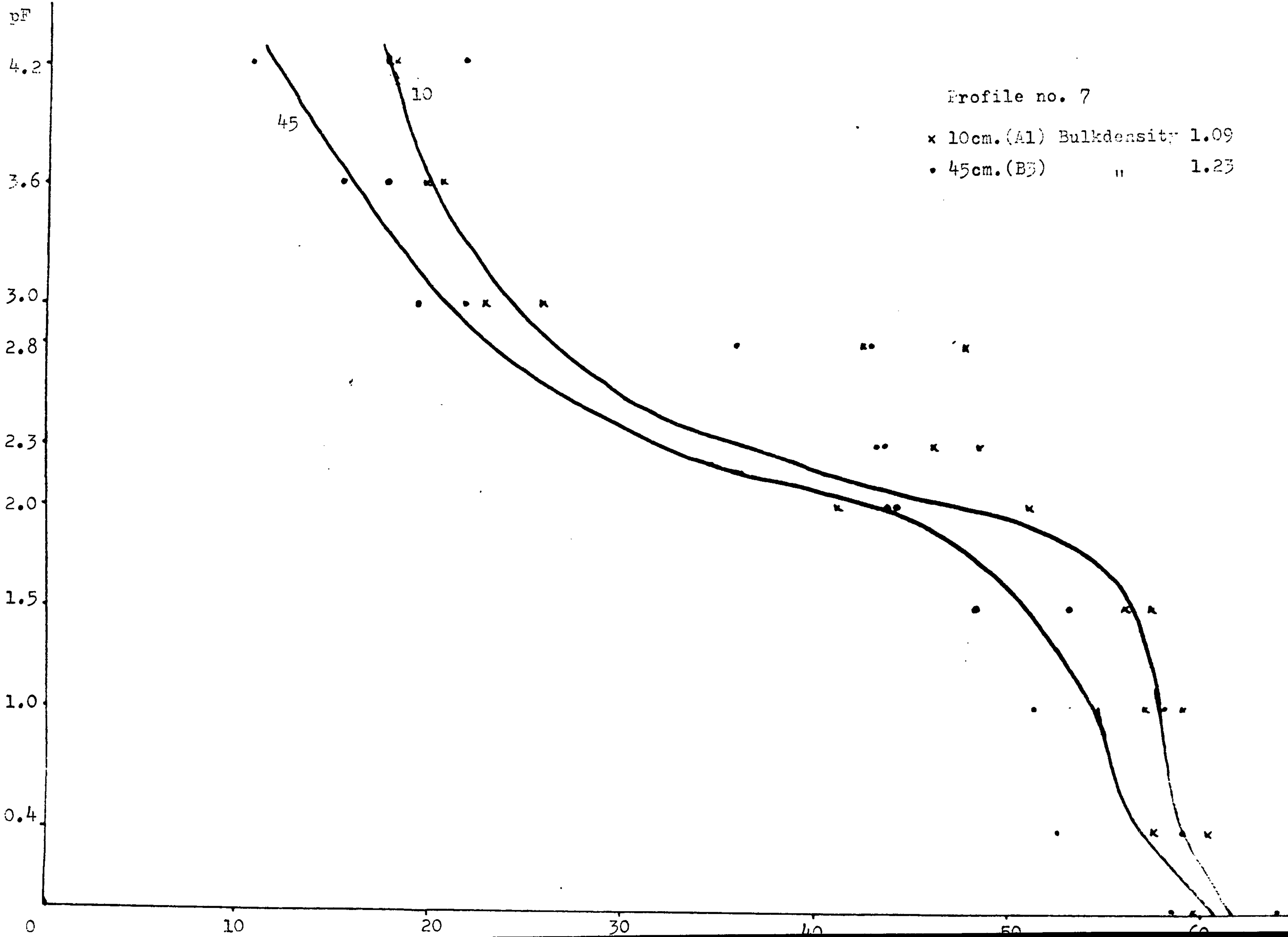
- 25 -

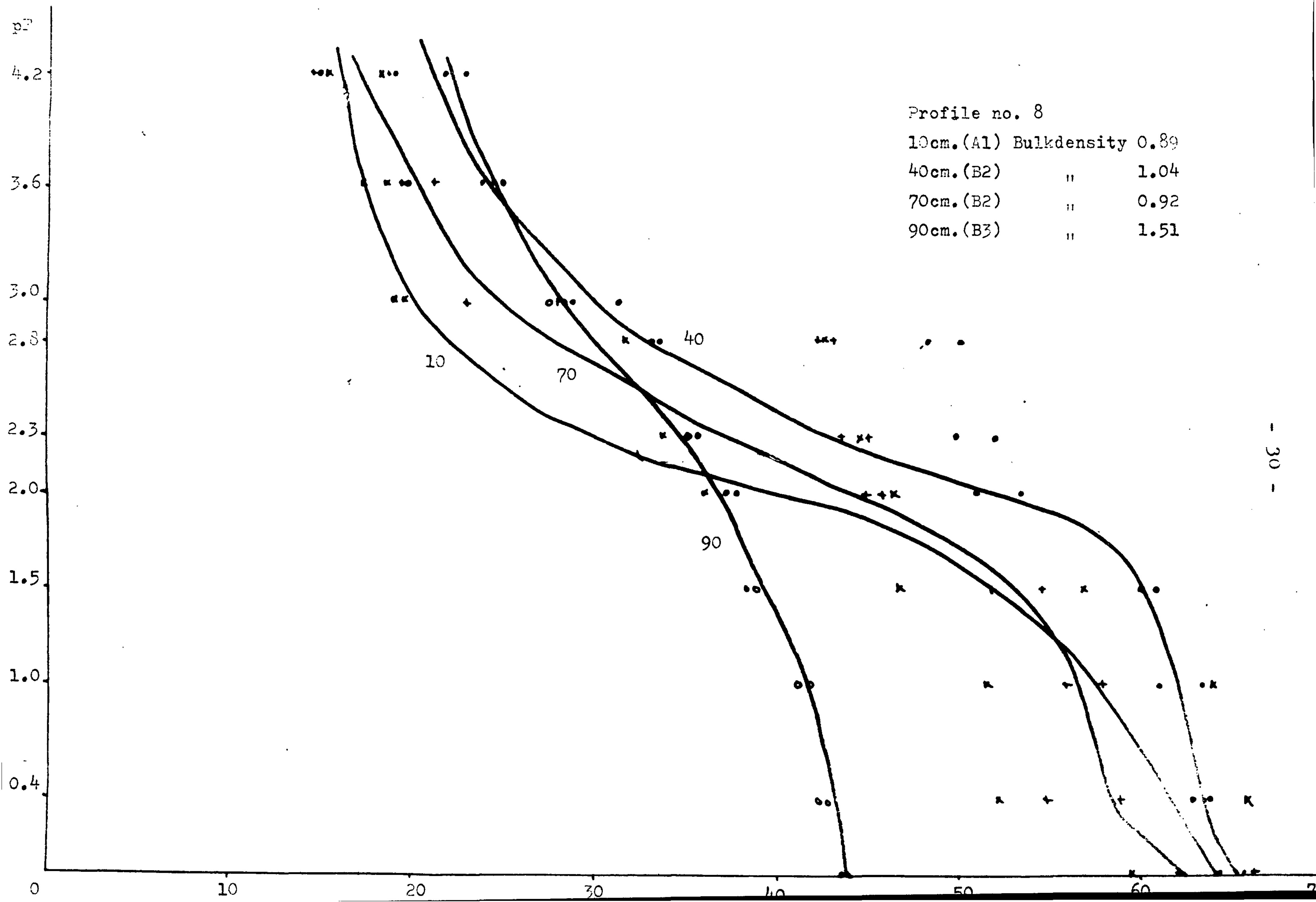

Profile no.4
× 10cm.(A1) Bulkdensity 1.05
• 30cm.(C/R) " 1.42
30
10
.2
.6
.0
.8
.3
.0
.5
.0
4
0
10
20
30



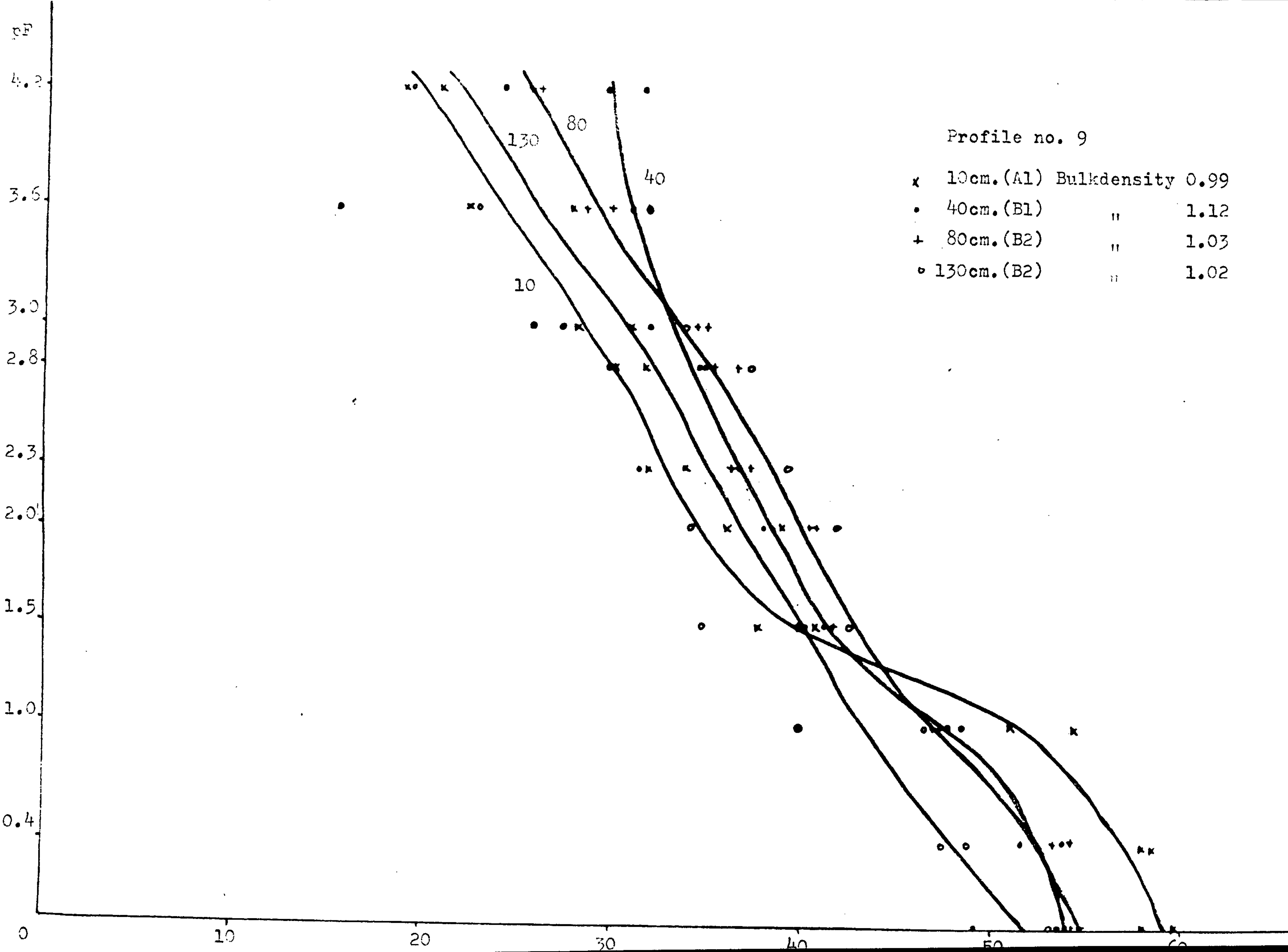
pF
4.2
3.6
3.0
2.8
2.3
2.0
1.5
1.0
0.4
0
10
20
30
40
50
60
Profile no. 5
10cm.(A1) Bulkdensity 1.10
40cm.(B1) " 1.04
70cm.(B2) " 0.94
90cm.(B3) " 1.52
90
40
10
70


pF
4.2
3.6
3.0
2.8
2.3
2.0
1.5
1.0
0.4
0
10
20
30
40
50
60
Profile no. 6
x 10cm.(A1) Bulkdensity 1.02
• 40cm.(B1) " 1.04
+ 80cm.(B2) " 1.16
o 130cm.(B2) " 1.01
10
40
130
80

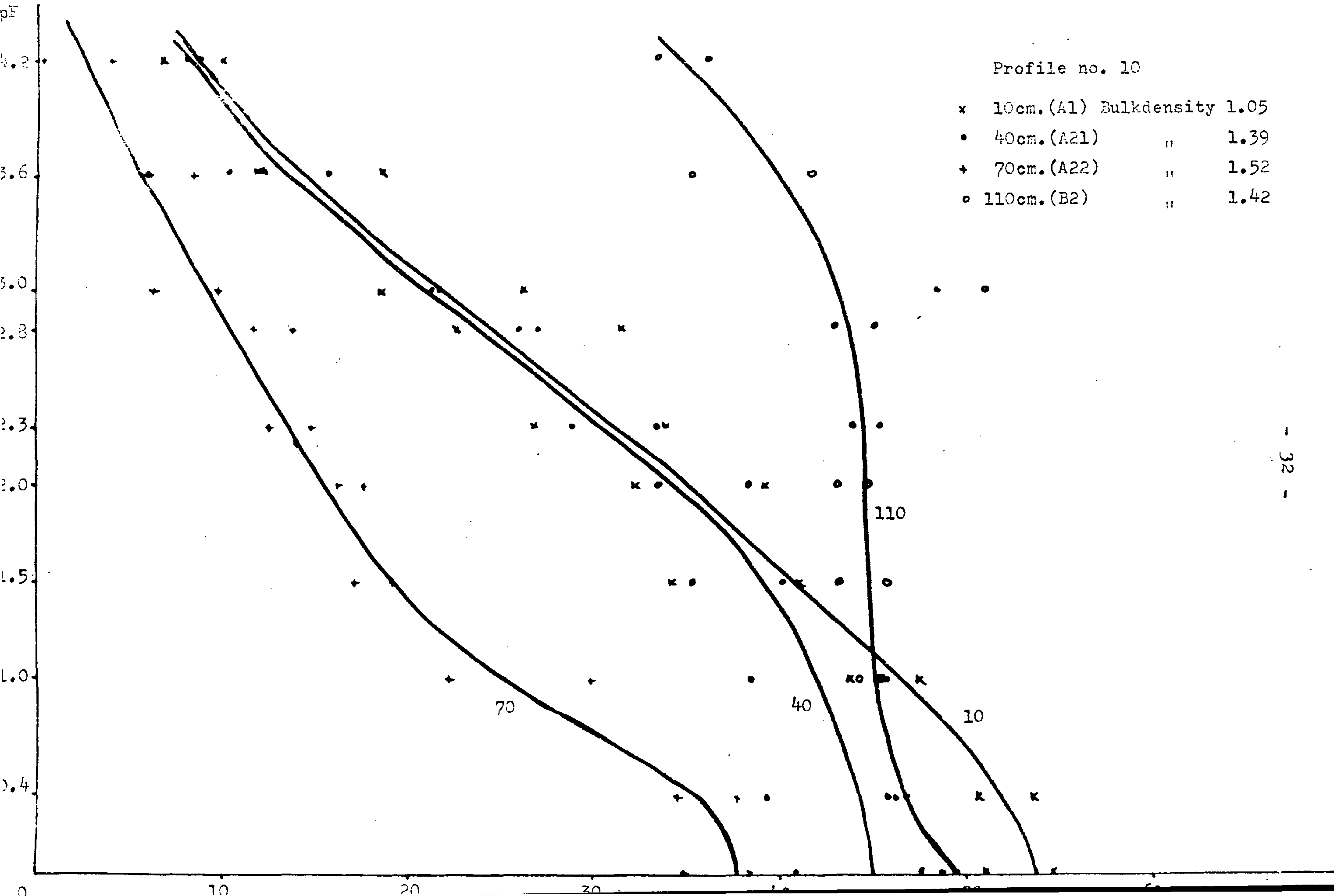

Profile no. 7
× 10cm.(A1) Bulkdensity 1.09
• 45cm.(B3) " 1.23
pF
4.2
3.6
3.0
2.8
2.3
2.0
1.5
1.0
0.4
0
10
20
30
45
10



pF
4.2
3.6
3.0
2.8
2.3
2.0
1.5
1.0
0.4
0
10
20
30
40
50
60
Profile no. 8
10cm.(A1) Bulkdensity 0.89
40cm.(B2) " 1.04
70cm.(B2) " 0.92
90cm.(B3) " 1.51
10
40
70
90



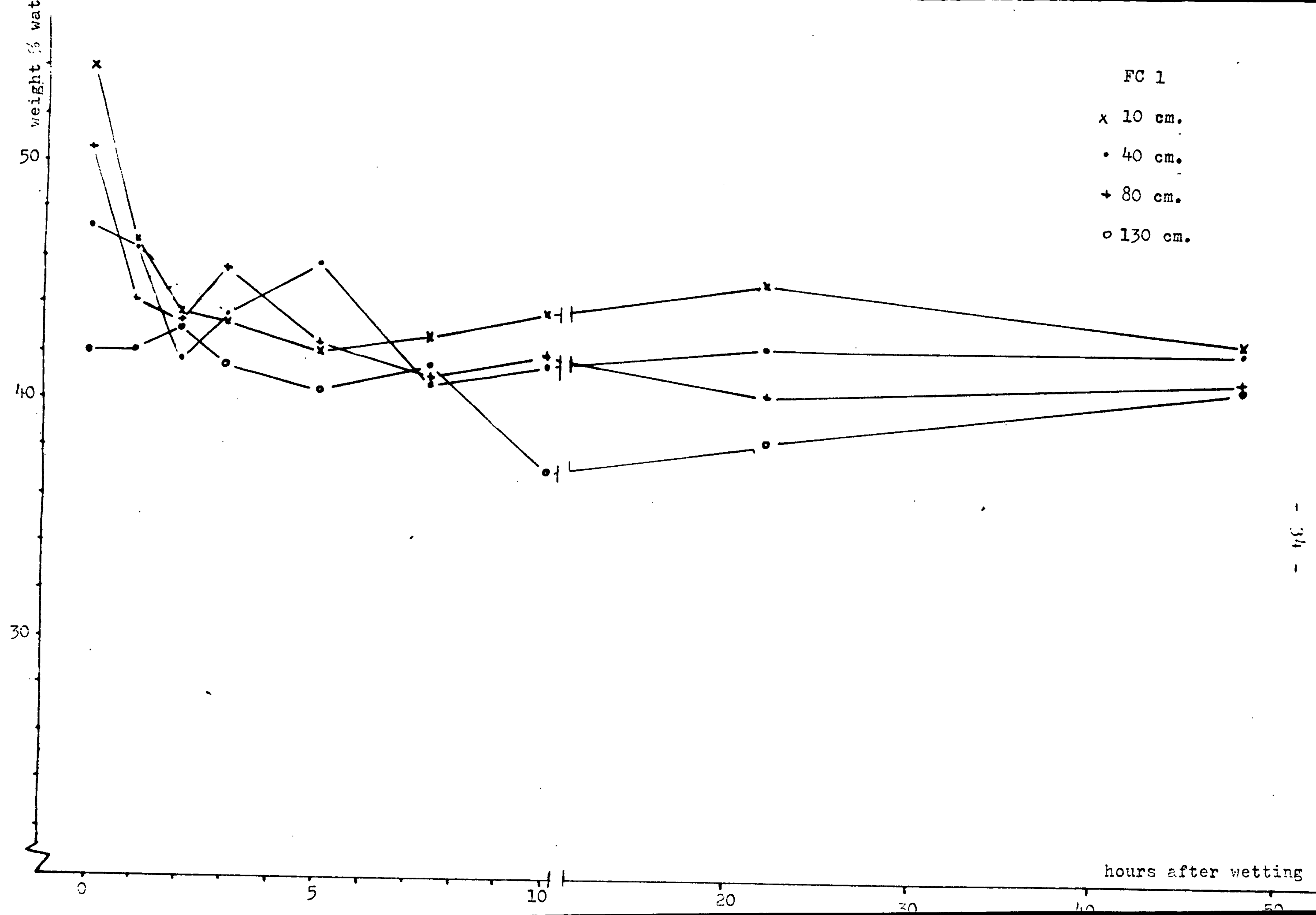
pF
4.2
3.6
3.0
2.8
2.3
2.0
1.5
1.0
0.4
0
10
20
30
40
130
80
40
10
Profile no. 9
x 10cm.(A1) Bulkdensity 0.99
• 40cm.(B1) " 1.12
+ 80cm.(B2) " 1.03
o 130cm.(B2) " 1.02

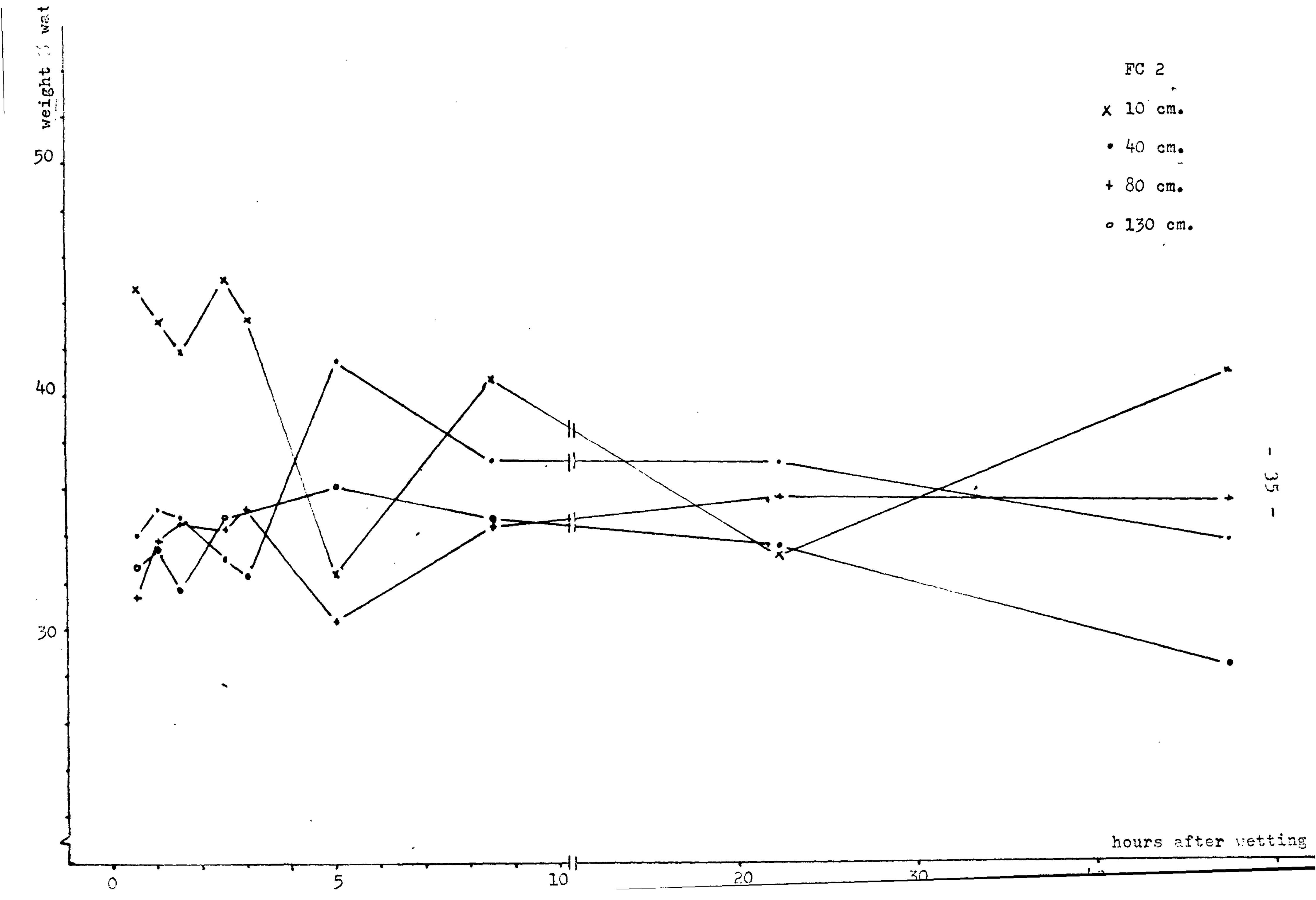

pF
4.2
3.6
3.0
2.8
2.3
2.0
1.5
1.0
0.4
0
10
20
30
Profile no. 10
x 10cm.(A1) Bulkdensity 1.05
• 40cm.(A21) " 1.39
+ 70cm.(A22) " 1.52
o 110cm.(B2) " 1.42
110
70
40
10

2. FC measurements

a. Results of the attempt to figure out the time after which FC is reached.
NOTE the different scales on the hor. axe.

b. Table with the measured FC, and the water content at the beginning of the research period. The last collumn shows the water content (vol.%) used in the report, as moisture content at field capacity, which may be derived from the measured FC, or from the moisture content at the beginning of the res. period or both.


weight % wat
50
40
30
FC 1
x 10 cm.
• 40 cm.
+ 80 cm.
o 130 cm.
hours after wetting
0
5
10
20


weight % wat
50
40
30
FC 2
x 10 cm.
• 40 cm.
+ 80 cm.
o 130 cm.
hours after wetting
0
5
10
20
30

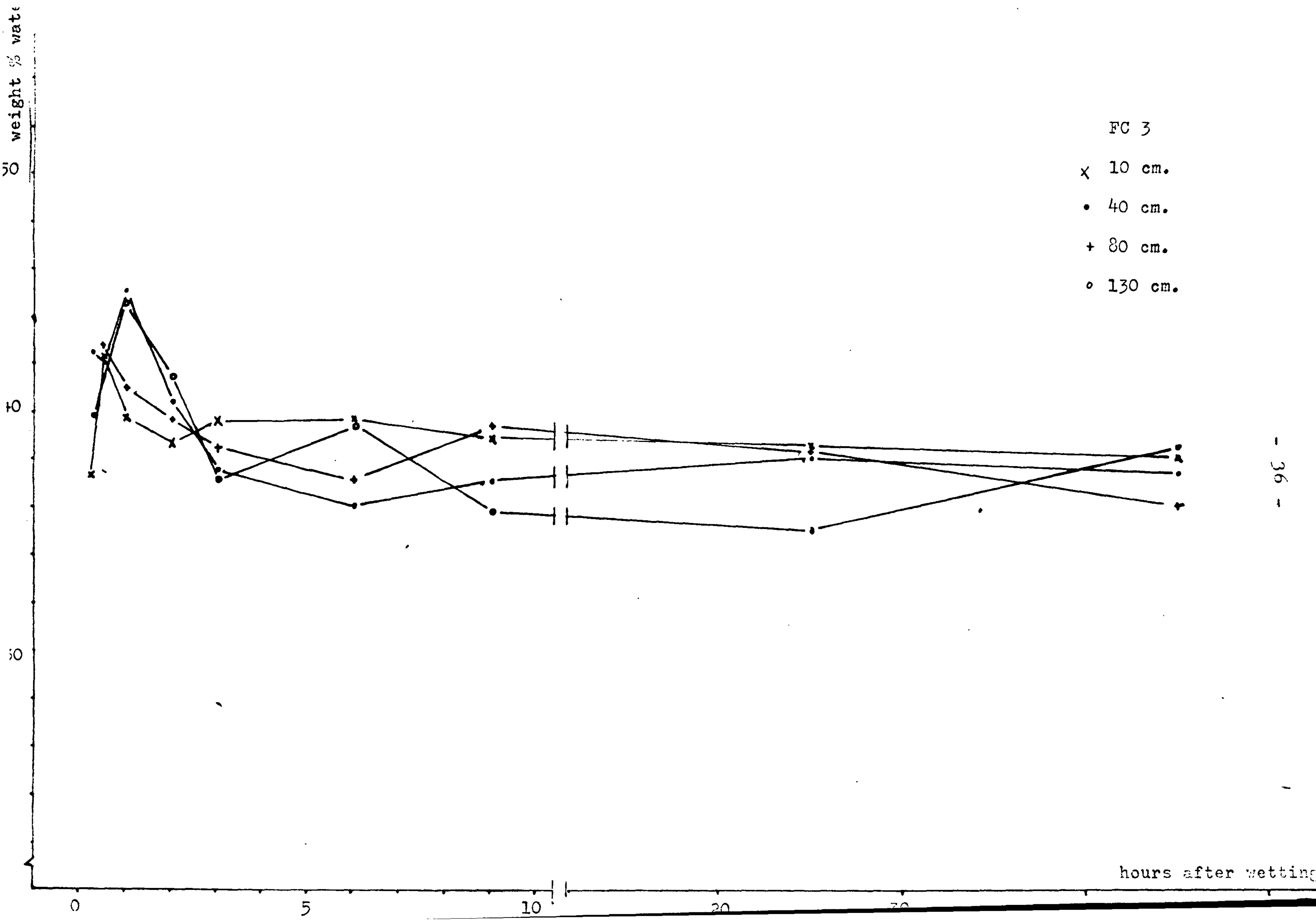
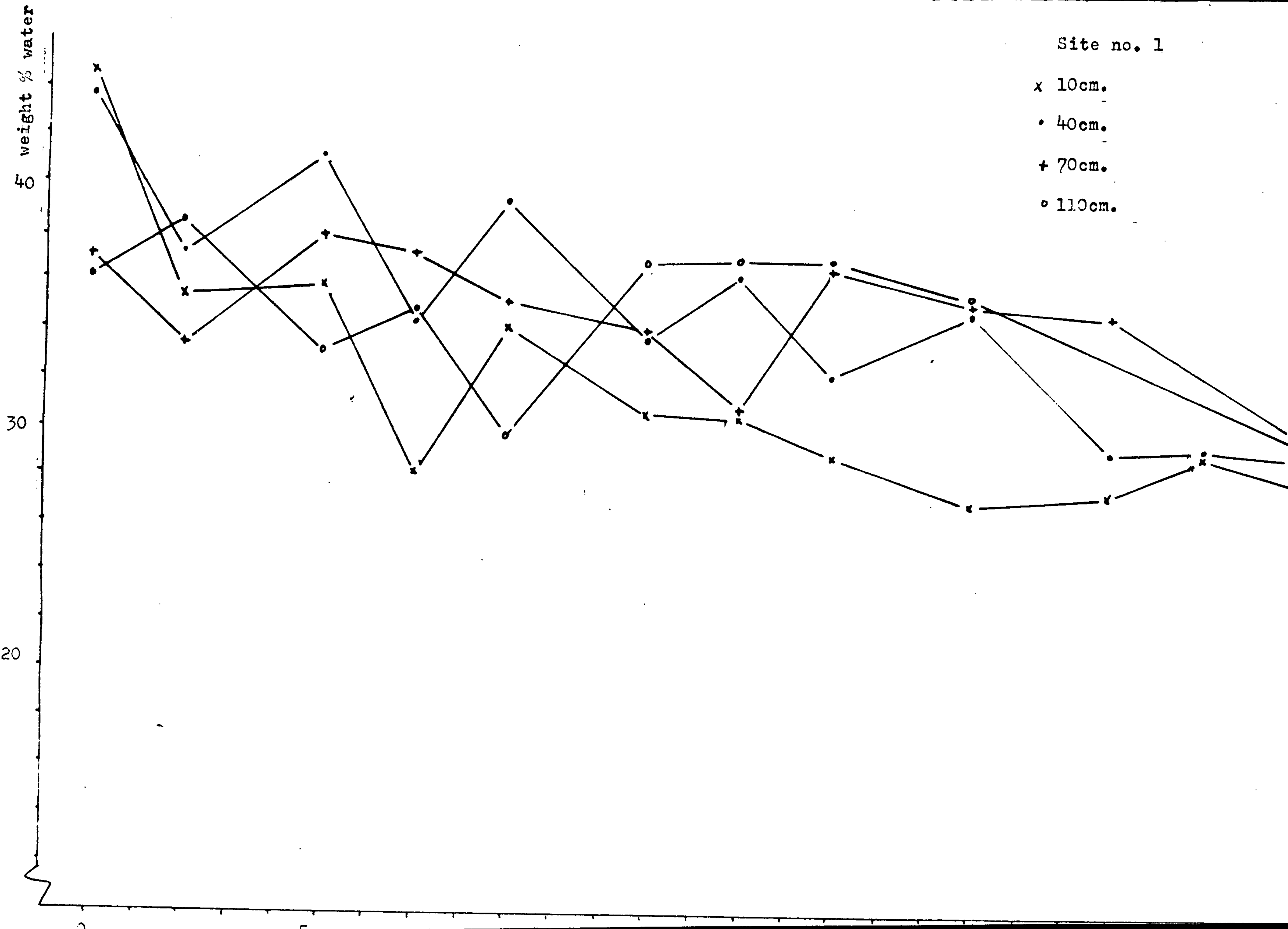

FC 3
10 cm.
40 cm.
80 cm.
130 cm.
hours after wetting
0
5
10

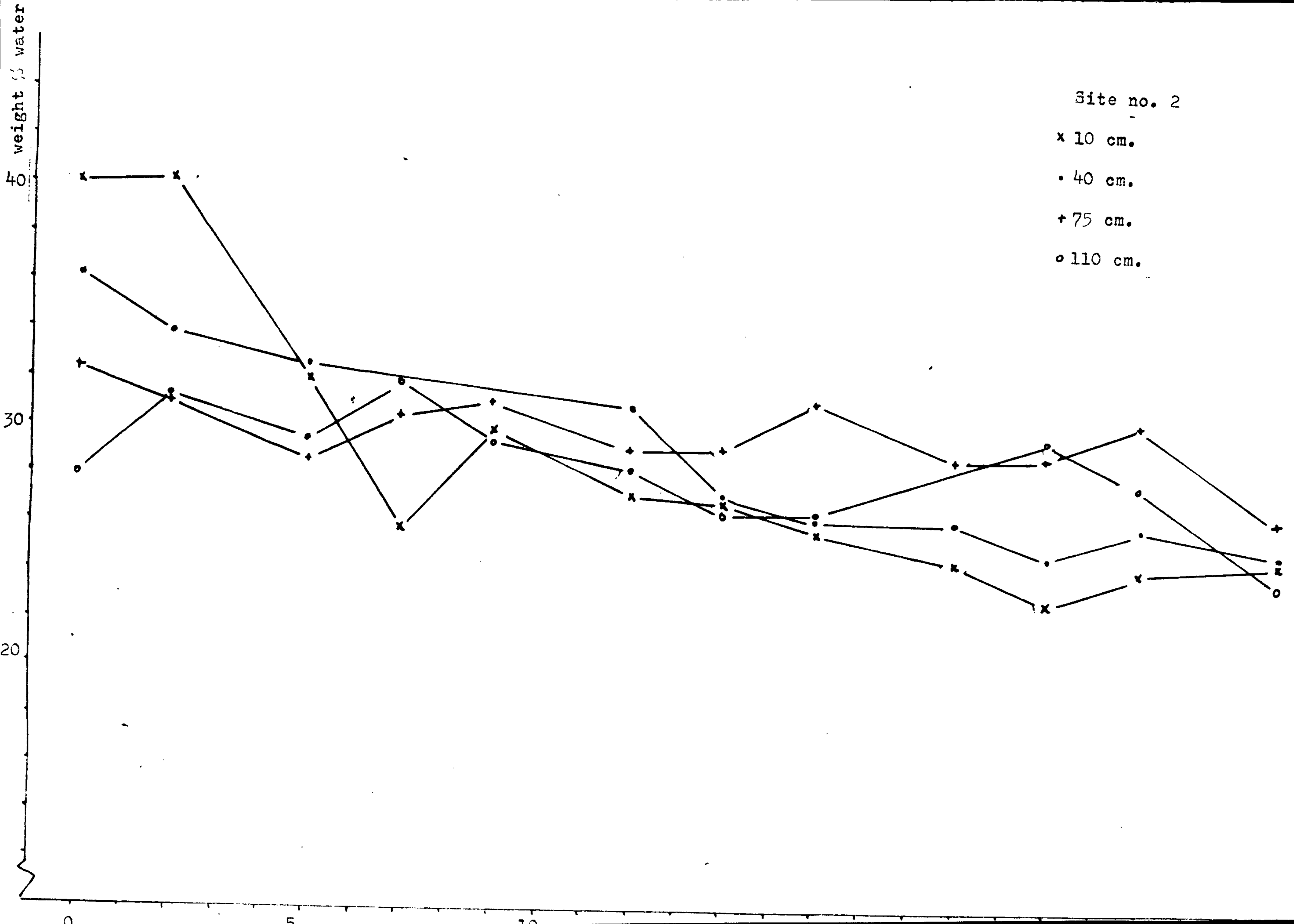
table 1

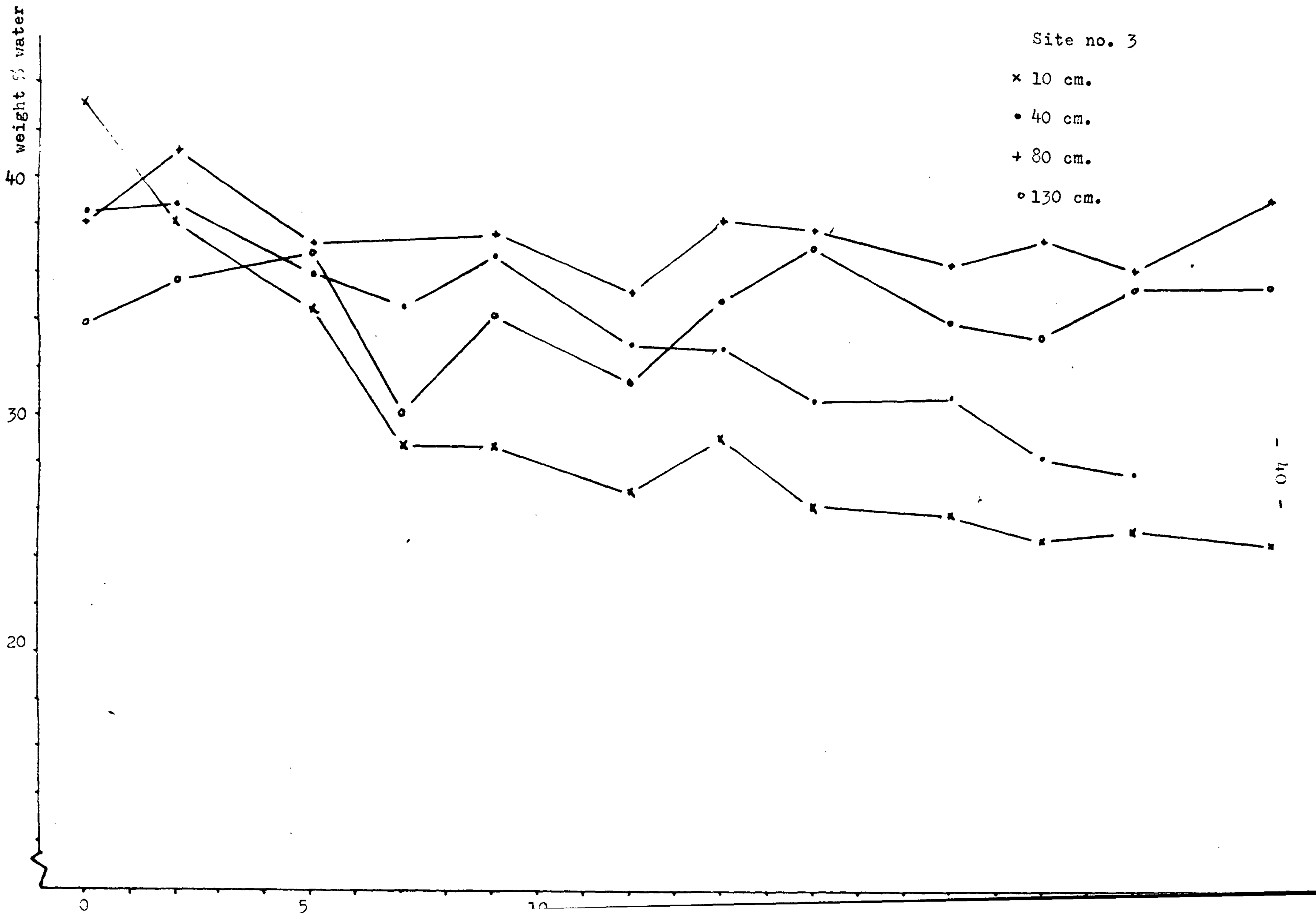
| Site | Depth | measured moisture content at FC (wght.%) | moisture content at the beginn. of the res. period (wght.%) | FC value used in the report (vol.%) |
|---|---|---|---|---|
| Site 1. | 10 cm. | nm 1.) | 40 | 41 3.) |
| | 40 | nm | 44 | 56 |
| | 70 | nm | 39 | 53 |
| | 110 | nm | 39 | 54 |
| Site 2. | 10 cm. | nm | 40 | 47 |
| | 40 | nm | 36 | 45 |
| | 75 | nm | 35 | 49 |
| | 110 | nm | 32 | 47 |
| Site 3. | 10 cm. | 40 | 42 | 43 |
| | 40 | 38 | 40 | 42 |
| | 80 | 38 | 39 | 40 |
| | 130 | 36 | 36 | 45 |
| Site 4. | 10 cm. | 20 | 19 | 21 |
| | 30 | 25 | 17 | 35 |
| Site 5. | 10 cm. | 30 | 25 | 33 |
| | 40 | 33 | 25 | 34 |
| | 70 | 27 | 29 | 27 |
| | 90 | - 2.) | 24 | 36 |
| Site 6. | 10 cm. | nm | 29 | 29 |
| | 40 | nm | 28 | 29 |
| | 80 | nm | 29 | 37 |
| | 130 | nm | 33 | 33 |
| Site 7. | 10 cm. | 34 | 30 | 37 |
| | 45 | 29 | 24 | 36 |
| Site 8. | 10 cm. | 40 | 33 | 35 |
| | 40 | 38 | 35 | 40 |
| | 70 | 36 | 37 | 34 |
| | 90 | 25 | 23 | 37 |
| Site 9. | 10 cm. | 43 | 35 | 43 |
| | 40 | - | 32 | 36 |
| | 80 | - | 36 | 37 |
| | 130 | - | 37 | 43 |
| Site 10. | 10 cm. | 26 | 23 | 27 |
| | 40 | 22 | 17 | 30 |
| | 70 | 9 | 7 | 14 |
| | 110 | 36 | 35 | 50 |

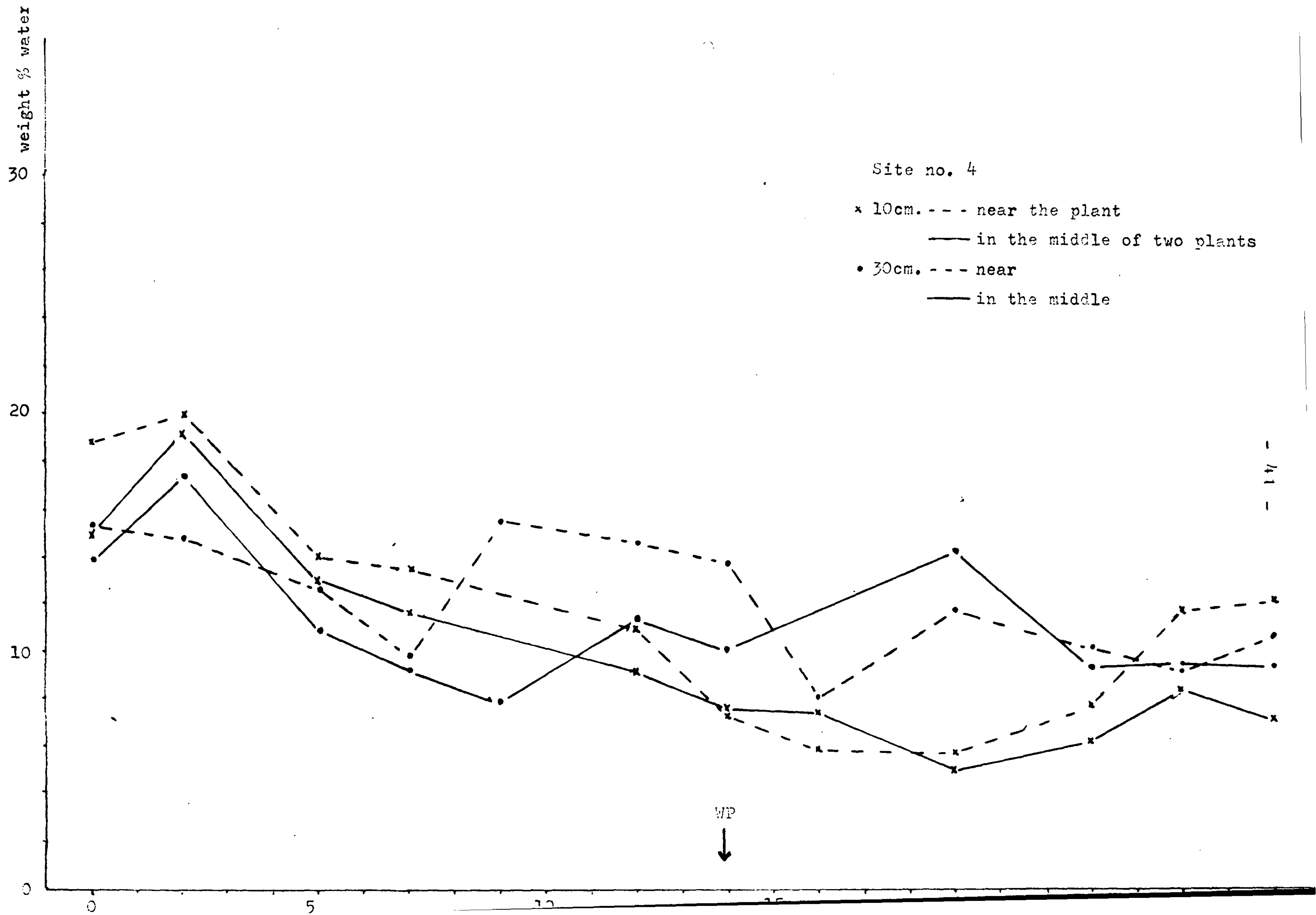
1.) nm - not measured
2.) - no reliable value
3.) underlining means taken value probably obviously lower than real FC.

3. WP measurements
   a. curves showing water content at different sites and the moment plants started to wilt.
   b. table showing the water content at wilting point or lowest measured water content, the water cont. at pF 4.2, the available moisture (derived from the pF 4.2 and FC data (see table 1.)), the percentage of the available water which has been used ( combination of collumns 3, 4 and 5).

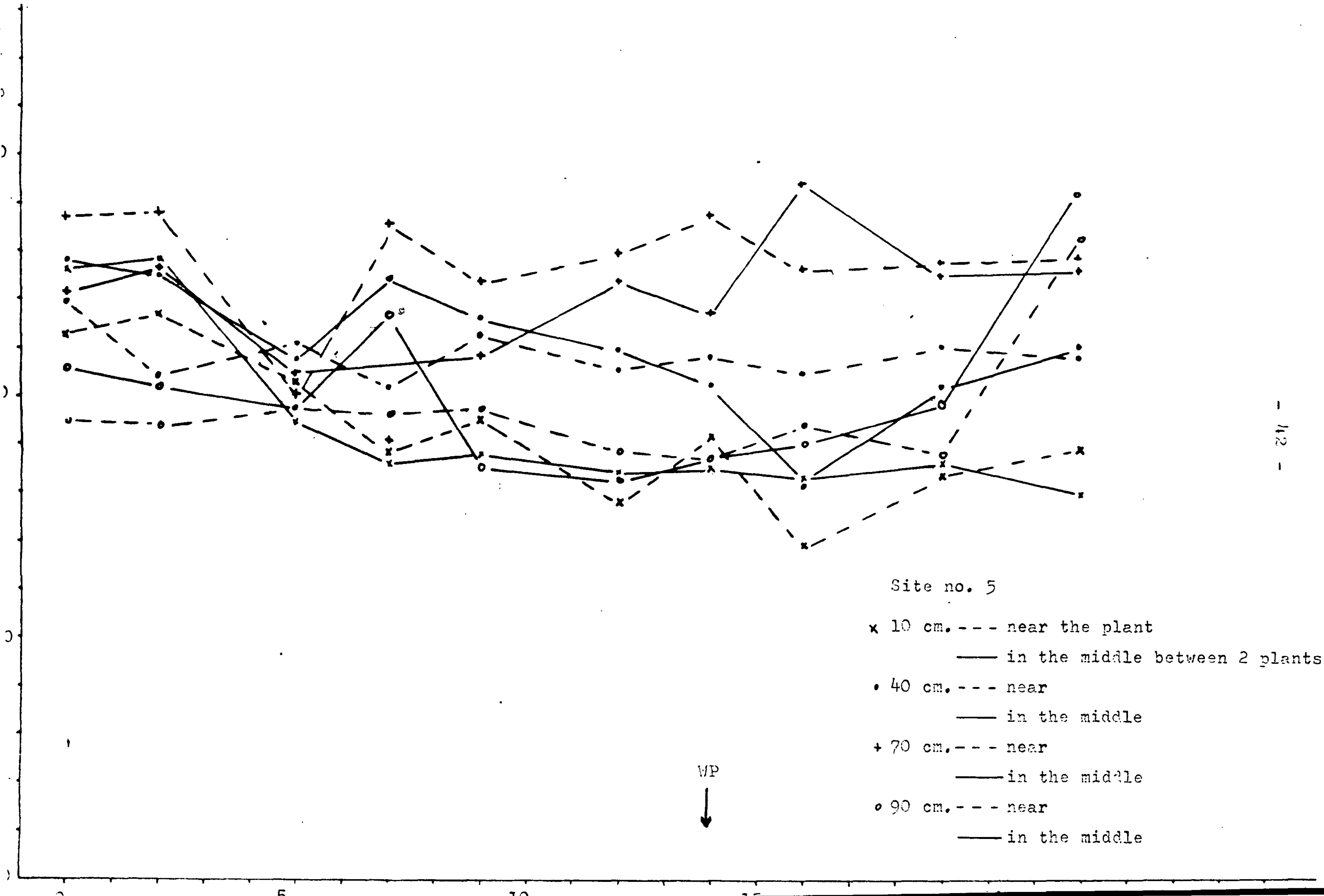

weight % water
40
30
20
Site no. 1
x 10cm.
• 40cm.
+ 70cm.
o 110cm.

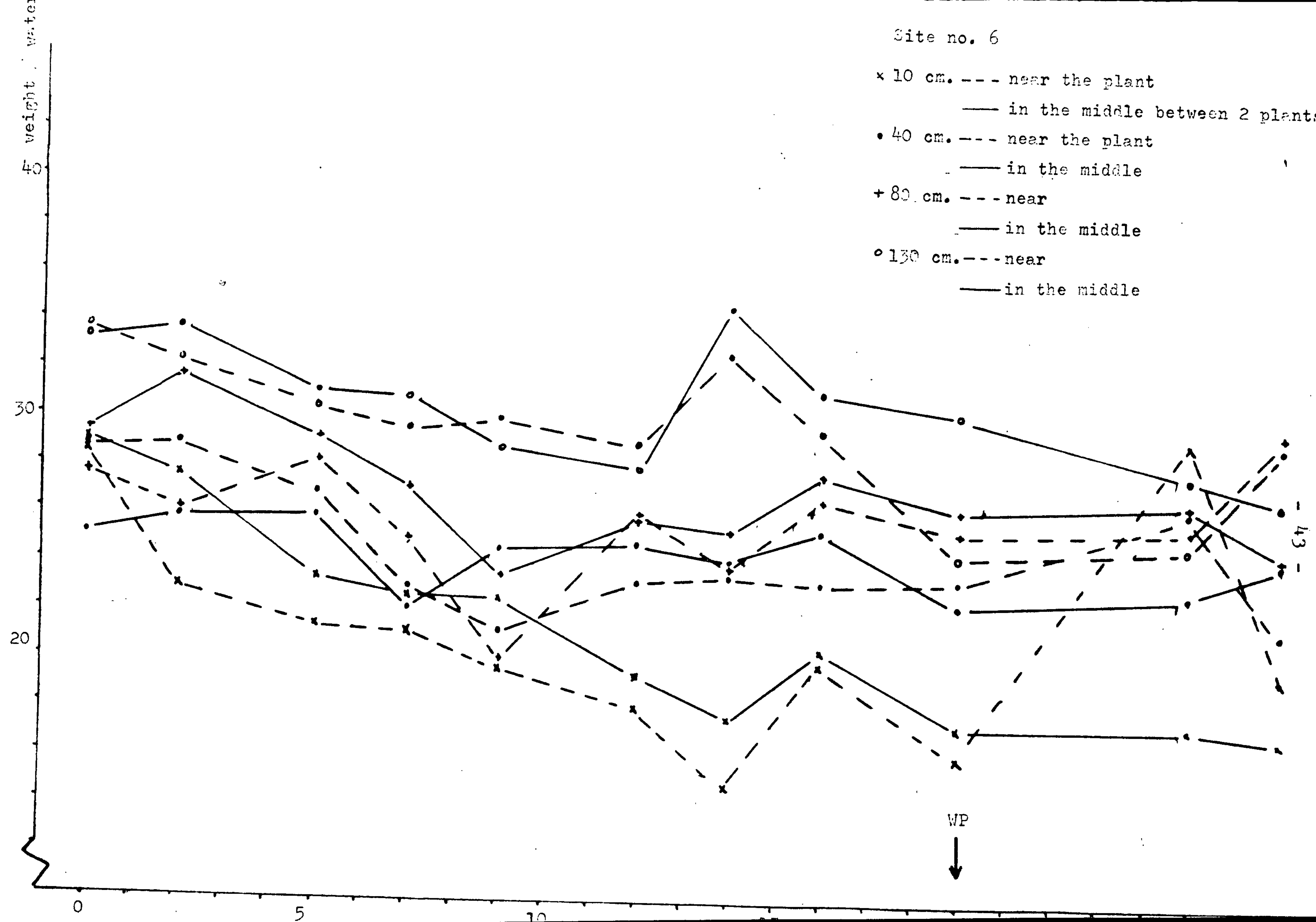

weight % water
40
30
20
Site no. 2
x 10 cm.
• 40 cm.
+ 75 cm.
o 110 cm.
0
5

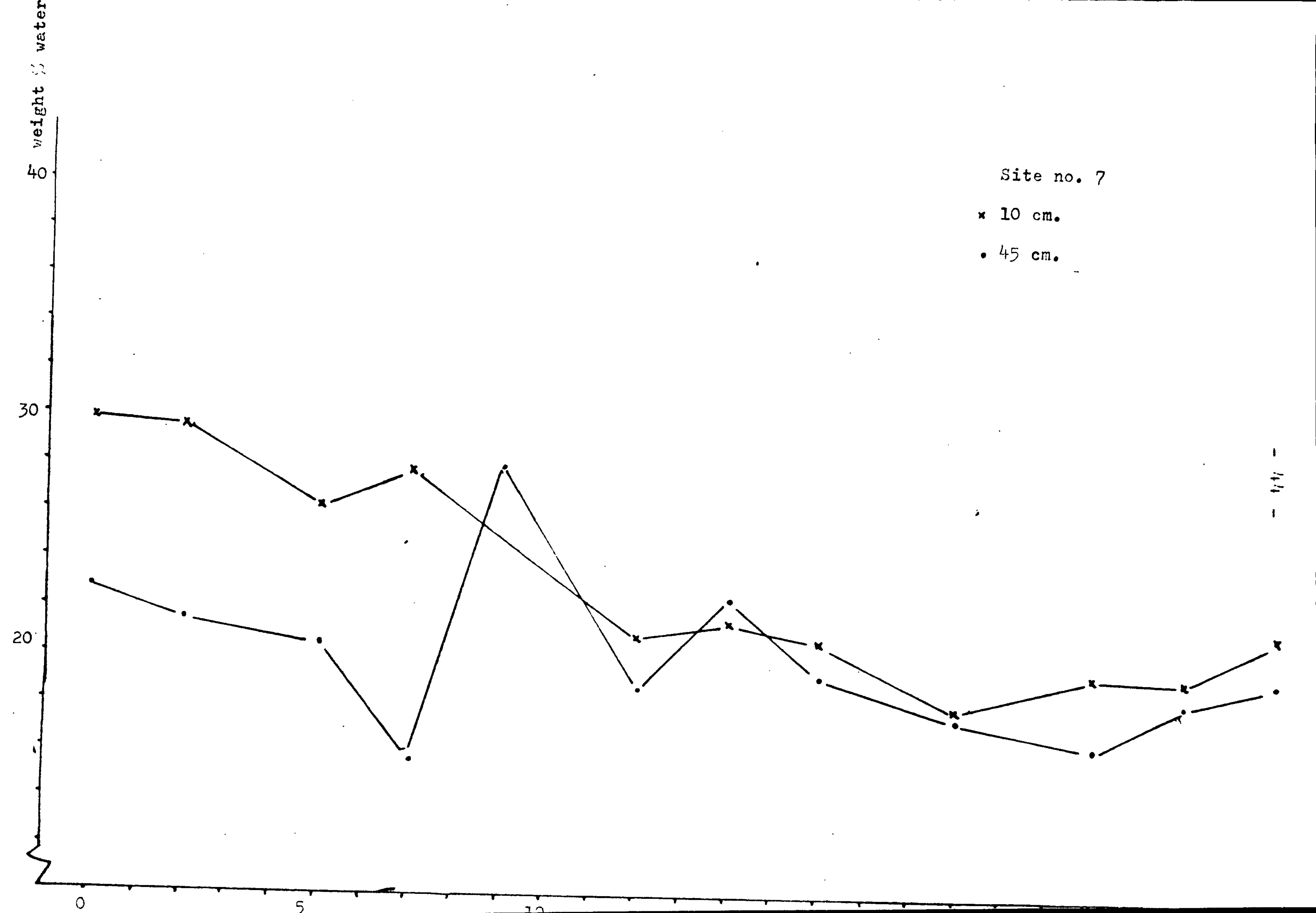

weight % water
40
30
20
0
5
Site no. 3
× 10 cm.
• 40 cm.
+ 80 cm.
∘ 130 cm.

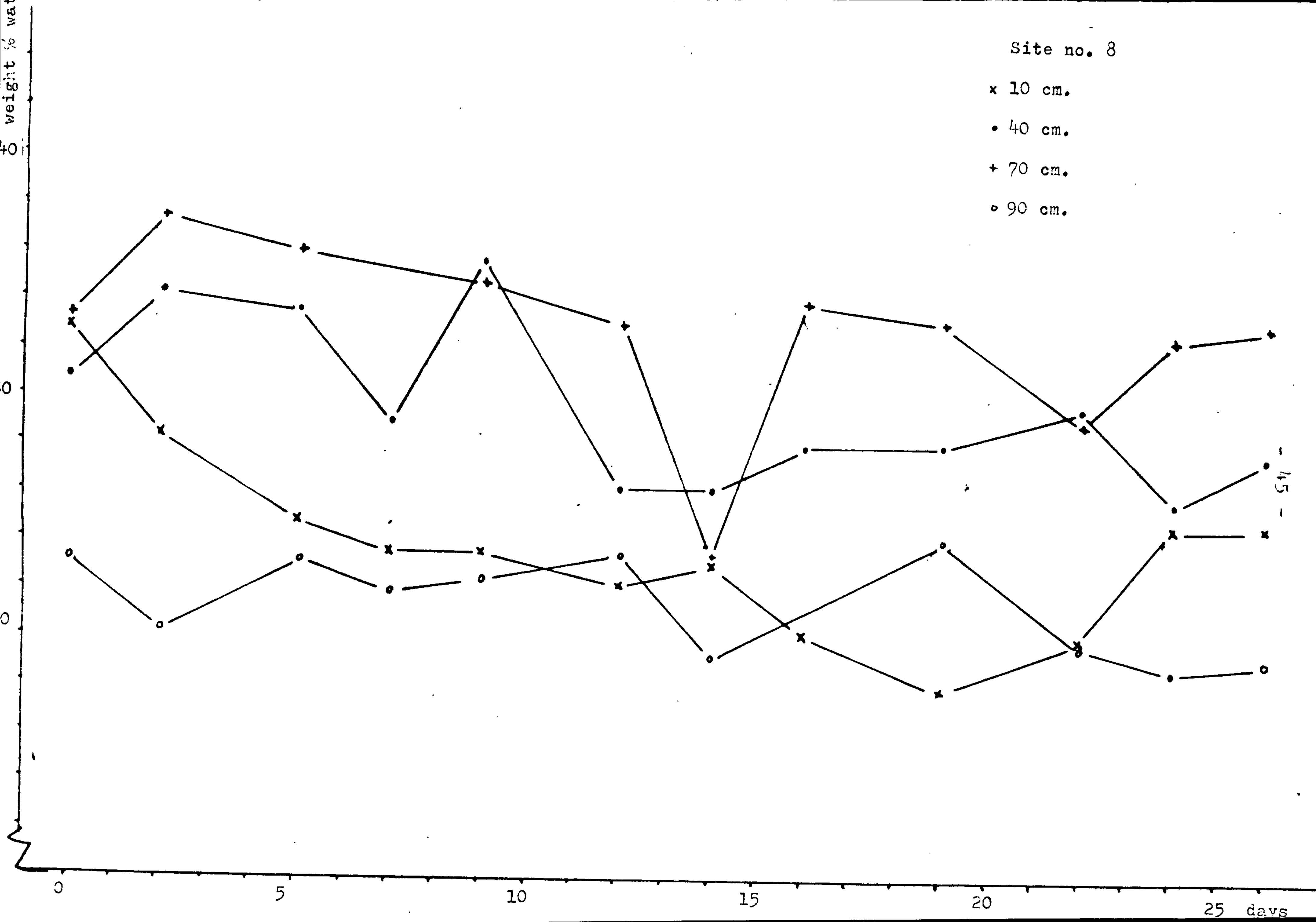

weight % water
30
20
10
0
0
5
WP
Site no. 4
× 10cm. - - - near the plant
—— in the middle of two plants
• 30cm. - - - near
—— in the middle

- 41 -

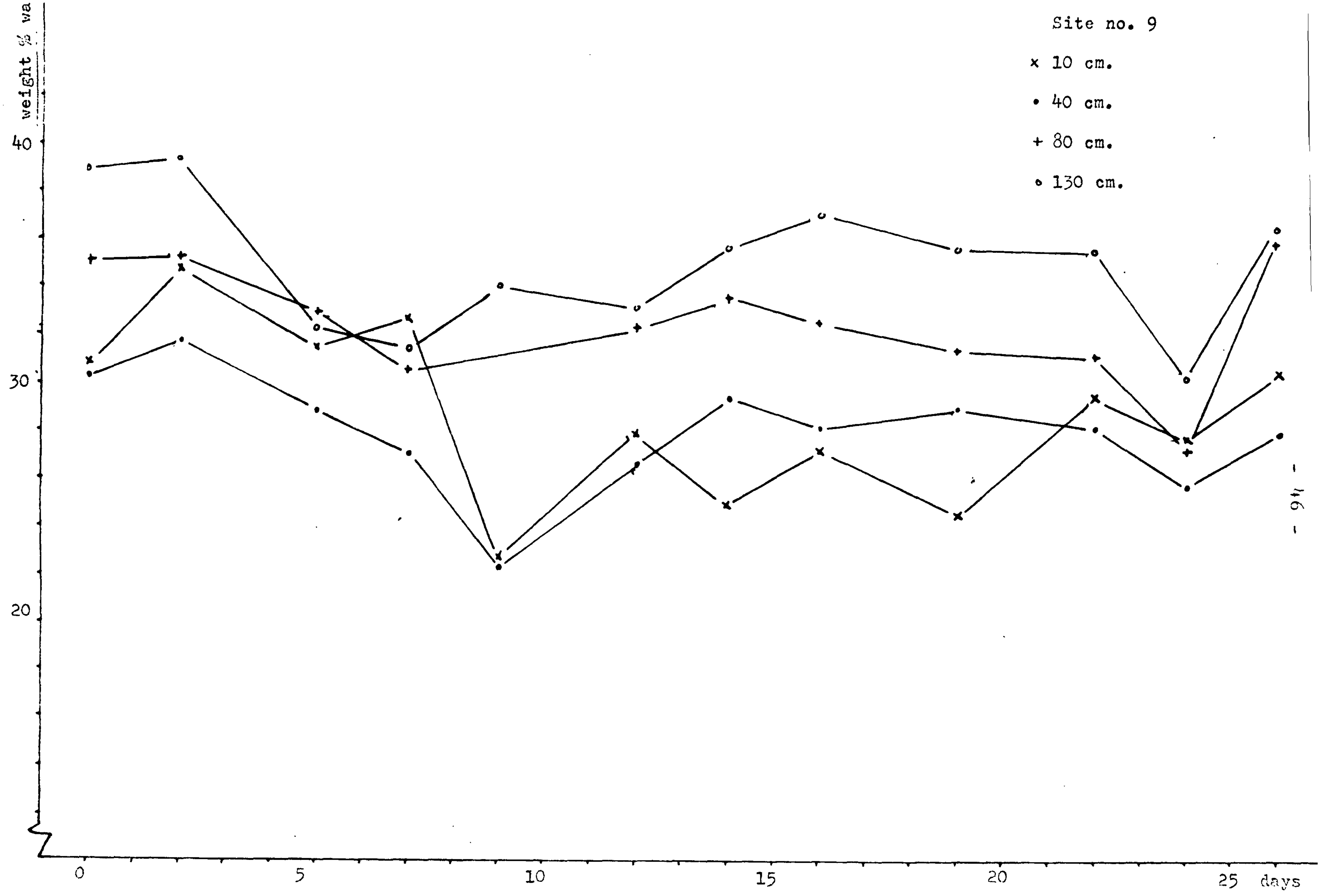

0
5
10
WP
Site no. 5
x 10 cm. - - - near the plant
—— in the middle between 2 plants
• 40 cm. - - - near
—— in the middle
+ 70 cm. - - - near
—— in the middle
o 90 cm. - - - near
—— in the middle

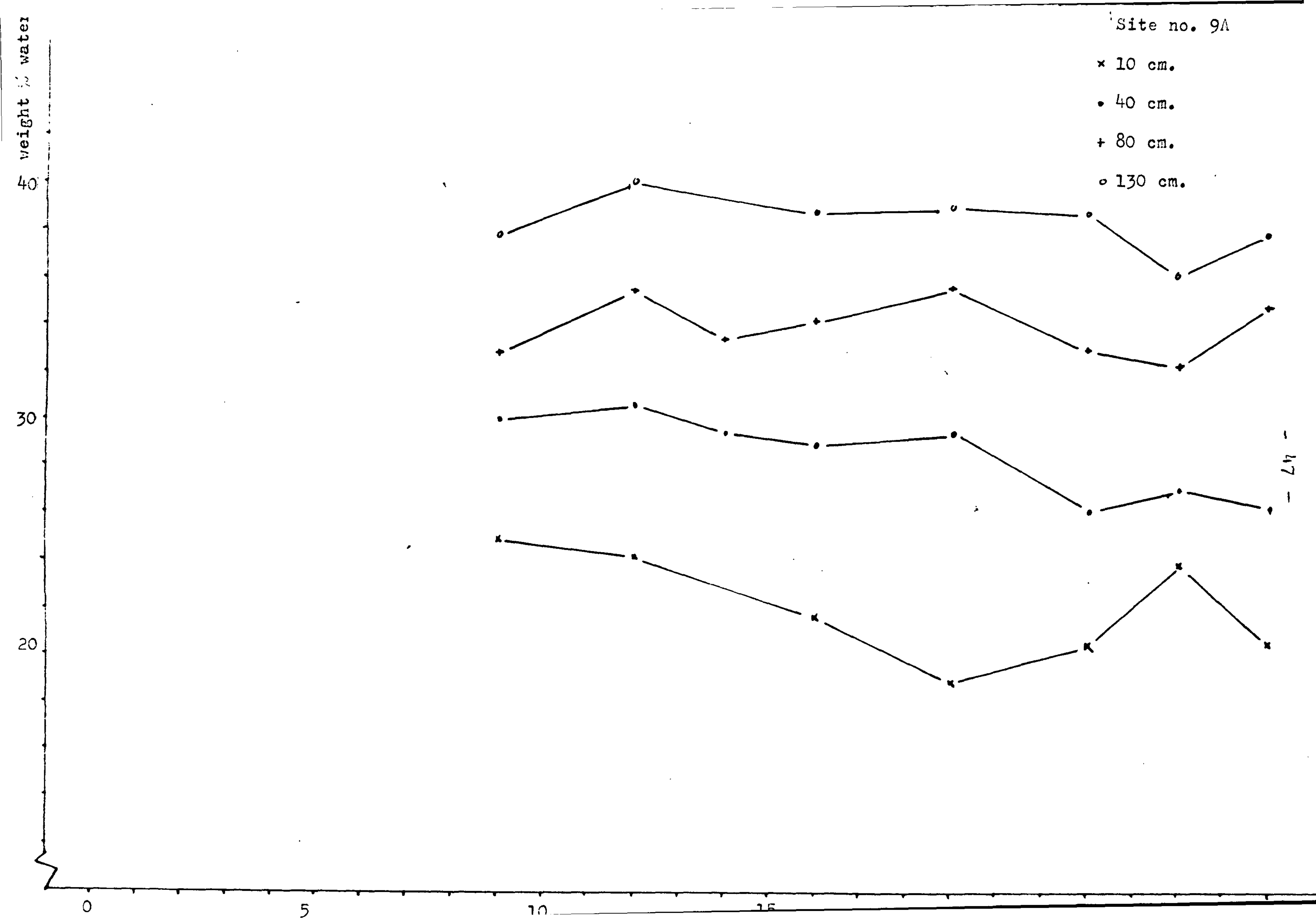

Site no. 6
× 10 cm. - - - near the plant
—— in the middle between 2 plants
• 40 cm. - - - near the plant
—— in the middle
+ 80 cm. - - - near
—— in the middle
o 130 cm. - - - near
—— in the middle
weight . water
40
30
20
0
5
10
WP


weight % water
40
30
20
0
5
Site no. 7
10 cm.
45 cm.



weight % wat
40
0
0
Site no. 8
x 10 cm.
• 40 cm.
+ 70 cm.
o 90 cm.
0
5
10
15
20
25 days


weight % wa
Site no. 9
× 10 cm.
• 40 cm.
+ 80 cm.
∘ 130 cm.
40
30
20
0
5
10
15
20
25 days


weight % water
40
30
20
0
5
10
Site no. 9A
× 10 cm.
• 40 cm.
+ 80 cm.
o 130 cm.

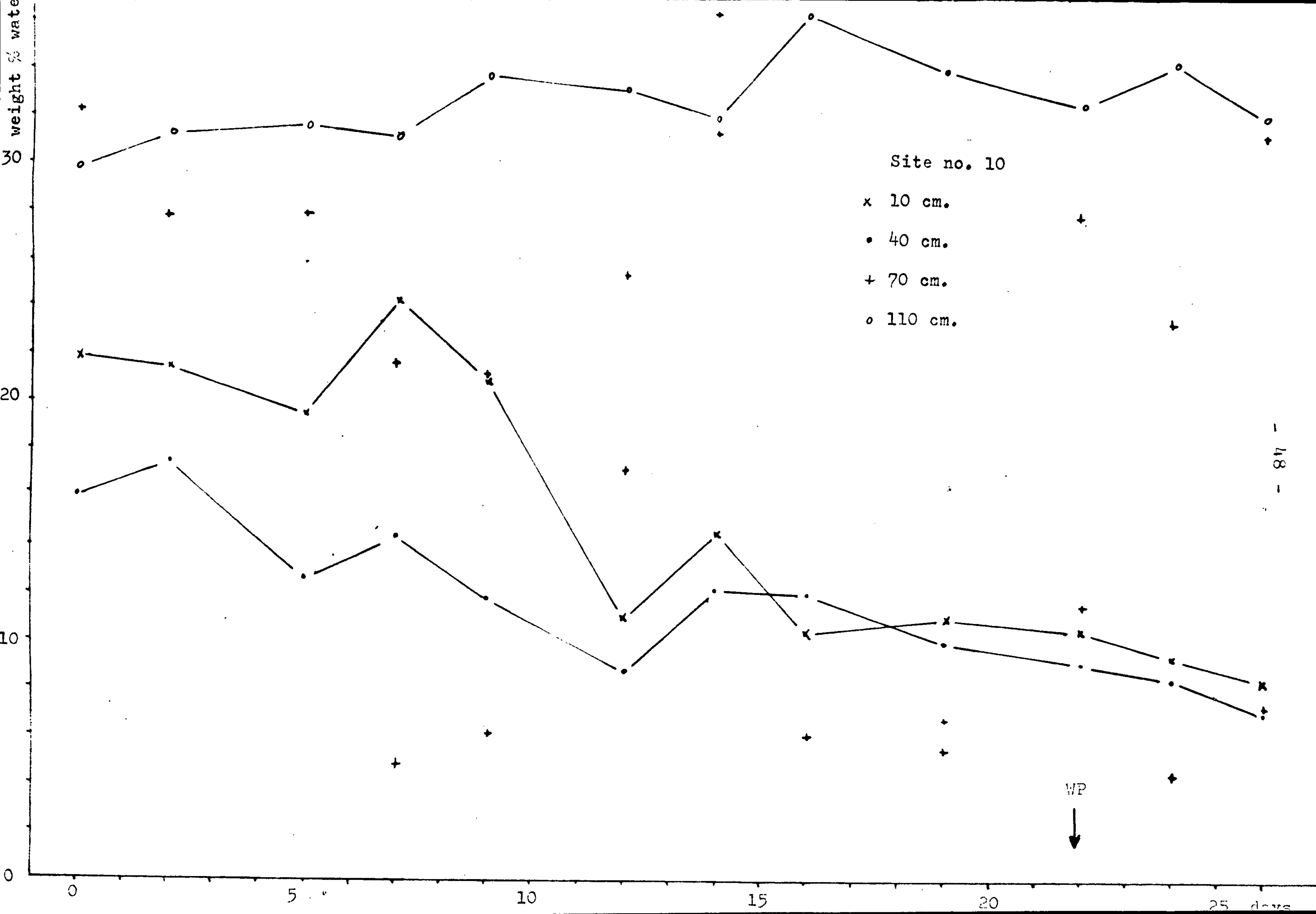

weight % wate
30
20
10
0
0
5
10
15
20
25 days
Site no. 10
× 10 cm.
• 40 cm.
+ 70 cm.
o 110 cm.
WP

table 2

| | | moisture content at WP (wght.%) 1 | lowest moisture content (wght.%) 2 | WP or lowest in vol.% 3 | moisture content at pF 4.2 4 | available moisture 5 | % used 6 |
|---|---|---|---|---|---|---|---|
| Site no. 1. | 10 cm. | | 28 | 29 | 26 | (25) 1) | 88 |
| | 40 | | 32 | 40 | 29 | 27 | 59 |
| | 70 | | 35 | 48 | 39 | 14 | 36 |
| | 110 | | 35 | 48 | 39 | 15 | 40 |
| Site no. 2. | 10 cm. | | 24 | 27 | 27 | (25) | 100 |
| | 40 | | 25 | 31 | 25 | (25) | 76 |
| | 75 | | 29 | 41 | 24 | 25 | 33 |
| | 110 | | 27 | 40 | 32 | 15 | 47 |
| Site no. 3. | 10 cm. | | 25 | 27 | 22 | 21 | 76 |
| | 40 | | 28 | 31 | 25 | 17 | 65 |
| | 80 | | 33 | 35 | 26 | 14 | 21 |
| | 130 | | 35 | 44 | 32 | 13 | 8 |
| Site no. 4. | 10 cm. | 7 | | 7 | 5 | (20) | 90 |
| | 30 | 11 | | 16 | 11 | 24 | 79 |
| Site no. 5. | 10 cm. | 17 | | 19 | 11 | 22 | 64 |
| | 40 | 21 | | 22 | 14 | 20 | 60 |
| | 70 | 25 | | 23 | 12 | 15 | 40 |
| | 90 | 17 | | 26 | 18 | 18 | 56 |
| Site no. 6. | 10 cm. | 18 | | 18 | 17 | (20) | 95 |
| | 40 | 24 | | 25 | 17 | (20) | 60 |
| | 80 | 26 | | 30 | 22 | 15 | 47 |
| | 130 | 30 | | 30 | 20 | 13 | 23 |
| Site no. 7. | 10 cm. | | 19 | 20 | 17 | 20 | 85 |
| | 45 | | 18 | 22 | 12 | 24 | 58 |
| Site no. 8. | 10 cm. | | 18 | 16 | 16 | 19 | 100 |
| | 40 | | 27 | 28 | 21 | 19 | 63 |
| | 70 | | 32 | 29 | 17 | 17 | 29 |
| | 90 | | 22 | 33 | 22 | 15 | 27 |
| Site no. 9. | 10 cm. | | 25 | 25 | 20 | 23 | 78 |
| | 40 | | 28 | 31 | 25 | (20) | 70 |
| | 80 | | 31 | 32 | 25 | 12 | 42 |
| | 130 | | 35 | 41 | 22 | 21 | 10 |
| Site no.10. | 10 cm. | 9 | | 9 | 8 | 19 | 95 |
| | 40 | 8 | | 11 | 8 | 22 | 86 |
| | 70 | - 2) | | - | 2 | 12 | - |
| | 110 | 35 | | 50 | 34 | 16 | 0 |

1) estimated ( no reliable FC value)
2) no reliable value

4. Root studies

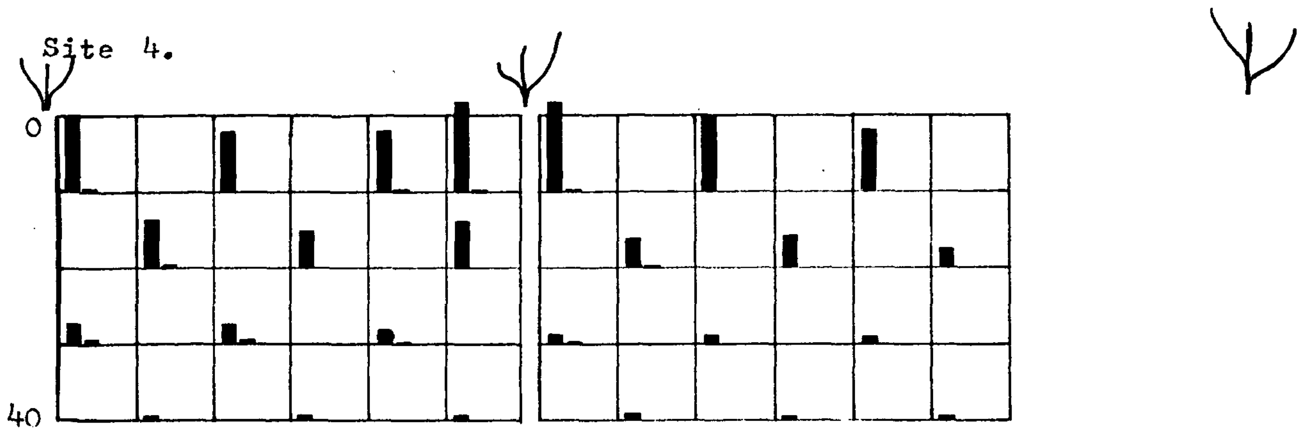
The results of the root countings are shown in diagrams which have to be read as follows: The diagram shows the 2 walls of the pit which have been counted, devided in squares of 100 cm2. (see Methods and materials, page 14). Every 100 cm2 is shown as a square of 1cm2. The amounts of roots which are counted in one square are re-presented - in this square - as small columns. 1. cm. hight of the column corresponds with 100 roots. The first column gives the amount in the first class of roots, the second the amount in the second class and the third the amount in the third and fourth class together.

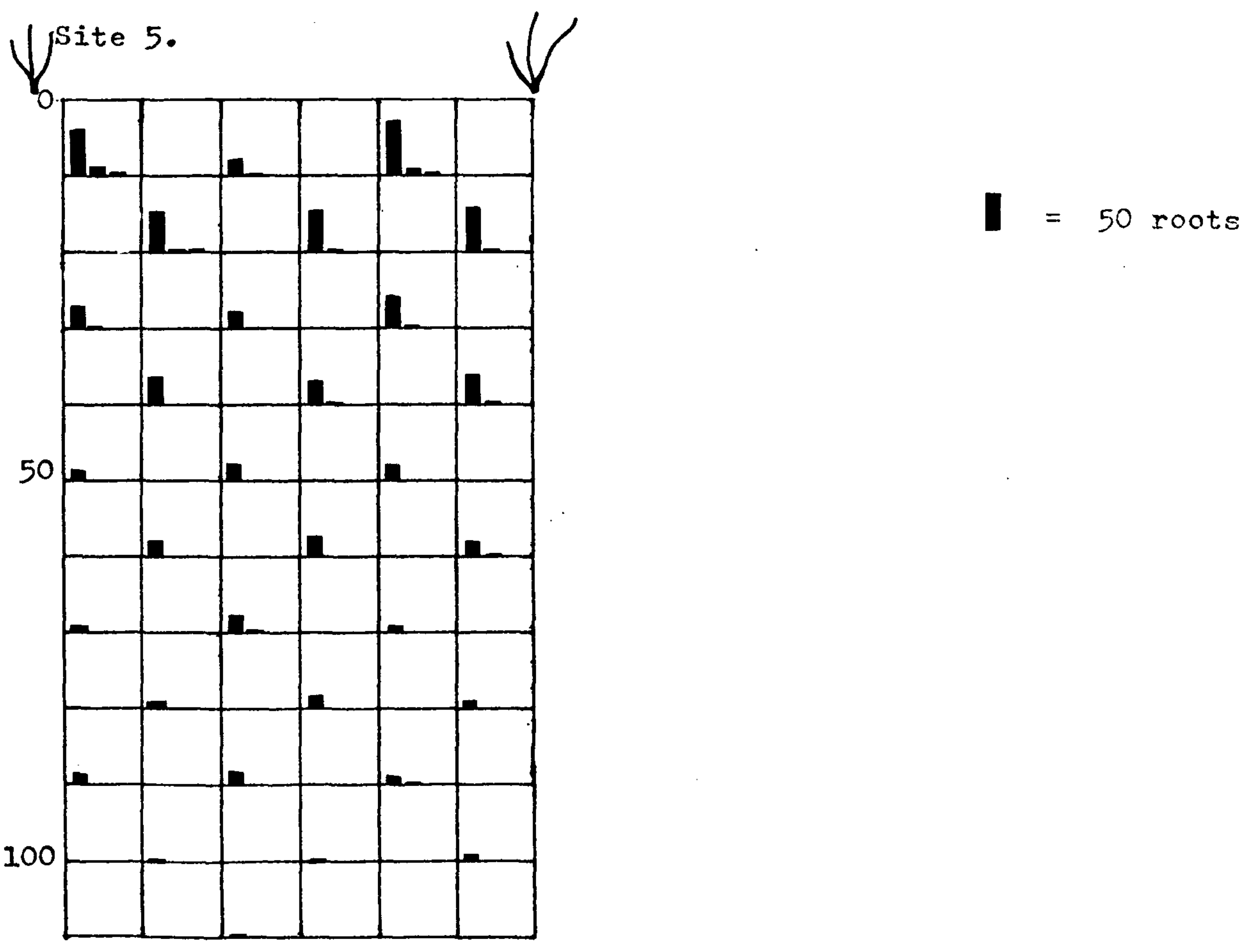
The used classes are 1. 0-$\frac{1}{2}$
2. $\frac{1}{2}$-1
3. 1-2
4. bigger than 2 mm.

Because hardly any roots were found, bigger than 2 mm., class 3. and 4. have been taken together in the diagram.

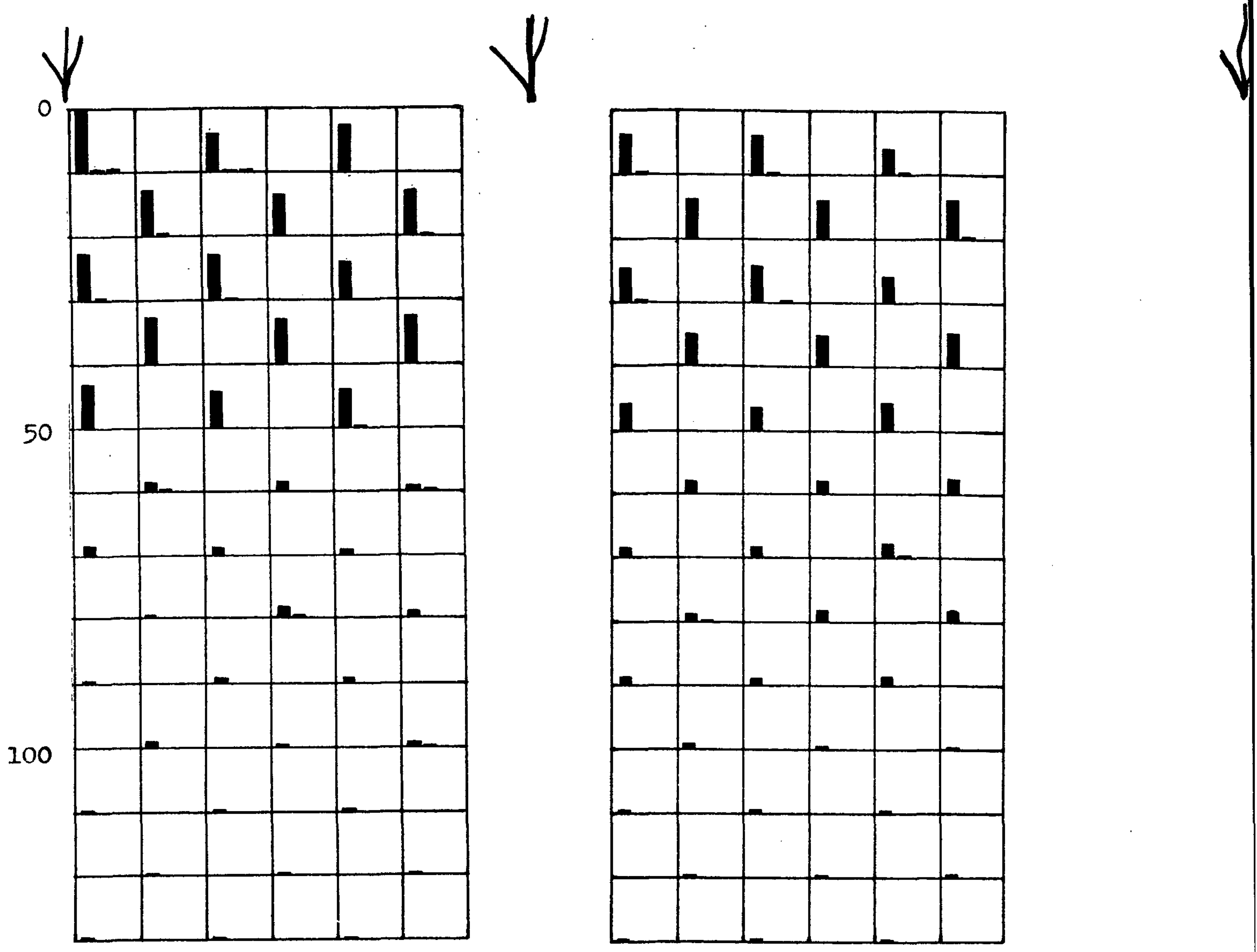
No root countings were carried out on site 1, 2, and 3. On site 5 only one wall is counted.

The situation of the plants near the profile is shown (  , 1cm. is 10 cm distance in the field).

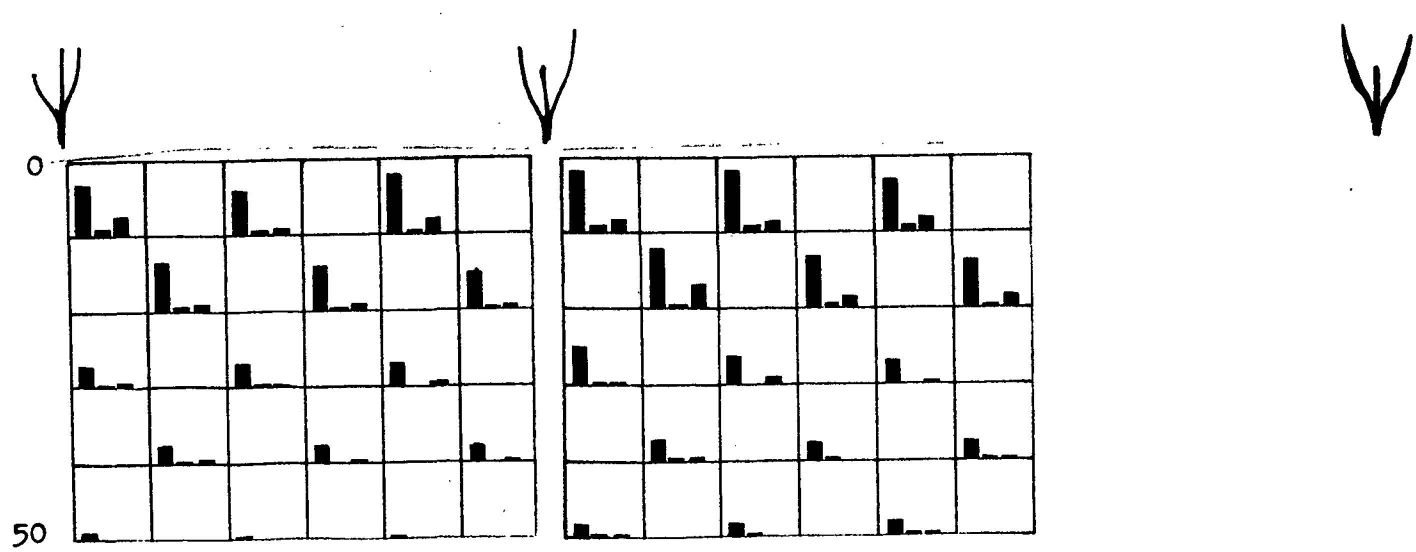

Site 4.
0
40


Site 5.
0
50
100
= 50 roots

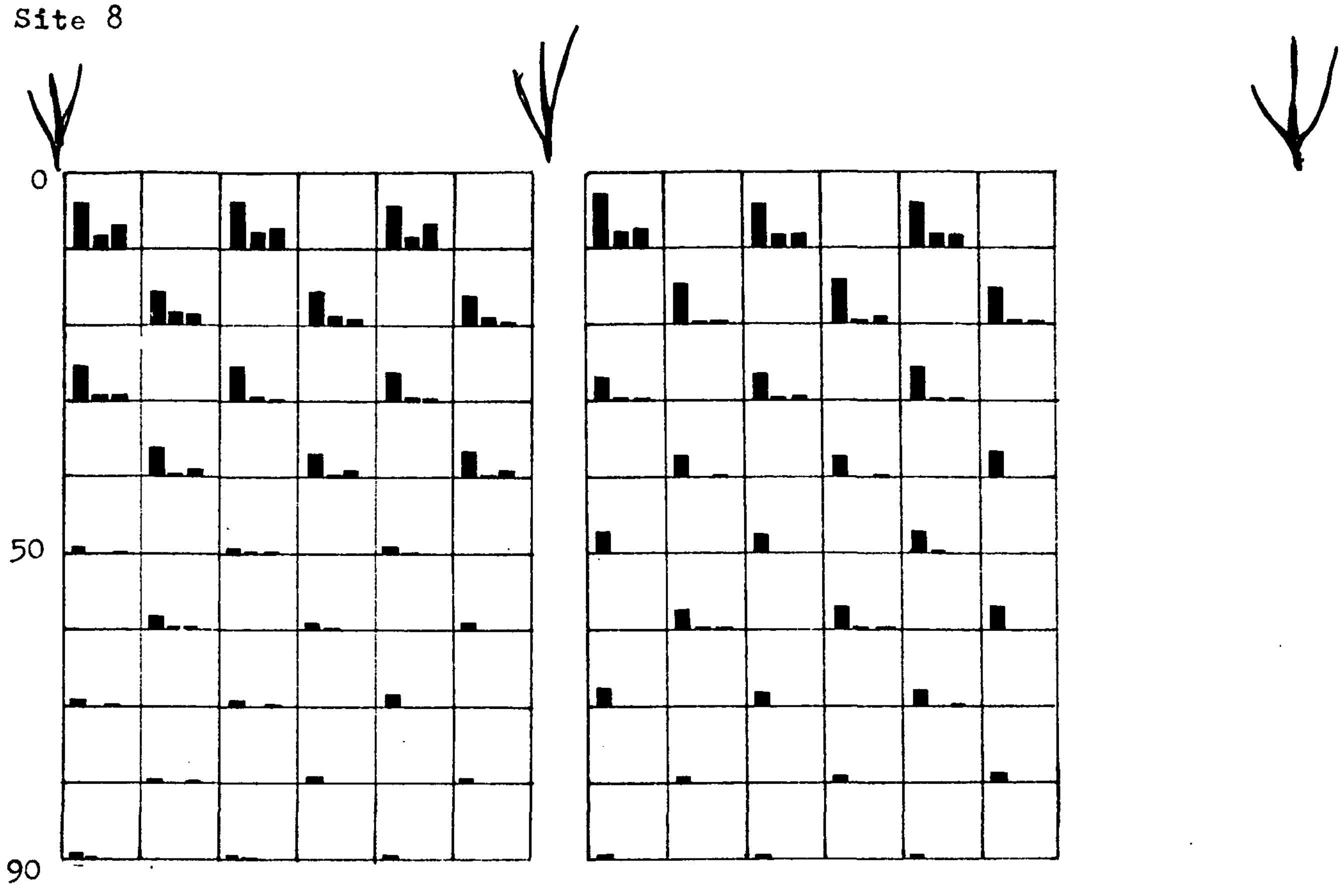
Site 6



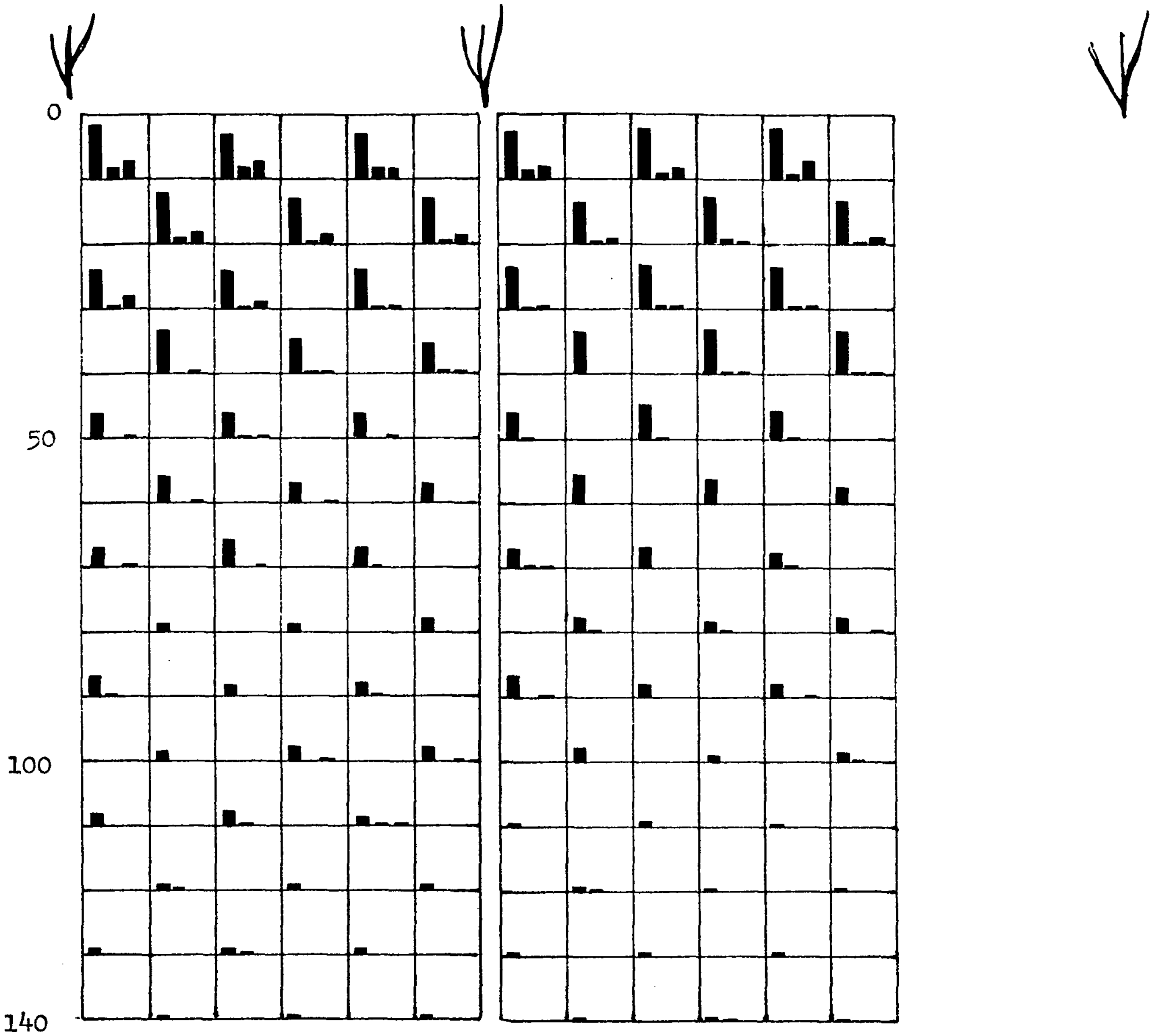

Site 7



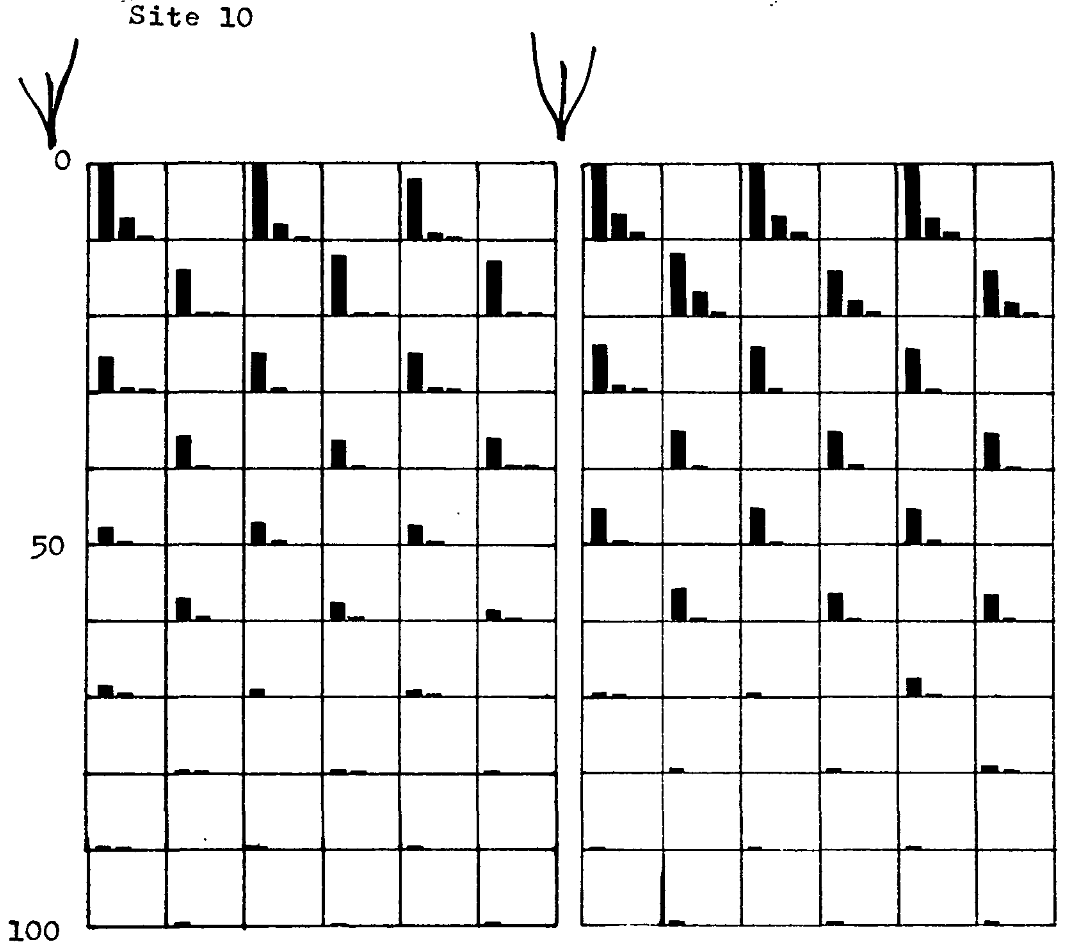
Site 8



Site 9



Site 10



Profile descriptions

Profile descriptions are made using the'Soil Description Form' with 'Guideliness'(1974), of the Kenya Soil Survey Project (derived from the Soil Survey Manual (1951) and the FAO guideliness for soil profile description), and Munsell color charts. Classifications and similar soils are given on a list at page 63.

Profile no. 1

Location : Nyanza Agricultural Research Station, Kisii.
Described by Job van Keulen (22-1-1976)
coord. :9924400mN and 698950mE.
elevation :5775 ft.

| | |
|---|---|
| Geological formation | : Bukoban. |
| Parentmaterial | : basalt. |
| Physiography | : slope of a rounded hill. |
| Topography | : rolling to hilly. |
| Slope gradient | : 18%. |
| Landuse | : grazing. |
| Surface stoniness | : 0-5%. |
| Soil fauna | : ants, moles, termites. |
| Root distribution | : 0-40 cm. abundant fine and very fine root<br>40- cm. few very fine roots. |
| Effective soil depth | : 40 cm. |
| Drainage class | : well drained |

Profile characteristics:

| | | |
|---|---|---|
| A1 | 0-25 | : 3YR4/2, clay, strong to moderate, fine, granular to subangular blocky, many very fine , common to many fine and few to common medium pores, hard when dry, friable when moist, slightly sticky and slightly plastic when wet, clear wavy boundary. |
| B21 | 25-40 | : 3YR4/4, clay, moderate medium subangular blocky, few weak clay skins, many very fine, common fine and few medium pores, hard when dry, friable when moist, sticky and slightly plastic when wet, clear wavy boundary, |
| B22 | 40-45 | : 3YR4/4 and weathering colours, clay, very stony and gravelly, abrupt to clear, wavy boundary. |
| B23 | 45- (buried B ?) | : 2,5YR4,5/6, many moderate clay skins, strong fine subangular blocky, clay, slightly gravelly, many very fine and common medium pores, hard when dry, friable when moist, sticky and slightly plastic when wet. |

Profile no. 2

Environmental characteristics see profile no 1.

| | |
|---|---|
| Slope gradient | : 19%. |
| Root distribution | : 0-40 cm. : ab. very fine and freq. fine,<br>40-80 cm. : fr. very fine and comm. fine,<br>80- cm. : few very fine roots. |
| Effective soil depth | : 80 cm. |

Stone layer at 80 cm.

Profile characteristics:

| | | |
|---|---|---|
| A1 | 0-20 | : 5YR4/2, clay, slightly gravelly, compound moderate coarse subangular blocky, fine to medium subangular blocky elements, many fine and common medium pores, hard when dry, friable when moist, slightly sticky and sl. plastic when wet, clear to gradual, wavy boundary. |
| B1 | 20-35 | : 3.5YR4/3, clay, slightly gravelly, moderate medium to coarse subangular blocky, many very fine,many fine and common medium pores, hard when dry, friable when moist, slightly sticky and sl. plastic when wet, common weak clay skins, clear to gradual, wavy boundary. |
| B21 | 35-83 | : 2.5YR4/5, clay, sl. gravelly, moderate medium to coarse subangular blocky, many very fine, many fine and few medium pores, common moderate clay skins, hard when dry, friable when moist, sl. sticky and sl. plastic when wet, abrupt to clear wavy boundary. |
| B22 | 83- | : like B21 but with many rounded stones (5-20 cm.) |

Profile no. 3

Environmental characteristics see profile no. 1

Slope gradient : 14%.

Root distribution : 0-100 : abundant fine and very fine,
100- : freq. fine and ab. very fine roots.

Effective soil depth : more than 150 cm.

Profile characteristics:

| | | |
|---|---|---|
| A1 | 0-95 | :3YR4/2, clay, medium to coarse, moderate subangular blocky compound of fine to very fine granular and subangular blocky elements, many very fine, common fine and few medium pores, very hard when dry, friable when moist,sl. sticky and sl. plastic when wet, gradual wavy boundary. |
| B1 | 95-115 | :2.5YR4/3, clay, moderate fine subangular blocky to angular blocky, common weak clay skins, many very fine and common fine pores, friable when moist,sl. sticky to sticky and sl. plastic to plastic when wet, gradual wavy boundary. |
| B2 | 115- | :2.5YR4/4, clay, weak fine angular blocky, common to abundant moderate clay skins, many very fine and few fine pores, hard when dry, firm when moist sticky and sl. plastic when wet. |

## Profile no. 4

Location : 400 m. west of Ranen market,
coord.: 9905030mN and 673740mE.
elevation : 4960 ft.

Geological formation :Nyanzian.

Parent material :rhyolite.

Physiography :slope of a low ridge in a foot slope.

Topography :undulating to rolling

Slope :6%.

Drainage :well to somewhat excessively drained.

Surface gravel :90%.

Soil fauna :moles. ants. termites.

Root distribution :0-20 :abundant very fine and common fine.
20- :common very fine roots.

Effective soil depth :35 cm.

Profile characteristics:

A1 0-16 :5YR3/2.5, clayloam, gravelly, moderate to strong very fine granular, maby very fine and fine pores, loose when dry, loose to very friable when moist, sl. sticky and non plastic when wet, clear wavy boundary.
B 16-22 :5YR3.5/4, clay, very gravelly and stony, many very fine and common fine pores, clear, wavy boundary.
C/R 22- :

## Profile no. 5

Location : 800 m. west of Ranen mkt.
coord. :9905190mN and 673320mE.
elevation : 4915 ft.
described by Job van Keulen (5-2-1976)

Geological formation :Nyanzian.

Parent material :rhyolite.

Physiography :footslope.

Topography :undulating to rolling.

Slope :8%.

Drainage :well drained.

Landuse :cropland

Soil fauna :moles, termites, ants.

Root distribution : 0-20 :abundant very fine and freq. fine,
20-90 :frequent very fine, few fine roots.

Effective soil depth :90 cm.

Profile characteristics:

A1 0-22 :3YR3.5/2, clay, weak to moderate, fine granular and subangular blocky, many very fine and common fine pores, hard when dry, friable when moist, sticky and slightly plastic when wet, clear and wavy boundary.

B1 22-50 :2.5YR4/3, clay, weak fine to medium subangular blocky, few weak clay skins, many very fine and few fine pores, hard when dry, friable when moist sticky and, slightly plastic when wet, gradual and wavy boundary.

B2 22-90 :2.5YR4/4, clay, moderate, fine to medium subangular blocky, common moderate clay skins, many very fine and few fine pores, hard when dry, friable to firm when moist, sticky and plastic when wet, abrupt to clear, wavy boundary.

B3 90- :2.5YR4/4 and rotten rock colours, black iron-manganese concretions.

<u>Profile no. 6</u>

Location : 800 m. west of Ranen market,
coord. :9904980mN and 673330mE
elevation :4890 ft.

Geological formation :Nyanzian.

Parent material :rhyolite.

Physiography :lower part of a footslope - valleyhead.

Topography :undulating to rolling.

Slope :9%.

Drainage :well drained.

Landuse :cropping.

Soil fauna :ants, moles, termites.

Root distribution : 0-10 :abundant very fine and fine rts.
10-40 :ab. very fine and freq. fine,
40- :freq very fine and common fine roots.

Effective soil depth : over 150 cm.

Remark :situated on lower edge of a terrace.

Profile characteristics:

A1 0-15 :5YR4/2, clay to clayloam, strong very fine granular and mderate fine to medium subangular blocky, many very fine and fine, and common medium pores, hard when dry, friable when moist, sticky and sl. plastic when wet, clear to gradual boundary.

B1 15-50 :2.5YR4/5, clay, moderate fine medium subangular blocky, few weak clay skins, many very fine and fine, and common medium pores, hard when dry, friable when moist, sticky and sl. plastic when wet, clear wavy boundary.

cont.

B2 50- :2.5YR4/5, clay, moderate fine to medium subangular blocky, common moderate clay skins, many very fine and common fine pores, hard when dry, friable when moist, sticky and sl. plastic when wet.

Profile no. 7

Location :500 m. east of Ranen market
coord. :9905140mN and 674870mE.
elevation :4930 ft.
described by Job van Keulen (31-1-1976)

Geological formation :Nyanzian.

Parent material :rhyolite.

Physiography :slope of a ridge.

Topography :undulating.

Slope :4%.

Drainage :well drained.

Landuse :cropping (sugarcane).

Soil fauna :moles, ants, termites.

Root distribution : 0-20 :ab. very fine, fine and very fine
20-50 :ab. fine and very fine , and freq. medium roots.

Effective soil depth :50 cm.

Profile characteristics:

A1 0-25 :3YR4/3, clayloam to clay, moderate fine subangular blocky to granular, many very fine, common fine and few medium pores, slightly hard when dry, friable when moist, sl. sticky and sl. plastic when wet, clear and wavy boundary.

B2 25-43 :2.5YR4/4, clay, moderate fine subangular blocky, few weak clay skins, maby very fine and few fine and medium pores, very friable when moist, sticky and sl. plastic when wet, abrupt to clear, wavy boundary.

B3 43- :2.5YR4/4 with weathering colours.

Profile no. 8

Environmental characteristics see profile no. 7

Slope :5%.

Root distribution : 0-15 :ab. very fine and fine, freq medium
15-90 :ab. very fine, frequent fine and medium roots.

Effective soil depth :100 cm.

Profile characteristics:

A1 0-22 :3YR3.5/2, clay to clayloam, moderate fine granular to subangular blocky, many fine and very fine pores, sl. hard to hard when dry, friable when moist, sticky and sl. plastic when wet, clear and wavy boundary.

B1 22-35 :2.5YR4/3, clay, moderate to strong, very fine to medium, granular and subangular blocky, few weak clay skins, many very fine and common fine pores, friable when moist, sticky and sl. plastic when wet, gradual and wavy boundary.

B2 35-90 :2.5YR4/5, clay, weak to moderate, very fine to fine subangular blocky, common weak clay skins, many very fine and few fine pores, very friable when moist, sticky and slightly plastic when wet, abrupt to clear wavy boundary.

B3 90- :2.5YR4/5 and mainly yellowish rotten rock colours, some iron-manganese concretions.

<u>Profile no. 9</u>

Environmental characteristics see pofile no. 7.

Slope :7%.

Root distribution : 0- 5 :ab. fine and very f.,common medium,
5- 30 :ab. very f, freq. fine, comm. med.,
30-100 :abundant very fine, common fine.
100- :few very fine roots.

Effective soil depth :150 cm.

Profile characteristics:

A1 0-20 :5YR3.5/2, clay, strong very fine granular to weak, fine to medium, subangular blocky, many very fine and fine, and common medium pores, hard when dry, friable when moist, sl. sticky and sl. plastic when wet, clear to diffuse boundary.

B1 20-70 :2.5YR3/4, clay, moderate, fine to medium, subangular blocky, few weak clay skins, many very fine and common fine pores, hard when dry, friable when moist sticky and sl. plastic when wet, diffuse boundary.

B2 70-150 :2.5YR4/5, clay, moderate, very fine to fine, subangular to angular blocky, common weak clay skins, many very fine and common fine pores, hard when dry, very friable when moist, sticky and plastic when wet, abrupt to clear, wavy boundary.

B3 150- :B2 material with rotten rock.

Profile no. 10

Location : 8 km. NW of Rongo mkt. ( near Magena).
coord. :9924300mN and 671600mE.
elevation :4360 ft.

Geological formation :Post Nyanzian intrusives.

Parent material :granite.

Physiography :valley bottom.

Topography :sl. undulating.

Slope :1%.

Drainage :poorly drained.

Landuse :sugarcane.

Root distribution : 0-15 :abundant fine and very fine roots
15-60 :ab, very fine, common fine roots.

Effective soil depth :60 cm.

Profile characteristics:

A1 0-22 :7.5YR3/1, loam, weak fine subangular blocky, abundant fine and very fine pores, loose when dry, very friable when moist, non sticky and non plastic when wet, abrupt to clear boundary.

A21 22-60 :5YR4.5/0.5, silt-loam, weak medium subangular blocky, many fine diffuse 5YR4/2 mottles, abundant very fine and common fine pores, hard when dry, friable when moist, non sticky and non plastic when wet, clear, . wavy boundary.

A22 60-90 :loose sand.

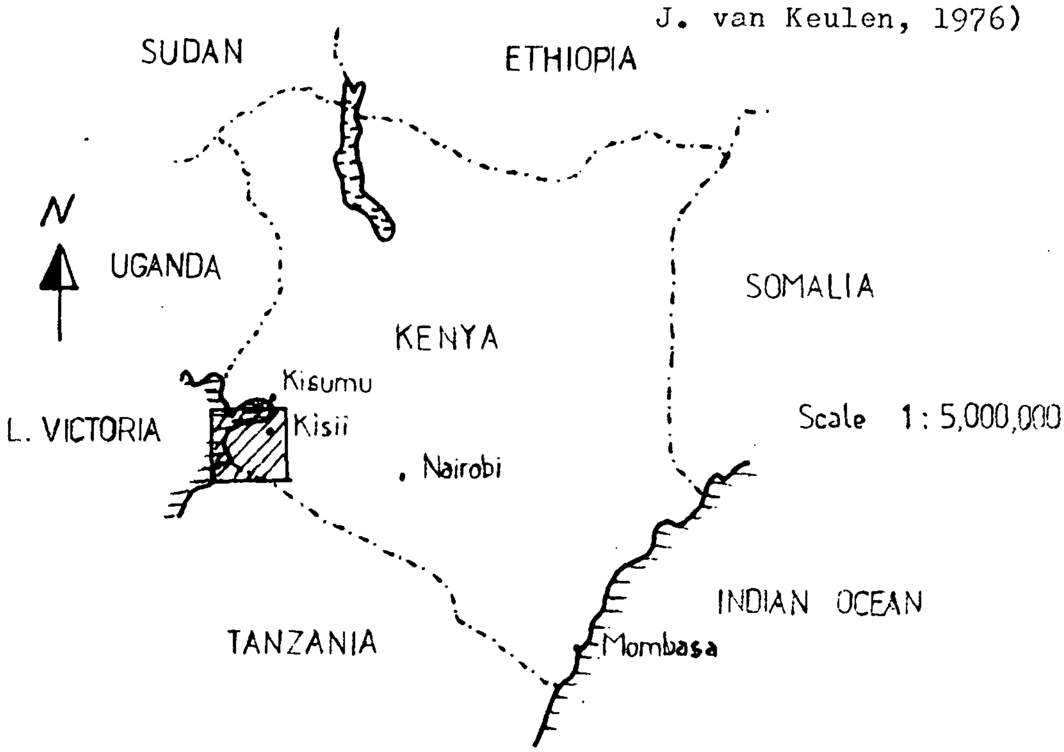
B2 90- :5YR4/1, clay, weak coarse subangular to angular blocky, many moderate clay skins, many thick. intersecting slickensides, frequent very fine and common fine pores, very hard when dry, firm when moist, sticky and plastic when wet.

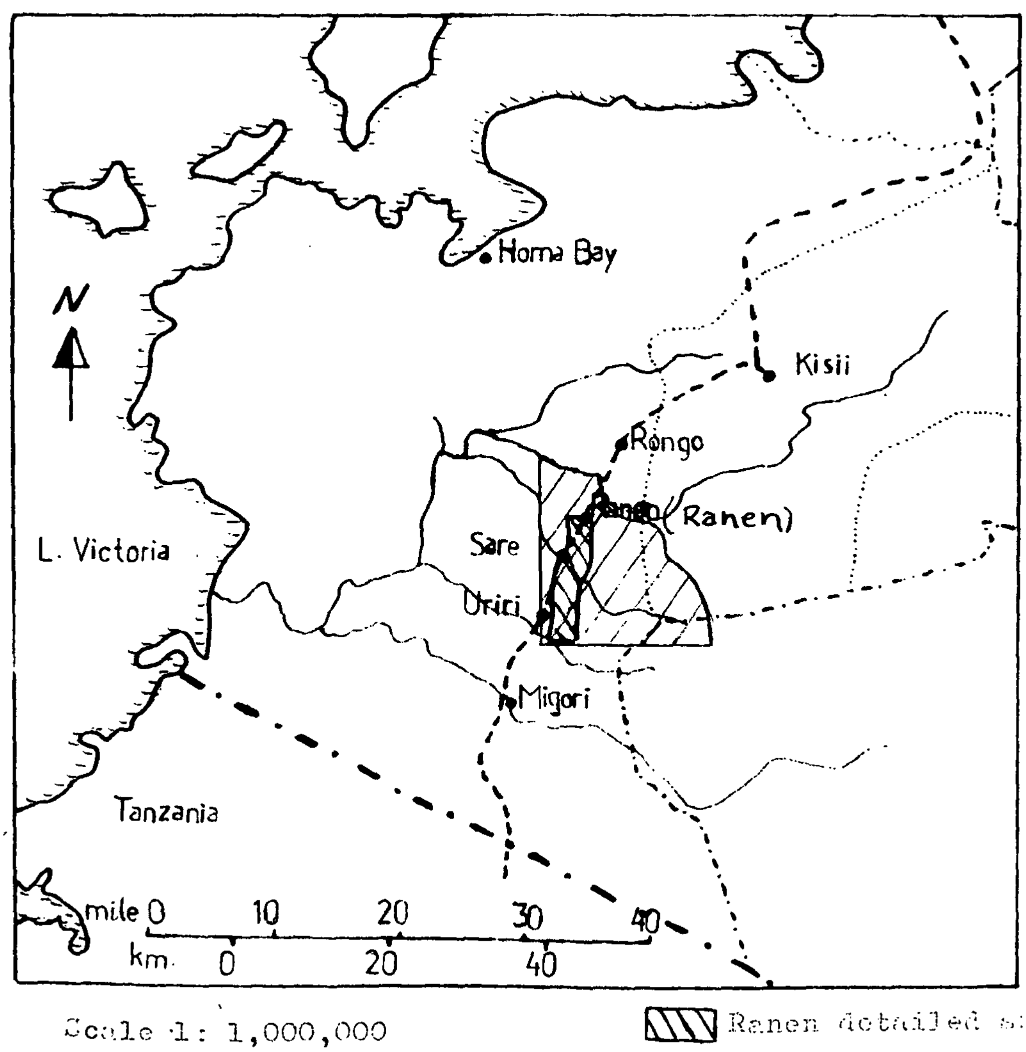
List with classifications and similar soils

| | | Classification (FAO) | series name in Ranen det. surv. | symbol on draf legend Kisii map sheet, 19? |
|---|---|---|---|---|
| Profile | 1 | Chromic Luvisol | - | $KmM_1$ |
| | 2 | " " | - | $KmM_1$ |
| | 3 | Luvic Phaeozem | - | $KdM_1$ |
| | 4 | Chromic Cambisol | Marando | Kss |
| | 5 | " Luvisol | Rabour | $RmM_2$ |
| | 6 | " " | Ranen | $RmM_2$ |
| | 7 | " Cambisol | Marando | Kss |
| | 8 | " Luvisol | Rabour | $RmM_2$ |
| | 9 | " " | Ranen | $RmM_2$ |
| | 10 | Eutric Planosol | Riana-Kuna | $PeM_1$ |

LOCATION MAPS

(From 'A semi-detailed survey of the South-Nyanza East area' by J. van Keulen, 1976)




Scale 1: 1,000,000

Ranen detailed survey area

South-Nyanza East area

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