EFFECT OF WATER TABLE DEPTH ON CROP (MAIZE) YIELD

BY

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SCHOOL OF ENGINEERING AND ENGINEERING TECHNOLOGY

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A FINAL YEAR PROJECT SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE AWARD OF THE DEGREE OF BACHELOR OF ENGINEERING (B.ENG) IN AGRICULTURAL ENGINEERING DEPARTMENT.

SCHOOL OF ENGINEERING AND ENGINEERING TECHNOLOGY
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CERTIFICATION

This is to certify that this project was carried out by SOLI NANEJE SHAIBOU REGISTRATION NO92/2795 of AGRIC ENGINEERING DEPARTMENT of Federal UNIVERSITY of TECHNOLOGY MINNA under my supervision

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HEAD OF DEPARTMENT

-------------------------- 25/3/98

EXTERNAL EXAMINER — Date

DEDICATION

This project is entirely dedicated to my mother, GOLMA, and to the Memory of my departed Father, Mr SOLI NANEJE

MAY HIS SOUL REST IN PERFECT PEACE (AMEN).

ACKNOWLEDGEMENT

I wish to express my sincere gratitude to ALMIGHTY ALLAH for sparing my life and seeing me through the course of this project/work. Also I wish to express my appreciation to Dr Akin Ajisegiri H.O.D AGRIC ENGINEERING DEPARTMENT, all the lecturers in the department and both the Head of farming system & his assistant (NCRI, BADEGGI) for their guidance cooperation and understanding during the course of this project.

I will not forget to appreciate with great satisfaction my understanding supervisors ENGR. N.A Egharevba and Dr. Adgidzi.

Moreso, I would like to thank Mr A. W. Salami for his best support and guidance in making this project a success.

I will not forget my friends indeed, Niger Republic Government and all Niger Republic students at F.U.T MINNA NIGERIA.

Finally, my appreciation goes to the following members of my family: My sisters(Fatima, Salamatou and Hassana) my brothers (Hassan, Housseyni, Amadou, Harouna & ILLA) as well as my mother Golma for their moral and immeasurable financial support.

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ABSTRACT

This project presents the effect of water table depth on crop yield. The crop investigated is maize. The field work covered the growing period (July 10th - November 3RD 1997). The field experiment was carried out at Badeggi National Cereals Research Institute,(NCRI), Bida Nigeria.

The actual average evapotranspiration (ETcrop) was obtained by direct method to be 38mm per period of 14days interval or 2.7mm/day.

The physical properties of the soil was obtained, the parameters such as infiltration depth, hydraulic conductivity, moisture content and porosity were obtained as 9.8cm/h, 0.605cm/h , 16.7% and 0.177 respectively. The dry and wet bulk density were also obtained as 1.79 and 2.1g/cm^3 respectively. Particle size analysis was also performed to know the distribution of soil grain size.

The following parameters were obtained for the crop planted: plant height, leaf area and quantity of water applied, as 122cm, 528cm^2, 44mm at 14days interval respectively. The yield obtained were 0.1455kg, 0.3438kg, 0.3466kg and 0.6708kg at water table of 10cm, 20cm, 30cm and at free drainage respectively.

Finally, the study establishes that the crop yield decreases with rise in water table.

CHAPTER ONE

1.1 INTRODUCTORY NOTE

Water is essential for crop production, available water must be used rationally for efficeint crop production and high yields. This requires a proper understanding of the effect of water- rainfall/ or irrigation on crop growth and yield under different growing conditions.

Much has been published on aspects of water relation in crop growth. Attempt to understand crop response to water through crop growth modelling have met with success. However, for practical application, a method is required to measure yield response to water supply, which should be simple, require only commonly available climatic, water, soil and crop data, be widely applicable with acceptable accuracy and allow easy verification through adaptive research. Based on present knowledge of the water-soil plant systems, and using the impressive amount of related research data, a methodology is presented for estimating yield response to water at the field level. The selected irrigation crop is maize . The research station is located at NCRI (National Cereals Research Institute) Badeggi, Bida Niger State .- the experiment is carried under Green House environment.

1.2 NATURE OF THE PROBLEM

The problem of inadequate water supply and lack of data on crop water needs and their relationship to yield have continued to pose major problems in agricultural production in most of the countries. These may be a result of lack of development of available water resources and the not available relevant studies that should provide such information.

Consequently, agricultural production in the country, has continued to be limited to the single rainfed cropping season even in areas where available water resources can readily be harvested for multiple cropping, [illegible] Ayotamuno (1975)

1.3 AIM AND OBJECTIVE OF THE PROJECT

In both developed and developing countries , several studies have investigated the role of water in promoting growth and enhancing yield of crops. As a model for maize crop, such studies will provide the vital information on the consumptive use values and their variations with growth stage required for irrigated production on this crop.

The desirable level of water required may be viewed from any of the following:

- The desirable level of water resulting in maximum water use efficiency.
- The desirable level of water required for maximum yield per unit area cropped - Ayotamuno (1995).

1.4 JUSTIFICATION OF THE OBJECTIVE

In many African countries, like in Nigeria we do not have full information on water requirements of our major agricultural crops. So there is the important need for relevant studies on the water needs and their relationship to yield of maize crop in the country. It's only with such information /data that we can plan and design effective irrigation system at a minimum cost.

It is a field study on water needs of maize and their relationship to yield at Badeggi National Cereal Research Institute in the middle belt of Nigeria. Specially, the study will attempt to establish

(i) The consumptive use of the maize crop and its variation with growth stages.

(ii) The full relationship between water requirement and yield of maize in the Badeggi research institute (middle belt of Nigeria).

1.5 LOCATION AND DESCRIPTION OF THE PROJECT AREA

It is localised on the outskirts of Badeggi village on kilometre 143 on the Bida- Suleja Highway in Niger state and situated in the southern guinea zone of the savanah region in latitude 9^{0}45' north and longitude 6^{0}07' East. National cereals Institute (NCRI) as it known today was established by an agricultural research institute order of 1975 but its history dates back to 1899 when first department of agriculture was established by British colonial administration. The department was later converted into the Federal department of agric research moor plantation at Ibadan and charged with the responsibility of conducting research on:

- cereals
- grain legumes
- roots crop
- pasture
- fruits and vegetables

The 1975 agricultural research institute(ARI) order lunched the research activities of the institutes to problems of rice, maize, grains legumes and sugar cane as well as farming systems throughout Nigeria. The headquarters of the institutes remained at moor plantation, Ibadan until 1978 when a decision was taken to move the headquarters of the institute of Badeggi near Bida in NIGER STATE, in the guinea savanah which is the primary ecological zone of its mandate crops rice, maize and sugar cane.

The NCRI reoganization was saddled with the responsibility for conducting research into the production and products of rice, maize, grain legumes, and sugar cane. Under the new dispensation, the institute has responsibility for research into the genetic improvement, agronomy and husband[illegible] pest and diseases and utilization of rice, oil seeds (soya beans [illegible]) and sugar cane. In its research assignment the institute is now restricted to middle belt zone of the country, the board ecological areas covered by Benue, Platau, Niger, Kwara state and the FEDERAL CAPITAL TERRITORY.

The institutes' research activities are organised along the following Programme.

(i) Rice research Programme

(ii) Oil seed research programme

(iii) Sugar cane research programme

(iv) Farming system research programme

The annual rainfall average at Badeggi is 1219mm. The wettest months are June, July, August and September. There is however a tendency for the rainfall to be rather irregular .

Dry season covered the period November to March with less than 38mm. Mean relative humidity at 0900 GMT ranges from 80% (June - September) to 60% (January - February) at times dropping to forthy-two percent of North -Eastly.

Harmattan wind prevails for any length of time.

Mean temperature are fairly regular throughout the year and range from 26.1^{0}C (June- February) to 30.2^{0}C (October - May) RISING TO 36.70^{0}C (March- April). A south-westernly wind prevails the rains while the North- Eastly harmattan blows during the period (November -February) in the dry season.

1.6 LIMITATION OF THE PROJECT

The constraint is that the project work is limited by the depth of the container used (40cm maximum). In addition, they were no instrumentation to monitor the actual miniclimate conditions of the Green House environment.

CHAPTER TWO

LITERATURE REVIEW

2.1 IRRIGATION & DRAINAGE

2.1.1 IRRIGATION

Irrigation is the artificial application of water to soil for the purpose of crop production. Irrigation water is supplied to supplement the water available from rainfall and the contribution to soil moisture from ground water. In many areas of the world the amount and timing of rainfall are not adequate to meet the moisture requirement of crops and irrigation is essential to raise crops necessary to meet the needs of food and fibre.

Irrigation is done for the followings purposes:

1. To add water to soil to supply the moisture essential for plant growth
2. To provide crop insurance against short duration droughts
3. To cool the soil and atmosphere, thereby making more favourable environment for plant growth.
4. To reduce the hazard of frost
5. To wash out dilute salt in the soil
6. To reduce the hazards of soil piping
7. To soften tillage pans and clods
8. To delay bud formation by evaporative cooling

Irrigation water can be achieved in five different ways:

(1) By flooding

(2) By means of furrow

(3) By applying water underneath the land surface through sub-irrigation, thus causing the water to rise

(4) By sprinkling through nozzle pipes

(5) By trickle system

However water to supply moisture essential for plant growth may come from five sources

(1) Precipitation

(2) Atmosphere water other than precipitation

(3) Flood water

(4) Ground water

(5) Irrigation

Failure to consider all five sources and the proportion to total plant needs may result in faulty design of an irrigation system.

2.1.2 DRAINAGE

Good drainage, both surface and internal, is essential to successful irrigation. Provision should be made to drain the excess rainfall promptly and safely. Surface drainage may be needed to prevent or modify saline- alkali conditions in a soil by leaching. If the land is not naturally well drained, artificial drainage must be established at the same time the irrigation system is installed -See page from over - irrigated areas at higher elevations and irrigation canals can damage lands in the law - lying areas. Interceptor drains may be necessary at the upper boundaries of the low-lying area to divert the seepage and prevent waterlogging - Integrated irrigation and drainage planning is often necessary for laying out a farm area for efficient water use.

- Benefits of drainage

1] Facilitate early plowing and planting.

2] Lengthens the crop-growing season

3] Provides more available soil moisture and plant food by increasing the depth of root -zone in soil

4] Helps soil in ventilation and leaches excess salts from soil

5] Decreases soil erosion and gulling by increasing water infiltration into soils and

6] Assures higher soil temperatures.

2.2 SOIL - WATER & PLANT RELATIONSHIPS

2.2.1 WATER RELATIONS OF SOIL

Soil serves as the storage reservoir of water. In almost all areas the soil contains it maximum quantity of water at the end of the cold period - water enters a ground water reservoir from natural or artificial recharge. The water table marks the division between the groundwater and the moisture zones in the soil.

In the unsaturated soil above the water table, the pores are partly occupied by water and partly by air. The soil water in this zone is commonly referred to as soil moisture. The amount of soil moisture varies greatly with depth and in time. The soil moisture profile as depicted would be typical of a soil with a fairly high water table (within 3m from the soil surface) shortly after a prolonged period of rainfall. In a narrow zone above the water table, pores fill by capillary rise from the ground water.

In the lower part of this capillary zone all pores are filled with water, making the soil in this so-called capillary fringe as saturated as in the ground water below the water table.

Above the capillary zone, pores fill with water mostly by retaining part of the percolating rain (or irrigation) water . When the ground water is very (>14-20m below the soil surface) the soil may be moist in the upper layers and also in a zone, immediately above the water table (capillary zone) while, in between, the soil may be much drier- the soil moisture content in the upper soil layer (down to 0.5 - 10m) is particularly variable mainly due to variations in daily weather conditions (especially rainfall variations). Deeper down, variations occur over a longer term, in parallel with seasonal weather variations.

2.2.2 MOVEMENT OF WATER WITHIN SOILS

2.2.2.1 SOIL STRUCTURE AND TEXTURE

(i) SOIL STRUCTURE

Structure is used to describe the arrangement of the primary particles into the natural aggregates or peds. The sand, silt and clay particles of the soil are cemented together in the soil to form natural units of compound particles or aggregates separated by pores , cracks or planes of weakness- structural units are of four principal types:

1. More or less flat or platy
2. Prism -shaped, predominantly vertically bounded by flat surfaces
3. Blocky or many sided
4. More or less round or spheroidal

The degree of development of the structure, where present, indicated by the terms weak (barely observable), moderate and strong (durable peds evident in an undisturbed soil).

Soil organic malter plays a major role in soil aggregation. The best structure is that which increases soil aeration and water-holding capacity and facilitates microbiological activity. The structural development in a soil greatly affects its agricultural productivity. A loose, friable, freely draining soil is easier to cultivate than a heavy compact soil. Wetting and drying, tillage and biological activities all contribute to the continuous building up and breaking down of soil aggregates.

(ii) SOIL TEXTURE

Soil texture refers to the fineness or coarseness of the mineral particles of the soil and is commonly defined as the relative proportions of sand, silt and clay- It exerts considerable influence on the capacity of the soil to hold water and to circulate air.

The rate of many important chemical reactions in soil is governed by soil texture because it determine the amount of surface area available for reaction. Soil texture critically influences the response of crops to fertilization. Three broad soil textural classes are recognized: sands, loams and clays. Most agricultural soils are in this group. There are about twelve textural classes graded from coarse-textured, easily worked (light or sandy) soils to very fine textured, not easily worked (heavy claying) soils.

2.2.2.2 MOVEMENT OF WATER AND TERMINOLOGY

The movement of water within the soil controls not only the rate of infiltration but also the rate of supply of moisture to plant roots and the rate of underground flow to springs and streams and recharge of ground water. Water in the liquid phase flows through the water filled pore space under the influence of gravity. In the films surrounding soil particles (under unsaturated conditions), it moves under the influence of surface tension forces. Water also diffuses as vapour through the air-filled pores spaces along gradients of decreasing vapour pressure- In all cases, the movement is along gradient of decreasing water potential.

2.2.2.2.1 WATER INTAKE

The movement of irrigation water from the soil surface into and through the soil is called water intake. It is the expression of several factors including infiltration and percolation.

2.2.2.2.2 PERCOLATION

Percolation is the downward movement of water through saturated or nearly saturated soil in response to the force of gravity. Percolation occurs when water is under pressure or when the tension is smaller than about 1/2 atmosphere-

Percolation rate is synonymous with infiltration rate with the qualitative provision of saturated or near saturated conditions.

2.2.2.2.3 INFILTRATION

It's the downward and lateral movements of water into soil or substracta from a source of supply such as irrigation canal or reservoir - Such water may reappear at the surface as wet spots or seeps or may percolate to join the ground water or may join the subsurface flow to springs or streams. Infiltration rate depends on the welted perimeter of the reservoir or the canal and the capacity of the soil to conduct water both vertically and laterally . The infiltration characteristics of the soil is one of the dominant variables influencing irrigation. The actual rate at which water is entering the soil at any given time is termed infiltration velocity the infiltration rate decreases during irrigation. Accumulative infiltration, also called cumulative infiltrationn is the total quantiy of water that enters the soil in a given time. Infiltration rate and accumulated infiltration are two parameters commonly used in evaluating the infiltration characteristics of soil.

2.2.2.2.4 PERMEABILITY

Permeability is defined as the readiness with which a soil transmits fluids. Soil permeability also depends on soil structure, texture and depth of water table. A high permeability is essential for leaching down the excessive salts or removal of Na released by the application of gypsums in alkali soil. Again the permeability of soil decreases with the increases of dispersibility and exchangeable Na percentage of the soil. Generally, water moves slowly downward through a highly dispersed soil because the micro-pores are closed by the swelting of dispersed clay. However, when they applied water contains sufficient divalent cations it suppresses the diffused double layer of clay particles and increases soil permeability.

In other to predict the success of irrigation in a particular situation, it essential to have adequate information on the quality of irrigation water, its effect on the physical and chemical properties of soil, water transmission characteristics and salt build up.

2.2.2.2.5 HYDRAULIC CONDUCTIVITY:

The hydraulic conductivity K_1 as applied to an acquifer is defined as the rate of flow of water in litres per day through a horizontal cross-sectional area of one square metre of the acquifer under a hydraulic gradient of one metre per metre at the prevaling temperature of water. The first rational analysis on the movement of water through sand was the work of (Henry Darcy 1856AD) who proposed the relationship expressed in the equation below which formed the basis of all studies of flow through porous media.

Darcy's experiments showed that the flow of water through a column of saturated sand is proportional to the difference in hydraulic head at the ends of the column, and inversely proportional to the lenght of the column. This is known as Darcy's law, expressed as

$$V = \frac{K(h_1 - h_2)}{L}$$

where V = velocity of flow , m/day

K = hydraulic conductivity, depending upon the properties of sand and the liquid, m/day

$h_1 - h_2$ = difference in hydraulic head, m

L = distance along the flow path between the points h_1 and h_2 ,m

We can more expressed the velocity of flow V in terms of K and i (hydraulic gradient)

$V = Ki$ 2.2

Often the quantity of flow may be of greater interest than the velocity. Hence, in terms of quantity of flow, Darcy's law may be expressed as follows

$Q = av = Kia$ 2.3

Where

Q = volume of water discharged in standard lenght of time usually expressed as m^3/day

a = cross-sectional area through which water moves, m^2

The value of K can be obtained by laboratory tests of the samples of the formation material. For field use, however, it is more appropriate to dteremine the values of K from pumping test data.

2.2.3 PLANT WATER RELATIONSHIP

Water is of such fundamental importance to crop production that an understanding of its role, is unvaluable to arable farmers and students of agriculture. Moreso, all plant growth depends upon a supply of water and this need has to be satisfied by the action of roots that extract water from the soil in which the plants grow. Water in soil at field capacity (FC) is only loosely held and easily extracted by plant roots, but as more and more water is removed from the soil from progressively smaller pores, the point is reached at which the maximum section that roots can developed, balance the energy with which water is held by the soil. At this point water removal falls to negligeable quantities, plants lose turger and wilting occurs and at this point soils feel nearly dry or only very slightly moist.(PWP). Although plants can make use of all water in the available range provided roots have excess to it , the strongly retained water is less easily extracted and cannot sustain the same rate of plant growth as water less tightly held. The available water capacity (AWC) of free draining soils is a very important chartacteristic, which , when taken in conjuction with average rainfall, gives a good measure of the cropping potential of land.

Moisture content of growing plant varies from 50 to 98 percent depending on the nature of the plant meterial.

Growth of most crop produced under irrigation farming is stimulated by moderate quantities of soil moisture and retarded by either exessise or defficient amounts. The factors influencing the water relations of plants, and thus their growth and yield responses, may be grouped into the following:

(i) soil factors = soil moisture content, texture, structure,density, salinity, fertility, aeration, temperature and drainage.

(ii) Plant factors = type of crop, density and depth of rooting, rate of root growth, aerodynamic roughness of the crop, drought tolerance and varietal effects.

tolerance and varietal effects.

(iii) Weather factors = sunshine, temperature, humidity wind and rainfall

(iv) Miscellaneous factors = soil volume and plant spacing, soil, fertility, and crop and sal management.

2.3 MAIZE CROP

A crop is a plant carefully selected and developed over many years, sown on cultivated land to produce food for man and animals or raw materials.

2.3.1 GENERAL VIEW

Maize crop belongs to graminae farmily. I's one of the world's three most important cereals crop (the others are rice and wheat). The crop is primarily grown for its grain which is consumed as human food. In some developed countries maize is also grown for animal feed and as a base for industrial products such as oils, syrup and starch. The grain may be fermented to produce beverages and then distilled to provide wisky or industrial alcohools, acids, acetaldehyde, acetone and glycerol. The crop residues can be used as folder, bedding, building meterials and fuel. Maize has the same calorific value as wheat or rice but has lower levels of essential amino acids lysine and tryptophane. It also has lower levels of triacin but it is higher in thiamine.

2.3.2 BOTANY (ZEA MAIZE)

Maize is an annual plant belonging to the grass family. It matures over a short period of a few months. individual plants are fairly large and unlike many grass species, ususally only one or two stems grow from each seed. Height varies from about 1.5m in short varieties to over 3m. Maturity time is usually 100- 120days, but some variation exist in this respect. Male flowers, called tassels, emerge after 50- 60days at the apex of the plant. Female flowers are formed in the ascils of the lower leaves at about the same time. The stigmatic surfaces of the female flowers, called silks, emerge from the leaf ascils shortly after tasseling. The seeds are formed on cobs which are the compacted staks of female inflorescences.

2.3.3 CLIMATE AND SOILS

Maize is essentially a tropical species. Very humid conditions are not considere good for maize, particularly during the maturations period. This is due to the low sunshine which is associated with humid conditions,and to the development of diseases of the flowers, cobs and leaves with high humidity. In very humid climates, the ripening period should be chosen to coincide with a seasonally dry spell if possible another problem of very humid and rainy regions is poor pollination which produces cobs with many missing grains. Maize is grown on a wide variety of soils. One essential requirement however is god drainage. The performance of maize in relation to soil type is =, as with all crops, closely related to climate, deeper soils with a higher moisture holding capacity being require in areas of marginal rainfall. Generally speaking, however, maize cannot be regarded as a crop which will yield well on poor sandy soils. Maize will grow on moderately acid soils but does not best on soils with PH value above 5.0- Limig is required for good yields on more acids, and many tropical soils require lime for good production. Maize can be grown well on alkaline soils provided nutirient defficiencies of iron and maganese are countered.

2.3.4 CULTIVATION AND MANAGEMENT

Maize is highly sensitive to environmental stress, competions, nutritions and moisture conditions and so as a result large variations in yields occur both within and between areas of production. Maize is generally grown in rotation with other crops or intercropped with a legume.

It's generally found that tillage operations are important in maize production. In heavy soils, particularly in regions of high rainfall, deep cultivation to 50cm and ridging is required to improve drainage, with light soils, shallow cultivation is satisfactory. Tilling the soil lightly and leaving the trash from the previous crop on the surface sometimes gives improved yields in light soils, for the previous crop residues form a mulch over the soil, conserving moisture.

2.3.5 PLANTING

Seed should be drilled or planted 2-3cm deep may be planted on the flat, on the tops of ridges, or in the furrows of ridges depending on conditions. Ridging is best in heavy soils and planting on top of the ridge improves drainage in such soils. Planting in funous (listing) can be used in a well draining soils and in dry areas. In tropical countries where maize is grown as a subsistence crop, mound planting is often practised. The soil is built up into mounds about 50cm high, and 1-1.5m apart after incorporating burnt trash which contains much potassium, animal manure top soil. Several plants are grown per hill. This method is well suited to small scale cultivation and to hand tillage. In regions of short rainy season planting must be done promptly so as to make full use of the rain and for this maize of quickly maturing varieties should be used.

2.3.6 FERTILIZERS

Maize responds well to increasing levels of fertility and can utilise high levels of nitrogen and phosphate. The crop needs a supply of nitrogen throughout its life and as nitrogen is very mobile in the soil the crop may respond to a split application of fertilizer. Part is applied at planting and part when the crop is about 50cm high and at the beginning of tasseling.

Maize removes the following quantities of nutrients for a crop of 4000kg per hectare

Nitrogen 100kg

Phosphous (P_2O_5) 40kg

Potassium (K_2O) 80Kg

In the tropics, soil below PH 5.0 may benefit, from a dressing of about 1 tonne of magnesium limestone per ha. Maize sometimes needs Zinc and molybdenum. Superphosphate with molybdenum added should be used. Zinc (ii) sulphate (vi) may be applied at 5kg per hectare

2.3.7 WEEDS PESTS AND DISEASES

Maize is highly sensitive to need competition during the first four weeks after emergence. These weeds can be controlled by mechanical means. Herbicides such as triazine that are highly effective under temperate conditions are generally less effective under dry tropical conditions. The major pests of maize are stem bores of the order lepidoptera; corn earworms, heliothis 5pp which damage the maturing ears in many areas, cutworms, agrotisspp and armyworms laplygmaspp that caused damage to the growing plants -The important diseases of maize are leaf blight. Most of these deseases are of greater importance in more humid areas or during exceptionally humid seasons in the dry tropics. Control measures vary from rotation and mixed cropping techniques to tthe use of resistant varieties in some cases and the appplication of fungicides in others.

2.3.8 HARVESTING AND VARIETIES

When the crop is mature, the leaves dry and the hurk surrounding the cob becomes dry and papery. The grains become hard as they lose moisture and the crop is often left in the field until the grain moisture content has dropped to 15 - 20%. Maize is harvested by hard by removal of the cob and husk from the plant. When required for eating as fresh vegetables, the cobs are picked before they are fully ripe, but if required for the grain they are left till the grains harden.

Maize varieties have been classified on the basis of the grain. The main groups are grown in tropical countries .

(i) Dent maize

These large cobs and large grains which shrunk on drying to produce a shallow hallow at the end of each grain.

(ii) Flent maize

These generally have smaller cobs which bear hard round grains.

(iii) Sweet cour

The grain are soft and sweet with little starsh and are grown for eating as a fresh vegetable.

(iv) Soft or flour maize

The grains do not have a dent. It consists also of soft starsh.

2.4 Maize : different stages of growth, water requirement and yield pattern.

Depending on the variety and growing temperatures, maize reaches physiologic maturity in about 90- 130 days after plant emergence when grown in the tropics. The growth stages may be viewed in three phases as follow:

2.4.1 FROM GERMINATION TO TASSELING

Plants will emerge in four to five days after planting under warm, moist conditions but may take up to two weeks or more during cool or very dry weather. Then the plants must rely on nutrents supplied by the soil or fertilizer up until knee-high stage, the three major nutrents, nitrogen, phosphorus and potassium are required in relatively small amounts. The primary roots reach full development about two weeks after seedling emergence and are then replaced by the permanent roots (called nodal roots) which begin growing from the ground.

The growing point plays a vegetative role by producing new leaves (about one every two days) until the plants are knee-high. Within a few days, the underground growing point is carried above ground by a lenghtening of the stalk and switches from leaf production to tassel initiation within the plant. From tassel initiation until tassel emergence take about five to six weeks and is a period of very rapid growth in plant height, leaf size, and root development. Maximum root depth can reach 80cm. Maximum nutrient iptake and maximum water use occur from tasseling through the soft-dough stage (about three weeks after tasseling).

2.4.2 TASSELING AND POLLINATION

Tasseling occurs about 40-70 days after plant emergence in 90- 130 days varieties. The tassel (flower) is thrust out of the leaf which about one to two days before it begins shedding pollen. Pollen shed starts two to three days before the silks emerge from the ear tip and continues for five to eight days. If conditions are favourable, all the silks emerge within three to five days and most are pollinated the first day.

Maize is cross-pollinated and usually 95% or more of the kernels of a cob receive their pollen from neigh-boring maize plants. Pollination is a very critical time during which there is a high demand for both water and nutrients. One to two days of wilting during this period can cut yields by as much as 22% and six to eight days of wilting can cut yields by 50 percent. A few days after pollination, the silks begin to wilt and turn brown.

2.4.3 FROM KERNEL DEVELOPMENT TO MATURITY

Ten days after pollination kernels begin to swell (Blister stage but contain liquid with ver y little solid matter. About 18-21 days after pollination (roasting ear stage). The kernels have accumulated only about one- third of the total dry matter yield they will have at physiologic maturity. From this time on any type of stress is more likely to affect kernel size rather than grain fill at the ear tip.

As maturity nears, the lower leaves begin to turn yellow and die. Ideally, most of the leaves should still be green when the husks begin to ripen and turn brown. Early death of the maize plant can greatly reduce yields and result in small, shrunken kernels. Note that any shortage of water, nutrients or sunlight during the first few weeks of kernel development usually affects the kernels at the tip of the ear first, making them shreved or abort. Maize is very prone to moisture stress (water deficiency) at this stage due to a heightened water requirement. References Traditional field crops David Leonard (1981) published by United State Peace Corps information collection and exchange manual M0013

2.5 YIELD RESPONSE TO WATER

For application in planning, design and operation of irrigation schemes, it is possible to analyse the effect of water supply on crop yields. The relationship between crop yield and water supply can be determined when crop water requirement and crop water deficit, on the one hand, maximum and actual crop yield, on the other hand can be quantified. Water deficit in crop affect crop evapotranspiration and crop yield. Water deficit can be quantified by the rate of actual evapotranspiration (ETA) in the relation to the rate of maximum evapotranspiration (Etcrop).

R_n = net radiation mm/day

$f(u)$ = function of wind speed

ℓ_s = saturated vapour pressure (mbar)

ℓ_o = actual vapour pressure (mbar).

When crop water requirement are fully met from available water suply then ETa = ETcrop when water supply is insufficient , ETa< ETcrop.For most crops and climates ETcrop and ETa can be quantified. The manner in which water defunt affects crop growth and yields, varies with the crop species and the crop growth period. To evaluate the effect of plant water stress on yield decrease through the quantification of relative evapotranspirstion (ETa/ETcrop), analysis of research result show that it is possible to determine relative yield losses if information is available on actual yield (ya) in relation to maximum yield (ym) under different water supply regimes. Where economic conditions do not restrict production and in a constraint,-free environments are met when full water requirements are not met by available water supply Ya < Ym. In order to quantify the effect of water stress it's necessary to derive the relationship between relative yield decrease and relattive evapotranspiration deficit given by the empirically derived yield response factor (Ky).

$$\left(1 - \frac{Y_a}{Ym}\right) = kg \left(1 - \frac{ETa}{ETcrop}\right)$$

Where

Ya = actual yield

Ym = maximum yield

Ky = yield response factor

ETa = actual evapotranspiration

ETcrop = maximum evapotranspiration obtained from Penman metod

JOHL(1980)

ETcrop = KETO

where K = crop coefficient

$ETO = WRn + (1-W) . F(U) \; (\ell_s - \ell_o)$

where

W = correction factor

CHAPTER THREE

MATERIALS USED AND METHODS.

3.0 FIELD LAYOUT

The study site is the NATIONAL Cereals, Research Institute, Badeggi, Bida. The entire experiment was carried out under Green House environment. This Green House was made in such away, that it's environmental conditions are almost the same like outside. On top it is covered with glass roofing sheets, the floor is well cemented with corridors inside that GREEN HOUSE. It is of good aeration condition ,the glass roofing sheet allow good radiation to growing crops for better photosynthesis. It's also prevent rain water to reach inside. The only available water for crops is irrigation. (Fig 4.7b)

3.1 MATERIAL & METHODOLGY

The experiment involves usiong containers/ buckets (35cm in diameter and 40 cm depth). All have been filled with soil. There are 48 containers made of 3 replications and for each replication there are 4 plots, 4 containers per plot and 4 treatments.

The treatments consist of different levels of water table. This is obtained by making a control hole on the contena. The perforation is at 10 cm, 20 cm and 30 cm from the soil surface and the free drainage plots.

Water is added inside the container in other to wet the soil before planting.

The recommended seeds is then planted at least 2 per bucket with 2.3 cm depth. After germination, the process has involved the use of scale for weighting to get the actual evapotranspiration (ETa) considering 2 weeks of time interval. The leaves area and rate of growth were monitored up to maturity.Water was applied from the surface at two weeks interval. Fertilizer is applied at planting and 42 days after planting, the amount used is 9.62g of NPK per pot and the total for each replication is 154g of NPK.

Finally, some tests have been carried out to determine the moisture content of the soil, the soil types, infiltrometer test, hydraulic conductivity, hydrometer test etc.

3.2 DETERMINATION OF MOISTURE CONTENT, BULK DENSITY, POROSITY AND WATER HOLDING CAPACITY.

3.2.1 MOISTURE CONTENT

Soils samples are collected with soil auger-The samples are taken from two desired depth(0-20 & 20-40) cm at two locations for each soil type. They are collected in air tight aluminium containers. The soil samples are weighted and they are dried in an oven at 105^0C

for about 24 hours, until all the moisture is driven off.

After removing from oven they are cooled slowly to room temperature and weighted again. The difference which is the amount of moisture in the soil was then determined.

3.2.2 BULK DENSITY

Cores samplers are commonly used to take undisturbed soil samples. The cylinder of the core sampler, which has its culting edge, is driven into the soil and an uncompacted core obtained within the tube. The samplers are carefully timmed at both ends of the core cylinders. They are dried in an oven at 105^0C for about 24hours until the moisture is driven off and the sample weight again. The volume of the soil core is the same as the inside volume of the core cylinder. The weight of the soil in grams divided by the volume of the soil core in cc is the bulk density or the numerical value of its apparent specific gravity..

3.2.3 POROSITY

Porosity is determined in terms of ratio of difference in wet density & dry density to that of dry density.

i.e $$\frac{Y_s - Y_d}{Y_d}$$

3.2.4 WATER HOLDING CAPACITY (WHC).

The water holding capacity can be calculated by

WHC $= MC.Y_d$

where MC = moisture content

Y_d = bulk density (dry)

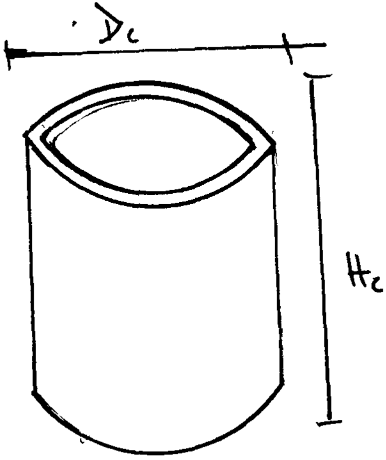
3.2.5 INFILTRATION RATE

After location of point, grasses and debris were removed just at the surface. The process involved the use of double metal cylinders. The inner of 25 cm depth and 30 cm iameter and the outer one of the same depth and 60 cm diameter. The cylinders are installed about 10 cm deep in the soil. This is accomplished by nmarking the outside of the cylinders at the 10 cm level and driving tthe cylinders up to the mark.

The cylinders are driven into the ground by a falling weight type hammer striking on a wooden plank placed on top of the cylinderor by light blows with an ordinary hammer using a hort wooden plank to prevent damage to the edges of the metal cylinder.

The inner cylinder has a ruler attached to the inner side which allows for the readings of the water level as infiltration progresses. A small quantity of grass is placed in the inner and outer cylinder or ring to avoid pudling when pouring water.

A stop watch is used to note the instant the addition of water begin and the time the water reaches the desired level. The level of 11 cm reading on the ruler in the inner cylinder was maintained as the reference point. Waterwas poured into the inner cylinder and simultaneously the watch was started. The water level in the inner ring was maintained as the same in the outer ring. Readings were tken for the first time each five minutes as the water level is lowered in the cylinder - Care is taken to fill the container completely each time before adding water to the cylinder as the process continue. The difference between the quantity of water added and the volume of water in the cylinder at the instant it reaches the desired point is taken as the quantity of water that infiltrates during the time interval between the start of filling and the first measurement. The experiments are continued beyond the estimated time the water would stand in borders or basin during an irrigation. Replicate test is conducted at another location in the same manner.



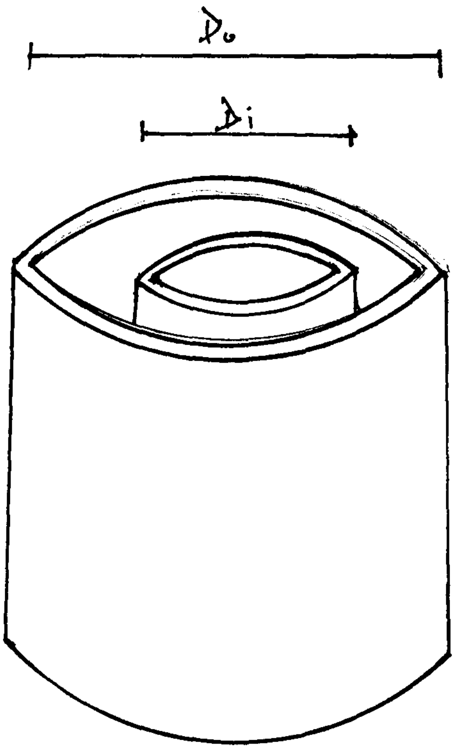


Fig 3.2 Metals cylinders used for infiltration rate measurement.

3.3 HYDRAULIC CONDUCTIVITY MEASUREMENT

Soil samples were collected from two different levels 0-20cm & 20-40 cm depth in undisturbed form using copre samplers and taken to the laboratory. The bottom end of the one dimentioned flow was sealed up with a permeable screen as show in figure below. They were then saturated for a certain time but not completly saturated. The experiment was set up by attaching another empty core sampler to the top of the sample filled core sample with the aid of ware and massing tape. They were then chared to a retort stand vertically. Water was slowly introduxced into the setup until it was full. After the water level on top of the sample has become stabilized, the percolate were collected in a beaker the volume of water flowing through the sample vertically wre at time "t" measured and the hydraulic difference Δh - the results are shown in chapter four. The figure below illustrate the experimental set up for measurement

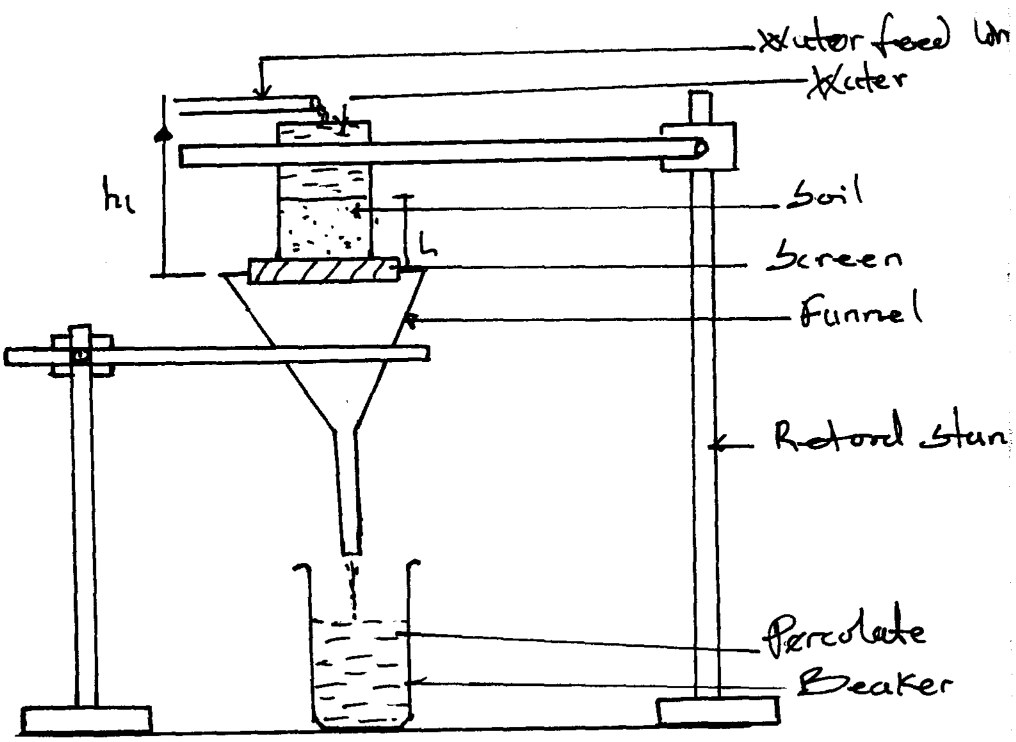


FIG 3.3CONSTANT HEAD PERMEABLE FOR HYDRAULIC CONDUCTIVITY DETERMINATION

3.4 DETERMINATION OF PARTICLE SIZE ANALYSIS BY HYDROMETER METHOD.

3.4.1 PROCEDURE

Two millimetre (2mm) air dry soil was served and 50g of the sample was weighed -100ml was added to the sample in a bottle and 5% sodium hexametaphosphate solution which serves as a dispersing agent was added. The mixer was placed in a shaker and the shaked content was transfered quantitatively without loosing any paeticle into the sedimentation cylinder up to 1l with distilled water the soil sample was disturbed with the aid of the plunger to bring the soil particle suspension. 40second reading of the hydrometer was taken and recorded. The blank experiment without soil sample in the sedimentation cylinder was done in the same way on that with the soil sample and the hydrometer reading for 40's was also recorded. The experiment were left for two hours to allow for maximum settling of the mixture. The hydrometer reading of the suspension were taking and recorded. Also the temperature of both were measured . After two hours the solution suspension was decanted and washed using distilled water several times to remove the organic malter an other susupension. The residue represent the soil sample of the soil. The sand grains were put in a cane and placed in an oven at 105^{0}C over night. Finally the weight of the beaker plus oven dry soil was recorded. The sand fractions was obtained by substracting the weight of the cane. The results are shown in chapter four.

3.5 FIELD CAPACITY

The field capacity is determined by allowing water to drain in the perforated pots at the bottom. These perforated pots are already filled with soil- the pots are covered with plastic to prevent water evaporation. After that, the pots were left to drain for two days. The first (wet) and second weighing (dry) are recorded the amount of water or the moisture content obtained from this is the field capacity. The result is presented in chapter four.

CHAPTER FOUR

RESULTS , ANALYSIS AND DISCUSSION

4.1 RESULTS

Results on various factors relating to soil test and row data obtained at the beginning and end of the experiments are as follows

4.1. FACTORS RELATING TO SOIL

(i) Moisture, Porosity, Bulk density & available moisture holding capacity date 02/10/97

VALLEY SECTION	DEPT(cm)	weight of wet soil (g)	weight of dry soil (g)	moisture content %	BULK DENSITY wet g/cm^3	bulk density dry g/cm^3	porosity	availability moisture holding cap(cm/m)	total available moisture cm/m
AA									57.15
AA_1	0-20	384.26	330.12	16.4	2.12	1.82	0.16	29.84	
AA_2	20-40	415.83	363.07	14.53	2.16	1.88	0.15	27.31	
AB									56.99
AB_1	0-20	412.2	352.13	17.03	2.08	1.76	0.18	29.97	
AB_2	20-40	435.40	380.42	14.30	2.16	1.89	0.14	27.02	

AA = Area A
AB = Area B

TABLE 42

(ii) CYLINDER INFILTROMETER TEST

SAMPLE DATA OF CYLINDER INFILTROMETER PONDING HEIGHT OF WATER = 11cm date 02/10/97

	water level reading cm	difference (cm)	Accum infiltration (cm)	Average rate (cm/h)	water level (cm)	Difference (cm)	Accum infiltration (cm)	Average rate (cm/hr)	Average infiltration
0.0	11.00	-	-	-	11.00				
5.00	9.5	1.5	1.50	18.07	9.4	1.60	1.60	19.27	18.67
10.00	9.8	1.20	2.70	14.45	9.7	1.30	2.90	15.66	15.05
15.00	10.00	1.00	3.70	12.04	10.1	0.90	3.80	10.84	11.44
25.00	9.50	1.50	5.20	9.37	9.5	1.50	5.30	9.37	9.37
35.00	9.50	1.50	6.70	9.37	9.50	1.50	6.80	9.37	7.40
50.00	9.30	1.70	8.40	9.37	9.00	2.00	8.80	8.00	7.40
65.00	9.30	1.70	10.10	6.8	9.00	2.00	10.80	8.00	6.59
85.00	9.00	2.00	12.10	6.06	8.50	2.50	13.30	7.12	6.59
105.00	9.00	2.00	14.60	6.06	8.50	2.50	15.80	7.12	6.59
125.00	9.00	2.00	17.10	6.06	8.50	2.50	18.30	7.12	6.59
145.00	9.00	2.00	19.60	6.06	8.50	2.50	20.80	7.12	6.59

TABLE 4.3 MEAN EVAPORATRANSPIRATION VALUES AT 2 WEEKS INTERVAL

WATER TABLE(cm) ----------- period	10	20	30	free drainage FD
14 DAP5	5.26	4.43	4.07	5.03
28 DAP	6.03	6.27	5.7	9.77
42 DAP	8.59	8.39	6.64	12.5
56 DAP	6.08	8.17	7.41	16.39
70 DAP	7.66	8.99	7.24	17.50
84 DAP	8.30	9.39	7.70	19.24
98 DAP	7.14	8.42	7.42	4.94
105 DAP	3.05	3.85	3.41	6.02
112 DAP	1.44	2.27	1.31	1.66
TOTAL	53.55	60.18	50.9	103.1
MEAN(ETa)	1.98	2.23	1.88	3.81

NOTE: The value of ET is the average of 3 replications.

TABLE 4.4 ETc values using PEnman method

PERIOD	TEMPERATURE			RH%	Mean Wind speed (km/h)	Sunshine hour	crop coeff K	ETO mm/d	ETcrop mm/d
	MIN	MAX	MEAN						
10 Jul-24	22.92	31.5	27.27	84.65	84.54	4.4	0.42	3.77	1.58
24Jul-7Aug	23.65	31.92	27.8	83.86	74.02	4.5	0.73	4.01	2.92
7Aug - 21Aug	24.93	31.07	28	84.43	74.54	4.6	0.93	3.94	3.67
21AUG - 4sept	25.57	32.21	27.8	82.43	80.57	5.1	1	4.22	4.22
4SEPT - 18 SEPT	22.85	32.14	27.5	81.07	86.67	5.5	0.9	4.41	3.97
18SEPT-2nd OCT	22.86	32.15	27.5	84.04	85.04	6.00	0.62	4.21	2.61
2ndOct-16 OCT	22.93	32.5	27.7	85.22	69.44	6.4	0.27	4.37	1.18
16 oct-3Nov	22.93	33.5	28.71	79.93	71.18	6.8	0.2	4.29	0.86
TOTAL									21.01
MEAN TOTAL									2.63

TABLE 4.5a PARTICLE SIZE ANALYSIS (HYDROMETER METHOD) Date 3-10-97
SAMPLE I

Area A_1/0-20cm	Blank		soil	Sample	Grain sizes	Textural class
Time	temperature	Hydrometer Reading	Temperature	Hydrometer Reading	%silt= 4% %clay= 6.6% %Sand= 89.4%	Sand soil
40sec	30°C	-1g/l	25°C	2.5g/l		
2hrs	33°C	-1g/l	50°C	0.5g/l		
Area A^2 20-40cm						
40sec	34°C	-2g/l	32°C	12g/l	%silt= 16.56% %clay= 20.08% %Sand= 63.36%	Sand clay loam
2hrs	35°C	-2g/l	34°C	3g/l		

SAMPLE II TABLE4.5b

Area A_1/0-20cm	Blank		soil	Sample	Grain sizes	Textural class
Time	temperature	Hydrometer Reading	Temperature	Hydrometer Reading	%silt= 2.84% %clay= 14.58% %Sand= 82.58%	Sand soil
40sec	31°C	-2g/l	26°C	2.75g/l		
2hrs	34°C	-2g/l	2°C	0.25g/l		
Area A^2 20-40cm						
40sec	32.5°C	-2g/l	31°C	13g/l	%silt= 17.42% %clay= 21.28% %Sand= 61%	Sand clay loam
2hrs	34.70°C	-2g/l	32°C	3.5g/l		

TABLE 4.6a HYDROMETER TEST ON SOIL SAMPLE PER POTS PER PLOTS AT NCRI BADEGGI DATE 8TH DECEMBER 97

	REPLICATION I				REPLICATION II				REPLICATION III			
Treatments	S_1	S_2	S_3	S_4	S_1	S_2	S_3	S_4	S_1	S_2	S_3	S_4
WT 10 cm	92%sand 5%silt 3%clay	57%Sand 29%clay 14%silt	94.3%sand 2.24%clay 3.46%silt	91%sand 2.24%clay 3.46%silt	62.4%sand 29%clay 8.6%silt	60.08% sand 30%clay 9.92%silt	58.75% sand 22%clay 10%silt	68%sand 22%clay 10%silt	93.5%sand 2.5%clay 4%silt	59%sand 27.8%clay 13.2%silt	90.97% sand 3.75%clay 5.28%silt	60%sand 25.80 %clay 14.2%silt
WT20 cm	63.4%Sand 13.70%silt 22.9%clay	59.05% Sand 32%clay 8.95%silt	27.75% clay 15% silt 57.25% sand	60%sand 28.3%clay 11.7%silt	61%sand 28.3%clay 10.15% silt	63.95% sand 25%clay 11.07silt	56.3%sand 23.7%clay 20%silt	64.45% sand 27.55% clay 8%silt	65%sand 27.65% clay 11%silt	62.35% sand 27.65% clay 10%silt	58%sand 30.75% clay 11.25% silt	61.80% sand 29%clay 9.2%silt
WT30 cm	67%sand 27%clay 4%silt	65.23% sand 24.77clay 10%silt	54.5%sand 25.5%clay 20% silt	90.85% sand 4.13%clay 5.02%silt	97%sand 14%clay 1.6%silt	92.55% sand 3.5%clay 3.95%silt	67%sand 16%silt 17%clay	60.8%sand 29.9%clay 10%silt	60%sand 30%clay 10%silt	58.75% sand 28%clay 13.25% silt	59.20% sand 28.75% clay 12.05% silt	94%sand 3%silt 3%clay
Free Drainage (FD)	62.75%sand 28.20%clay 9.05%silt	57.65% sand 20%silt 22.38% clay	66%sand 23%clay 11% silt	93.58% sand 3%silt 3.47%silt	50.55% sand 18.5%silt 30.65% clay	57.65% sand 25%clay 17.35% silt	95%sand 2%clay 3%silt	60%sand 27.5%clay 12.5%silt	62%sand 22%clay 16%silt	63.5%sand 26.5%clay 10%silt	60.48% sand 29%clay 10.52% silt	57.92% sand 25.52% clay 13.23% silt

TABLE 4.66 HYDROMETER TEST ON SOIL SAMPLES PER PLOTS PER POTS AT NCRI BADEGGI DATE 8th DECEMBER, 1997

TREATMENT	rep I S_1	REP I S_2	REP I S_3	REP I S_4	REP II S_1	REP II S_2	REP II S_3	REP II S_4	REP III S_1	REP III S_2	REP III S_3	REP III S_4
WTat 10 cm	SS	SCL	SS	SS	SCL	SCL	SCL	SCL	SS	SCL	SS	SCL
WT at 20 cm	SCL	SCL	SCL	SCL	SCL	SCL	SCL	SCL	SCL	SCL	SCL	SCL
WT at 30 cm	SCL	SCL	SCL	SS	SS	SS	SCL	SCL	SCL	SCL	SCL	SS
Free Drainage	SCL	SCL	SCL	SCL	SCL	SCL	SS	SCL	SCL	SCL	SCL	SCL

SS = Sandy Soil
SCL = Sandy Clay Loam
HYDRAULIC CONDUCTIVITY TEST AT NCRI DATE 2/10/97
AREA = $38.5cm^2$
L = 7.5cm
hc = 15cm

TABLE4.7

Time min	AREA $AA_{1(0-20cm)}$ VOLUME of H_2O (cm^3)	AREA AA_2 (20-40cm) VOL of water (cm^3)	Area B_1 (0-20cm) Vol of water (cm^3)	Area B_2 (20-40cm) Vol of water(cm^3)
5.00	6.10	4.75	6.02	4.70
10.00	5.90	4.60	5.80	4.55
15.00	5.75	4.12	5.70	4.40
20.00	5.40	3.85	5.43	4.32
25.00	5.13	3.60	5.10	4.25
30.00	4.90	3.47	4.80	3.90
35.00	4.85	3.35	4.72	3.87
40.00	4.80	3.20	4.60	3.70
45.00	4.65	3.00	4.55	3.20
50.00	4.40	2.87	4.39	3.20
55.00	4.25	2.80	4.20	3.20
60.00	3.34	2.80	3.13	3.20
65.00	3.14	2.80	3.00	3.20
70.00	3.03	2.80	2.60	3.20
75.00	2.50		2.25	3.20
80.00	2.50		2.25	3.20
85.00	2.50		2.25	
90.00	2.50		2.25	
total	75.62	50.81	74.11	57.39
DISCHARGE	50.41	40.65	49.40	45.91
HYDRAULIC CONDUCTIVITY (K)	6.5510^{-1}	5.2810^{-1}	6.4110^{-1}	5.9610^{-1}

TABLE 4.8 RESULT OF FIELD CAPACITY

	SANDY CLAY LOAM	SANDY SOIL
1ST WEIGHING (Kg)	39.13	38.40
2nd weighing (kg)	34.25	36.5
Field capacity % moisture content	14.25%	5.2%
Field capacity (mm)	50.72mm	19.74mm

4.11 ROW DATA OBTAINED FROM THE EXPERIMENT

TABLE 4.9 shows leaf area data (cm^2)
TABLE 4.10 Shows water apply (mm)
TABLE 4.11 shws yield (Kg)
note DAP = Days After Planting

TABLE 4.9a LEAF AREA DATA FOR 14 DAP (cm^2)

treatment cm	Replicate I				REPLICATE II				REPLICATE III			
	S_1	S_2	S_3	S_4	S_1	S_2	S_3	S_4	S_1	S_2	S_3	S_4
10	14.4	11	8	3.75	5.7	14.3	2	14.4	9	6.07	14.3	29.4
20	8	13.75	18	11.25	9.9	10	5.06	15	22	10.4	18	9.5
30	5.4	6	8.25	17.75	16.25	7.2	4.8	9	24	17.25	14.75	X
FD	22.75	28	27	19.25	12.1	13.5	24	27.3	20.125	26	28	18

X = Means no germination
FD = Free Drainage

TABLE 4.9b LEAF AREA DATA FOR 28 DAP (cm^2)

Treatment cm	Replicate I				REPLICATE II				REPLICATE III			
	S_1	S_2	S_3	S_4	S_1	S_2	S_3	S_4	S_1	S_2	S_3	S_4
10	51	64	30.8	22	100	51	66	45	95	24	X	116.1
20	49.6	108	64	49.5	31.2	17.25	66	52	56	78	159	151.2
30	50	130.2	56.1	48	85	48	137	175.5	96.25	64.33	805	X
FD	92	80.2	80.5	119	138	48	96	134.4	103	100	96.8	69

TABLE 4.9c LEAF AREA DATA FOR 42 DAP (cm^2)

treatment cm	Replicate I S_1	S_2	S_3	S_4	REPLICAT II S_1	S_2	S_3	S_4	REPLICATE III S_1	S_2	S_3	S_4
10	99	129	53	54	256.2	121.5	88	131.6	207.5	207.5	X	192.5
20	213.5	159	85.1	125	145	54	171.6	135	186.75	186.75	314.9	265.5
30	160	208	112.5	858	177.6	226.95	288	341	156	418.7	330	X
FD	229.4	220	226.2	164	288	275	234	216	167.28	208	272.5	296

TABLE 4.9d LEAF AREA DATA FOR 56 DAP (cm^2)

Treatment cm	Replicate I S_1	S_2	S_3	S_4	Replicate II S_1	S_2	S_3	S_4	Replicate III S_1	S_2	S_3	S_4
10	X	X	X	X	338	162	X	352	403.2	348.4	X	X
20	450.5	288	X	X	260	X	285	X	357.5	301.6	X	396.6
30	212	435.5	X	X	X	410.4	301.5	482.6	281.4	X	X	X
FD	416.1	312.7	288	286	488.4	524.8	487.5	440	252	370.5	520	484.5

TABLE 4.9e LEAF AREA DATA FOR 70 DAP (cm^2)

	Replicate I				Replicate II				Replicate III			
Treatment cm	S_1	S_2	S_3	S_4	S_1	S_2	S_3	S_4	S_1	S_2	S_3	S_4
10	X	X	X	X	570	244.4	X	511	518	475.6	X	X
20	528	504	X	X	379.5	X	416	X	642.4	481	X	483.6
30	450	560.9	X	X	X	492.28	463.6	576.7	426	X	X	X
FD	516.8	435.2	427	378	608	702	646	603	546	476	648	673

TABLE 4.9f LEAF AREA DATA FOR 84 DAP (cm^2)

	Replicate I				Replicate II				Replicate III			
Treatment cm	S_1	S_2	S_3	S_4	S_1	S_2	S_3	S_4	S_1	S_2	S_3	S_4
10	X	X	X	X	705.5	310	X	657	535	534	X	X
20	572	584	X	X	456	X	462	X	642.4	518	X	504
30	516.8	616	X	X	X	619.2	600.3	684	516.6	X	X	X
FD	584.8	435.2	427	584	729	720	717.6	675	546	603.3	708.1	684

TABLE 4.9g LEAF AREA DATA FOR 98 DAP (cm^2)

	Replicate I				Replicate II				Replicate III			
Treatment cm	S_1	S_2	S_3	S_4	S_1	S_2	S_3	S_4	S_1	S_2	S_3	S4
10	X	X	X	X	705.5	310	X	657	535	534	X	X
20	572	584	X	X	456	X	462	X	642.4	518	X	504
30	516.8	616	X	X	X	619.2	600.3	684	516.6	X	X	X
FD	584.8	435.2	427	584	729	720	717.6	675	546	603.3	708.1	684

x = means no germination

TABLE 4.9h LEAF AREA DATA FOR 112 DAP (cm^2)

	Replicate I				Replicate II				Replicate III			
Trea t[illegible]	S_1	S_2	S_3	S_4	S_1	S_2	S_3	S_4	S_1	S_2	S_3	S_4
10	X	X	X	X	705.5	310	X	657	535	534	X	X
20	572	584	X	X	456	X	462	X	642.4	518	X	504
30	516.8	616	X	X	X	619.2	600.3	684	516.6	X	X	X
FD	584.8	435.2	427	584	729	720	717.6	675	546	603.3	708.1	684

TABLE 4.10a water apply data at planting (mm)

Treat	Replicate I				Replicate II				ReplicateIII			
	S_1	S_2	S_3	S_4	S_1	S_2	S_3	S_4	S_1	S_2	S_3	S_4
10	67.55	62.36	67.55	67.5	62.36	64.44	64.44	67.55	62.38	67.55	60.28	62.36
20	57.17	62.36	57.99	62.36	57.17	63.3	63.3	62.36	59.24	64.144	62.36	63.92
30	51.97	56.12	57.17	51.97	53.53	51.97	51.97	55.08	54.24	51.17	51.17	57.17
FD	51.97	51.97	51.97	51.97	51.97	51.97	51.97	51.97	51.97	51.97	51.97	51.97

TABLE 4.10b water apply data for 14 DAP (mm)

Treat	Replicate I				Replicate II				Replicate III			
	S_1	S_2	S_3	S_4	S_1	S_2	S_3	S_4	S_1	S_2	S_3	S_4
10	23.38	17.46	25.25	31.18	22.42	24.85	26.81	20.76	28.58	25.98	X	20.57
20	13.00	21.50	13.51	27.54	25.67	18.70	14.03	27.02	23.69	26.50	21.82	19.22
30	15.59	21.82	25.98	29.62	18.19	24.94	19.75	18.50	23.7	22.34	20.47	X
FD	38.97	38.97	48.33	31.70	41.50	53.00	37.41	55.91	41.67	48.85	45.52	49.50

TABLE 4.10c water apply data for 28 DAP (mm)

Treat	Replicate I				Replicate II				Replicate III			
	S_1	S_2	S_3	S_4	S_1	S_2	S_3	S_4	S_1	S_2	S_3	S_4
10	31.70	29.31	21.51	9.56	27.02	22.34	32.01	41.57	25.36	35.85	X	24.11
20	24.94	19.22	31.70	31.18	36.58	25.15	28.58	37.52	26.75	35.65	24.21	29.83
30	17.35	31.18	21.82	20.78	23.80	30.66	33.77	31.18	20.78	31.38	28.88	X
FD	54.56	48.85	63.40	45.32	68.28	55.91	54.04	64.4	68.28	55.91	54.04	64.4

TABLE 4.10d Water apply data for 42 DAP (mm)

Treatment cm	Replicate I				Replicate II				Replicate III			
	S_1	S_2	S_3	S_4	S_1	S_2	S_3	S_4	S_1	S_2	S_3	S_4
10	29.51	38.45	39.80	34.09	37.41	49.37	35.85	45.52	36.58	38.97	X	48.53
20	38.45	27.54	34.81	29.62	32.01	38.56	42.40	42.82	34.50	29.31	36.89	36.37
30	28.16	35.23	41.57	29.54	38.24	32.42	28.58	40.84	33.26	33.98	28.47	X
FD	80.55	53.42	69.84	78.26	69.32	61.63	73.27	57.16	67.45	22.74	53.94	66.31

TABLE 4.10e Water apply data for 56 DAP (mm)

Treatment cm	Replicate I				Replicate II				Replicate III			
	S_1	S_2	S_3	S_4	S_1	S_2	S_3	S_4	S_1	S_2	S_3	S_4
10	X	X	X	X	62.36	70.15	X	51.97	59.76	50.61	X	X
20	55.39	54.98	X	X	59.14	X	50.09	X	71.50	45.94	X	61.01
30	54.87	47.39	X	X	X	47.81	43.86	60.49	58.72	X	X	X
FD	90.42	89.28	87.93	91.88	74.83	86.78	87.34	88.34	78.47	85.54	91.88	83.15

TABLE 4.10f Water apply data for 70 DAP (mm)

Treatment cm	Replicate I				Replicate II				Replicate III			
	S_1	S_2	S_3	S_4	S_1	S_2	S_3	S_4	S_1	S_2	S_3	S_4
10	X	X	X	X	72.75	66	X	68.60	72.75	76.91	X	X
20	62.36	59.76	X	X	62.36	X	58.20	60.28	58.20	49.39	X	76
30	54.04	62.36	X	X	X	51.97	54.56	58.20	57.16	X	X	X
FD	88.34	83.25	87.30	80.03	80.55	89.38	77.95	72.75	77.12	83.15	75.87	75.85

TABLE 4.10g Water apply data for 84 DAP (mm)

Treatment cm	Replicate I				Replicate II				Replicate III			
	S_1	S_2	S_3	S_4	S_1	S_2	S_3	S_4	S_1	S_2	S_3	S_4
10	X	X	X	X	70.67	51.97	X	62.36	65.48	77.43	X	X
20	51.97	49.39	X	X	54.04	X	56.54	X	59.97	45.73	X	68.18
30	41.57	53.00	X	X	X	51.97	56.12	63.40	60.28	X	X	X
FD	81.07	83.15	60.28	72.75	65.48	67.55	50.72	58.20	72.75	64.44	67.55	58.20

TABLE 4.10h Water apply data for 98 DAP (mm)

Treatment cm	Replicate I				Replicate II				Replicate III			
	S_1	S_2	S_3	S_4	S_1	S_2	S_3	S_4	S_1	S_2	S_3	S_4
10	X	X	X	X	53.52	56.12	X	41.37	37.41	46.77	X	X
20	44.69	54.04	X	X	41.57	X	35.83	X	39.80	28.58	X	28.06
30	31.18	46.77	X	X	X	31.18	37.41	43.13	36.37	X	X	X
FD	65.48	63.40	69.63	67.55	41.57	46.77	44.17	41.57	62.36	56.02	58.93	56.02

TABLE 4.11 YIELD (Kg)

Treatment cm	Replicate I				Replicate II				Replicate III			
	S_1	S_2	S_3	S_4	S_1	S_2	S_3	S_4	S_1	S_2	S_3	S_4
10	X	X	X	X	0.0224	0.0435	X	0.0398	0.0148	0.0258	X	X
20	0.1432	0.0353	X	X	0.0422	X	0.033	X	0.0299	0.028	X	0.0322
30	0.1454	0.0289	X	X	X	0.0727	0.0318	0.382	0.031	X	X	X
FD	0.015	0.0472	0.0387	0.0362	0.0383	0.0140	0.0110	0.168	0.0379	0.200	0.0289	0.0356

4.2 DATA ANALYSIS

4.2.1 ANALYSIS OF VARIANCE: The randomaized complete block (RCB) design is one of the most widely used experimental designs in agricultural research. The design is especially suited for field experiments where the number of treatments is not large. The primary distinguishing featre of the RCB design is the presence of blocks or replications of equal size each of which contains all the treatments. The experimental area is divide into three blocks or replications, four treatments (10cm, 20cm, 30cm & free drainage). All the steps to compute analysis of variance for various data are shown in Appebndix B

4.2.1 ANALYSIS OF VARIANCE OF PLANT HEIGHT

ANALYSIS OF VARIANCE OF PLANT HEIGHT DATA IN TABLE 4.1201

source of variation	Degree of Freedom df	Sum of squares SS	Mean Squares MS	Computed Fvalue	Tabular 5%	F 1%
Replication	2	0.644	0.322			
treatment	3	26.16	8.72	2.10^{ns}	4.76	9.78
exp error	6	24.87	4.145			
sampling error	36	64.876	1.802			
Total	47					

a_{cv} = 9.81%
b_{ns} = not significant

ANALYSIS OF VARIANCE OF PLANT HEIGHT DATA IN TABLE 4.12b

source of variation	Degree of Freedom	Sum of squares SS	Mean Squares	Computed Fvalue	Tabular 5%	F 1%
Replication	2	29.20	14.6			
treatment	3	158.88	52.96	2.19^{ns}	4.76	9.78
exp error	6	265.59	44.265			
sampling error	36	570	15.83			
Total	47	1023.67				

a_{cv} = 12.6%
b_{ns} = not significant

ANALYSIS OF VARIANCE OF PLANT HEIGHT DATA IN TABLE 4.12c

source of variation	Degree of Freedom	Sum of squares SS	Mean Squares	Computed Fvalue	Tabular 5%	F 1%
Replication	2	60.123	30.61			
treatment	3	694.6	231.53	1.13^{ns}	4.76	9.78
exp error	6	1231.09	205.18			
sampling error	36	2139.50	59.43			
Total	47	4125.31				

a_{cv} = 12.16%
b_{ns} = not significant

ANALYSIS OF VARIANCE OF PLANT HEIGHT DATA IN TABLE 4 12d

source of variation	Degree of Freedom	Sum of squares SS	Mean Squares	Computed Fvalue	Tabular 5%	F 1%
Replication	2	2022.425	1011.06			
treatment	3	10406.5	3468.83	2.23^{ns}	4.76	9.78
exp error	6	9332.375	1555.395			
sampling error	36	40348	1120.778			
Total	47	62109				

a_{cv} = 24.2%
b_{ns} = not significant

ANALYSIS OF VARIANCE OF PLANT HEIGHT DATA IN TABLE 4.12e

source of variation	Degree of Freedom	Sum of squares SS	Mean Squares	Computed Fvalue	Tabular 5%	F 1%
Replication	2	1584.514	792.257			
treatment	3	48179.462	16059.821	3.73^{ns}	4.76	9.78
exp error	6	25843.564	4307.26			
sampling error	36	141212.88	3922.58			
Total	47	216820.42				

a_{cv} = 21.67%
b_{ns} = not significant

ANALYSIS OF VARIANCE OF PLANT HEIGHT DATA IN TABLE 4.12

source of variation	Degree of Freedom	Sum of squares SS	Mean Squares	Computed Fvalue	Tabular 5%	F 1%
Replication	2	4073.5525	2036.78			
treatment	3	47437.112	15812.37	3.54^{ns}	4.76	9.78
exp error	6	26756.825	4459.47			
sampling error	36	145781.95	4049.50			
Total	47	224049.44				

a_{cv} = 19.81%
b_{ns} = not significant

ANALYSIS OF VARIANCE OF PLANT HEIGHT DATA IN TABLE 4.12

source of variation	Degree of Freedom	Sum of squares SS	Mean Squares	Computed Fvalue	Tabular 5%	F 1%
Replication	2	4073.5525	2036.78			
treatment	3	47437.112	15812.37	3.54^{ns}	4.76	9.78
exp error	6	26756.825	4459.47			
sampling error	36	145781.95	4049.50			
Total	47	224049.44				

a_{cv} = 19.81%
b_{ns} = not significant

ANALYSIS OF VARIANCE OF PLANT HEIGHT DATA ~~IN~~ TABLE 4.12b

source of variation	Degree of Freedom	Sum of squares SS	Mean Squares	Computed Fvalue	Tabular 5%	F 1%
Replication	2	4073.5525	2036.78			
treatment	3	47437.112	15812.37	3.54^{ns}	4.76	9.78
exp error	6	26756.825	4459.47			
sampling error	36	145781.95	4049.50			
Total	47	224049.44				

a_{cv} = 19.81%
b_{ns} = not significant

4.2.2 analysis of variance of leaf Area

ANALYSIS OF VARIANCE OFLEAF AREA DATA IN TABLE 4.13a

source of variation	Degree of Freedom	Sum of squares SS	Mean Squares	Computed Fvalue	Tabular 5%	F 1%
Replication	2	235.19	117.66			
treatment	3	1009.354	336.45	21.6**	4.76	9.78
exp error	6	93.115	15.52			
sampling error	36	904.42	25.12			
Total	47	2242.12				

a_{cv} = 27.15%
b_{**} = significant at 1% level

ANALYSIS OF VARIANCE OFLEAF AREA DATA IN TABLE 4.13b

source of variation	Degree of Freedom	Sum of squares SS	Mean Squares	Computed Fvalue	Tabular 5%	F 1%
Replication	2	15887.723	794.36			
treatment	3	10463.94	3487.98	3.32^{ns}	4.76	9.78
exp error	6	6291.67	1048.61			
sampling error	36	59781.737	1660.6			
Total	47	78126.07				

a_{cv} = 10.57%
b_{ns} = not significant

ANALYSIS OF VARIANCE OFLEAF AREA DATA IN TABLE 4.13C

source of variation	Degree of Freedom	Sum of squares SS	Mean Squares	Computed Fvalue	Tabular 5%	F 1%
Replication	2	30563.6	15281.08			
treatment	3	79651.87	26550.51	4.54^{ns}	4.76	9.78
exp error	6	219806.22	5845.31			
sampling error	36	365093.22	6105.73			
Total	47	2242.12				

a_{cv} = 10.38%
b_{ns} = not significant

ANALYSIS OF VARIANCE OF LEAF AREA DATA IN TABLE 4.13d

source of variation	Degree of Freedom	Sum of squares SS	Mean Squares	Computed Fvalue	Tabular 5%	F 1%
Replication	2	103125.07	51562.53			
treatment	3	535827.334	178609.11	5.81*	4.76	9.78
exp error	6	184218.633	30703.103			
sampling error	36	887772.93	24660.36			
Total	47	1710943.95				

a_{cv} = 19.32%
b_* = significant at 5% level

ANALYSIS OF VARIANCE OF LEAF AREA DATA IN TABLE 4.13e

source of variation	Degree of Freedom	Sum of squares SS	Mean Squares	Computed Fvalue	Tabular 5%	F 1%
Replication	2	187455.445	93727.72			
treatment	3	932797.77	310932.6	4.94*	4.76	9.78
exp error	6	376930.26	62821.71			
sampling error	36	1751357.53	48648.62			
Total	47	324854.028				

a_{cv} = 4.64%
b_* = significant at 5% level

ANALYSIS OF VARIANCE OF LEAF AREA DATA IN TABLE 4.13f

source of variation	Degree of Freedom	Sum of squares SS	Mean Squares	Computed Fvalue	Tabular 5%	F 1%
Replication	2	284492.42	142246.21			
treatment	3	1082020.335	360673.445	4.58^{ns}	4.76	9.78
exp error	6	472285.145	78714.19			
sampling error	36	2272802.38	63133.40			
Total	47	411600.28				

a_{cv} = 19.3%
b_{ns} = non significant

ANALYSIS OF VARIANCE OF LEAF AREA DATA IN TABLE 4.13g

source of variation	Degree of Freedom	Sum of squares SS	Mean Squares	Computed Fvalue	Tabular 5%	F 1%
Replication	2	284492.42	142246.42			
treatment	3	1082020.43	360673.445	4.58^{ns}	4.76	9.78
exp error	6	472285.145	78714.19			
sampling error	36	2272802.38	63133.40			
Total	47	411600.28				

a_{cv} = 19.3%
B_{ns} = non significant

ANALYSIS OF VARIANCE OF LEAF AREA DATA IN TABLE 4.13b

source of variation	Degree of Freedom	Sum of squares SS	Mean Squares	Computed Fvalue	Tabular 5%	F 1%
Replication	2	284492.42	142246.42			
treatment	3	1082020.43	360673.445	4.58^{ns}	4.76	9.78
exp error	6	472285.145	78714.19			
sampling error	36	2272802.38	63133.40			
Total	47	411600.28				

a_{cv} = 19.3%
b_{ns} = non significant

4.2.3 ANALYSIS OF VARIANCE OF EVAPOTRANSPIRATION DATA

ANALYSIS OF VARIANCE OF ETdata IN table 4.14a

source of variation	Degree of Freedom	Sum of squares SS	Mean Squares MS	OBSERVED F	Tabular 5%	F 1%
Replication	2	43.89	21.94			
treatment	3	130.54	43.13	1.4^{ns}	4.76	9.78
exp error	6	186.42	31.07			
sampling error	36	1047.28	39.09			
Total	47	1408.133				

a_{cv} = 8.46%
b_{ns} = non significant

ANALYSIS OF VARIANCE OF ETdata IN table 4.14b

source of variation	Degree of Freedom	Sum of squares SS	Mean Squares MS	OBSERVED F	Tabular 5%	F 1%
Replication	2	4405.3	202.51			
treatment	3	1587.69	529.23	7.56*	4.76	9.78
exp error	6	157.41	26.235			
sampling error	36	1395.74	68.23			
Total	47	3545.87				

a_{cv} = 5.26%

b_* = significant at 5% level

ANALYSIS OF VARIANCE OF ETdata IN table 4.14C

source of variation	Degree of Freedom	Sum of squares SS	Mean Squares MS	OBSERVED F	Tabular 5%	F 1%
Replication	2	220.40	110.2			
treatment	3	2709.71	903.23	34.98**	4.76	9.78
exp error	6	154.93	25.82			
sampling error	36	2165.54	60.154			
Total	47	5250.58				

a_{cv} = 4.01%

b_{**} = significant at 1% level

ANALYSIS OF VARIANCE OF ETdata IN table 4.14d

source of variation	Degree of Freedom	Sum of squares SS	Mean Squares MS	OBSERVED F	Tabular 5%	F 1%
Replication	2	1097.64	548.82			
treatment	3	10765.13	3588.37	0.93^{ns}	4.76	9.78
exp error	6	2305.55	3839.25			
sampling error	36	15458.08	122.09			
Total	47	29626.24				

a_{cv} = 46.5%
b_{ns} = not significant

ANALYSIS OF VARIANCE OF ETdata IN table 4.14e

source of variation	Degree of Freedom	Sum of squares SS	Mean Squares MS	OBSERVED F	Tabular 5%	F 1%
Replication	2	680.23	840.11			
treatment	3	11086.58	3695.52	4.75^{ns}	4.76	9.78
exp error	6	4667.64	177.94			
sampling error	36	22492.16	624.78			
Total	47	39926.61				

a_{cv} = 46.5%
b_{ns} = not significant

ANALYSIS OF VARIANCE OF ETdata IN table 4.14f

source of variation	Degree of Freedom	Sum of squares SS	Mean Squares MS	computed F	Tabular 5%	F 1%
Replication	2	2310.26	1155.13			
treatment	3	10795.84	3598.61	4.69^{ns}	4.76	9.78
exp error	6	4599.95	766.65			
sampling error	36	25420.91	706.13			
Total	47	43126.96				

a_{cv} = 17.09%
b_{ns} = not significant

ANALYSIS OF VARIANCE OF ETdata IN table 4.14g

source of variation	Degree of Freedom	Sum of squares SS	Mean Squares MS	COMPUTED F	Tabular 5%	F 1%
Replication	2	340.402	170.201			
treatment	3	861.17	287.05	2.99^{ns}	4.76	9.78
exp error	6	575	95.83			
sampling error	36	4964.9	52.81			
Total	47	6741.48				

a_{cv}=23.25%
b_{ns} = not significant

ANALYSIS OF VARIANCE OF ETdata IN table 4.14h

source of variation	Degree of Freedom	Sum of squares SS	Mean Sqwares MS	COMPUTED F	Tabular 5%	F 1%
Replication	2	340.402	170.201			
treatment	3	861.17	287.05	2.99^{ns}	4.76	9.78
exp error	6	575	95.83			
sampling error	36	4964.9	52.81			
Total	47	6741.48				

a_{cv} = 17.09%
b_{ns} = not significant

ANALYSIS OF VARIANCE OF ETdata IN table 4.14i

source of variation	Degree of Freedom	Sum of squares SS	Mean Sqwares MS	COMPUTED F	Tabular 5%	F 1%
Replication	2	51	25.5			
treatment	3	61.84	20.61	0.23^{ns}	4.76	9.78
exp error	6	535.430	89.23			
sampling error	36	4207.77	11.83			
Total	47	4856.04				

a_{cv} = 40.26%
b_{ns} = not significant

4.2.4 Analysis of variance of water apply data in table 4.15a

source of variation	Degree of Freedom	Sum of squares SS	Mean Sqwares MS	COMPUTED F	Tabular 5%	F 1%
Replication	2	16.77	8.38			
treatment	3	1226.70	408.9	89.67**	4.76	9.78
exp error	6	27.38	4.56			
sampling error	36	185.14	5.14			
Total	47	1455.99				

a_{cv} = 0.9%
b** = significant at 1% level

Analysis of variance of water apply data in table 4.15b

source of variation	Degree of Freedom	Sum of squares SS	Mean Sqwares MS	COMPUTED F	Tabular 5%	F 1%
Replication	2	430.83	215.41			
treatment	3	19351.62	3117.20	98.86**	4.76	9.78
exp error	6	9351.62	31.53			
sampling error	36	250.225	69.50			
Total	47	12473.88				

a_{cv} = 5.27%
b** = significant at 1% level

Analysis of variance of water apply data in table 4.15c

source of variation	Degree of Freedom	Sum of squares SS	Mean Sqwares MS	COMPUTED F	Tabular 5%	F 1%
Replication	2	31.91	15.95			
treatment	3	4796.72	1589.90	26.52**	4.76	9.78
exp error	6	359.72	59.95			
sampling error	36	1840.28	51.11			
Total	47	7001.63				

a_{cv} = 5.76%
b_{**} = significant at 1% level

Analysis of variance of water apply data in table 4.15d

source of variation	Degree of Freedom	Sum of squares SS	Mean Sqwares MS	COMPUTED F	Tabular 5%	F 1%
Replication	2	800.56	400.28			
treatment	3	7830.33	2610.11	35.51**	4.76	9.78
exp error	6	441	73.50			
sampling error	36	4605.52	127.93			
Total	47	13678				

a_{cv} = 5.18%
b_{**} = significant at 1% level

Analysis of variance of water apply data in table 4.15e

source of variation	Degree of Freedom	Sum of squares SS	Mean Sqwares MS	COMPUTED F	Tabular 5%	F 1%
Replication	2	1392.89	696.44			
treatment	3	31268.22	10422.74	12.83**	4.76	9.78
exp error	6	4873.41	812.23			
sampling error	36	22677.22	629.92			
Total	47	60211.75				

a_{cv} = 16.17%
b_{**} = significant at 1% level

Analysis of variance of water apply data in table 4.15f

source of variation	Degree of Freedom	Sum of squares SS	Mean Sqwares MS	COMPUTED F	Tabular 5%	F 1%
Replication	2	363.23	121.01			
treatment	3	46561.14	23280.72	1.64ns	4.76	9.78
exp error	6	28444.24	4740.70			
sampling error	36	28278.75	785.52			
Total	47	103518.12				

a_{cv} = 38.29%
b_{ns} = not significant

Analysis of variance of water apply data in table 4.15g

source of variation	Degree of Freedom	Sum of squares SS	Mean Sqwares MS	COMPUTED F	Tabular 5%	F 1%
Replication	2	1608.83	804.41			
treatment	3	12976.95	4325.65	4.18^{ns}	4.76	9.78
exp error	6	6196.34	1032.720			
sampling error	36	24925.41	692.37			
Total	47	45707.53				

a_{cv} = 20.92%
b_{ns} = not significant
Analysis of variance of water apply data in table 4.15h

source of variation	Degree of Freedom	Sum of squares SS	Mean Sqwares MS	COMPUTED F	Tabular 5%	F 1%
Replication	2	190.97	95.18			
treatment	3	11599.39	3866.53	5.09^{*}	4.76	9.78
exp error	6	4550.39	758.39			
sampling error	36	12494.30	34.70			
Total	47	28835.27				

a_{cv} = 23.48%
b_{*} = significant at 5% level

4.2.5 Analysis of variance of yield data in table 4.16

source of variation	Degree of Freedom	Sum of squares SS	Mean Sqwares MS	COMPUTED F	Tabular 5%	F 1%
Replication	2	0.000275	0.001372			
treatment	3	0.01182	0.00394	2.65^{ns}	4.76	9.78
exp error	6	0.00893	0.00149			
sampling error	36	0.0718	0.002			
Total	47	0.092825				

a_{cv} = 30.75%
b_{ns} = not significant

4.3 DISCUSSION

4.3.1 SOIL TEST RESULT

The textural class of soil is obtained by using the following equation

C = R -RL + 0.36T

Where C = CORRECTED HYDROMETER READING
R = SOIL HYDROMETER READING
RL= BLANK HYDROMETER READING
T = ROOM TEMPERATURE 20^0C

AREA A_1 (0-20cm) SAMPLE I

HYDROMETER READING AT 40S is given by

C = R - RL +0.36T
= 2.5 +1+0.36(25-20)
= 3.5 +1.8
= 5.3g/l

percentage silt + clay = $\frac{5.3\times100}{50}$ = 10.6%

Corrected hydrometer reading at 2hrs

C = R -RL +0.336T
= 0.5 +1+0.36(5)
= 3.3g/l

%clay = $\frac{3.3\times100}{50}$ = 6.6%

% sand = 100-10.6
= 89.4%

For that area the proportion of the soil sample is sand = 89.4%
clay = 6.6%
%silt= 10.6% -6.6%= 4%

This imples that the soil is sandy

Area A_2(20-40cm)

Corrected hydrometer reading at 40s is given by

C_{40s} = R - RL +0.36T
= 12+2+0.36(32-20)
= 14+0.36x12
= 18.32g/l

% silt + clay = $\frac{18.32\times100}{50}$ = 36.64%

Corrected hydrometer reading at 2hrs

C = R-RL +0.36T
= 3+2+0.36(34-20)
= 5+0.36x14
= 10.04g/l

%clay = $\frac{10.04\times100}{50}$ = 20.08%

percentage coarse sand in the sample

%sand = 100-(silt +clay)
= 100-36.64 = 63.36

%clay = 20.08%

This means that the textural class of that soil is sandy clay loam.

SAMPLE II AREA B

AREA B_1(0-20cm)

Corrected hydrometer reading at 40s is given by

C_{40SEC} = R-RL +0.36T
= 2.75 +2 0.36(31-20)
= 4.75 + 3.96 = 8.71

%SILT CLAY = $\frac{8.71\times100}{50}$ = 17.42%

C_{2hrs} = R-RL +0.36T
= 0.25+ 2+0.36(34-20)
= 2.25+ 0.36x14= 7.29

%CLAY = $\frac{7.29\times100}{50}$ = 14.58%

Percentage coarse sand

100-17.42 = 82.58%

%silt = %(silty +clay) -%clay
= 17.42-14.58 = 2.84%

sand	clay	silt
82.50%	14.58%	2.84%

Textural class = sandy soil

AREA B_2 (20-40)

C_{40SEC} = 13+2+0.36(32.50-20)
= 15+0.36x12.50

%(SILT CLAY) = $\frac{19.50\times100}{50}$ = 39%

C_{2hrs} = 3.5g/l +2 +0.36(34.70-20)
= 5.5 0.36x14.70 = 10.79

%clay = $\frac{10.79\times100}{50}$ = 21.58%

%sand = 100-39 = 61%

%silt = (silt +clay) -%clay
= 39-21.58% = 17.42%

sand 61%; clay 21.58%; 17.42%silt

Textural group sandy clay loam
The result from pots sampling shows that majority are of sandy clay loam while few are sandy soil.

Where there is sandy soil, the crop is either died or is of low yield. Where there is sandy clay loam, the crop gives better yield. This will help us to conclude that maize crops grow better in sandy clay loam than in a sandy soil.

4.3.2 PLANT HEIGHT, LEAF AREA, EVAPOTRANSPIRATION & WATER APPLY

4.3.2.1 PLANT HEIGHT (Table 4.12)

In the analysis of variance data of plant height experiment shows as a nonsignificance test. This prove us that the treatments difference is not detectable. There is no difference among the treatments fore each replications. Here the mean cv value 17.05% is low which implies that the experiment is reliable.

4.3.2.1 LEAF AREA (Table 4.13)

In the analysis of variance data of leaf area, experiment shows us 62.5% of a nonsignificane test and 37.5% of a significant test. This tell us that there is difference amoung the treatments for greater period of our experiment.

The mean cv value 16.24% is low which means that the experiment on leaf area parameters is reliable.

4.3.1.2 EVAPOTRANSPIRATION(ET) (Table 4.14)

In the analysis of variance data of ET, experiment shows us 77.78% of a nonsignificance test and 22.22% of a significant test. This means that there is no difference amoung the treatments for greater period of our experiment.

The mean cv value 20.12% is low which means that the experiment on ET is reliable.

4.3.1.3 WATER APPLY (Table 4.15)

In the analysis of variance of WATER APPLY, experiment shows us 75% of a significance test and 25% of a non-significance test. This means that there is difference amoung the treatmewnt for a greater period of the experiment.

The mean cv value 14.62% is low which means that the experiment on water apply parameters is reliable.

4.3.1.4 YIELD (Table 4.16)

In the analysis of variance data of yield, experiment shows us a nonsignificant test. This means that the treatment difference is nit of great consideration here by RCB design. In other words all the treatments have the same effect in each replication by RCB design the cv value 30.75% is low which means the experiment is reliable.

Grains yield was at 19.42% moisture content

From the analysis, the yield against water table is as follow

TABLE 4.17

water table(cm)	10	20	30	free drainage(fd
yield* (Kg)	0.1455	0.3438	0.3466	0.6708

It can be observed that the relation between the water table depth and the yield is linear. In other words, the lower the water table, the better the yield, or the higher the water table, the less the yield. This is illustrated in fig 4.2

Moreso, the use of empirically derived yield response factor below, will tell us more about the effect of water stress

$$\left(1 - \frac{Ya}{Ym}\right) = Ky \left(1 - \frac{ETa}{ETC}\right) \ldots\ldots\ldots\ldots\ldots\ldots 4.1$$

Where Ya = actual yield

Ym = maximum yield

Ky = yield response factor

ETa = actual evapotranspiration

ETc = maximum evapotranspiration

The essence is to get the maximum yield, that is when full water requirement are met:

The actual yield (Ya) is shown in table above

Maize yield response factor is equal to 1.25(Appendix f)

ETa is the direct ET measured

ETc is obtained using Penman method appendix c

(Here ETc is the average value for the complete of going period

- Estimated yield or maximum yield under normal condition)

Now for water table at 10cm

Using equation (4.1) above

$$Ym = \frac{Ya}{1-kg + kg\left(\frac{ETa}{ETC}\right)}$$

But $Ya = 0.1455$ $kg = 1.25$

$ETa = 1.98$ $ETC = 2.63$

$$Ym = \frac{0.1455}{1-(1.25)+(1.25\left(\frac{1.98}{2.63}\right)}$$

$= 0.2106$ kg

* Water table at 20cm

$$Ym = \frac{Ya}{1-kg + kg\left(\frac{ETa}{ETc}\right)}$$

But $Ya = 0.3438$ $kg = 1.25$

$ETa = 2.23$ $ETc = 2.63$

$$Ym = \frac{0.3438}{1-(1.25) + 1.25\left(\frac{2.23}{2.63}\right)}$$

$= 0.4245$kg

* Water table at 30cm

using equation(4)

$$Ym = \frac{Ya}{1-kg + \left(\frac{ETa}{ETC}\right)}$$

But $Ya = 0.3466$ $kg = 1.25$

$ETa = 1.88$ $ETc = 2.63$

$$Ym = \frac{0.3466}{1-(1.25)+1.25\left(\frac{1.88}{2.63}\right)}$$

$= 0.5386$kg

Free drainage

Using equation (4)

$$Ym = \frac{Ya}{1-kg+kg\left(\frac{ETa}{ETc}\right)}$$

But $Ya = 0.6708$ $kg = 1.25$

$ETa = 3.81$ $ETc = 2.63$

$$Ym = \frac{0.6708}{1-1.25+1.25\left(\frac{3.81}{2.63}\right)}$$

$= 0.4298$kg

Results obtained from the calculation of maximum yield show that the water table against yield is also linear. In other words the lower the water table the higher the maximum yield and the better the yield. Except at free drainage where the maximum yield (Ym) is lower than the actual yield (Ya).

4.3.2 DISCUSSION ON CROP HEIGHT AND EVAPOTRANSPIRATION FOR THE DIFFERENTS WATER TABLE

4.3.2.1 WATER TABLE AT 10cm (Fig 4.3)

The graphs show that both the Evapotranspiration and crop height increased from 14 days (at planting date) to 84 days after planting. At this last point (84DAP) crop height growth remain constant while ET decreases to maturity period (116 days). Also a particularity is observed for certains replicationas. For example in replicate I, both the ET and crop height curves end at 42 days after plating this is due to plant deaf in the whole plot.

The growth is generally high or considerable between 42-84 DAP, that is vegetative period to pollination. At this interval we may say that there is high evapotranspiration, hence high demand of water for maize growth. Any shortage of water stress at this stage will drastically affect maize crop for the remaining growing period.

From this, it can be concluded that the 3 replications present the same effect for both plant height and evapotranspiration for the whole growing period of maize crop.

4.3.2.2 WATER TABLE AT 20cm (Fig 4.4)

The same thing is applied here, but the behaviour of evapotranspiration curve for the 3 replications showed that there is little difference between replicates. For example in replicate II. There are 2 peaks points for ET curve (42 DAP, 84 DAP), that's tasseling and pollination period, and beginning the kernel development period. For these 2 points, the demand of water is at the same level.

From 42 DAP, ET decrease to 56 DAP, this is due to shortage of water within that period. The behaviour of crop height curve is almost the same like in water table at 10cm. That is the increase from planting date to 84 DAP whereby it's remain constant to maturity status.

From these, it can be concluded that the 3 replications present the same effector plant height, but one replication differe from the two others on evapotranspiration.

4.3.2.3 WATER TABLE 30cm (Fig 4.5)

Here the behaviour of crop height curve is exactly the same thing like the 2 water tables above but different in evapotranspiration for a certain period of maize growth. That is 42 DAP to 84 DAP, for the two replications (REP I and REP III) ET decreases at 42 DAP while for REP II, ET decreases at 56 DAP. For one case or another, the cause is due to shortage of water.

In REP III the peak period is 42 DAP of ET and decreases for the remaining period. This may be due to both water deficit and other factor non favourable for evapotranspiration. Observation on this water table for the 3 replications show us little difference on ET maize yield and no difference on plant height growth.

4.3.2.4 FREE DRAINAGE (Fig 4.6)

Here the 3 replications present the same effect on both Evapotranspiration and plant height curves. The ET increases from 14 days after planting to 84 (peak period) where it decreases to maturity period (116days). Also crop height increase to 84 days , period from with it remain constant to maturity.

In general the behaviour of EVAPOTRANSPIRATION and plant height during the maize crop growing period present the same characters. The peak period remain 84 days after planting for both ET and crop height.

The period of high ET being 42 -84 dap, any shortage of water within this interval will automatically affect the maize crop. For this given maize crop, ETincrease from planting date to 84 days after planting (beginning of kernel development) and decrease at the same point to maturity period.

In other word ET increases from a minimum during the establishment stage to a maximum during the vegetative stage and pollinatin and therafter decreased.

However, the highest period crop water demand occured during the polination stage with peak at 84 DAP.

Looking through crop height, the study establishes that the crop height versus growing period is directly proportional up to 84 DAP (beginning of kernel development) point from which it remains constant. Fig 4.7a

0.2:2

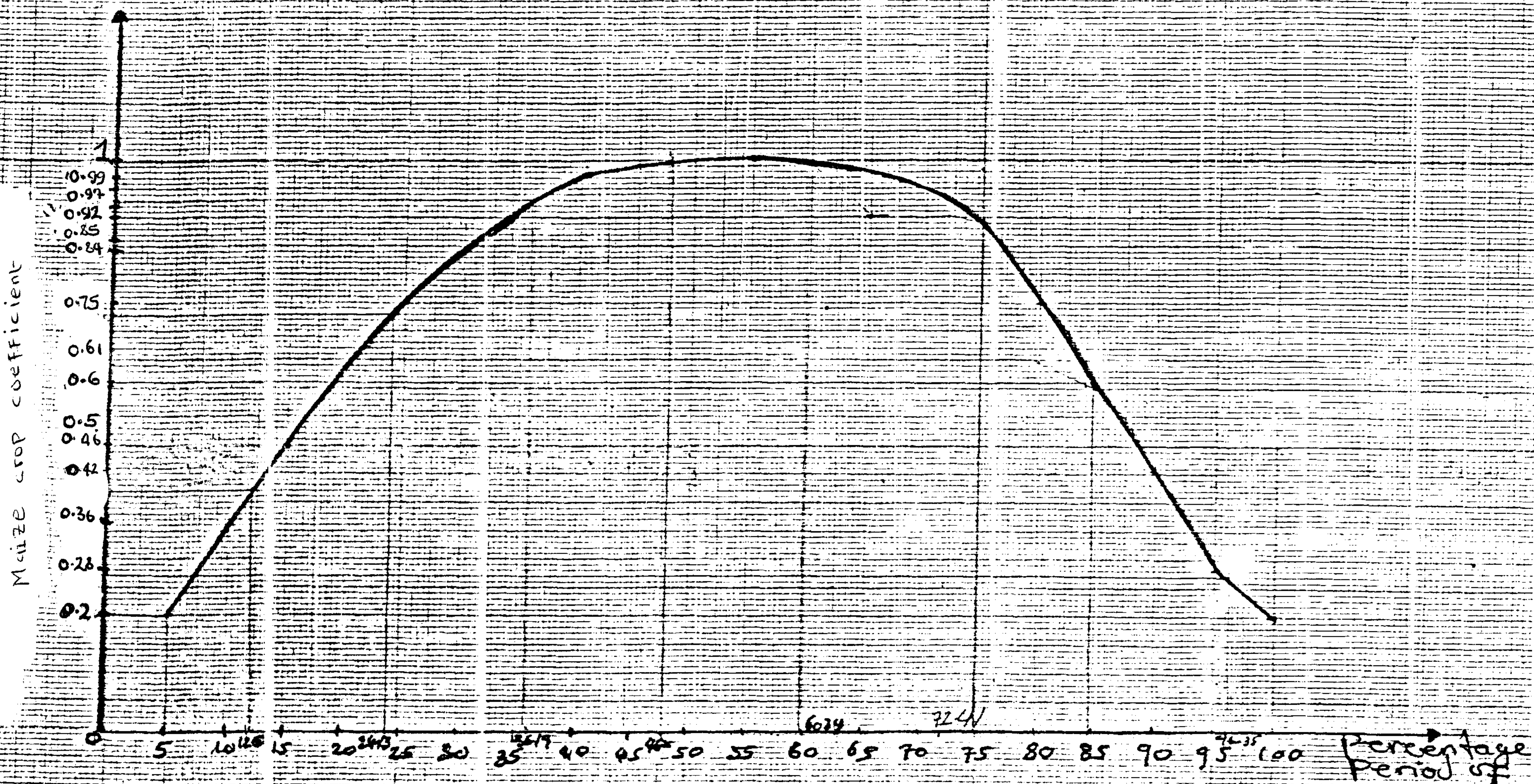


Fig. 4.1 Crop(Maize) Coefficient curve against its percentage growing p

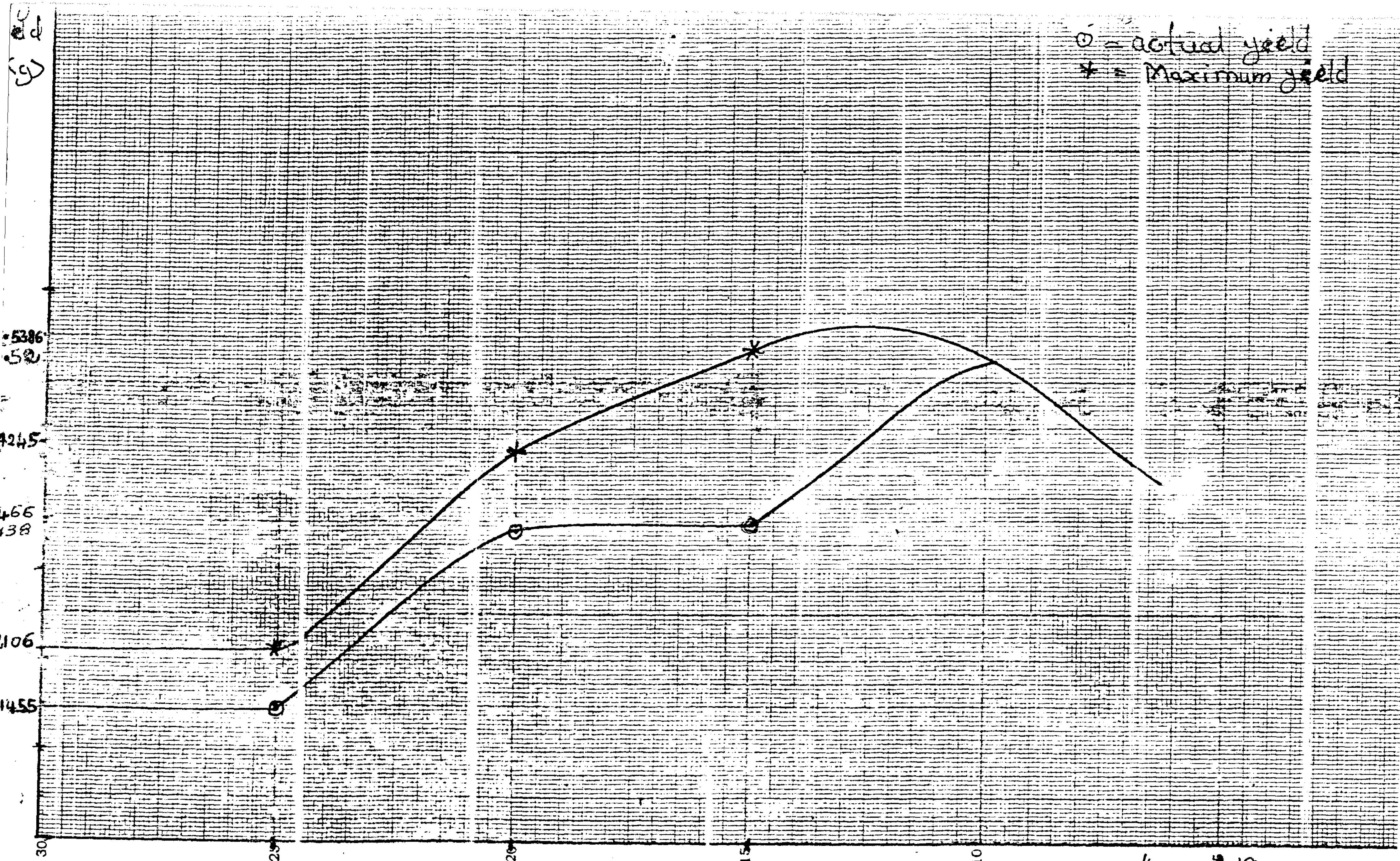


Fig 4.2 yield variation with water table

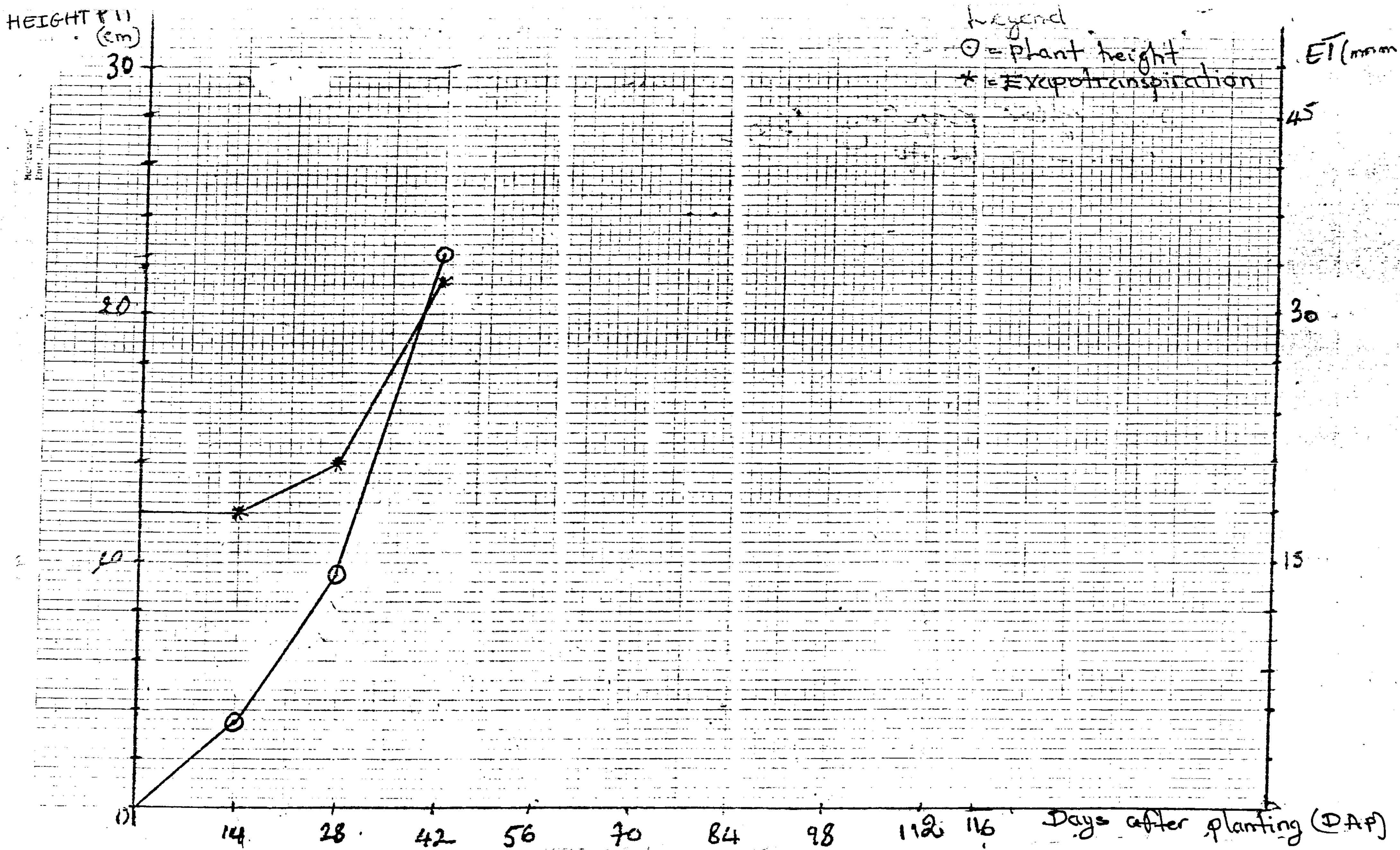


Fig 4.3a Mean Evapotranspiration and plant height at 10cm water table (REPI)

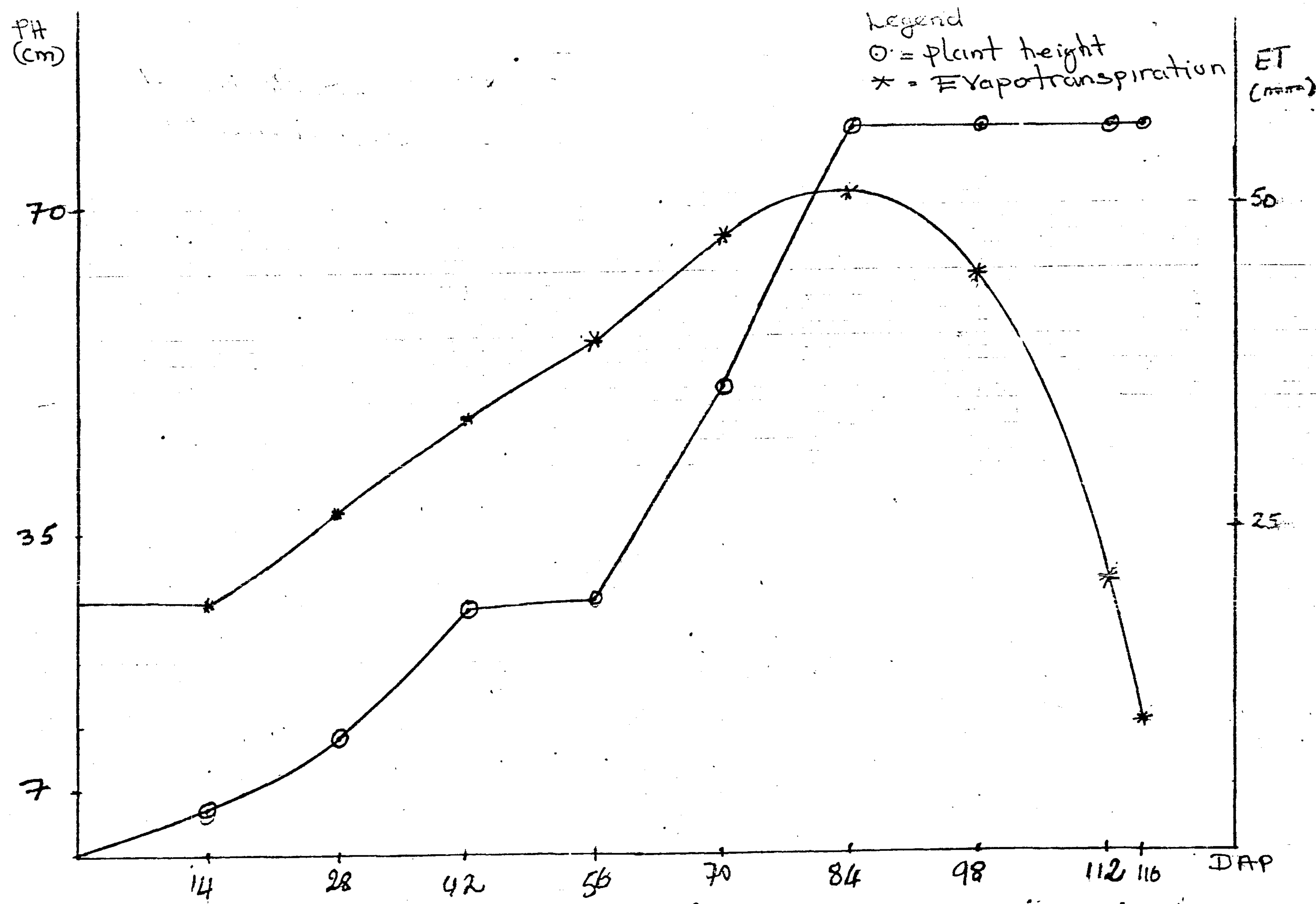


Fig. 4.36. Mean Exapotranspiration and plant height at 10cm water table (REPI

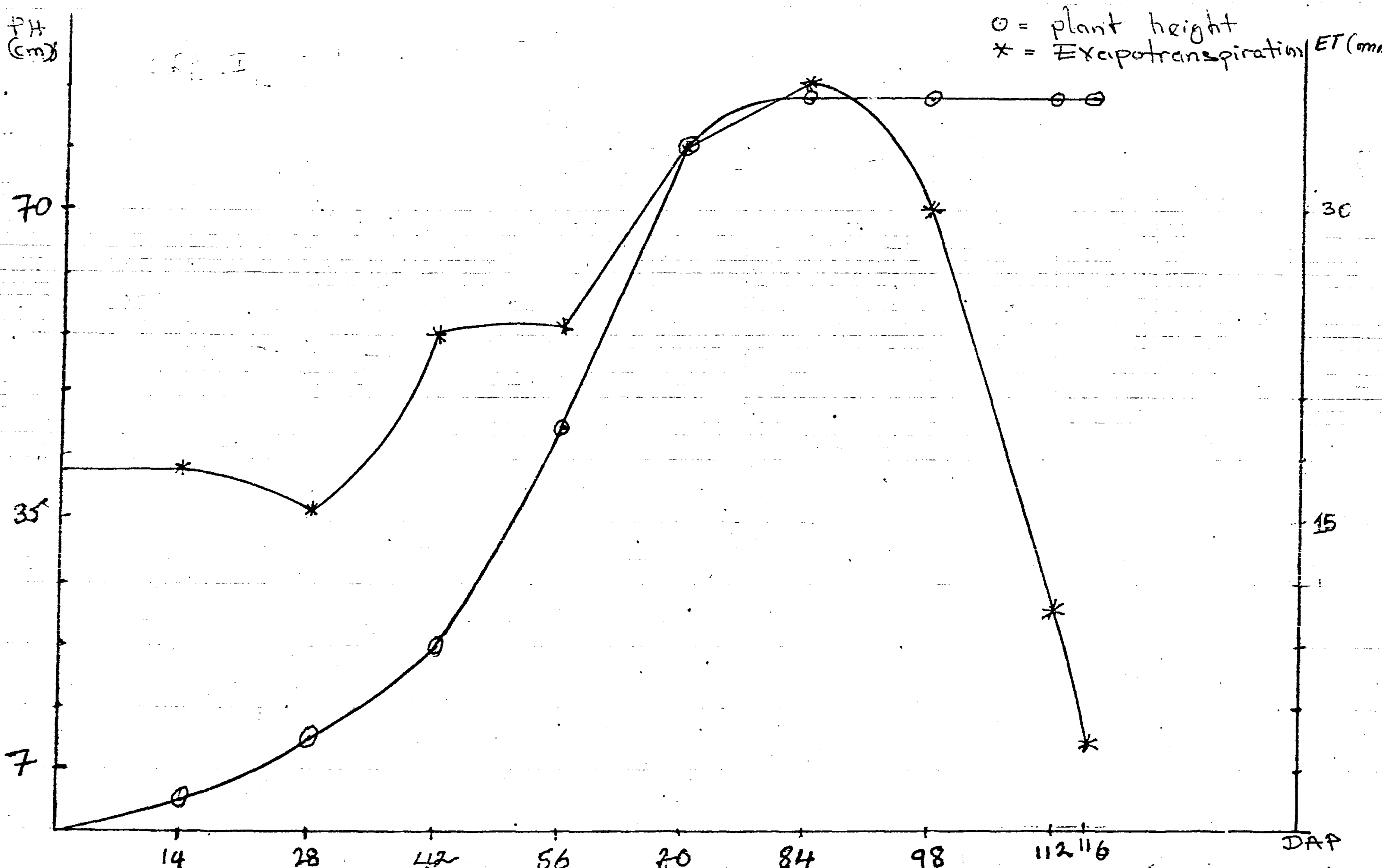


Fig 4.3c Mean Exapotranspiration and plant height at 10cm water table (RE

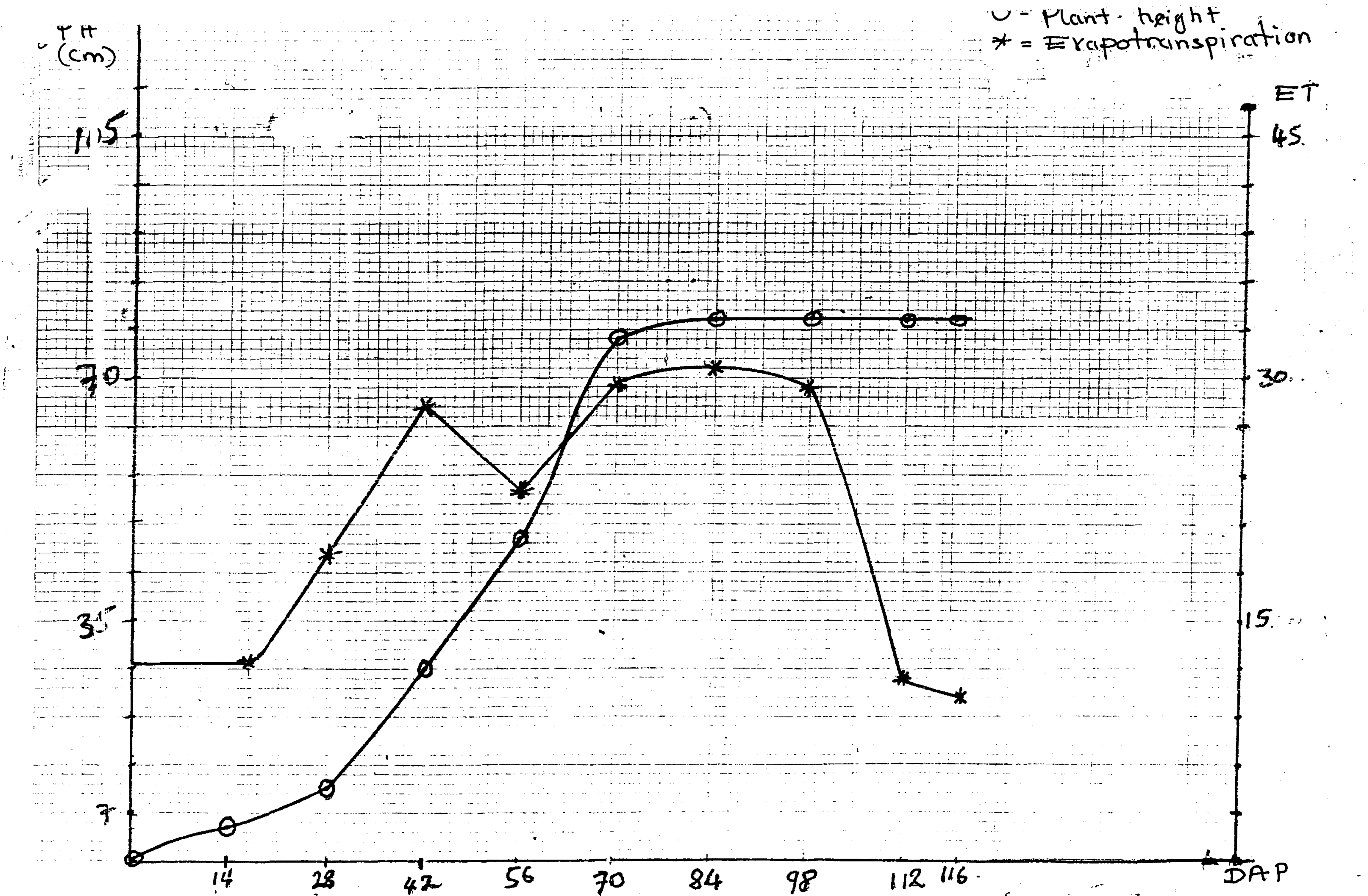


Fig 4.4a Mean Evapotranspiration and plant height at 20cm water table (REP I)

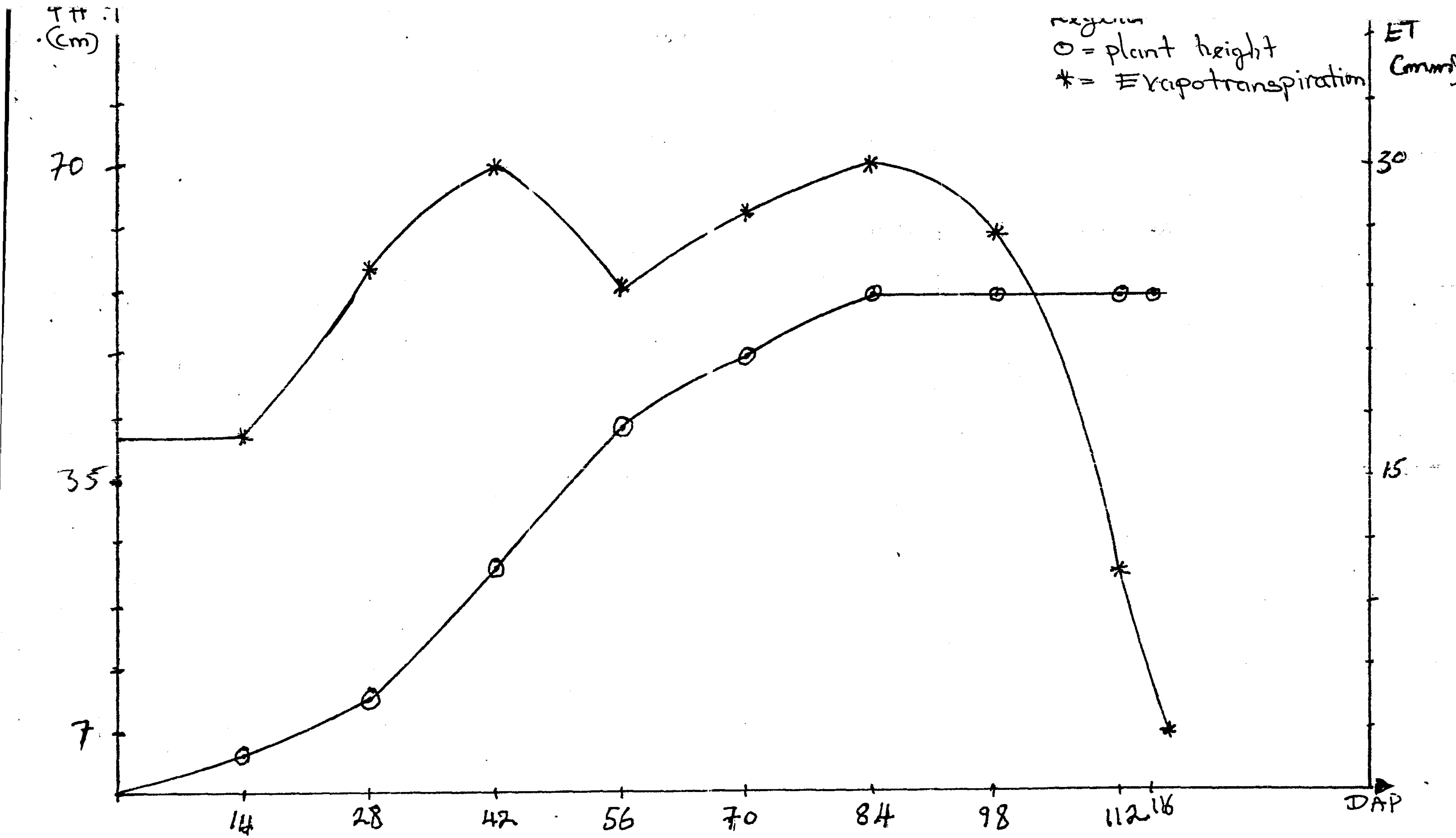


Fig 4.4.b Mean Evapotranspiration and plant height at 20cm water table (REP II)

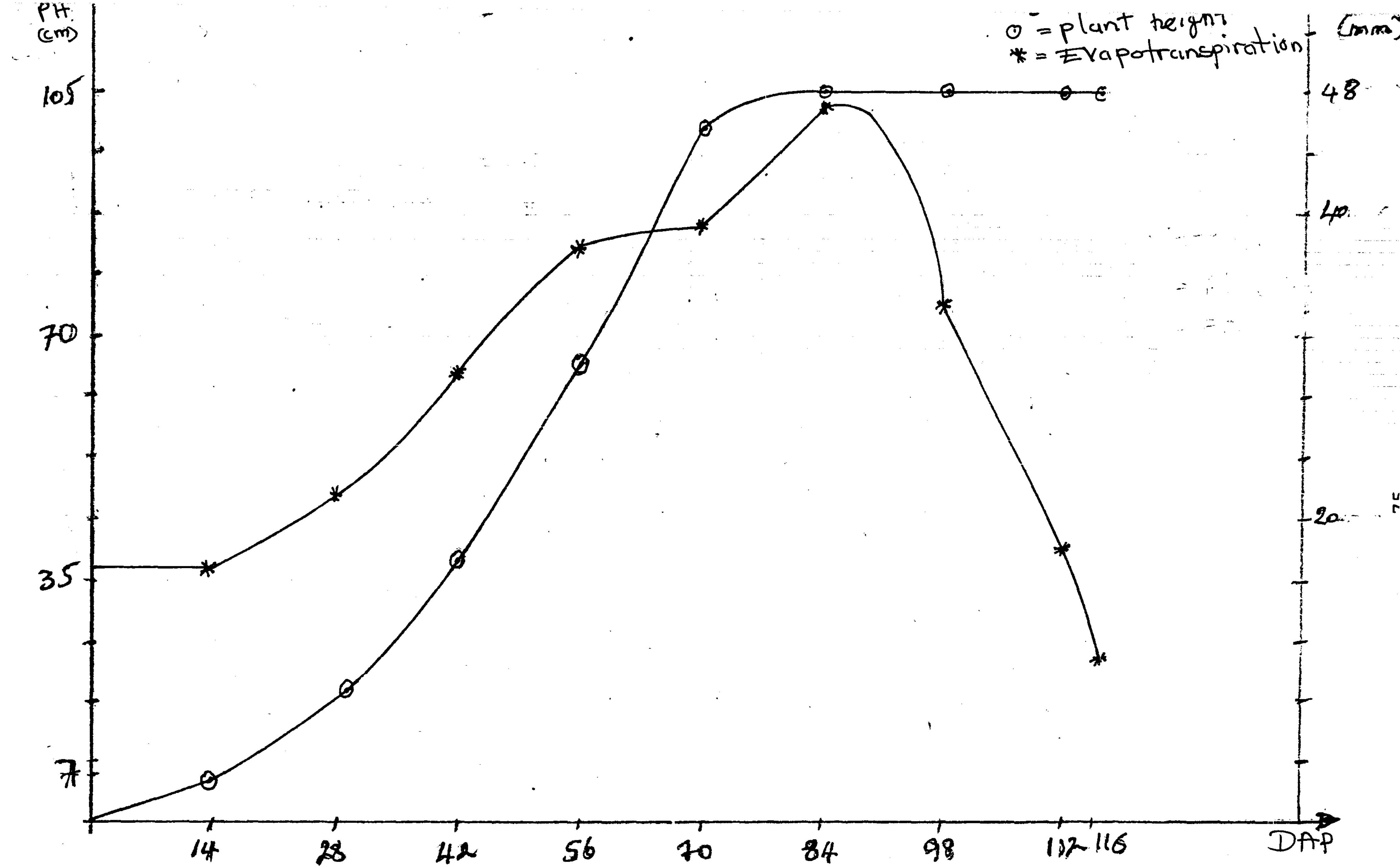


Fig 4.4C Mean Evapotranspiration and plant. height at 20cm water table (REP III)

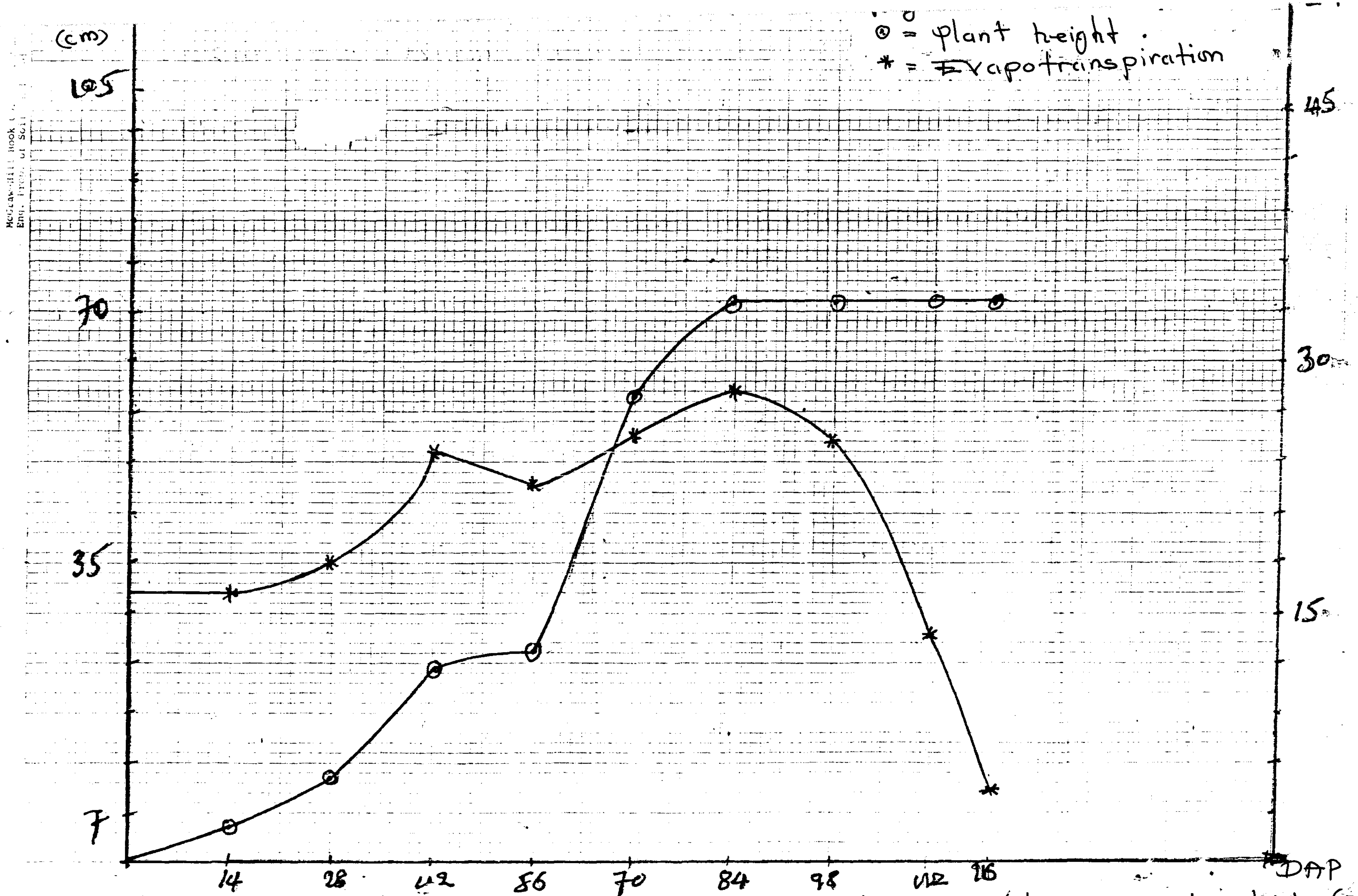


Fig 4.5a Mean Evapotranspiration and plant height at 30cm water table (REPI

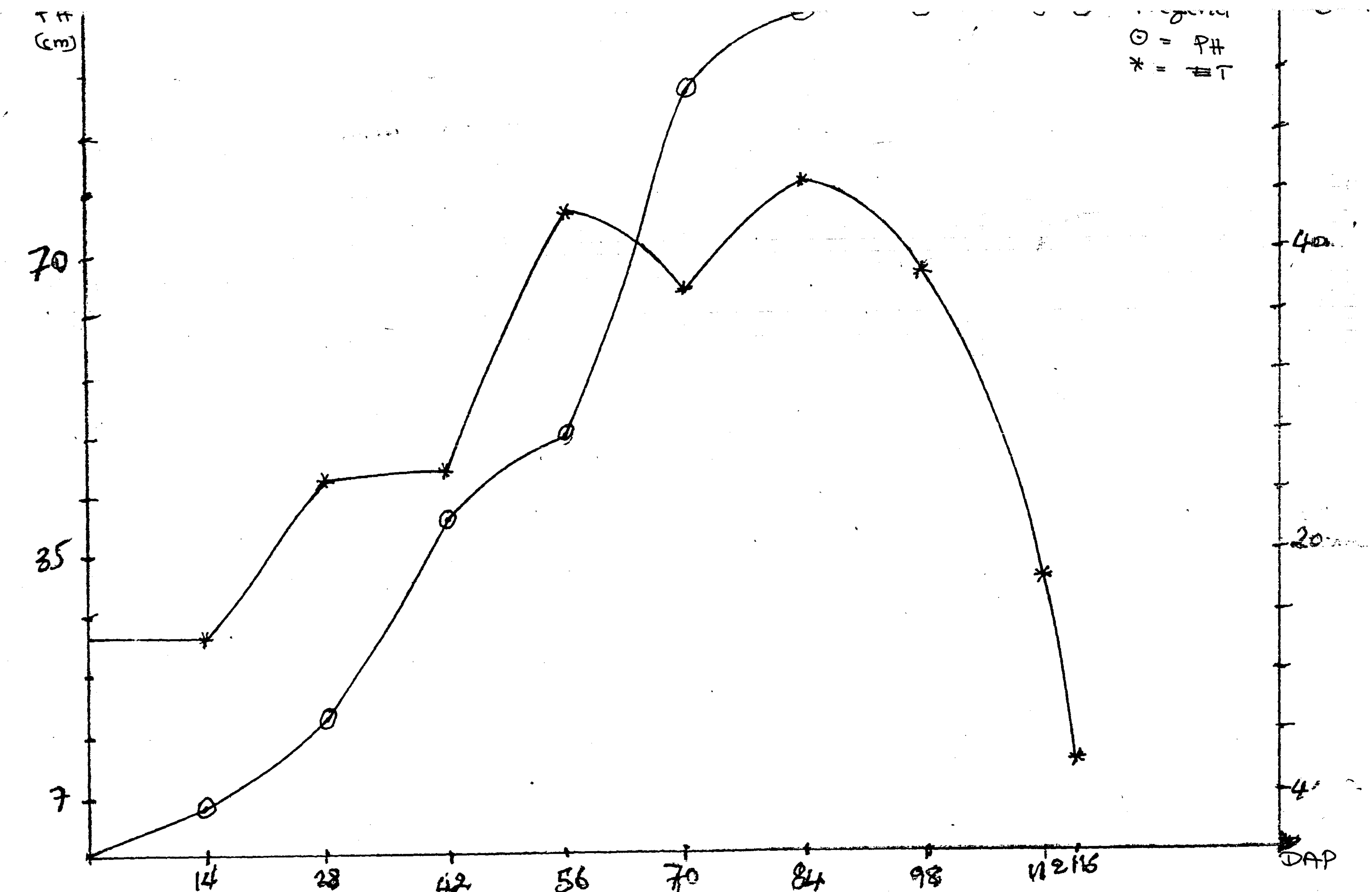


Fig 4.51 Mean Evapotranspiration and plant height at 30cm water table (REP II

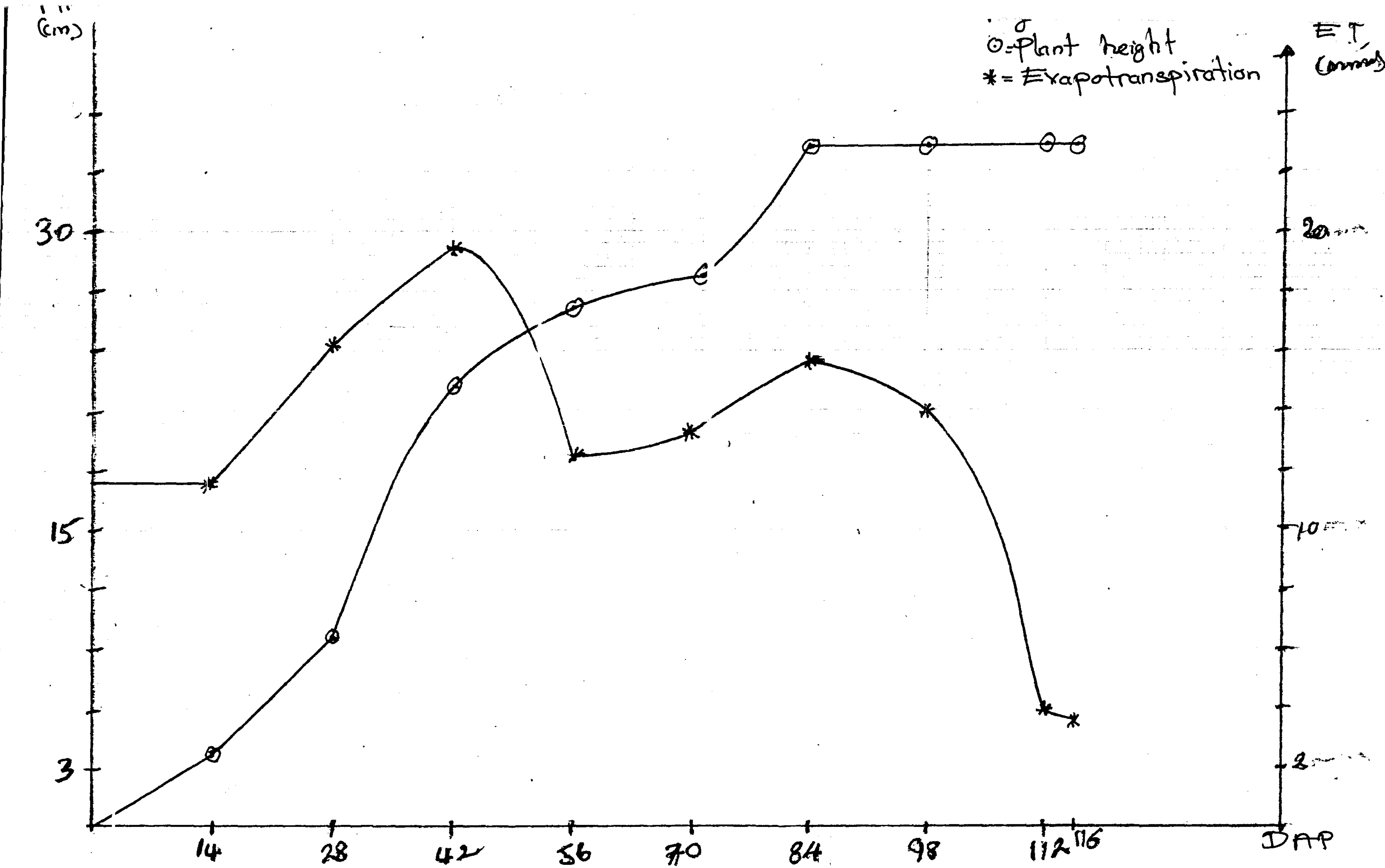


Fig 4.5c Mean Evapotranspiration and plant height 30cm water table (REP III)

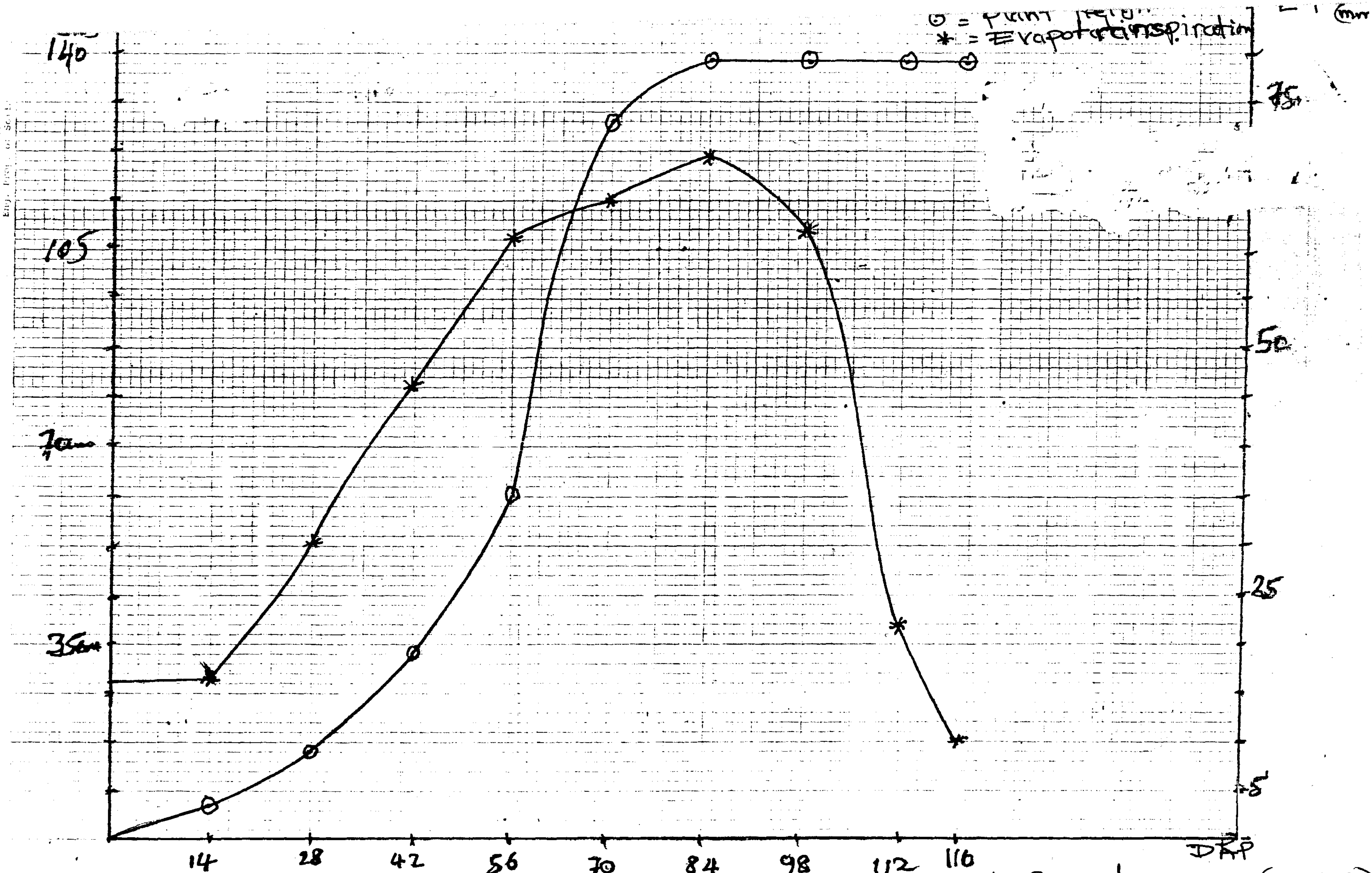


Fig 4.6a Mean Evapotranspiration and plant height at free drainage (REP I)

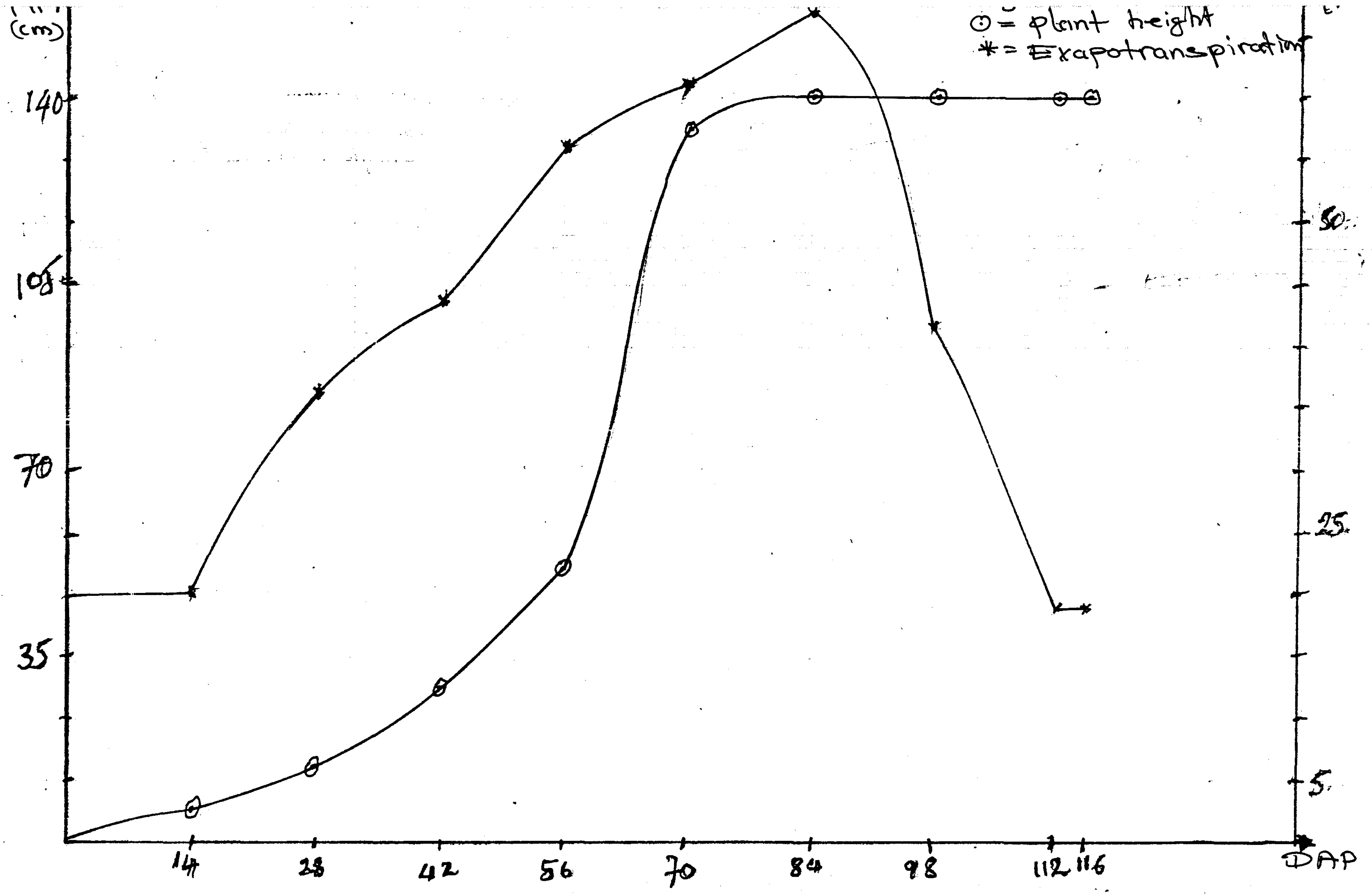


Fig 4.6b mean Exapotranspiration and plant height at free drainage (REP II)

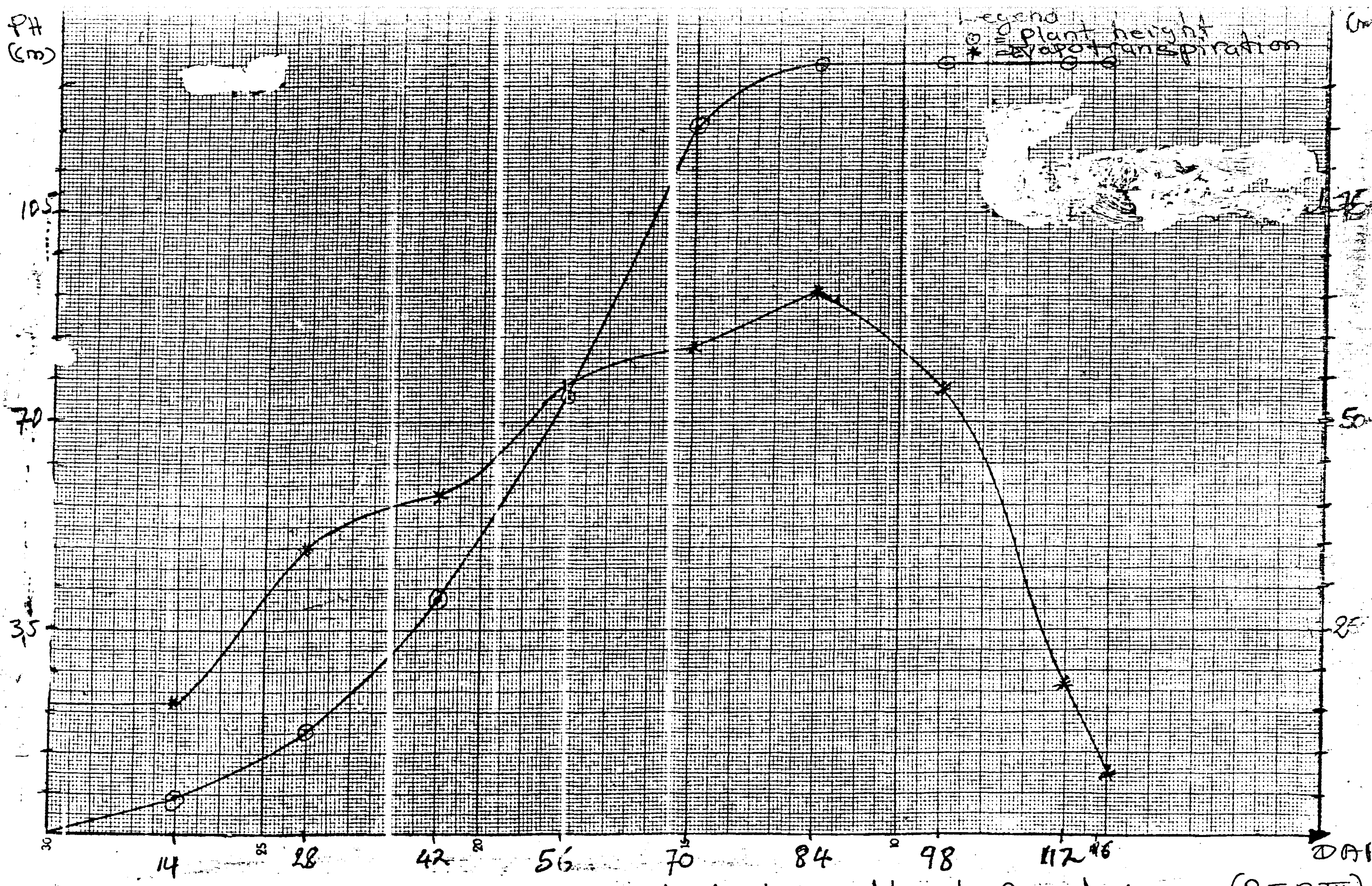


Fig 4.6c Mean Evapotranspiration and plant height at free drainage (REP III)

Fig 4.7a. Maize Crop 84 days after planting

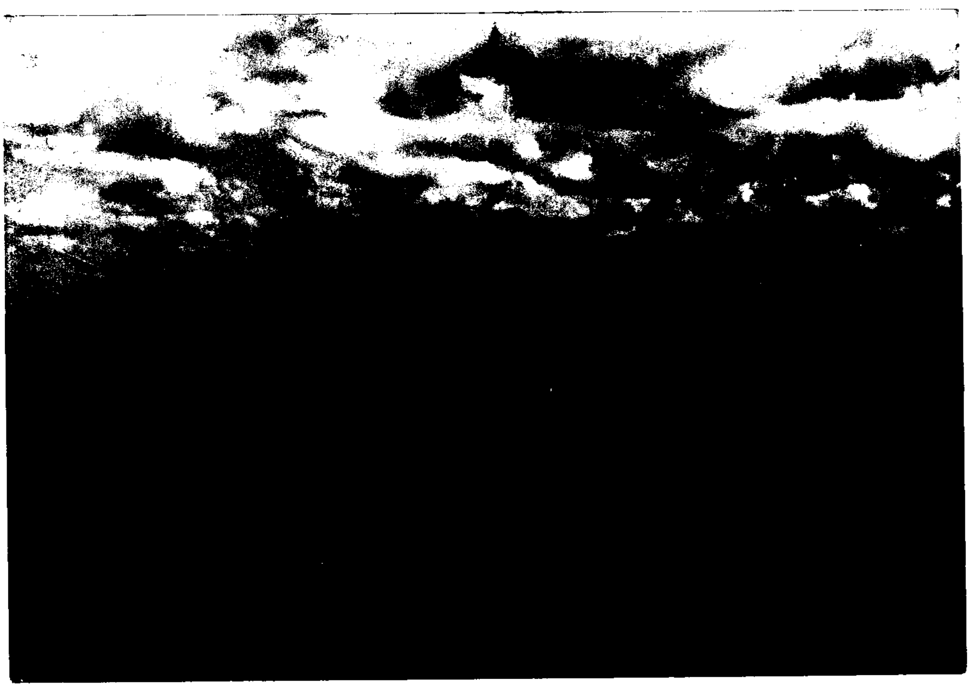


Fig. 4.7b. Front view of green house

CHAPTER FIVE

CONCLUSION AND RECOMMENDATION

5.1 CONCLUSION

The persent study permits us to understand, the fundamental concept of irrigation aspects.

The project area, National Cerals Reseaech Institute (NCRI) Badeggi where the entire experiment took place, provided with great deal satisfaction all the informations useful for the success of the project work.

Experiment carried out under green house has been achieved within 116 days from July to November. Various aspects including, water apply, plant height, leaf area, evapotranspiration have been monitored, recorded and analysed.

It can be cocluded from the analysis and discussion of results that crop yield of maize decreases with increases in water table.

To know finally the characteristic of the soil, various items including moisture content, bulk density, porosity, infiltration rate, hydraulic conductivity have been determined.

5.2 RECOMMENDATION

The most important aspect to underline in recommendation is that the depth of container used in experiment must normally be greater than 40cm.

For this I recommended 60 - 100cm and also the number of treatments should be reduced. By so doing we can further, with such information data, plan and design effective irrigation system at a minimum cost.

APPENDIX A

1. FORMULAR USED IN CALCULATING PHYSICAL PROPERTIES

(1) MOISTURE CONTENT $MD = \frac{Ww - Wd \times 100}{Wd}$ 2.1

Where Ww = wet weight of sample
Wd = Dry weight of soil
Md = moisture content expressed as percentage

$Mv = Md \times As$ 2.2
where Mv = Available moisture holding capacity
As = Apparent specific gravity of soil

$$As = \frac{\text{Weight of a given volume of soil}}{\text{Weight of an equal volume of water}}$$

(2) BULK DENSITY

$$\ell_B = \frac{Ms}{Vt} = As\left(1 - \frac{n}{100}\right) \text{ ....2.3}$$

Where ℓ_B = BULK DENSITY
Ms = Mass of soil
Vt = Total volume of soil
n = porosity

$$\ell_t = \frac{Mt}{Vt} \qquad n = \frac{Wa + Vw}{Va + Vw + Vs}$$

where ℓt = Total bulk density
Mt = Total mass of soil
Va, Vw, Vs = volume of air, water and soil respectively

(3) AVAILABLE MOISTURE TO PLANTS.

$$d = \frac{Md \times As \times D}{100}$$

WHERE d = Available moisture to plants
As = Apparent specific gravity
D = Depth of soil

(4) HYDRAULIC CONDUCTIVITY

$$K = \frac{QL}{AH_L}$$

WHERE K = HYDRAULIC CONDUCTIVITY
Q = VOLUME OF WATER PERCOLATE
L = FLOW LENGTH
A = CROSS SECTIONAL AREA AT RIGHT ANGLE
h_L = LOSS OF HYDRAULIC HEAD

(5) SOIL CLASSIFICATION

$C = R - R_L + 0.36T$ (g/l)

where C= CORRECTED HYDROMETER reading
T = ROOM TEMPERATURE MINUS 20^0C
R = hydrometer reading in the soil suspension (g/l)
R_L = Hydrometer reading in the blank.

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APPENDIX B

Steps to compute analysis of variance are:

Step1 construct an appropriate outline of the analysis of variance of data from plot sampling based on the experimental design used. For this example, the form of the analysis of variance is shown in chapter 4.2

Step2 Construct the replication X treatment table of totals (RT) and compute the replication totals(R), the treatment totals (T), AND THE GRAND TOTAL(G).

Step3 compute the correction factor and the sums of squares as

(1) $CF = \frac{G2}{Trs}$

(2) Total SS = $\Sigma X^2 - CF$

(3) REPLICATION SS = $\frac{\Sigma R^2}{ts} - CF$

(4) treatment SS = $\Sigma T^2 - CF$

(5) EXPERIMENTAL ERRORS = $\Sigma \frac{(RT)^2}{S} - CF - SSR - SST$

(6) SAMPLING ERRORS SS = TOTAL SS- (SUM OF ALL OTHER SS)

STEP4 : For each source of variation, compute the mean square by by dividing the SS by its corresponding d.f

(1) REPLICATION MS= $\frac{\text{REPLICATION SS}}{r-1}$

(2) TREATMENT MS = $\frac{\text{TREATMENT SS}}{t-1}$

(3) EXPERIMENTAL ERROR MS = $\frac{\text{EXPERIMENTAL ERROR SS}}{(r-1)(t-1)}$

(4) SAMPLING ERROR MS = $\frac{\text{SAMPLING ERROR SS}}{tr(s-1)}$

STEP6: To test the significance of the treatment effect, compute the F value as:

$$F = \frac{\text{Treatment MS}}{\text{EXPERIMENTAL ERROR MS}}$$

and compare it with the tabular F values (APPENDIX E) with $f_1 = (t-1)$ and $f_2 = (r-1)(t-1)$ (Page 635 by GOMEZ)

STEP6: Enter all values obtained in step2 to 5 in the analysis of variance outline of step1.

Step7: For mean comparison, compute the standard error of the difference between the treatments as

$$Sd = \sqrt{\frac{2(MS2)}{rs}}$$

Where MS2 is the experimental error MS in the analysis of variance.

STEP8: Compute the extimates of the sampling error of the experimental error variance

$$Ss^2 = MS_1 \qquad S_E^2 = \frac{M_{S2} - M_{S1}}{S}$$

Where MS_1 is the sampling error Ms in the analysis of variance.
Step9: compute the grand mean and the coefficient of variance cv as follow:

$$\text{Grand mean} = \frac{G}{n}$$

$$cv = \frac{\sqrt{\text{error MS}}}{\text{Grand mean}} \times 100$$

The cv indicates the degree of precision with which the treatments are compared and is a good index of the reliability of the experiment.

APPENDIX C

Example for the use of the following equation

$ET_o = Wrn + (1-W) f(u) (\ell s - \ell_o)$ c1

Where W = correction factor

Rn = Net radiation (mm/day)

f(u) values of wind function for wind run

ℓs = saturated vapour pressure (mbar)

ℓ_o = vapour pressure at any level (mbar)

To determine ETo from August 7^{th}- 20, 1997

Given data

Latitude 10^0 North, Altitude 70.57M

Number of sunshine hour (n) = 4.6

Wind of speed km/day (u) = 74.54

Relative humidity (RH) = 0.8443

Mean temperature = 28^0c

From table3 (Appendix G) at $t=28^0C$ $\ell s = 35.7$ mbar

$\ell_o = RH\ell_S = 0.8443 \times 35.7$

$= 30.2$mbar

$\ell s - \ell_o = 35.7 - 30.2 = 5.5$

From table 4 (Appendix G) $f(u) = 0.27(1+\frac{u}{100})$ c2

$u = 74.54 \Rightarrow f(u) = 027(1+\frac{74.54}{100}) = 0.47126$

At altitude 70.57M, we consider 500 (table 5 appendix G) under 28^0c

$1 - W = 0.22$

$\Rightarrow W = 0.78$

Referring to table 1 and table 7 Appendix G under latitude 10^0 North for the month of AUGUST N = 12.4

given $n = 4.6 \Rightarrow \frac{n}{N} = \frac{4.6}{12.4} = 0.37$

AT $\frac{n}{N} = 0.37$ from table 8

By interpolation $(1-a)(0.25+0.50\frac{n}{N}) = 0.33$

where a = Reflectivity factor assumed to be 0.25.

Now Rn = Rns-Rnl c3

where Rns = short wave radiation (mm/day)

Rnl = long wave radiation (mm/day)

and Rns = 0.33Ra..............c4

where Ra = Terrestal radiation (mm/day)

From table2 at 10^0North under month of AUGUST $\ell_a = 15.5$

$\Rightarrow Rns = 0.33 \times 15.5 = 5.115$

$Rnl = f(t).f(e).f(\frac{n}{N})$ c5

where f(t) = correction temperature on long wave radiation Rnl

f(e) = correction for vapour pressure on long wave radiation Rnl

$f(\frac{n}{N})$ = correction for the ratio of actual and maximum bright

N sunshine hours on long wave radiation Rnl..
From table 8, table 9, table 10 respectively (Appendix G)

$f(t)$ at $t = 28^0C = 16.3$

$f(e)$ at $t = 28^0C = 0.11$

$f(\frac{n}{N})$ for $\frac{n}{N} = 0.37$ $f(\frac{n}{N}) = 0.44$ BY INTERPOLATION

From equation c5 Rnl = 16.3×0.11×0.44 = 0.79

Therefore from C3 Rn = 5.115-079

= 4.32

So from equation c1

ETo = Wrn + (1-W).f(u).(ℓs-ℓ_o)

= 0.78×4.32+0.22×0.47126×5.5

= 3.94mm/day

for Ke = 093 (table4.4)

ETc = 0.93×3.94

= 3.67mm/day

APPENDIX D climatological Data

Table D_1

DATE	MONTH	TEMPERA MAX °C	MIN °C	RELATIVE HUMMIDITY %	WIND SPEED W KM/DAY	SUNSHINE HOUR n
10	JULY	34	23	80	68.38	4.2
11		30	20	87	93.02	4.3
12		31	23	85	68.22	4.6
13		32	22	81	92.50	4.4
14		32	24	84	62.98	4.5
15		30	23	90	114.95	4.6
16		32	23	90	81.11	4.6
17		31	23	76	84.95	4.4
18		29	23	95	48.28	4.6
19		32	23	87	132.43	4.3
20		31	23	88	90.82	4.3
21		33	24	76	76.66	4.3
22		33	23	86	53.13	4.2
23		31	24	80	116.09	4.3
TOTAL		441	321	1185	1183.52	61.6
MEAN		31.5	22.92	84.65	84.54	4.4

TABLE D_2

DATE	MONTH	TEMPERA MAX °C	MIN °C	RELATIVE HUMMIDITY %	WIND SPEED W KM/DAY	SUNSHINE HOUR n
24	JULY	33	21	92	51.34	4.6
25		33	24	84	57.01	4.3
26		34	24	87	108.24	4.2
27		34	24	87	90.39	4.3
28		32	25	81	60.67	4.3
29		31	25	84	129.22	4.6
30		27	24	88	50.85	4.8
31		32	24	81	12.41	4.6
01	AUGUST	31	23	91	87.03	4.6
02		31	23	81	34.47	4.8
03		33	23	81	84.04	4.4
04		34	24	75	92.83	4.6
05		31	23	84	91.07	4.2
06		31	24	93	86.75	4.3
TOTAL		447	331	1173	1036.32	63.3
MEAN		31.92	23.65	83.86	74.02	4.5

APPENDIX D

TABLE D_3

DATE	MONTH	TEMPERA MAX °C	MIN °C	RELATIVE HUMMIDITY %	WIND SPEED W KM/DAY	SUNSHINE HOUR n
07	AUGUST	33	24	73	59.76	4.4
08		33	24	81	104.62	4.5
09		30	24	77	96.42	4.7
10		32	23	83	73.54	4.8
11		32	24	85	68.80	4.8
12		33	24	84	115.04	4.7
13		31	22	84	74.17	4.3
14		31	24	86	76.12	4.9
15		30	23	90	60.52	4.3
16		27	24	90	61.22	4.6
17		30	23	88	73.47	4.6
18		30	21	92	42.18	4.8
19		31	23	81	63.06	4.6
20		32	23	88	74.72	4.4
TOTAL		435	349	1182	1043.64	64.4
MEAN		3107	24.93	84.43	74.54	4.6

TABLE D_4

DATE	MONTH	TEMPERA MAX °C	MIN °C	RELATIVE HUMMIDITY %	WIND SPEED W KM/DAY	SUNSHINE HOUR n
21	AUGUST	33	23	76	72.33	5.7
22		33	23	89	77.44	5.5
23		34	24	77	70.69	5.5
24		33	25	79	61.26	5.4
25		33	23	88	62.62	5.6
26		30	24	87	48.86	5.8
27		33	25	74	89.64	4.6
28		31	23	84	88.92	4.6
29		33	23	74	83.86	4.9
30		33	23	75	57.10	4.3
31		32	23	77	100.68	4.7
01	SEPT	32	24	84	109.5	4.3
02		31	24	94	64.11	5.8
03		30	23	96	140.98	4.8
TOTAL		451	330	1154	1128	71.4
MEAN		32.21	23.57	82.43	80.57	5.1

APPENDIX D

TABLE D_5

DATE	MONTH	TEMPERA MAX •C	MIN •C	RELATIVE HUMMIDITY %	WIND SPEED W KM/DAY	SUNSHINE HOUR n
04	SEPT	32	23	84	46.50	5.8
05		32	22	81	76.72	5.8
06		33	23	74	101.53	5.3
07		31	23	81	110.68	5.7
08		31	24	84	68.00	5.3
09		34	23	85	81.78	5.9
10		33	22	81	99.58	4.6
11		31	23	77	126.76	4.6
12		30	21	77	73.93	5.9
13		33	24	81	85.47	5.7
14		34	22	74	80.58	5.5
15		33	24	80	115.35	5.6
16		31	22	91	67.17	5.6
17		32	24	85	79.33	5.7
TOTAL		431	320	1135	1213.38	77
MEAN		32.14	22.85	81.07	86.67	5.5

TABLE D_6

DATE	MONTH	TEMPERA MAX	MIN	RELATIVE HUMMIDITY %	WIND SPEED W KM/DAY	SUNSHINE HOUR n
18		32	24	84	94.47	6.7
19		31	22	87	63.47	6.6
20		32	22	84	133.13	6.6
21		27	21	91	76.92	6.5
22		31	23	89	58.76	5.3
23		32	23	82	106.50	5.7
24		31	23	81	121.20	5.3
25		31	22	82	63.02	5.9
26		35	24	85	66.64	4.6
27		30	23	87	89.44	4.6
28		33	23	75	66.76	5.9
29		33	25	81	107.62	6.7
30	OCTOBER	29	22	86	67.50	6.8
01		33	23	91	75.04	6.8
TOTAL		450	320	1185	1190.47	84
MEAN		32.15	22.86	84.65	85.04	6.00

APPENDIX D

TABLE D_7

DATE	MONTH	TEMPERA MAX •C	MIN •C	RELATIVE HUMMIDITY %	WIND SPEED W KM/DAY	SUNSHINE HOUR n
02	OCTOBER	33	22	85	71.44	6.8
03		33	22	87	89.73	6.8
04		29	22	94	39.90	6.7
05		33	22	99	91.43	5.9
06		29	21	98	66.40	6.7
07		34	22	89	71.74	6.6
08		33	23	77	54.34	6.6
09		34	25	75	68.92	6.7
10		34	24	80	70.34	6.6
11		35	25	84	83.11	5.6
12		34	24	81	42.39	5.7
13		35	24	71	57.54	5.7
14		29	24	92	102	6.3
15		30	21	81	62.80	6.9
TOTAL		455	321	1193	972.08	89.6
MEAN		32.5	22.93	85.22	69.44	6.4

TABLE D_8

DATE	MONTH	TEMPERA MAX •C	MIN •C	RELATIVE HUMMIDITY %	WIND SPEED W KM/DAY	SUNSHINE HOUR n
16	OCTOBER	33	24	78	124	6.9
17		33	23	75	52.98	6.9
18		35	23	80	79.80	6.7
19		32	22	90	59.78	6.6
20		33	24	84	58.81	6.8
21		35	24	80	77.89	6.8
22		32	23	87	60.78	6.9
23		35	22	76	46.88	6.9
24		33	25	79	66.05	6.9
25		35	23	72	44.68	6.9
26		30	23	83	97.68	6.6
27		34	23	79	77.07	6.7
28		36	23	75	77.54	6.7
29		33	24	81	72.55	6.9
TOTAL		469	326	1119	996.44	95.2
MEAN		33.5	23.29	79.93	71.18	6.8

APPENDIX E

REPLICATION X TREATMENT TABLE G1.1 (cm) PH 14DAP

treatments	REP I	REP II	REP III	TOTAL(T)
10	15	19.175	15.75	50.5
20	20.5	18	26.5	65
30	20	24.25	14.5	58.75
FD	25.5	23.5	25.75	74.75
REP TOTAL R	81	85.5	82.5	
GRAND TOTAL (T)				249

REPLICATION X TREATMENT TABLE G.2 (cm) PH 28DAP

treatments	REP I	REP II	REP III	TOTAL(T)
10	39	49.5	41.50	130
20	47	43	76.00	166.5
30	46.50	64	38.00	148.5
FD	63	56	70	189
REP TOTAL R	195.5	212.5	226	
GRAND TOTAL (T)				634

REPLICATION X TREATMENT TABLE G1.3 (cm) PH 42DAP

treatments	REP I	REP II	REP III	TOTAL(T)
10	90	106.5	85	281.5
20	113	101	152.5	366.5
30	110	157.5	89.5	357
FD	133	115	160	408
REP TOTAL R	446	480	487	
GRAND TOTAL (R)				1413

REPLICATION X TREATMENT (cm) PH 56 DAP

TABLE Ej.4

treatments	REP I	REP II	REP III	TOTAL (T)
10	X	109	183	292
20	191	93	260	544
30	117	197	105	369
FD	247	206	298	751
REP TOTAL R	555	605	796	
GRAND TOTAL (T)				1956

REPLICATION X TREATMENT TABLE Ej.5 (cm) PH 70 DAP

treatments	REP I	REP II	REP III	TOTAL (T)
10	X	202	307	509
20	305	193	398.5	865.5
30	265	355.5	110	730.5
FD	513	538	478	1529
REP TOTAL R	1083	1257.5	1293.5	
GRAND TOTAL (T)				3634

REPLICATION X TREATMENT TABLE Ej.6 (cm) PH 84 DAP

treatments	REP I	REP II	REP III	TOTAL (T)
10	X	315	330	645
20	315	222	421	958
30	274.5	394	137	805.5
FD	55.7	560	520	1635.7
REP TOTAL R	1145.2	1491	1408	
GRAND TOTAL (T)				4044.2

REPLICATION X TREATMENT TABLE E1.7 (cm) PH 98 DAP

treatments	REP I	REP II	REP III	TOTAL(T)
10	X	315	330	645
20	315	222	421	958
30	274.5	394	137	805.5
FD	55.7	560	520	1635.7
REP TOTAL R	1145.2	1491	1408	
GRAND TOTAL (T)				4044.2

REPLICATION X TREATMENT TABLE E1.8 (cm) PH 112 DAP

treatments	REP I	REP II	REP III	TOTAL(T)
10	X	315	330	645
20	315	222	421	958
30	274.5	394	137	805.5
FD	55.7	560	520	1635.7
REP TOTAL R	1145.2	1491	1408	
GRAND TOTAL (T)				4044.2

REPLICATION X TREATMENT TABLE E2.1 (cm^2) LA Leaf Area 14 DAP

treatments	REP I	REP II	REP III	TOTAL(T)
10	371.5	36.4	58.77	132.32
20	51	39.96	59.9	150.86
30	34.4	37.25	65	136.65
FD	97	76.9	92.125	266.025
REP TOTAL R	219.55	190.51	275.8	
GRAND TOTAL (T)				685.85

REPLICATION X TREATMENT TABLE E2.2 (cm^2) LA 28 DAP

treatments	REP I	REP II	REP III	TOTAL (T)
10	167.2	262	235.1	664.3
20	271.1	166.45	444.2	881.75
30	284.5	445.5	241.08	971.08
FD	371.7	416.4	368.8	1156.9
REP TOTAL R	1094.5	1290.35	1281.18	
GRAND TOTAL (T)				3674.03

REPLICATION X TREATMENT TABLE E2.3 (cm^2) LA 42 DAP

treatments	REP I	REP II	REP III	TOTAL (T)
10	367.1	597.3	546.61	1511.01
20	610	485.6	922.95	2018.55
30	566.3	1033.55	904.7	2504.55
FD	839.6	1013	943.78	2796.38
REP TOTAL R	2383	3129.45	3318.04	
GRAND TOTAL T				8830.49

REPLICATION X TREATMENT TABLE E2.4 (cm^2) LA 56 DAP

treatments	REP I	REP II	REP III	TOTAL (T)
10	X	852	751.6	1603.6
20	738.5	545	1028.7	2312.2
30	647.5	1164.5	281.4	2093.4
FD	1302.8	1940.7	1627	4870.5
REP TOTAL R	2658.8	4502.2	3688.7	
GRAND TOTAL T				10879.7

REPLICATION X TREATMENT TABLE E2.5 (cm^2) LA 70 DAP

treatments	REP I	REP II	REP III	TOTAL(T)
10	X	1325.4	993.6	2319
20	1032	795.5	1607	3434.5
30	1010.9	1532.58	426	2969.48
FD	1757	2559	2345	6661
REP TOTAL R	3799.9	6212.48	5371.6	
GRAND TOTAL T				15383.98

REPLICATION X TREATMENT TABLE E2.6 (cm^2) LA 84 DAP

treatments	REP I	REP II	REP III	TOTAL(T)
10	X	1672.5	1069	27415
20	1156	918	1664.4	3738.4
30	1132.8	1903.5	516.6	3552.9
FD	2031	2841.6	2541.4	7414
REP TOTAL R	4319.8	7335.6	5791.4	
GRAND TOTAL T				17446.8

REPLICATION X TREATMENT TABLE E2.7 (cm^2) LA 98 DAP

treatments	REP I	REP II	REP III	TOTAL(T)
10	X	1672.5	1069	27415
20	1156	918	1664.4	3738.4
30	1132.8	1903.5	516.6	3552.9
FD	2031	2841.6	2541.4	7414
REP TOTAL R	4319.8	7335.6	5791.4	
GRAND TOTAL T				17446.8

REPLICATION X TREATMENT TABLE E2.8 (cm^2) LA 112 DAP

treatments	REP I	REP II	REP III	TOTAL(T)
10	X	1672.5	1069	27415
20	1156	918	1664.4	3738.4
30	1132.8	1903.5	516.6	3552.9
FD	2031	2841.6	2541.4	7414
REP TOTAL R	4319.8	7335.6	5791.4	
GRAND TOTAL T				17446.8

REPLICATION X TREATMENT TABLE E3.1 E_1(mm) ET = Evapotranspiration ET 14 DAP

treatments	REP I	REP II	REP III	TOTAL(T)
10	72.76	77.96	70.45	221.17
20	49.48	68.72	67.56	186.16
30	64.96	59.56	46.77	171.29
FD	66.5	81.4	63.41	211.31
REP TOTAL R	253.70	287.64	248.19	
GRAND TOTAL T				789.93

REPLICATION X TREATMENT TABLE E3.2 (mm) ET 28 DAP

treatments	REP I	REP II	REP III	TOTAL(T)
10	84.74	105.83	62.89	253.46
20	76.4	101.5	86.29	263.74
30	73.28	101.36	65.08	239.72
FD	123.2	146.6	140.67	410.47
REP TOTAL R	357.62	454.84	354.93	
GRAND TOTAL				1167.39

REPLICATION X TREATMENT TABLE E3.3 (mm) ET 42 DAP

treatments	REP I	REP II	REP III	TOTAL(T)
10	130.26	133.91	96.81	360.98
20	112.8	121.02	118.94	352.76
30	99.28	102.51	77.45	279.24
FD	187.16	174.06	164.59	525.81
REP TOTAL R	529.5	531.5	457.79	
GRAND TOTAL T				1518.79

REPLICATION X TREATMENT TABLE E3.4 (mm) ET 56 DAP

treatments	REP I	REP II	REP III	TOTAL(T)
10	X	157.95	97.64	255.59
20	94.12	96.49	152.85	343.46
30	90.04	171.53	49.91	311.48
FD	245.82	223.77	218.85	688.44
REP TOTAL R	429.98	649.74	519.25	
GRAND TOTAL T				1598.97

REPLICATION X TREATMENT TABLE E3.5 (mm) ET 70 DAP

treatments	REP I	REP II	REP III	TOTAL(T)
10	X	190.6	132.06	322.66
20	109.18	111.26	157.32	377.76
30	102.21	149.73	52.51	304.45
FD	258.4	245.09	233.75	737.24
REP TOTAL R	469.79	696.68	575.64	
GRAND TOTAL T				1742.11

REPLICATION X TREATMENT TABLE E3.6 (mm) ET 84 DAP

treatments	REP I	REP II	REP III	TOTAL(T)
10	X	203.08	145.58	348.66
20	122.18	120.93	189.05	432.16
30	112.82	179.37	62.39	354.58
FD	279.51	267.76	261.21	808 .48
REP TOTAL R	514.51	771.14	658.23	
GRAND TOTAL T				1943.88

REPLICATION X TREATMENT TABLE E3.7 (mm) ET 98 DAP

treatments	REP I	REP II	REP III	TOTAL(T)
10	X	179.37	120.72	300.09
20	109.7	107.62	136.42	353.84
30	100.55	155.45	55.84	311.84
FD	248.52	165.84	213.49	627.85
REP TOTAL R	458.77	608.28	526.47	
GRAND TOTAL T				1593.52

REPLICATION X TREATMENT TABLE E3.8 (mm) ET 112 DAP

treatments	REP I	REP II	REP III	TOTAL(T)
10	X	85.16	43.25	128.41
20	47.2	42.62	72.25	162.07
30	54.48	73.4	15.54	143.42
FD	105.52	76.4	71.2	253.12
REP TOTAL R	207.2	277.58	202.24	
GRAND TOTAL T				687.02

REPLICATION X TREATMENT TABLE E3.9 (mm) ET 126 DAP

treatments	REP I	REP II	REP III	TOTAL(T)
10	X	40.54	20.07	60.61
20	40.65	11.75	43.25	95.65
30	16.65	24.59	14.22	55.38
FD	41.70	76.4	28.17	69.87
REP TOTAL R	98.92	76.88	105.71	
GRAND TOTAL T				281.51

REPLICATION X TREATMENT TABLE E4.1 (mm) WA = Water Apply at planting

treatments	REP I	REP II	REP III	TOTAL(T)
10	264.96	260.87	253.47	779.3
20	239.88	245.19	249.96	735.03
30	217.23	217.55	220.55	655.33
FD	207.88	207.88	207.88	623.64
REP TOTAL R	929.95	931.49	931.86	
GRAND TOTAL T				2793.3

REPLICATION X TREATMENT Table E4.2 (mm) 14 DAP(WA)

treatments	REP I	REP II	REP III	TOTAL(T)
10	97.17	93.83	75.13	266.13
20	75.35	85.42	91.23	252
30	93.01	81.38	66.51	240.9
FD	157.97	187.37	185.09	530.43
REP TOTAL R	423.5	448	417.96	
GRAND TOTAL T				1289.46

REPLICATION X TREATMENT TABLE 4.3 (mm) 28 DAP(WA)

treatments	REP I	REP II	REP III	TOTAL(T)
10	92.08	122.94	85.32	300.34
20	107.04	127.83	86.4	321.27
30	91.13	119.41	80.74	291.28
FD	212.13	242.63	242.63	697.39
REP TOTAL R	502.38	612.81	494.69	
GRAND TOTAL T				1610.28

REPLICATION X TREATMENT TABLE 4.4 (mm) WA 42 DAP

treatments	REP I	REP II	REP III	TOTAL(T)
10	141.85	168.15	124.08	434.08
20	130.42	155.79	137.07	423.28
30	134.47	140.08	95.71	370.26
FD	282.07	261.38	214.44	757.89
REP TOTAL R	688.81	725.4	571.3	
GRAND TOTAL T				1985.51

REPLICATION X TREATMENT TABLE 4.5 (mm) WA 56 DAP

treatments	REP I	REP II	REP III	TOTAL(T)
10	X	184.48	110.37	294.85
20	110.37	109.23	178.45	398.05
30	102.26	152.16	58.72	313.14
FD	359.51	337.773	338.84	1036.123
REP TOTAT R	572.14	783.64	686.38	
GRAND TOTAL T				2042.16

REPLICATION X TREATMENT TABLE 4.6 (mm) WA 70 DAP

treatments	REP I	REP II	REP III	TOTAL (T)
10	X	207.35	149.66	357.01
20	122.12	180.84	184.09	487.05
30	116.4	164.73	57.16	338.29
FD	338.82	320.63	315.99	975.44
REP TOTAL R	577.34	873.55	706.9	
GRAND TOTAL T				2157.8

REPLICATION X TREATMENT TABLE 4.7 (mm) WA 84 DAP

treatments	REP I	REP II	REP III	TOTAL (T)
10	X	122.64	205.27	327.81
20	101.86	110.58	173.88	386.32
30	94.57	171.49	60.28	326.34
FD	297.25	241.95	262.94	802.14
REP TOTAL R	493.68	646.66	702.37	
GRAND TOTAL T				1842.71

REPLICATION X TREATMENT TABLE 4.8 (mm) WA 98 DAP

treatments	REP I	REP II	REP III	TOTAL (T)
10	X	151.21	84.18	235.39
20	98.73	76.9	96.37	272
30	77.95	111.72	36.37	226.04
FD	266.06	174.08	233.33	673.47
REP TOTAL R	442.74	513.91	450.25	
GRAND TOTAL T				1406.9

REPLICATION X TREATMENT TABLE E.5 (Kg) YIELD

treatments	REP I	REP II	REP III	TOTAL (T)
10	x	0.1057	0.0398	0.1455
20	0.1785	0.0752	0.0901	0.3438
30	0.1729	0.1427	0.031	0.3466
FD	0.1371	0.2313	0.3024	0.6708
REP TOTAL R	0.4885	0.5549	0.4633	
GRAND TOTAL T				1.5067

TABLE 2 (continued)

Crop	Sensitivity to salinity	Fertilizer requirements kg/ha/growing period			Water requirements mm/growing period	Sensitivity to water supply (ky)[2/]	Water utilization efficiency for harvested yield Ey, kg/m^3 (% moisture)
		N	P	K			
Alfalfa	moderately sensitive	0-40	55-65	75-100	800-1600	low to medium high (0.7-1.1)	1.5 - 2.0 hay (10-15%)
Banana	sensitive	200-400	45-60	240-480	1200-2200	high (1.2-1.35)	plant crop: 2.5-4 ratoon : 3.5-6 fruit (70%)
Bean	sensitive	20-40	40-60	50-120	300-500	medium-high (1.15)	pod: 1.5-2.0 (80-90%) grain: 0.3-0.6 (10%)
Cabbage	moderately sensitive	100-150	50-65	100-130	380-500	medium-low (0.95)	12-20 head (90-95%)
Citrus	sensitive	100-200	35-45	50-160	900-1200	low to medium-high (0.8-1.1)	2-5 fruit (85%, lime; 70%)
Cotton	tolerant	60-150	20-60	50-80	700-1300	medium-low (0.85)	0.4-0.6 seed cotton (10%)
Grape	moderately sensitive	100-160	40-60	160-230	500-1200	medium-low (0.85)	2-4 fresh fruit (80%)
Groundnut	moderately sensitive	10-20	15-40	25-40	500-700	low (0.7)	0.6-0.8 unshelled dry nut (15%)
Maize	moderately sensitive	100-200	50-80	60-100	500-800	high (1.25)	0.8-1.6 grain (10-13%)
Olive	moderately tolerant	200-250	55-70	160-210	600-800	low	1.5-2.0 fresh fruit (30%)
Onion	sensitive	60-100	25-45	45-80	350-550	medium-high (1.1)	8-10 bulb (85-90%)
Pea	sensitive	20-40	40-60	80-160	350-500	medium-high (1.15)	pod: 0.5-0.7 shelled (70-80%) grain: 0.15-0.2 (12%)
Pepper	moderately sensitive	100-170	25-50	50-100	600-900 (1250)	medium-high (1.1)	1.5-3.0 fresh fruit (90%)
Pineapple		230-300	45-65	110-220	700-1000	low	plant crop: 5-10 ratoon : 8-12 fruit (85%)

TABLE 1G **Mean daily maximum duration of bright sunshine hours N for different months and latitudes.**

(*Source*: Doorenbos and Pruitt, 1975)

Northern Latitudes	*Jan.*	*Feb.*	*March*	*April*	*May*	*June*	*July*	*Aug.*	*Sept.*	*Oct.*	*Nov.*	*Dec.*
Southern Latitudes	*July*	*Aug.*	*Sept.*	*Oct.*	*Nov.*	*Dec.*	*Jan.*	*Feb.*	*March*	*April*	*May*	*June*
50°	8.5	10.1	11.8	13.8	15.4	16.3	15.9	14.5	12.7	10.8	9.1	8.1
48°	8.8	10.2	11.8	13.6	15.2	16.0	15.6	14.3	12.6	10.9	9.3	8.3
46°	9.1	10.4	11.9	13.5	14.9	15.7	15.4	14.2	12.6	10.9	9.5	8.7
44°	9.3	10.5	11.9	13.4	14.7	15.4	15.2	14.0	12.6	11.0	9.7	8.9
42°	9.4	10.6	11.9	13.4	14.6	15.2	14.9	13.9	12.9	11.1	9.8	9.1
40°	9.6	10.7	11.9	13.3	14.4	15.0	14.7	13.7	12.5	11.2	10.0	9.3
35°	10.1	11.0	11.9	13.1	14.0	14.5	14.3	13.5	12.4	11.3	10.3	9.8
30°	10.4	11.1	12.0	12.9	13.6	14.0	13.9	13.2	12.4	11.5	10.6	10.2
25°	10.7	11.3	12.0	12.7	13.3	13.7	13.5	13.0	12.3	11.6	10.9	10.6
20°	11.0	11.5	12.0	12.6	13.1	13.3	13.2	12.8	12.3	11.7	11.2	10.9
15°	11.3	11.6	12.0	12.5	12.8	13.0	12.9	12.6	12.2	[illegible]	11.4	11.2
10°	11.6	11.8	12.0	12.3	12.6	12.7	12.6	12.4	12.1	11.8	11.6	11.5
5°	11.8	11.9	12.0	12.2	12.3	12.4	12.3	12.3	12.1	12.0	11.9	11.8
0°	12.1	12.1	12.1	12.1	12.1	12.1	12.1	12.1	12.1	12.1	12.1	12.1

Table 26 Extra-terrestrial radiation R_a expressed in equivalent evaporation in mm/day.

Northern hemisphere												Southern hemisphere											
Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Lat.	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
6.1	9.1	12.7	15.8	17.1	16.4	14.1	10.9	7.4	4.5	3.2	50°	17.5	14.7	10.9	7.0	4.2	3.1	3.5	5.5	3.9	12.9	16.5	18.2
6.6	9.1	13.0	15.9	17.2	16.5	14.3	11.2	7.8	5.0	3.7	48	17.6	14.9	11.2	7.5	4.7	3.5	4.0	6.0	9.3	13.2	16.6	18.2
7.1	10.1	13.3	16.0	17.2	16.6	14.5	11.5	8.3	5.5	4.3	46	17.7	15.1	11.5	7.9	5.2	4.0	4.4	6.5	9.7	13.4	16.7	18.3
7.6	10.1	13.7	16.1	17.2	16.6	14.7	11.9	8.7	6.0	4.7	44	17.8	15.3	11.9	8.4	5.7	4.4	4.9	6.9	10.2	13.7	16.7	18.3
8.1	11.0	14.0	16.2	17.3	16.7	15.0	12.2	9.1	6.5	5.2	42	17.8	15.5	12.2	8.8	6.1	4.9	5.4	7.4	10.6	14.0	16.8	18.3
8.6	11.4	14.3	16.4	17.3	16.7	15.2	12.5	9.6	7.0	5.7	40	17.9	15.7	12.5	9.2	6.6	5.3	5.9	7.9	11.0	14.2	16.9	18.3
9.0	11.8	14.5	16.4	17.2	16.7	15.3	12.8	10.0	7.5	6.1	38	17.9	15.8	12.8	9.6	7.1	5.8	6.3	8.3	11.4	14.4	17.0	18.3
9.4	12.1	14.7	16.4	17.2	16.7	15.4	13.1	10.6	8.0	6.6	36	17.9	16.0	13.2	10.1	7.5	6.3	6.8	8.8	11.7	14.6	17.0	18.2
9.8	12.4	14.8	16.5	17.1	16.8	15.5	13.4	10.8	8.5	7.2	34	17.8	16.1	13.5	10.5	8.0	6.8*	7.2	9.2	12.0	14.9	17.1	18.2
10.2	12.8	15.0	16.5	17.0	16.8	15.6	13.6	11.2	9.0	7.8	32	17.8	16.2	13.8	10.9	8.5	7.3	7.7	9.6	12.4	15.1	17.2	18.1
10.7	13.1	15.2	16.5	17.0	16.8*	15.7	13.9	11.6	9.5	8.3	30	17.8	16.4	14.0	11.3	8.9	7.8	8.1	10.1	12.7	15.3	17.3	18.1
11.1	13.4	15.3	16.5	16.8	16.7	15.7	14.1	12.0	9.9	8.8	28	17.7	16.4	14.3	11.6	9.3	8.2	8.6	10.4	13.0	15.4	17.2	17.9
11.5	13.7	15.3	16.4	16.7	16.6	15.7	14.3	12.3	10.3	9.3	26	17.6	16.4	14.4	12.0	9.7	8.7	9.1	10.9	13.2	15.5	17.2	17.8
11.9	13.9	15.4	16.4	16.6	16.5	15.8	14.5	12.6	10.7	9.7	24	17.5	16.5	14.6	12.3	10.2	9.1	9.5	11.2	13.4	15.6	17.1	17.7
12.3	14.2	15.5	16.3	16.4	16.4	15.8	14.6	13.0	11.1	10.2	22	17.4	16.5	14.8	12.6	10.6	9.6	10.0	11.6	13.7	15.7	17.0	17.5
12.7	14.4	15.6	16.3	16.4	16.3	15.9	14.8	13.3	11.6	10.7	20	17.3	16.5	15.0	13.0	11.0	10.0	10.4	12.0	13.9	15.8	17.0	17.4
13.0	14.1	16.6	16.1	16.1	16.1	15.8	14.9	13.6	12.0	11.1	18	17.1	16.5	15.1	13.2	11.4	10.4	10.8	12.3	14.1	15.8	16.8	[illegible]
13.3	14.7	15.6	16.0	15.9	15.9	15.7	15.0	13.9	12.4	11.6	16	16.9	16.4	15.2	13.5	11.7	10.8	11.2	12.6	14.3	15.8	16.7	[illegible]
13.6	14.9	15.7	15.8	15.7	15.7	15.7	15.1	14.1	12.8	12.0	14	16.7	16.4	15.3	13.7	12.1	11.2	11.6	12.9	14.5	15.8	[illegible]	[illegible]
13.9	15.1	15.7	15.7	15.5	15.5	15.6	15.2	14.4	13.3	12.5	12	16.6	16.3	15.4	14.0	12.5	11.6	12.0	13.2	14.7	15.8	16.4	[illegible]
14.2	15.3	15.7	15.5	15.3	15.3	15.5	15.3	14.7	13.6	12.9	10	16.4	16.3	15.5	14.2	12.8	12.0	12.4	13.5	14.8	15.9	16.2	16.2
14.5	15.3	15.6	15.3	15.0	15.1	15.4	15.3	14.8	13.9	13.3	8	16.1	16.1	15.5	14.4	13.1	12.4	12.7	13.7	14.9	15.8	16.0	16.0
14.8	15.4	15.4	15.1	14.7	14.9	15.2	15.3	15.0	14.2	13.7	6	15.8	16.0	15.6	14.7	13.4	12.8	13.1	14.0	15.0	15.7	15.8	15.7
15.0	15.5	15.5	14.9	14.4	14.6	15.1	15.3	15.1	14.5	14.1	4	15.5	15.8	15.6	14.9	13.8	13.2	13.4	14.3	15.1	15.6	15.5	15.4
15.3	15.6	15.3	14.6	14.2	14.3	14.9	15.3	15.3	14.8	14.4	2	15.3	15.7	15.7	15.1	14.1	13.5	13.7	14.5	15.2	15.5	15.3	15.1
15.5	15.7	15.3	14.4	13.9	14.1	14.8	15.3	15.4	15.1	14.8	0	15.0	15.5	15.7	15.3	14.4	13.9	14.1	14.8	15.3	15.4	15.1	14.8

TABLE 3G [illegible] mean air temperature t in °C.

Temperature °C	$e_s m$ bar
0	6.1
1	6.6
2	7.1
3	7.6
4	8.1
5	8.7
6	9.4
7	10.0
8	10.7
9	11.5
10	12.3
11	13.1
12	14.0
13	15.0
14	16.1
15	17.0
16	18.2
17	19.4
18	20.6
19	22.0
20	23.4
21	24.9
22	26.4
23	28.1
24	29.3
25	31.7
26	33.6
27	35.[illegible]
28	37.[illegible]
29	40.[illegible]
30	42.[illegible]
31	44.[illegible]
32	47.[illegible]
33	50.[illegible]
34	53.[illegible]
35	56.[illegible]
36	59.[illegible]
37	62.[illegible]
38	66.[illegible]
39	69.9

3.·17

TABLE 4G **Values of wind function, $f(u) = 0.27\ (1 + W'_2/100)$ for wind run at a 2 m height in km/day.**

·d d ·y	*0*	*10*	*20*	*30*	*40*	*50*	*60*	*70*	*80*	*90*
		0.30	0.32	0.35	0.38	0.41	0.43	0.46	0.49	0.51
·0	0.54	0.54	0.59	0.62	0.65	0.67	0.70	0.73	0.76	0.78
·0	0.81	0.84	0.86	0.89*	0.92	0.94	0.97	1.00	1.03	1.05
·0	1.08	1.11	1.13	1.16	1.19	1.21	1.24	1.27	1.30	1.32
·0	1.35	1.38	1.40	1.43	1.46	1.39	1.51	1.54	1.57	1.59
·0	[illegible]	1.65	1.67	1.70	1.73	1.76	1.78	1.81	1.84	1.80
·00	1.89	1.92	1.94	1.97	2.00	2.02	2.05	2.08	2.11	2.15
·00	2.16	2.19	2.21	2.24	2.27	2.29	2.32	2.35	2.38	2.40
·00	2.43	2.46	2.48	2.51	2.54	2.56	2.59	2.62	2.65	2.65
·00	2.70									

* Where wind data are not collected at 2 metre height the appropriate corrections for wind measurements taken at different heights are ...n below:

Measurement height, *m*	0.5	1.0	1.5	2.0	3.0	4.0	5.0	6.0	10.0
Correction factor	1.35	1.15	1.06	1.00	0.93*	0.88	0.85	0.83	0.77

erature °C		2	4	6	8	10	12	14	16	18	20	22	24	26	28	30	32	34	36	38	40
W) at	m																				
altitude	0	0.57	0.54	0.51	0.48	0.45	0.42	0.39	0.36	0.34	0.32	0.29	0.27	0.25	0.23*	0.22	0.20	0.18	0.17	0.16	0.15
	500	0.56	0.52	0.49	0.46	0.43	0.45	0.38	0.35	0.33	0.30	0.28	0.26	0.24	0.22	0.21	0.19	0.18	0.16	0.15	0.14
	1000	0.54	0.51	0.48	0.45	0.42	0.39	0.36	0.34	0.31	0.29	0.27	0.25	0.23	0.21	0.20	0.18	0.17	0.15	0.14	0.13
	2000	0.51	0.48	0.45	0.42	0.39	0.36	0.34	0.31	0.29	0.27	0.25	0.23	0.21	0.19	0.18	0.16	0.15	0.14	0.13	0.12
	3000	0.48	0.45	0.42	0.39	0.36	0.34	0.31	0.29	0.27	0.25	0.23	0.21	0.19	0.18	0.16	0.15	0.14	0.13	0.12	0.11
	4000	0.46	0.42	0.39	0.36	0.34	0.31	0.29	0.27	0.25	0.23	0.21	0.19	0.18	0.16	0.15	0.14	0.13	0.12	0.11	0.10

$W = \Delta / (\Delta + r)$ in which Δ is the rate of change of the saturation vapour pressure with temperature and r is the psychrometric constant.

TABLE 66 **Values of weighting factor W for the effect of radiation of ET_o at different temperatures and altitudes.**

emperature °C		2	4	6	8	10	12	14	16	18	20	22	24	26	28	30	32	34	36	38	40
W at altitude	m																				
	0	0.43	0.46	0.49	0.52	0.55	0.58	0.61	0.64	0.66	0.68	0.71	0.73	0.75	0.77*	0.78	0.80	0.82	0.83	0.84	0.85
	500	0.44	0.48	0.51	0.54	0.57	0.60	0.62	0.65	0.67	0.70	0.72	0.74	0.76	0.78	0.79	0.81	0.82	0.84	0.85	0.86
	1000	0.46	0.49	0.52	0.55	0.58	0.61	0.64	0.66	0.69	0.71	0.73	0.75	0.77	0.79	0.80	0.82	0.83	0.85	0.86	0.87
	2000	0.49	0.52	0.55	0.58	0.61	0.64	0.66	0.69	0.71	0.73	0.75	0.77	0.79	0.81	0.82	0.84	0.85	0.86	0.87	0.88
	3000	0.52	0.55	0.58	0.61	0.64	0.66	0.69	0.71	0.73	0.75	0.77	0,79	0.81	0.82	0.84	0.85	0.86	0.87	0.88	0.89
	4000	0.54	0.58	0.61	0.64	0.66	0.69	0.71	0.73	0.75	0.77	0.79	0.81	0.82	0.64	0.85	0.86	0.87	0.89	0.90	0.90