THE UNIVERSITY OF MANITOBA

THE EFFECTIVE LIFE OF 'VIAFLO' DRIP TUBING FOR IRRIGATION

by

MAITREE JUANGPANICH

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ABSTRACT

The performance of Viaflo drip irrigation tubing used for one season was compared to the performance of previously unused tubing in laboratory and field tests. The experimental field layout consisted of six treatments: irrigation by surface and subsurface installed Viaflo tubing previously used for one year, surface and subsurface installed Viaflo tubing previously unused, furrow irrigation and no irrigation.

Fertilizer was not applied until the corn showed a nitrogen deficiency. At that point in time, 100 kg/ha of ammonium nitrate (formula 32-0-0) was applied directly near the root zone in every treatment.

A Troxler depth moisture gauge Model 1255 and a Troxler ratemeter Model 2651 were used for soil moisture measurements.

The soil moisture content under drip irrigation fluctuated down to the 60-cm depth while moisture levels below a depth of 100 cm remained fairly constant. Under furrow irrigation the moisture content increased considerably after irrigation up to the 140-cm depth.

The maximum yield of corn was obtained with the furrow-irrigation treatment but, in terms of water use efficiency, all drip-irrigation treatments were better than furrow irrigation and both new tubing installations

were substantially better than the old tubing installations. Nitrogen deficiency and weeds evidently affected yields appreciably.

'Viaflo' tubing was very susceptible to mechanical damage, algae growth and ultraviolet degradation, especially in the surface installations. In surface installations, 'Viaflo' tubing could not be used for more than two seasons, while in subsurface installations it appeared to be in good condition and suitable for use in third season.

Drip irrigation in this study failed to control weeds, because of rainfall, weeds could grow between the crop rows and some, such as the broadleaved Plantain (Plantago Major L), were even more abundant and stronger in the area near the drip lines. Their roots developed close to the subsurface drip lines and may have adversely affected the uniformity of water application from the drip lines.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER I

INTRODUCTION

Demand for water is increasing due to increase in population, rapid industrialization and increasing requirements for irrigation. When water resources are limited, water must be used more effectively. In the agricultural sector, this is possible by using irrigation methods which have high water use efficiency. Advancement of technology resulted in the development of irrigation methods from surface methods to sprinkler and drip irrigation in the pursuit of this goal.

Surface irrigation was the first method practised many thousand years ago. Even now, it still is the most important irrigation method in many developing countries. The water-use efficiency of surface irrigation is very low and it is often characterized by waterlogging and salinity problems.

From 1920 to 1940 manufacturers were becoming interested in sprinkler systems and the first impact-type rotating sprinklers were developed. In 1945 the introduction of aluminum tubing gained added acceptance for sprinkler irrigation (Lanham 1976). The main advantages of sprinkler irrigation are the water economy possible and its universality. It can be used where it is either difficult or impractical to irrigate by any of the surface methods. But the high cost and poor uniformity of water application during windy days may limit its water use efficiency (Agriculture Canada 1975).

The practice of subsurface irrigation, in which water is applied directly to the root zone of the crop, resulted not only in increased crop yields but also in savings of water. From the idea of subsurface irrigation, trickle irrigation was developed. In Israel trickle irrigation has been employed as a tool to greatly improve the desert agriculture. Now trickle irrigation is used in many countries around the world including Israel, Australia, the USA and South Africa. Gustafson et al. (1974) estimated that Israel had over 6,000 ha, Australia over 10,000 ha, Mexico about 6,500 ha, the USA over 28,700 ha, South Africa about 3,500 ha and British Columbia in Canada more than 200 ha under trickle irrigation. There were about 60,000 ha under trickle irrigation in the world at that time and it was projected to reach 150,000 ha within the next five years.

At present, there are many trickle irrigation systems and components already on the market. But many problems have to be solved or at least better illustrated before recommendations can be made about the use of a particular type of trickle system in a particular set of conditions (Spiess 1973). The high-frequency porous tubing 'Viaflo' is one of the trickle irrigation systems available on the market. It has been tested and it showed good performance in the distribution of the wetting pattern at various application rates. At the end of the first season it appeared to be in suitable condition for use in the next season (Spiess 1974 and Udeh 1975).

The objectives of this study were to evaluate the porous tubing 'Viaflo' that was used during May through September in 1975 as compared to new 'Viaflo' tubing available for use in the irrigation of row crops in Manitoba. The comparison of the used and new 'Viaflo' tubing was based on:

1. laboratory and field performance characteristics,
2. crop response to surface and subsurface installations of used and new tubing each compared with crop responses under furrow irrigation, and
3. water-use efficiency of each treatment.

CHAPTER II

REVIEW OF LITERATURE

2.1 Trickle Irrigation Systems Definition and Concepts

Trickle irrigation is a new approach to irrigated agriculture characterized by the development of new irrigation water application techniques (Edminster 1974). The term 'trickle' was introduced in England, 'drip' in Israel and 'daily flow' in Australia (Kenworthy 1972).

Karmeli and Keller (1975) explained that trickle irrigation is a system for supplying filtered water (and fertilizer) directly onto or into the soil. It eliminates spraying water or running it down furrows or rills and allows water to dissipate under low pressure in exact, predetermined patterns. They also stated that the water outlets dissipate the pressure in the pipe distribution network by means of either a small-diameter orifice or a long flow path, and thereby decrease the water pressure to allow discharge of only a few litres per hour.

Aggarwal et al. (1973) defined drip irrigation as a modification of the conventional old type of sub-surface irrigation system, the main difference being that a small measured quantity of water is applied daily instead of higher applications at intervals of a few days as is usual in the older subirrigation practices. Howell and Hiller

(1974) described drip irrigation as a method of watering plants frequently with volumes of water approaching the consumptive use of the plants thereby minimizing such 'conventional' losses as deep percolation, runoff, and soil water evaporation. Another basic concept taken into account with trickle irrigation is that the soil needs water only in the area where the plant roots are situated and not over the entire field (Udeh 1975).

2.2 Development of Trickle Irrigation

Trickle irrigation was developed originally as subsurface irrigation. The first experiments began in Germany in 1860 as a combination of irrigation with a tile drainage system. Similar experiments followed in the U.S.S.R. and in France (Karmeli and Keller 1975).

The development of low-cost perforated plastic pipe started the introduction of trickle irrigation systems similar to those in use today. The first trickle irrigation system of the type used today was introduced in the early 1940's for use in greenhouses in England. It was developed to provide both irrigation and fertilization in a single system. A significant step in the evaluation of this method was made in Israel in the late 1950's and from 1960, trickle irrigation developed into an important new method of irrigation (Aggarwal et al. 1973 and Karmeli and Keller 1975). Since then trickle irrigation has raised considerable interest among many users in many countries, in the growing of many different crops. Today it is used extensively in fields, orchards and greenhouses in Australia, Europe, Israel, Japan, Mexico, South Africa and the USA. The size of the trickle-irrigated area keeps increasing rapidly every year (Grossi 1974).

2.3 Trickle Irrigation System Components

A trickle irrigation system consists of the following components (Goldberg and Shmueli 1970, Spiess 1973 and Udeh 1975).

1. The 'head unit' connected to the main water supply and including a pump, filters, valves, a water meter, pressure gauges, pressure regulators and a fertilizer apparatus if fertilizer is applied with the system.
2. Conduction pipes (main lines) of the proper diameter according to distance and discharge.
3. The drip lines with emitters as the outlet device that emits water into the soil.

2.4 Operation of Trickle Irrigation Systems

2.4.1 The head unit.

The head unit is often located at the source of water supply. Suspended solids are removed from the water by filters which need cleaning from time to time due to clogging. Pressure gauges are usually used to monitor pressure differences across the filter. The pressure drop indicates the degree of clogging in the filter and the need for its cleaning. The criteria for the selection of the required level of filtration for trickle irrigation depend upon the type of emitters used in the system. The selection of filters for some systems may result in the use of a combination of two or more types of filters (Goldberg and Shmueli 1970).

The pressure regulators are often located at the entrance to the conduction pipes or distribution tubes. This is a safety precaution designed to maintain a constant head for a uniform distribution of pressure at the emitters.

2.4.2 The conduction pipes or main lines.

The conduction pipes or main lines bring water from the head unit to the field. They may be made of any non-corroding and non-scaling materials to avoid water contamination problems from within the pipe system.

2.4.3 The drip lines with emitters.

The drip lines with emitters release water from the pipes or tubes and supply it to the root zone of the crops. They can be designed in many forms in order to reduce the pipe pressure so that the water leaves the system in the form of drops. After leaving the emitters, water is distributed by its natural movement through the soil profile.

The simplest emitter system can be made from plastic pipe material, with punched holes of 0.5 mm to 2.0 mm in diameter in the pipe wall but such systems are not very effective (Wolff 1974). Recently there have been many types of more sophisticated emitters available commercially in North America and in Europe. Such emitters dissipate the pressure in the pipe distribution network by means of small diameter orifices or of long flow paths. Another drip irrigation system uses tubings with permeable walls through which irrigation water penetrates at low rates. One such system called 'Viaflo', is the subject of this study.

Viaflo, a product of the Dupont Company of the USA, is a 1.6-cm diameter white porous polyethelene tubing which allows the trickling of water along its entire length. The recommended water pressure in Viaflo lines is 20.68 KPa to 27.58 KPa. At this pressure water oozes through the pipe wall at a rate of 1,253 litres per day per 100 m of tubing length. The pore size is normally four microns and the pores occupy 50 percent of the wall area.

2.5 Research on Trickle Irrigation

2.5.1 Crop rooting pattern and soil moisture under trickle irrigation.

Typically a trickle irrigation system wets only a portion of the soil surface. Goldberg and Shmueli (1970) and Berstein and Francois (1973) found that in arid regions the development of the crop root system is limited to the area of moisture surrounding each emitter but that roots from adjacent crop rows may overlap in their search for water and nutrients. The application of fertilizers with irrigation water helps to balance the nutrients required for optimum growth.

In humid regions rainfall supplies most of the moisture needs of the crops and rooting system is not restricted to the volume of soil that is wetted by the emitters. The roots will grow into soil zones that are wetted by rainfall (Harrison and Myers 1974).

With trickle irrigation the soil moisture stress should never exceed 75 KPa. In fact, a desirable limit is 50 KPa. Within this limited readily available moisture range, tensiometers can operate properly, continuously and reliably as soil moisture detectors (Goldberg 1971).

2.5.2 Application of fertilizers through a trickle irrigation system.

Water-soluble fertilizers like urea, mono-ammonium phosphate, potassium nitrate and others are easily applied through the system. The advantages of this technique are the precision of application and distribution and the placement of nutrients in the root zone to reduce losses.

In low-rainfall areas where there is not sufficient rainfall to move the plant nutrients into the soil if applied on the soil surface, the most effective method to get nutrients into the root zone is the application of fertilizer with irrigation water (Grobbelaar and Lourens 1974).

Water-soluble forms of N, P, K, Ca and Mg applied through the system have proven practical (Grobbelaar and Lourens 1974, Gustafson et al. 1974 and Rolston et al. 1974).

2.5.3 Trickle irrigation with saline water.

Saline water can be used with drip irrigation, but it is necessary to use high-frequency drip irrigation to maintain a continuously high soil moisture content. In such a way concentration of salts in the soil water will be held below damaging levels. Goldberg and Shmueli (1970) successfully used irrigation water with high sulphate salts content with electric conductance of 3,000 micro-mhos per cm to irrigate tomatoes in Israel. In Abu Dhabi, Tahnoon and Aljibury (1974) used water with 5 $g.l^{-1}$ dissolved salts for drip irrigation in afforestation. Read et al. (1974) used sewage of high salinity for trickle irrigation of wine grapes in South Australia for four years. The plant growth and vigor have been satisfactory and soil salinity has remained within acceptable limits. Seifert et al. (1975) conducted an experiment in which grain sorghums were grown using trickle and surface irrigations. With irrigation water having an electrolyte concentration of 1.60 $g.l^{-1}$, the trickle-irrigated treatment resulted in yields, dry matter production and water use efficiencies significantly higher than the surface-irrigated treatment.

2.5.4 Trickle irrigation in greenhouses.

Furuta et al. (1974) compared drip, sprinkler and spray irrigation of Blue Gum eucalyptus grown in containers in a greenhouse. The soil moisture was a loam soil amended with redwood sawdust (2/3 sawdust and 1/3 soil). They found that drip irrigation could be utilized for the production of quality plants in containers and had a higher efficiency of water and fertilizers use than did other irrigation methods.

New and Roberts (1974) used switching tensiometers for soil moisture sensors with automatic drip irrigation of tomatoes in a greenhouse. They reported that an automatically controlled drip-irrigation system improved soil moisture control and crop production and reduced labor, management and water application.

2.5.5 Mechanical-move trickle irrigation system.

Wilke (1974) successfully developed a travelling trickle system in which the number of emitters could be reduced from 17,500 to 10 per ha and the diameter of the orifices increased from 0.2 mm to 20 mm. The advantage of this system is that it greatly reduces the problem of maintaining uniform flow from each emitter and the problem of clogging is eliminated.

2.5.6 Crop response to trickle irrigation.

Many studies indicated that trickle irrigation resulted in higher crop yields and considerable water savings (Goldberg and Shmueli 1970, Aggarwal et al. 1973, Bester 1974, Phene 1974 and Sterling and Pugh 1974). Bigger plants, bigger flowers, earlier flowering and more flowers were reported in Germany (Wolff 1974). But often the highest yields were obtained with sprinkler or furrow irrigation and not with trickle irrigation as reported by many researchers (Hanson and Patterson 1974, Mehdizadeh and Jahromi 1974 and Udeh 1975).

Udeh (1975) concluded that trickle irrigation does not necessarily increase yields when compared with well managed alternative systems particularly in areas of moderate climate with an adequate supply of water of reasonable quality.

2.6 Advantages of Trickle Irrigation

Many researchers have demonstrated various advantages of trickle irrigation. Beside increased crop production, the following advantages have been attributed to trickle irrigation (Grossi 1974, Paldi 1974 and Rawitz and Hillel 1974):

1. the water use efficiency of trickle irrigation is higher than the efficiency of any other method due to near elimination of deep percolation, surface runoff and evaporation losses;

2. the possibility of frequent replenishment of moisture and nutrients to the root zone reduces labor requirements;
3. drip irrigation can be successfully used where soil texture, slope or wind conditions would make the use of sprinkler or surface methods inefficient;
4. the need for spraying and dusting against some pests is reduced because the plant foliage is not wetted. The development of many insect, disease and fungi problems are claimed to be reduced;
5. reduced weed control is possible since the wetted area of soil is limited only to the root zone and the weeds can not grow well in the dry surface soil between the rows;
6. because trickle irrigation requires a smaller operating pressure and low water supply rates, it requires smaller and more economic pumping and water conveyance capacities.

2.7 Potential Problems of Trickle Irrigation

The potential problems that often plague the trickle irrigation system are enumerated below (Roberts 1974 and Karmeli and Keller 1975).

1. Because trickle irrigation supplies water in amounts approaching the consumptive use of the plant for a short time, it will not supply water for storage in the soil and, therefore, eliminates

the risk of deep percolation. The water, therefore, must be available every day or at most every few days. If for some technical problem the interval is longer than this, there will be a moisture deficit.

2. Salt accumulation often takes place along the fringes of the wetted soil parcels if low quality water is used and at least periodic natural leaching by rainfall is absent. However, only light rains can move this accumulated salt down into the zone of extensive root activity and severely injure the plants. In areas where rainfall is lower than 250 mm per year, application of sprinkler or surface irrigation may be necessary to eliminate critical levels of salt build-up.
3. The development of a crop root system may be restricted because trickle irrigation supplies moisture to a limited area and not the entire field. It is very difficult to design a system so that it will wet the optimal area required for crop growth.
4. Clogging of emitters is a serious problem. Even if effective filters are used, clogging can be caused by organic growths inside the system.
5. Periodic cleaning of filters interrupts irrigation and is time and labor-consuming.

CHAPTER III

INVESTIGATION PROCEDURES AND INSTRUMENTATION

A study comparing the performance of Viaflo tubing used for one growing season in 1975 with unused Viaflo tubing was conducted in the winter of 1975-76 in the laboratory and from May till September of 1976 in the field at Glenlea Research Station of the University of Manitoba's Faculty of Agriculture.

3.1 Laboratory Experiments

In the laboratory tests a special apparatus identical with the apparatus used by Udeh (1975) in his tests, was used to determine:

1. the head-discharge relations
2. the critical operating head at which the drip line samples failed.

3.1.1 The testing apparatus.

A water reservoir with a manometer was located on an elevated platform and supplied water through a 25-micron filter and a control valve to a container through a plastic tube. The plastic tube was connected to a float valve installed in the container to maintain a constant water level in the container. The container supplied water to the test samples by a feeder rubber tube. The container itself was attached to an electric hoist and could be moved up and down in order to provide the desired pressure head for the test samples up to 4.5 m (Figure 3.1).

The quantity of water discharged from the test samples could be determined from the drop in the water level in the reservoir as measured on the manometer attached to the reservoir. After setting the water level in the container at the predetermined operation head, the water from the container was allowed to flow and to drip from the sample. At the same time, as the water level in the container decreased, the float valve opened and the reservoir supplied more water to the container, maintaining a constant water level. The volume of water supplied from the reservoir could be read at selected time intervals on the manometer and the drip line discharge could be determined.

3.1.2 Viaflo discharge measurements.

Three types of Viaflo tubing were tested in the laboratory:

1. tubing previously unused (referred to as the NL treatment);
2. tubing previously used for one season in a surface field installation (referred to as SUL treatment);
3. tubing previously used for one season in a buried field installation (referred to as BUL treatment).

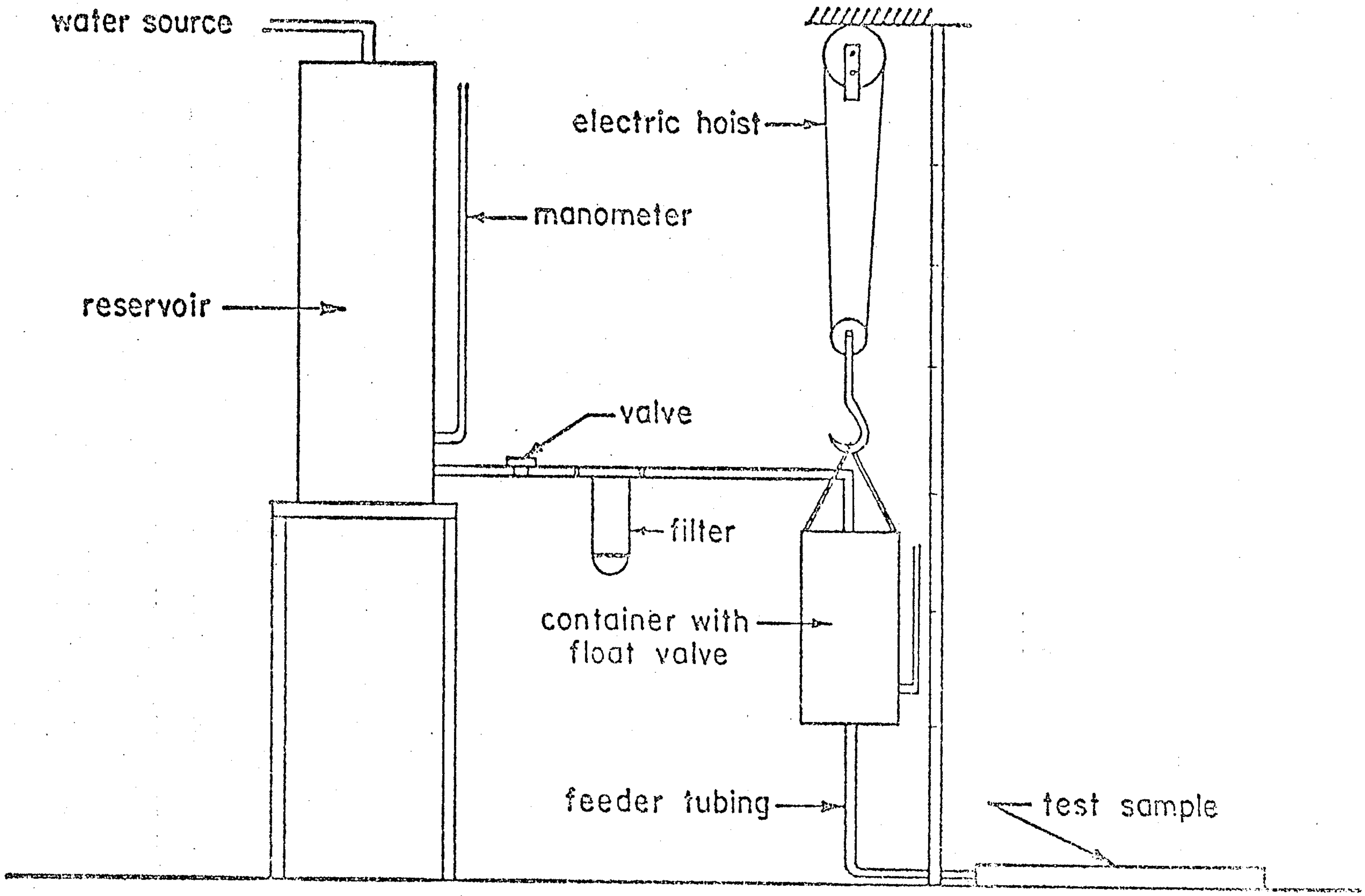

Figure 3.1 Laboratory experimental apparatus (From Udeh, 1975)

Samples 3 m long were tested at operating pressure heads of 2.5 m, 3.0 m, 3.5 m, 4.0 m and 4.5 m. Tested samples were connected to the supply tubing and left dripping for two days to reach stable condition, before the first discharge measurements were taken. A 24-hour average discharge for each operating head, was recorded for each sample.

Three different types of Viaflo tubing were tested at those pressures in the order listed above and testing of each treatment (i.e. NL, SUL, BUL) was repeated with three different samples of the same Viaflo tubing type.

3.2 Field Experiments

3.2.1 Experimental field.

Field experiments were conducted on the same location as in the 1975 season at the Glenlea Research Station of the University of Manitoba's Faculty of Agriculture. The size of the field was 100 m by 23 m and the average field slope was 1.1 percent. The field was located about 30 m from a dugout, which served as the source of irrigation water. Twenty-four rows of corn spaced 91 cm (3 ft) apart were sown on 1976 06 18.

The experimental field consisted of six plots with the following treatments:

1. a surface installation of Viaflo tubing previously used for one season in a surface field installation

(referred to as the SUF treatment);

2. a buried installation of Viaflo tubing previously used for one season in a buried field installation (referred to as the BUF treatment);
3. a surface installation of previously unused Viaflo tubing (referred to as the SNF treatment);
4. a buried installation of previously unused Viaflo tubing (referred to as the BNF treatment);
5. a furrow-irrigated control plot (referred to as the FF treatment);
6. a non-irrigated control plot (referred to as the NF treatment).

There were three rows of corn in each of the six treatments (plots) separated by a single-row buffer zone.

The layout is shown in Figure 3.2.

3.2.2 Installation of drip lines.

The drip lines were installed manually on 1976 05 24, one week after the crop was planted. The drip lines used for the surface irrigation method were laid on the surface about 5 cm from the crop row (Figure 3.3) and fixed with steel wickets to secure them against wind damage. In the subsurface irrigation method, the drip lines were buried at a depth of 5 cm and also 5 cm from the crop row.

For convenience the abbreviations listed in section 3.2.1 will be used to refer to each of the six treatments.

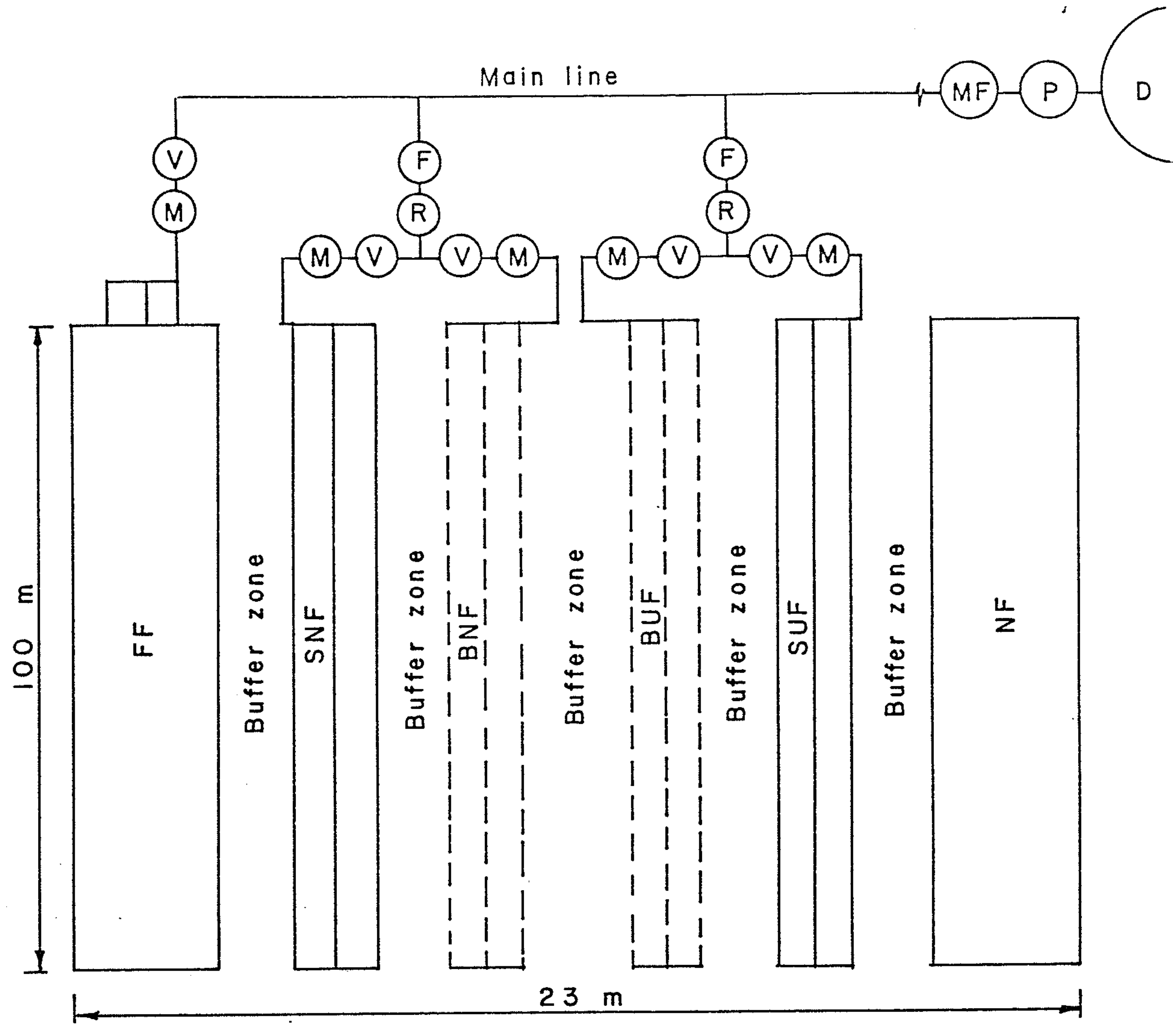

Figure 3.2 Schematic field layout (not to scale)

LEGEND

D	dugout
P	pump
MF	74-micron filter
F	25-micron filter
R	water tank with float valve mounted on wooden stand
V	control valve
M	water meter
NF	non-irrigated plot
SUF	surface installation of Viaflo tubing previously used for one season in a surface field installation plot
BUF	buried installation of Viaflo tubing previously used for one season in a buried field installation plot
SNF	surface installation of previously unused Viaflo tubing plot
BNF	buried installation of previously unused Viaflo tubing plot
FF	furrow irrigated plot

3.2.3 Installation of access tubes and tensiometers.

A neutron depth moisture probe (Troxler Model 1255) was used to monitor the soil moisture (Figure 3.4) in vertical access tubes that had been installed at selected strategic locations in each plot for this purpose. Except for the non-irrigated plot, the aluminum access tubes were installed in groups of four, referred to as moisture monitoring stations. There were three stations for each treatment. Moisture monitoring station I was located 15 m from the edge of each field, station II was in the middle of the field, 35 m from the first station. Station III was installed 35 m from the second station and 15 m from the end of the field.

In all drip-irrigated treatments, four aluminum access tubes 1.50 m in length were installed in each station to an average depth of 1.40 m, spaced approximately 45 cm apart in a row perpendicular to the crop row. Access tube no. 1 in each station was located on the crop row in the buffer zone, tube no. 2 was installed midway between the buffer zone crop row and the first crop row irrigated by drip tubing. The access tube located on the first drip-irrigated crop row was called no. 3, and tube no. 4 was situated between two crop rows irrigated by drip irrigation. In the furrow-irrigated treatment, three access tubes were installed in each station. One was in the buffer zone, another was on the crop row beside the first irrigated furrow and the third one was on the crop

Figure 3.3 Viaflo drip tube along a crop row

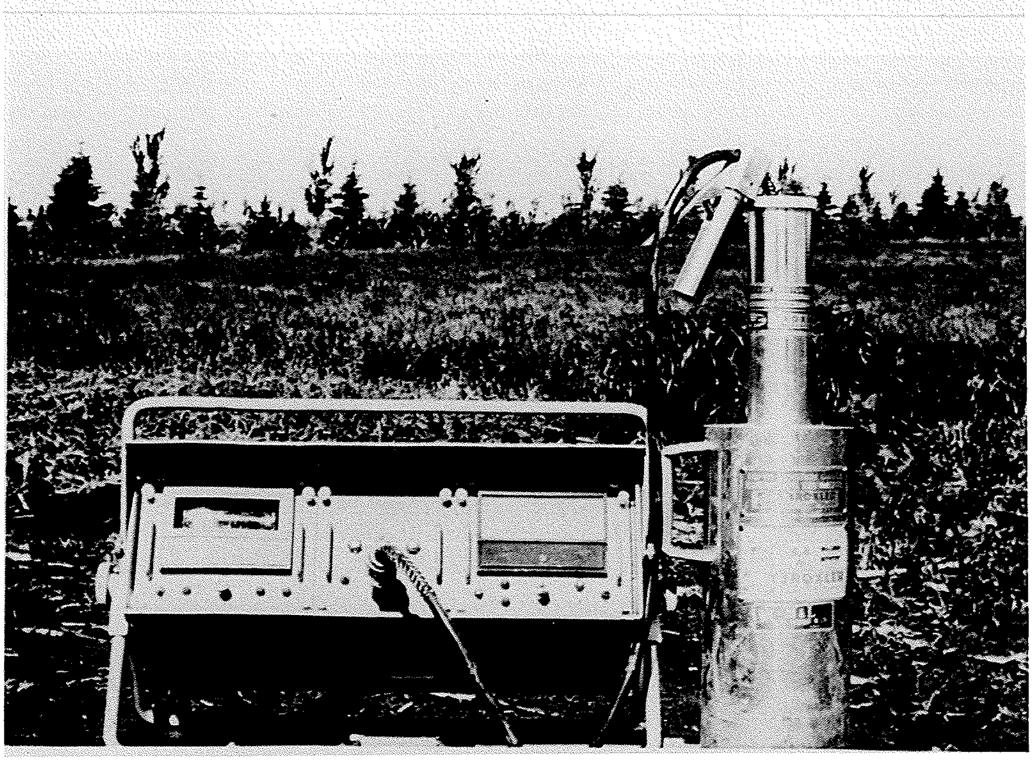

Figure 3.4 Troxler depth moisture gauge Model 1255 and Troxler ratemeter Model 2651

row between the first and the second irrigated furrows. These access tubes were called tubes nos. 1, 2 and 3, respectively. The location of the access tubes for all irrigated treatments is shown in Figure 3.5, 3.6 and 3.7.

For easy reference to each particular treatment, station and access tube, the treatment abbreviations, station and tube numbers have been used. So, for example, access tube marked SUF-I-1 is the acces tube in the surface installation of Viaflo tubing previously used for one season in a surface field installation, station I, in the buffer zone.

The access tubes were installed manually.

Irrometers (tensiometers) for monitoring the moisture stress were installed between two irrigated crop rows at a depth of 30 cm, 3 m away from each moisture monitoring station. Irrigation started when the moisture stress exceeded 20 KPa.

3.2.4 Irrigation water supply.

Water was supplied from a dugout about 30 m from the field. A Monarch* jet pump, R 120 series, 373 W and 74-micron filter located at the dugout (Figure 3.8) delivered water through a 2.5-cm diameter PVC main line to the field. The pressure switch of the pump was set to cut in at 207 KPa (30 psi) and to cut out at 345 KPa

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*Trade name.

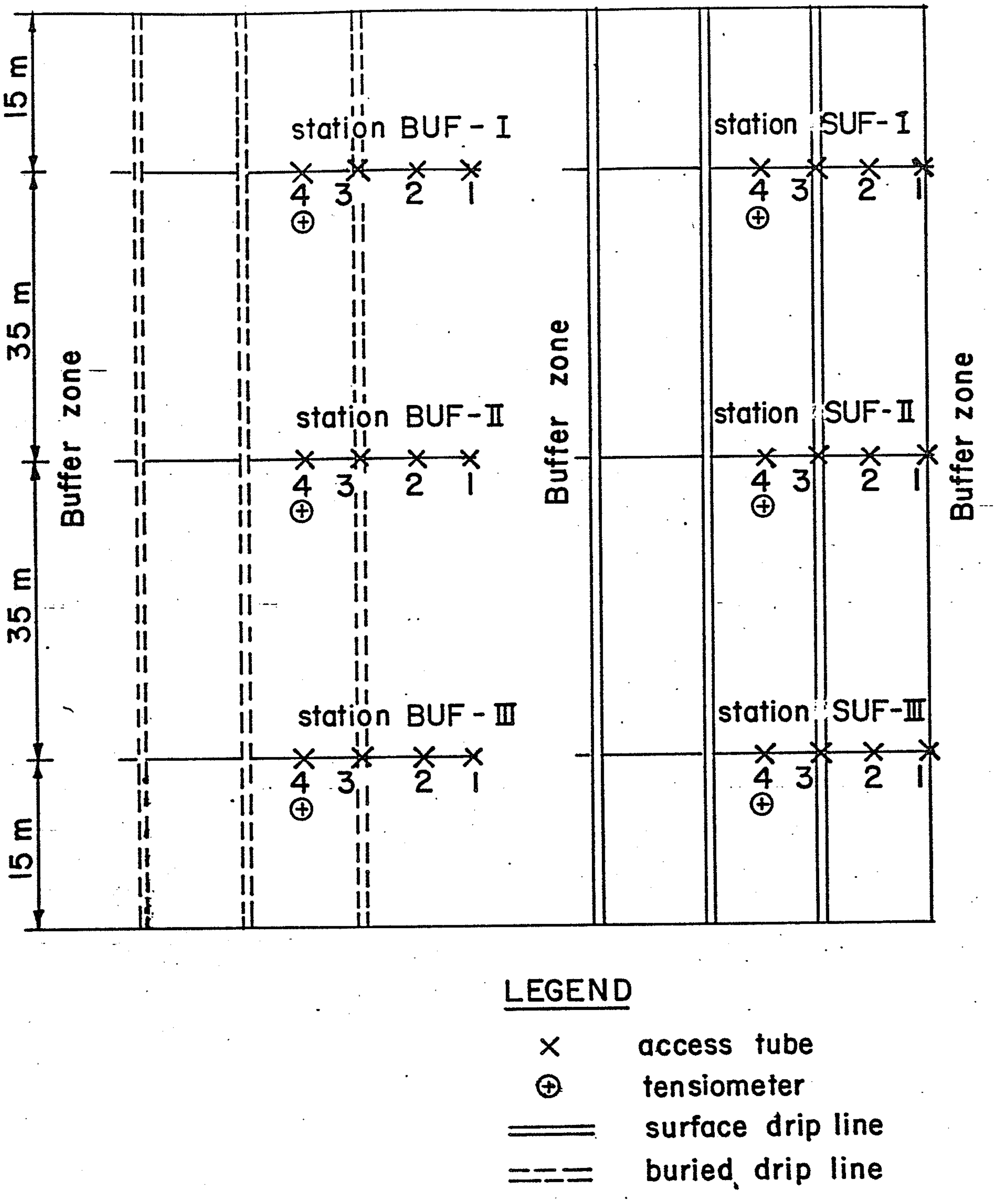

Figure 3.5 Schematic diagram of the BUF and SUF treatments. (not to scale)

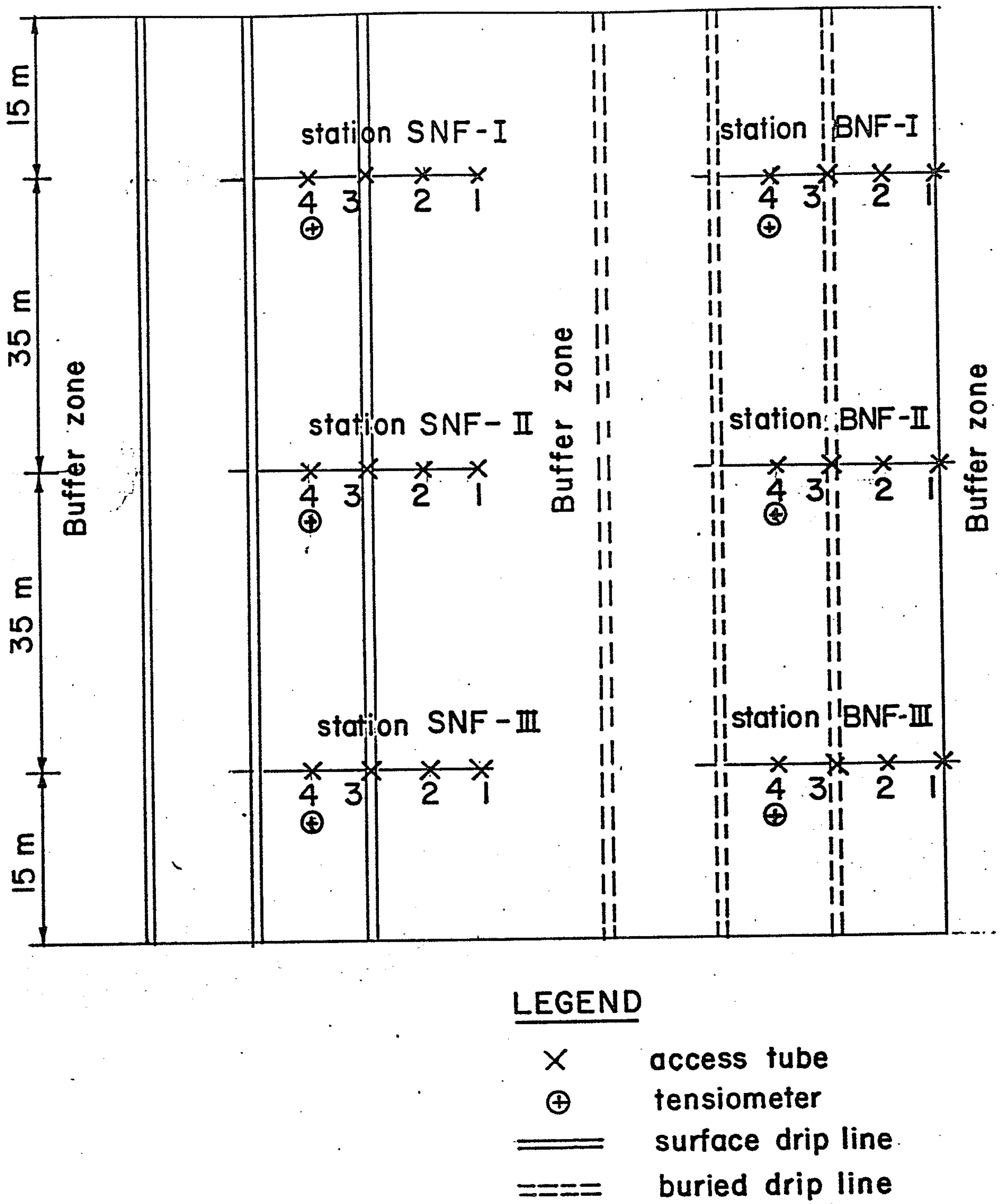

Figure 3.6 Schematic diagram of the SNF and BNF treatments (not to scale)

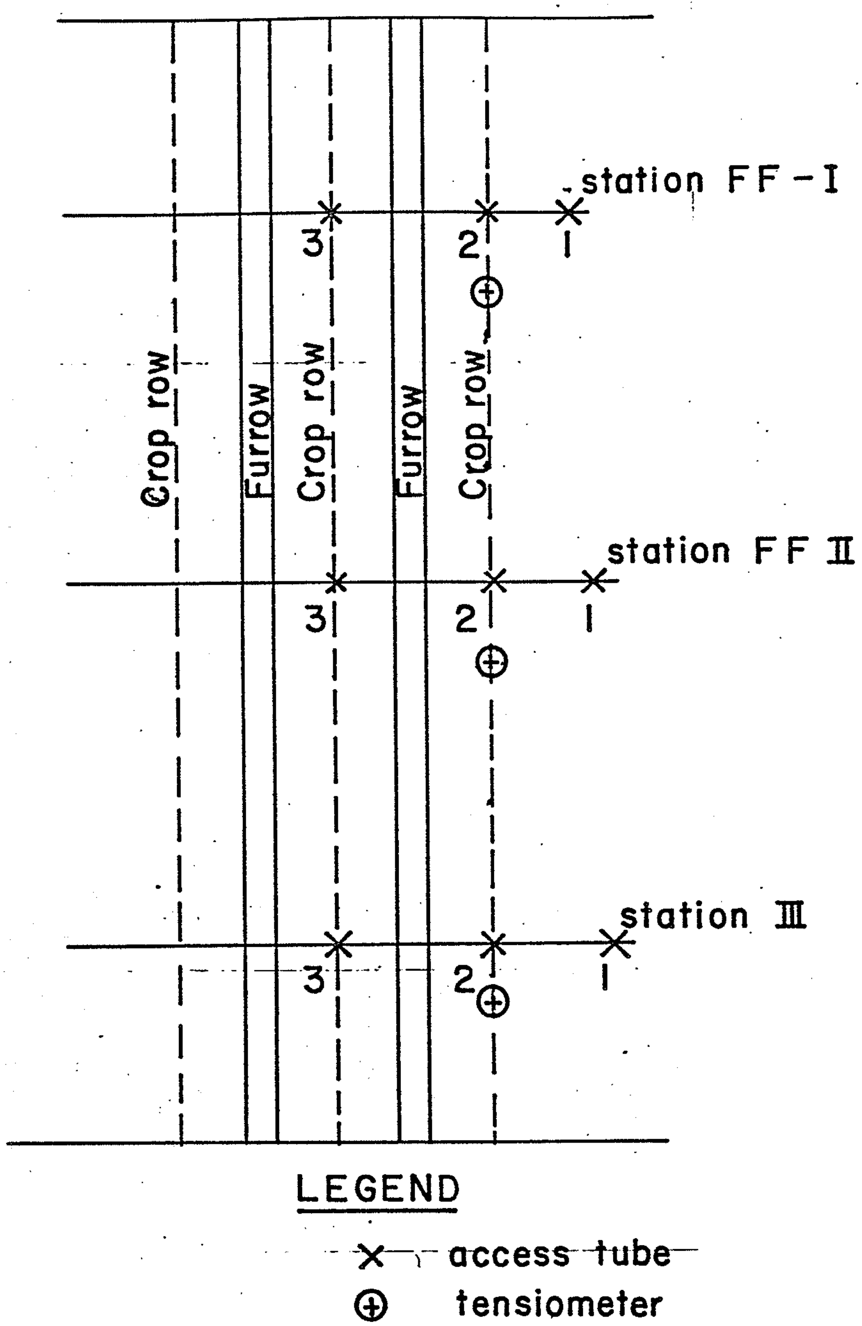

Figure 3.7 Schematic diagram of the furrow-irrigated plot (not to scale)

(50 psi). Water from the pump passed through the 74-micron filter. Two pressure gauges attached to the filter to measure the water pressure loss in the filter indicated the degree of clogging at the filter screen. The filter was cleaned when the pressure difference exceeded 138 KPa (20 psi). When this filtered water reached the field, the tubing branched and the three branches led to the furrow-irrigated plot and to two similar 25-micron filters. From each filter, water was delivered through 1.5-cm diameter plastic tubing to a container with a float valve. The two containers with float valves mounted on wooden stands located at the edge of the field maintained a constant pressure head of 3.3 m (Figure 3.9). One container supplied water to plots SUF and BUF, the other container supplied plots SNF and BNF. Water from each container was divided by a tee junction to the surface and buried drip lines. Before it reached each drip-irrigated plot, the water passed through a control valve and a water meter (Figure 3.10). From each of the four meters, water passed through a 'header line' supplying three parallel 'feeder tubes' to which the individual Viaflo drip lines were connected.

Water used for the furrow-irrigated plot came directly from the 74-micron filter and after passing through a valve and a water meter it was applied to the furrows by two 2.5-cm diameter PVC lines. The furrow irrigated plot is shown in Figure 3.11.

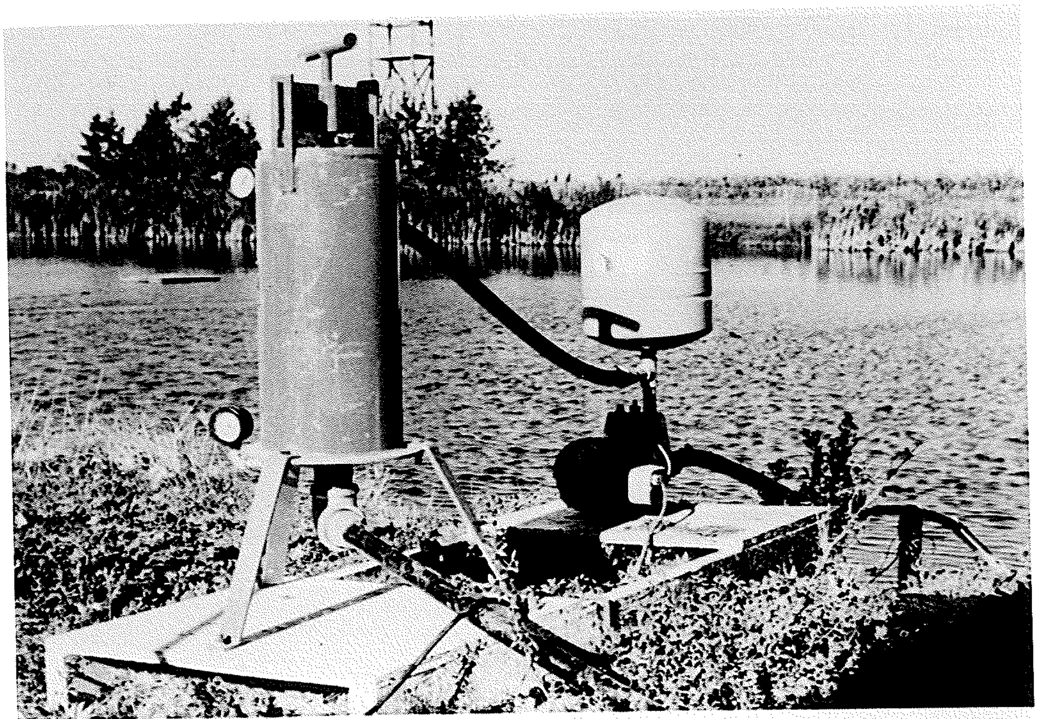

Figure 3.8 Pump and 74-micron filter at the dugout

Figure 3.9 Towers and pressure regulating water reservoirs

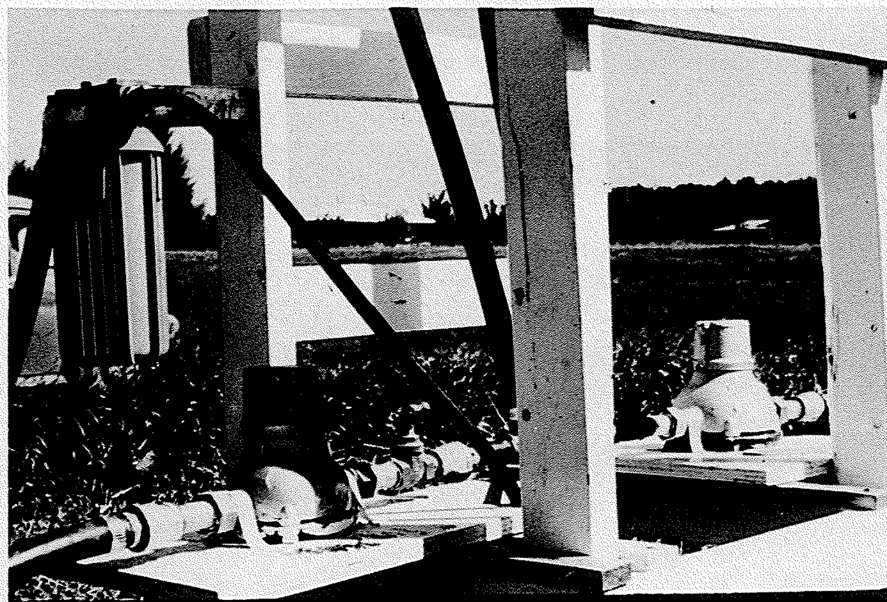

Figure 3.10 A 25-micron filter and water meters

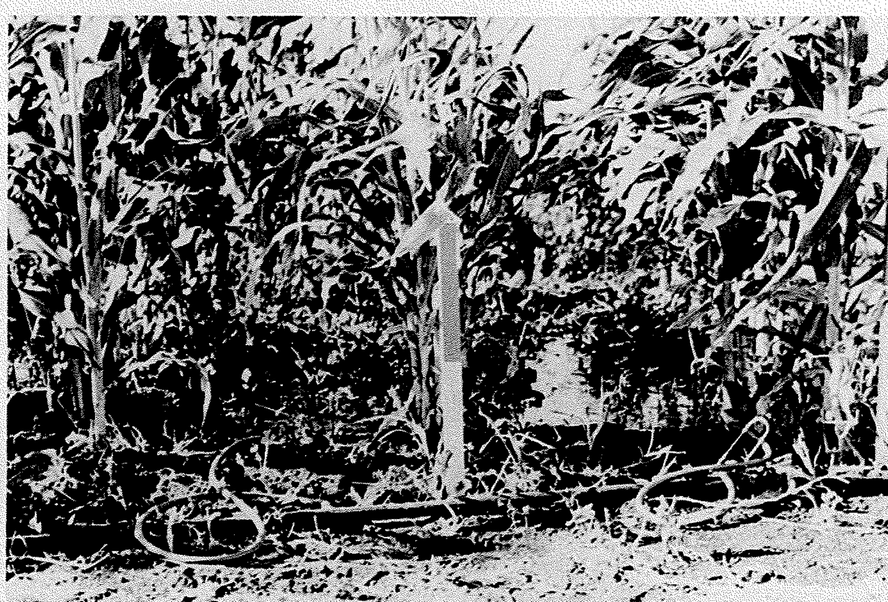

Figure 3.11 Furrow irrigation plot

3.3 Management and Monitoring of the Field Experiment

3.3.1 Irrigation water analysis.

Three water samples, one of the non-filtered water from the dugout, a second of the water which passed through the 74-micron filter only (used for furrow irrigation) and a third of the water which passed through both the 74- and the 25-micron filters (for drip irrigation) were collected. The water was analysed at the Agricultural Waste Management Laboratory in the Department of Agricultural Engineering at the University of Manitoba.

3.3.2 Weed control.

Weeds that occurred in the experiment were Barnyard grass (Echinochloa crusgalli) and broad-leaved Plantain (Plantago major). Weeding was done manually because the use of chemical to control those weeds during the previous season proved ineffective.

3.3.3 Fertilizer application.

No fertilizer was applied until the corn showed a nitrogen deficiency. Then 23 kg (50 lbs) of ammonium nitrate (formula 32-0-0) was used on 1976 08 05. The fertilizer was applied for all treatments directly to the soil near the root zone.

3.3.4 Irrigation scheduling.

All drip irrigation treatments were irrigated every workday (5 days a week), except when it rained and a few days after a heavy rain. Tensiometers were used to monitor the need for irrigation and moisture stress was maintained between 20-50 KPa.

3.3.5 Measurement of soil moisture.

Soil moisture was measured at five different levels; on the soil surface and at the depths of 30 cm, 60 cm, 100 cm and 140 cm. For the measurement of soil moisture on the surface, random soil samples from a location close to the access tubes were collected for moisture determination by the oven method. A Troxler depth moisture gauge Model 1255 and a Troxler ratemeter Model 2651 (Figure 3.4) were used for the moisture measurement at depths of 30 cm, 60 cm, 100 cm and 140 cm in every access tube. The measurements were taken almost every workday from 1976 07 02 till 1976 07 21 and from 1976 08 09 till 1976 09 02. During 1976 07 22 to 1976 08 08, the soil moisture measurement was stopped for weeding because the weed problem was so serious; it required control urgently.

CHAPTER IV

RESULTS AND DISCUSSION

4.1 Results of the Water Analysis

The combination of a 74-micron and a 25-micron filter to achieve adequate filtration of irrigation water obtained from the dugout appeared to be effective in removing a large amount of suspended solids. But according to the results of the water analysis (Table 4.1), the total residue decreased only by 6.2 percent and 1.0 percent after the water passed through the 74-micron and 25-micron filters, respectively. This apparent discrepancy occurred because the water sample from the dugout was taken near the water surface where the suspended solids content was substantially smaller than in the water near the bottom of the dugout which was disturbed by the suction pressure before it entered the pipe systems.

During the experiment, silt kept accumulating on the screen of the 74-micron filter at a rate such that it required cleaning every few days. When the water level in the dugout was low, the quantity of sediment in water increased and cleaning of the filter was required more than once a day.

TABLE 4.1

Physical and chemical properties of irrigation water (field experiment)

	Water directly from dugout ($mg.l^{-1}$)	Filtered water from 74-micron filter for furrow ($mg.l^{-1}$)	Filtered water from 74-micron & 25-micron filters for drip irrigation ($mg.l^{-1}$)
Bicarbonate	82.0	95.0	106.0
Hydroxide	0.0	0.0	0.0
Alkalinity total	140.0	175.0	220.0
pH[1]	8.4	8.2	7.6
Residue total	501.0	470.0	465.0
Phosphorous total	0.2	0.3	0.3
Chloride soluble	28.0	28.0	28.0

[1] no units

4.2 Laboratory Performance of the Viaflo Tubing

The laboratory tests had two goals: to find and to compare the head-discharge relations for the three different types of tested tubes (NL, SUL and BUL) and to determine if, and at what operating pressure, the tubes would break and to make comparisons.

The discharge from Viaflo tubes previously used for one year (SUL and BUL) was very low as compared to the previously unused tubes (NL) due to the large quantities of slurries remaining inside the tubes. The tubing previously used for one season in the buried field installation (BUL) was stronger than the tube which was previously used in the surface field installation (SUL). In the measurement of discharge at various pressure heads up to 4.5 m, only one sample out of three of each of the NL and BUL treatments ruptured while in the case of the SUL treatment two out of three samples ruptured. From the laboratory tests it appeared that the buried field installation of Viaflo tubing can be used longer than the surface field installation. All tested samples could withstand pressure head up to 3.5 m. When the pressure head was increased to 4 m, one sample of each of the NL, BUL and SUL treatments ruptured. Another SUL sample was broken at a pressure head of 4.5 m while the remaining samples i.e. one SUL and two of each of the NL and BUL treatments could withstand the pressure at that operating head. The discharges of unbroken samples increased sharply as the pressure head increased from 3.5 m to 4.0 m and from 4.0 m to 4.5 m. They would probably break if the pressure head was increased further. The relationship between pressure head and discharge for the SUL, BUL and NL treatments is shown in Figures 4.1, 4.2 and 4.3.

4.3 Field Performance of Drip Lines

As in the laboratory tests, the evaluation of the performance of the tubing in terms of water discharge and reliability (number of failures) was the main goal of the field tests.

In monitoring the discharge, however, some difficulties due to the limited water supply and the consequences of frequent ruptures of the tubing affected the results.

When the water level of the dugout was very low, the concentration of suspended solids increased and a large amount of silt accumulated at the screen of the 74-micron filter and cleaning of the filter was required several times a day. If continuous irrigation was required under such conditions, sometime the pressure in the drip line could not be maintained at 3.3 m of pressure head because of the limited water supply resulting from clogging at the screen of the 74-micron filter. Another problem that affected the discharge results arose from damage to the drip lines during the experiment. When a tube was broken, the repair was done as soon as possible by reconnecting it

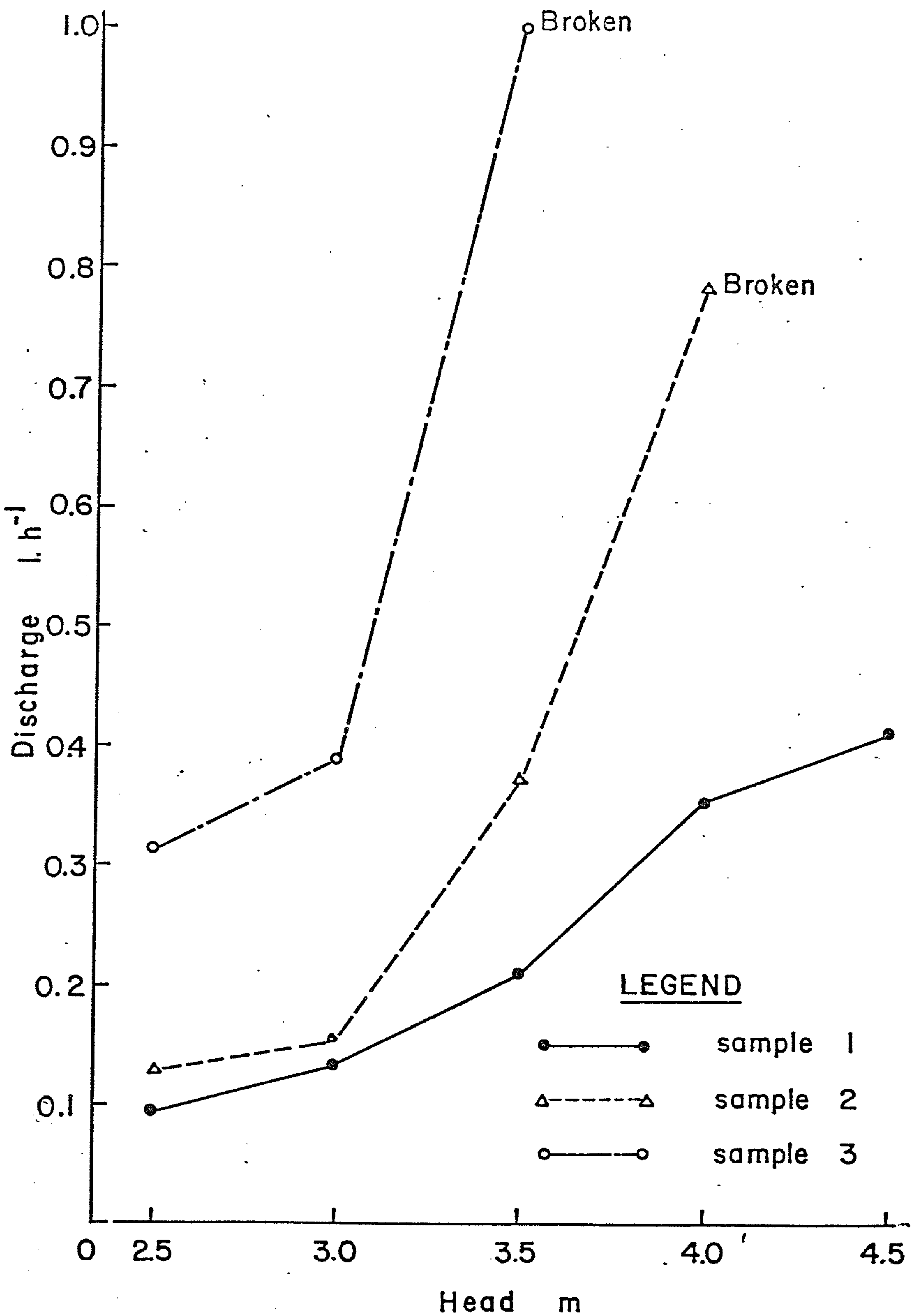

Figure 4.1 Pressure head – dischage relation (SUL treatment)

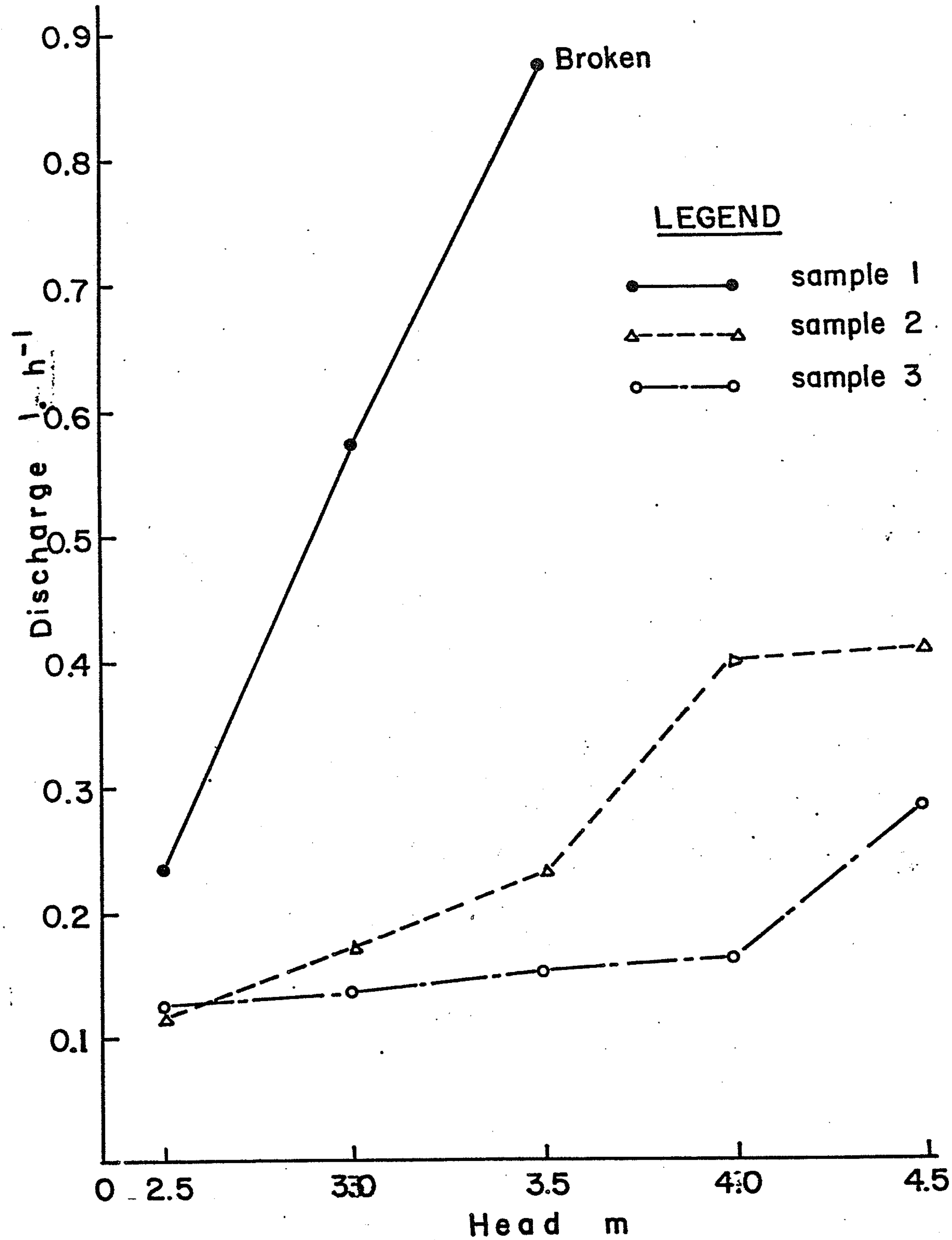

Figure 4.2 Pressure head – discharge relation (BUL treatment)

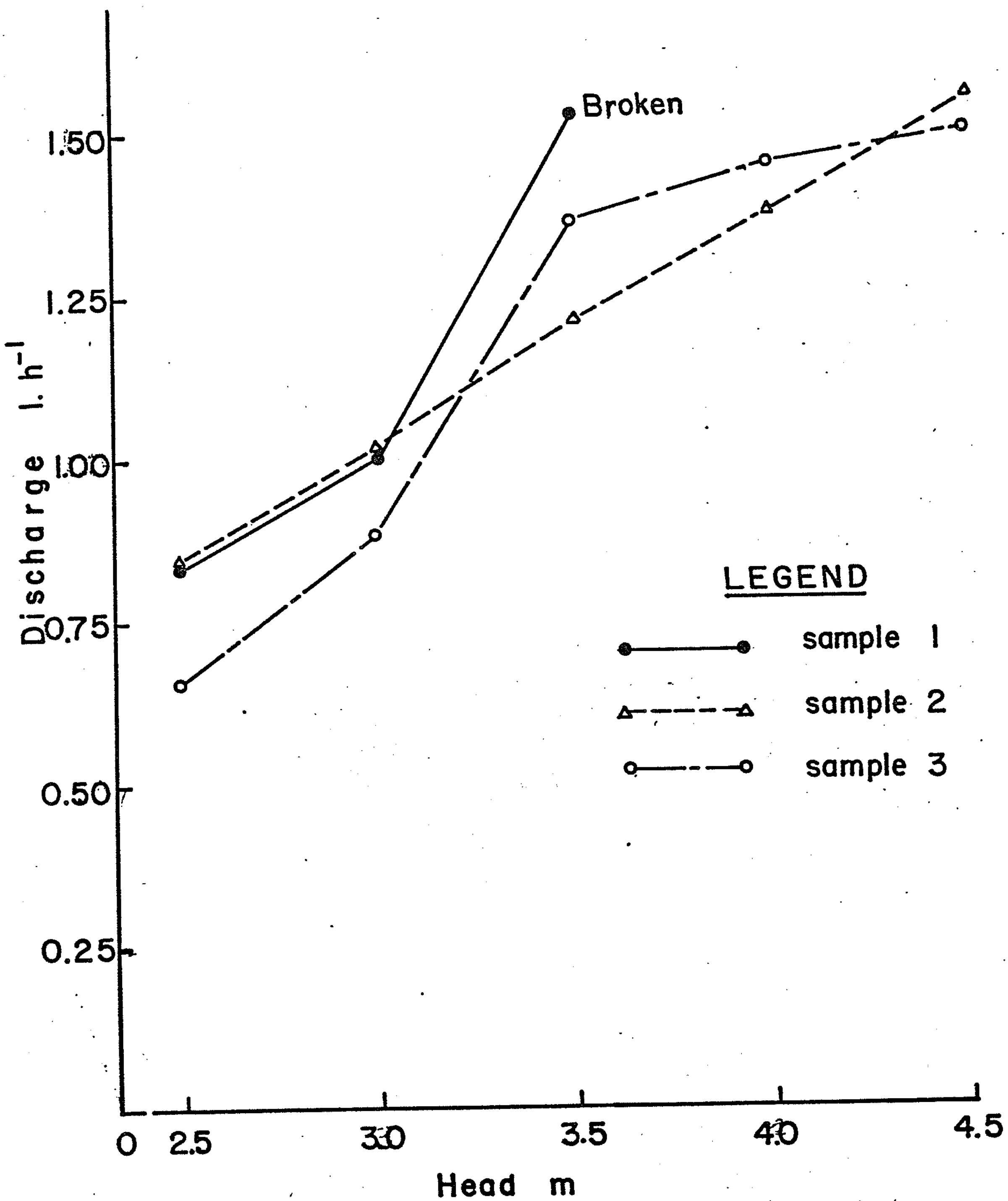

Figure 4.3 Pressure head-discharge relation (NL treatment)

with a small rubber tube. In spite of this repair, however, water usually continued to leak from this connection. The recorded discharge of the drip lines increased after the failure took place due to the leaking after the repair and due to the spillage before the damage could be detected and repaired.

For those reasons no conclusive comparisons could be made about the performance of drip lines in the field. The number of damage sites are shown in Table 4.2. Discharge results are presented in Tables 4.3 and 4.4.

The failure of the drip tubing occurred in two ways: either a small hole developed in the wall of the tubing and the water jetted away (Figure 4.4a) or the tubing ruptured along the seams of the tube (Figure 4.4b). The maximum number of damage sites occurred in the SUF drip tubes due to deterioration from algae and ultraviolet degradation from the last growing season. Because the SUF drip tubes had the highest number of damage sites, the discharge from SUF lines was also the highest.

The uniformity of water distribution from buried drip lines was better than from the surface drip lines because the seams of the surface drip lines often folded up forming water channels and water then flowed along the channels until it reached a depression. Water then spilled into the depressions, leaving some sections dry and over-irrigating others.

TABLE 4.2

Number of damage sites in Viaflo tubing in the field experiment

Treatment	Line number	Number of damage sites: Line	Number of damage sites: Treatment
SUF	1	14	38
	2	12	
	3	12	
BUF	1	5	10
	2	3	
	3	2	
SNF	1	5	11
	2	4	
	3	2	
BNF	1	3	4
	2	1	
	3	-	

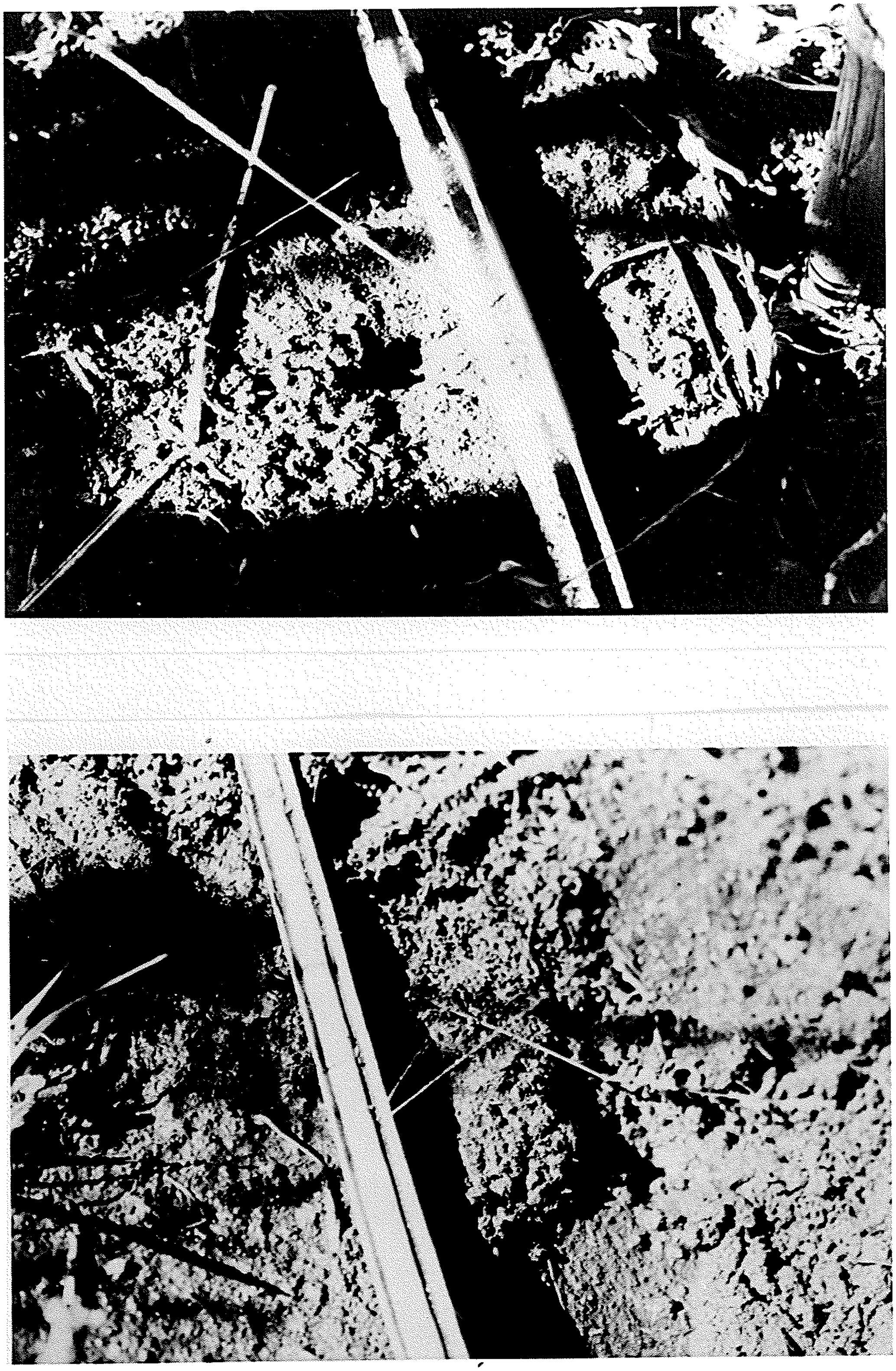

Figure 4.4a, b   Typical damages of 'Viaflo' tubing

4.4 Irrigation Periods and Application Volumes

The irrigation periods and application volumes are shown in Tables 4.3 and 4.4. A total of about 5,750 l was applied in the SUF treatment, 5,240 l in the BUF treatment, 4,570 l in the SNF treatment and 4,370 l in the BNF treatment. A total of about 6,970 l was applied to the furrow treatment (Table 4.21).

4.5 Soil Moisture Profiles

The soil moisture content at the depths of 30 cm, 60 cm, 100 cm and 140 cm was recorded for almost every access tube except for access tubes SNF-I-1, BNF-III-3, BNF-III-4, FF-III-1, FF-III-2 and FF-III-3 which were filled with runoff water after heavy rains. The moisture measurements of the soil surface where the neutron probe was not considered reliable, were determined by the gravitational method. Due to the limited capacity of the oven and of the number of sample containers, the surface soil samples had to be taken from the same locations only at selected access tubes for every measurement. The soil moisture contents for all measurements are presented in Appendixes B, C, D, E and F. Because of the incompleteness of data at some stations and at the soil surfaces, it was impossible to average the data from all three stations in each treatment. However, the average moisture contents of the SUF treatment which was calculated (Appendix G), indicate similar trends in moisture conditions to those found at

TABLE 4.3

Irrigation applications and discharge rates in field treatments (SUF and BUF) with Viaflo tubing previously used for one year

SUF				BUF			
Date (1976)	Irrigation duration (h)	Irrigation Volume (l)	Drip-line discharge rate ($l.h^{-1}.100\ m^{-1}$)	Date (1976)	Irrigation duration (h)	Irrigation Volume (l)	Drip-line discharge rate ($l.h^{-1}.100\ m^{-1}$)
06 01	3.0	31.82	3.53	06 01	3.0	28.59	3.17
06 02	4.0	46.82	3.85	06 02	4.0	39.73	3.27
06 03	6.0	71.01	3.94	06 03	6.0	66.01	3.67
06 04	7.0	86.37	4.11	06 04	7.0	81.24	3.86
06 22	9.0	109.10	4.04	06 22	7.0	66.00	3.14
06 25	4.0	45.41	3.78	06 25	4.0	40.91	3.41
06 30	8.5	90.92	3.56	06 30	8.0	77.28	3.22
07 05	3.0	33.19	3.69	07 05	3.0	29.42	3.27
07 06	3.0	32.81	3.64	07 06	3.0	30.05	3.34
07 07	6.0	72.74	4.04	07 07	6.0	59.40	3.30
07 08	6.0	70.51	3.92	07 08	6.0	60.22	3.34
07 13-07 14	21.5	273.76	4.24	07 13-07 14	21.5	221.88	3.44
07 14-07 15	22.0	256.74	3.89	07 14-07 15	22.0	225.72	3.42
07 21	6.0	53.10	2.95	07 21	6.0	48.64	2.70
07 23	5.0	44.46	2.96	07 23	8.0	75.01	3.12
07 26-07 27	22.0	190.79	2.89	07 26-07 27	22.0	175.71	2.66
07 28	8.0	78.64	3.28	07 28	8.0	59.10	2.46
08 02-08 04	48.0	443.01	3.08	08 02-08 04	48.0	401.71	2.79
08 05-08 06	24.0	227.53	3.16	08 05-08 06	24.0	216.62	3.01
08 09	4.5	41.37	3.06	08 09	4.5	40.91	3.03
08 11	4.0	42.28	3.52	08 11	4.0	37.28	3.11
08 13	6.0	65.16	3.62	08 13	6.0	60.92	3.38
08 16-08 20	102.0	1,445.63	4.72	08 06-08 20	102.0	1,353.80	4.42
08 23-08 27	96.0	1,319.04	4.58	08 23-08 27	96.0	1,284.48	4.46
08 31	5.0	59.55	3.97	08 31	5.0	45.46	3.03
09 01-09 03	48.0	512.79	3.56	09 01-09 03	48.0	415.05	2.88
Total	481.5	5,753.55		Total	482.0	5,241.14	

TABLE 4.4

Irrigation applications and discharge rates in field treatments (SNF and BNF) with previously unused Viaflo tubing

SNF				BNF			
Date (1976)	Irrigation duration (h)	Irrigation Volume (l)	Drip-line discharge rate ($l.h^{-1}.100\ m^{-1}$)	Date (1976)	Irrigation duration (h)	Irrigation Volume (l)	Drip-line discharge rate ($l.h^{-1}.100\ m^{-1}$)
06 01	3.0	32.59	3.62	06 01	3.0	29.78	3.31
06 02	4.0	46.46	3.87	06 02	4.0	43.64	3.64
06 03	6.0	56.88	3.16	06 03	6.0	64.26	3.57
06 04	7.0	57.96	2.76	06 04	7.0	78.75	3.75
06 22	9.0	75.60	2.80	06 22	9.0	89.64	3.32
06 25	4.0	33.00	2.75	06 25	4.0	35.04	2.92
06 30	8.5	68.19	2.67	06 30	8.5	62.73	2.46
07 05	3.0	26.87	2.98	07 05	3.0	27.96	3.11
07 06	4.0	39.25	3.27	07 06	4.0	36.69	3.06
07 07	6.0	54.05	3.00	07 07	6.0	56.42	3.13
07 08	6.0	46.78	2.60	07 08	6.0	57.14	3.17
07 13-07 14	21.5	190.25	2.95	07 13-07 14	21.5	193.20	2.99
07 14-07 15	22.0	179.06	2.71	07 14-07 15	22.0	192.97	2.92
07 21	6.0	54.78	3.04	07 21	6.0	49.00	2.72
07 23	3.0	25.00	2.78	07 23	3.0	23.96	2.66
07 26-07 27	22.0	198.61	3.01	07 26-07 27	22.0	173.52	2.63
07 28	8.0	66.32	2.76	07 28	8.0	59.78	2.49
08 02-08 04	48.0	370.95	2.58	08 02-08 04	48.0	370.32	2.57
08 05-08 06	24.0	201.84	2.80	08 05-08 06	24.0	186.93	2.60
08 09	4.5	43.19	3.20	08 09	4.5	39.09	2.89
08 11	4.0	39.55	3.29	08 11	4.0	37.96	3.16
08 13	6.0	55.23	3.07	08 13	6.0	52.96	2.94
08 16-08 20	102.0	1,081.04	3.53	08 16-08 20	102.0	1,047.31	3.42
08 23-08 27	96.0	1,002.62	3.48	08 23-08 27	96.0	882.70	3.06
08 31	5.0	51.34	3.42	08 31	5.0	48.41	3.23
09 01-09 03	48.0	446.87	3.10	09 01-09 03	48.0	429.14	2.98
Total	480.5	4,573.98		Total	480.5	4,369.30	

the selected station (Appendix B). It is considered, therefore, that the moisture profile at the selected stations represent the moisture condition at all stations of that particular treatment.

4.5.1 Used Viaflo tubing.

4.5.1.1 The SUF treatment. Almost constant moisture levels were maintained through the season at a depth of 140 cm. Except for the SUF-II-4 tube, moisture at this depth was also practically the same for all access tubes in the profile (i.e. in the buffer zone, between the buffer zone and the drip line and under the drip line). It fluctuated only very slightly mostly in the 580 $g.l^{-1}$ to 600 $g.l^{-1}$ range. For the SUF-II-4 tube, located between the irrigated crop rows, the moisture at the 140-cm depth fluctuated more than at other locations, especially after a heavy rain (Table 4.8 and Figure 4.8). Moisture at this location dropped from 600 $g.l^{-1}$ at the beginning of the season to 574 $g.l^{-1}$ on 1976 08 09 and then increased to 606 $g.l^{-1}$ after the rains on 1976 08 09 and 1976 08 11. This was probably due to the loose soil at that location allowing a deeper water infiltration.

At the 100-cm depth also, except for access tube SUF-II-4, the moisture was still practically the same at all locations and the fluctuations were minimal, but there was a slight decrease in the moisture during the season from approximately the 590 $g.l^{-1}$ to 600 $g.l^{-1}$ range at the beginning of the season to approximately the 560 $g.l^{-1}$ to 580 $g.l^{-1}$ range at the end of the season. At the beginning of the season the moisture at 100 cm was very nearly the same as the moisture at 140 cm while at the end of the season the moisture at 100 cm was slightly but clearly lower than the moisture at 140 cm.

There was, however, much more differentiation in both time and location at the shallower depths. At the depth of 60 cm, there was a visible difference between the buffer zone, the interrow and the in-the-row locations. The moisture at the buffer zone (access tube SUF-III-1) decreased from 540 $g.l^{-1}$ at the beginning of the season to 510 $g.l^{-1}$ on 1976 08 18 and slightly increased to 570 $g.l^{-1}$ on 1976 08 22 due to the rains on 1976 08 09, 1976 08 11 and 1976 08 18. Then the moisture slightly decreased to 540 $g.l^{-1}$ at the end of the season. The moisture near and below the drip line (access tubes SUF-I-2 and SUF-I-3) was not much different; they were decreased from 580 $g.l^{-1}$ and 590 $g.l^{-1}$ at the beginning to 500 $g.l^{-1}$ and 530 $g.l^{-1}$ at the end of the season and after the rains the moisture slightly increased for a few days and decreased again. The moisture at access tube SUF-II-4 was fluctuated more than those found in access tubes SUF-I-2 and SUF-I-3 especially after the rains.

Relationships that were similar but more accentuated were observed at a depth of 30 cm. Here, the moisture at the drip line increased substantially during the first part of the growing season and was generally slightly higher at the end of the season than at the beginning, while there was a general decrease and slight increase again after the rains at all other locations. Short-term fluctuations in moisture were naturally higher and more frequent at the shallower depths.

Surface moisture conditions were similar to those discussed in the last paragraph and showed even more fluctuations in response to both irrigation and rainfall. The general seasonal trend, however, was towards appreciable depletion away from the drip line and towards an increase in moisture content near the drip line.

Generally moisture in the profile decreased with decreasing depth with some temporary reversal of this phenomenon between the surface and the 30-cm depth (frequent at the drip line, exceptional away from it) caused by the rains and especially by the combination of rain and irrigation. The moisture gradient with depth was more pronounced at the end than at the beginning of the season with the exception of the profile at, and very close to, the drip line, where it remained fairly constant through the season.

4.5.1.2 <u>The BUF treatment</u>. Almost constant moisture levels at 140-cm depth for all access tubes, it fluctuated very slightly mostly in the 575 $g.l^{-1}$ to 605 $g.l^{-1}$.

TABLE 4.5

Moisture content $(g.l^{-1})$ for access tube SUF-III-1

Date 1976	Soil depths (cm) surface	30	60	100	140
07 02	399	432	543	589	591
07 05	359	438	545	594	594
07 06	355	438	550	590	592
07 07	329	497	551	593	595
07 08	327	462	541	592	595
07 09	401	482	565	595	598
07 12	286	476	515	592	598
07 14	275	464	518	592	596
07 16	268	455	516	589	596
07 21	252	449	500	589	598
08 09	157	424	498	582	597
08 11	-	-	-	-	-
08 12	413	440	513	588	597
08 13	412	427	507	586	595
08 16	309	428	532	582	588
08 17	343	425	534	580	592
08 18	291	430	535	580	590
08 19	456	448	542	585	596
08 20	472	450	545	586	590
08 21	444	462	565	591	595
08 22	388	468	570	588	600
08 23	346	466	571	589	600
08 24	290	461	569	585	590
08 25	376	465	567	581	592
08 26	195	457	556	581	590
08 31	343	439	549	579	584
09 01	241	435	542	572	590
09 02	249	428	541	576	596

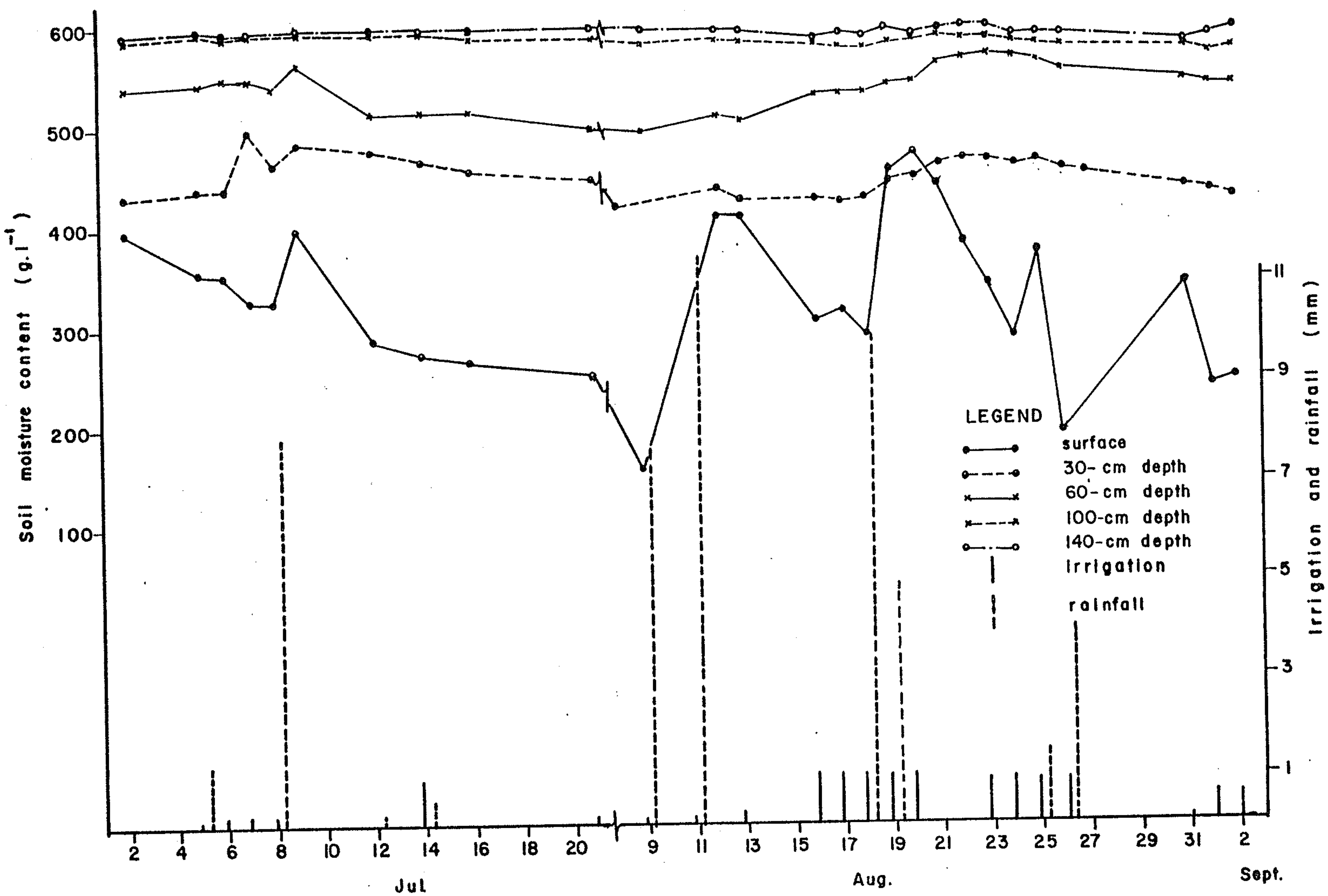

Figure 4.5 Soil moisture profile for access tube SUF - III - I

TABLE 4.6

Moisture content $(g.l^{-1})$ for access tube SUF-I-2

Date 1976	Soil depths (cm) surface	30	60	100	140
07 02	395	423	536	576	581
07 05	368	476	580	596	595
07 06	329	477	571	600	594
07 07	363	504	573	600	601
07 08	322	503	558	592	596
07 09	447	510	560	593	598
07 12	304	524	566	591	591
07 13	-	487	553	581	587
07 14	366	512	564	588	592
07 16	315	518	560	585	590
07 21	229	481	532	577	582
08 09	142	460	520	560	577
08 11	255	467	527	568	585
08 12	385	496	530	562	586
08 13	363	462	515	565	587
08 16	233	464	520	565	585
08 17	262	463	515	559	588
08 18	255	468	516	558	586
08 19	383	479	527	549	589
08 20	448	475	515	546	583
08 21	372	473	512	546	588
08 22	355	491	524	563	582
08 23	289	517	526	572	587
08 24	367	502	512	560	584
08 25	310	484	509	559	584
08 26	345	489	512	545	582
08 31	327	478	501	546	581
09 01	250	468	503	543	587
09 02	232	479	518	558	585

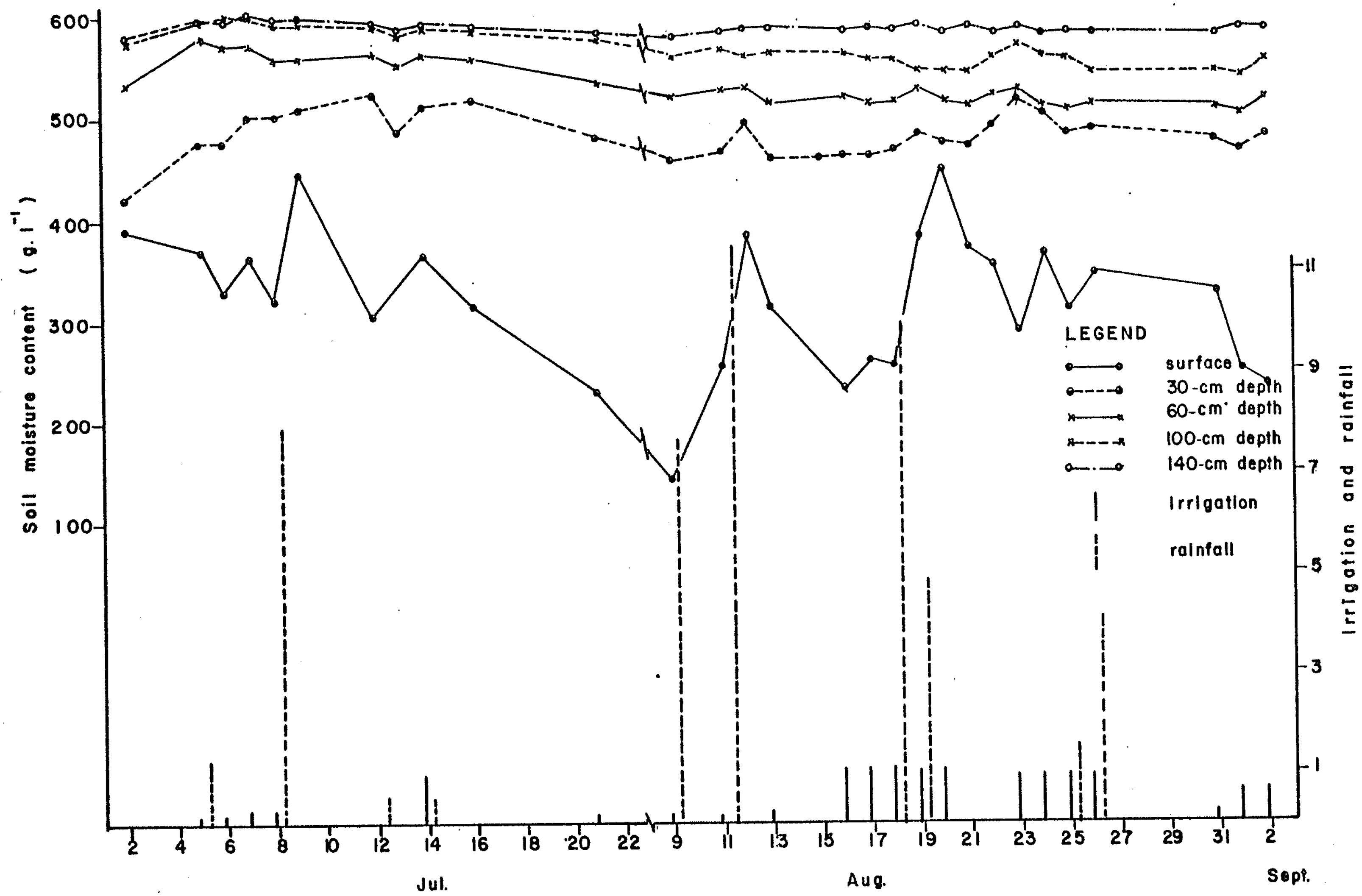

Figure 4.6 Soil moisture profile for access tube SUF - I - 2

TABLE 4.7

Moisture content ($g.l^{-1}$) for access tube SUF-I-3

Date 1976	Soil depths (cm) surface	30	60	100	140
07 02	418	441	546	587	590
07 05	358	484	590	600	602
07 06	331	465	592	600	600
07 07	398	478	588	597	593
07 08	477	460	584	590	590
07 09	459	456	571	588	591
07 12	436	474	556	586	588
07 13	-	478	571	595	592
07 14	434	485	558	586	591
07 16	509	515	553	582	592
07 21	308	473	552	578	594
08 09	378	441	537	576	586
08 11	478	473	540	584	592
08 12	543	484	544	585	592
08 13	528	471	546	585	589
08 16	349	472	545	570	589
08 17	349	506	543	575	584
08 18	454	510	550	579	591
08 19	495	518	554	581	590
08 20	626	533	551	583	596
08 21	514	494	545	585	595
08 22	563	539	556	580	597
08 23	574	557	570	590	606
08 24	600	530	550	584	593
08 25	510	532	549	580	594
08 26	528	515	547	580	594
08 31	362	499	530	578	585
09 01	457	485	534	570	588
09 02	542	509	540	575	588

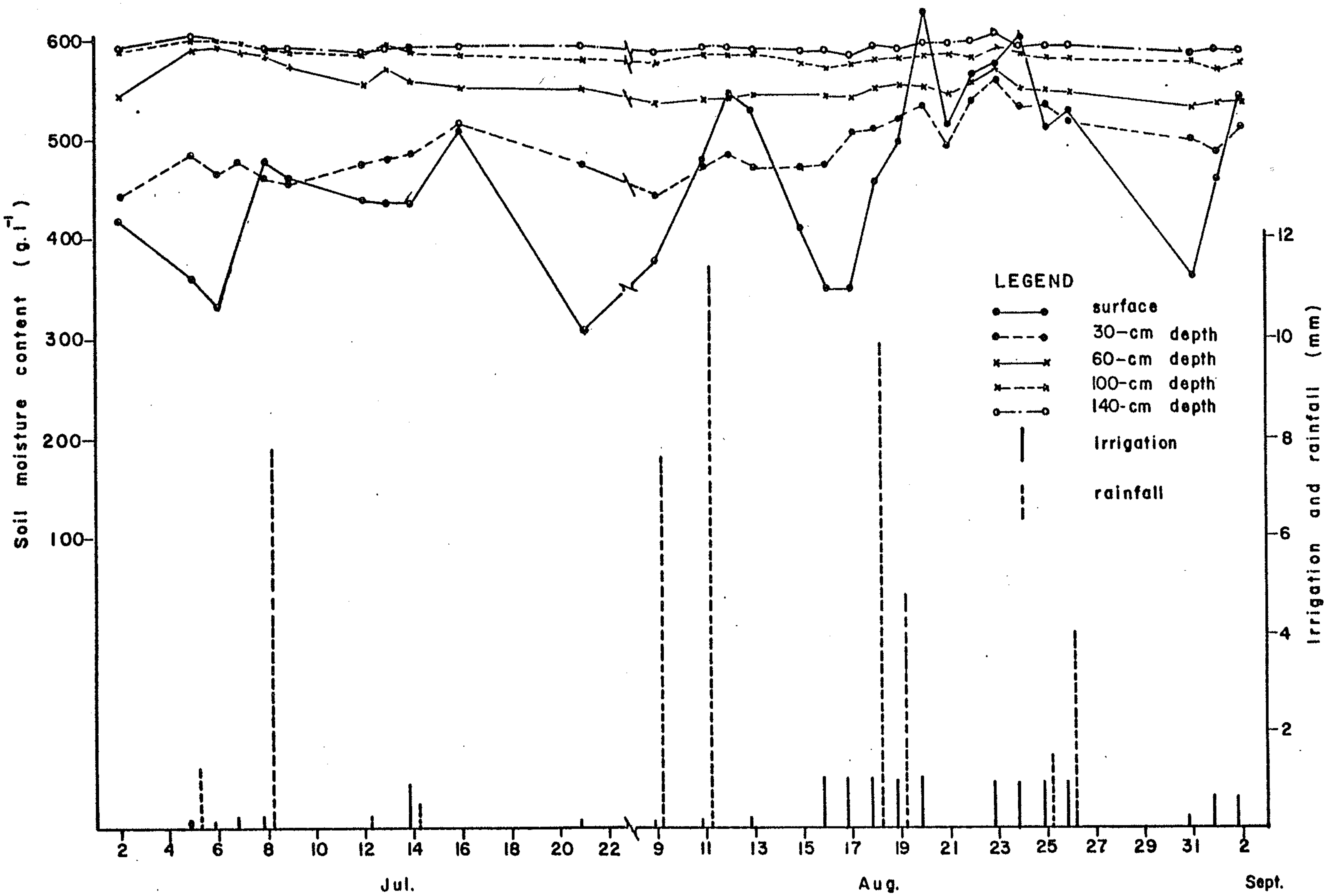

Figure 4.7 Soil moisture profile for access tube SUF - I - 3

TABLE 4.8

Moisture content $(g.l^{-1})$ for access tube SUF-II-4

Date 1976	Soil depths (cm)				
	surface	30	60	100	140
07 02	459	510	568	583	603
07 05	395	506	563	596	602
07 06	381	500	565	590	600
07 07	345	525	589	615	600
07 08	301	507	562	581	601
07 09	404	515	558	586	597
07 12	352	-	-	-	-
07 13	-	529	557	592	606
07 14	323	520	550	579	589
07 16	305	518	546	580	590
07 21	254	499	515	555	580
08 09	221	485	495	539	574
08 11	287	500	508	542	581
08 12	438	519	526	560	606
08 13	372	491	506	534	576
08 16	286	496	515	537	583
08 17	246	498	515	535	591
08 18	288	500	515	541	589
08 19	429	495	515	542	588
08 20	-	491	548	559	576
08 21	355	494	543	560	567
08 22	297	523	565	602	614
08 23	267	533	584	603	620
08 24	241	502	547	584	595
08 25	312	504	541	572	597
08 26	222	517	569	578	589
08 31	250	502	529	572	586
09 01	175	498	523	569	578
09 02	198	499	517	562	580

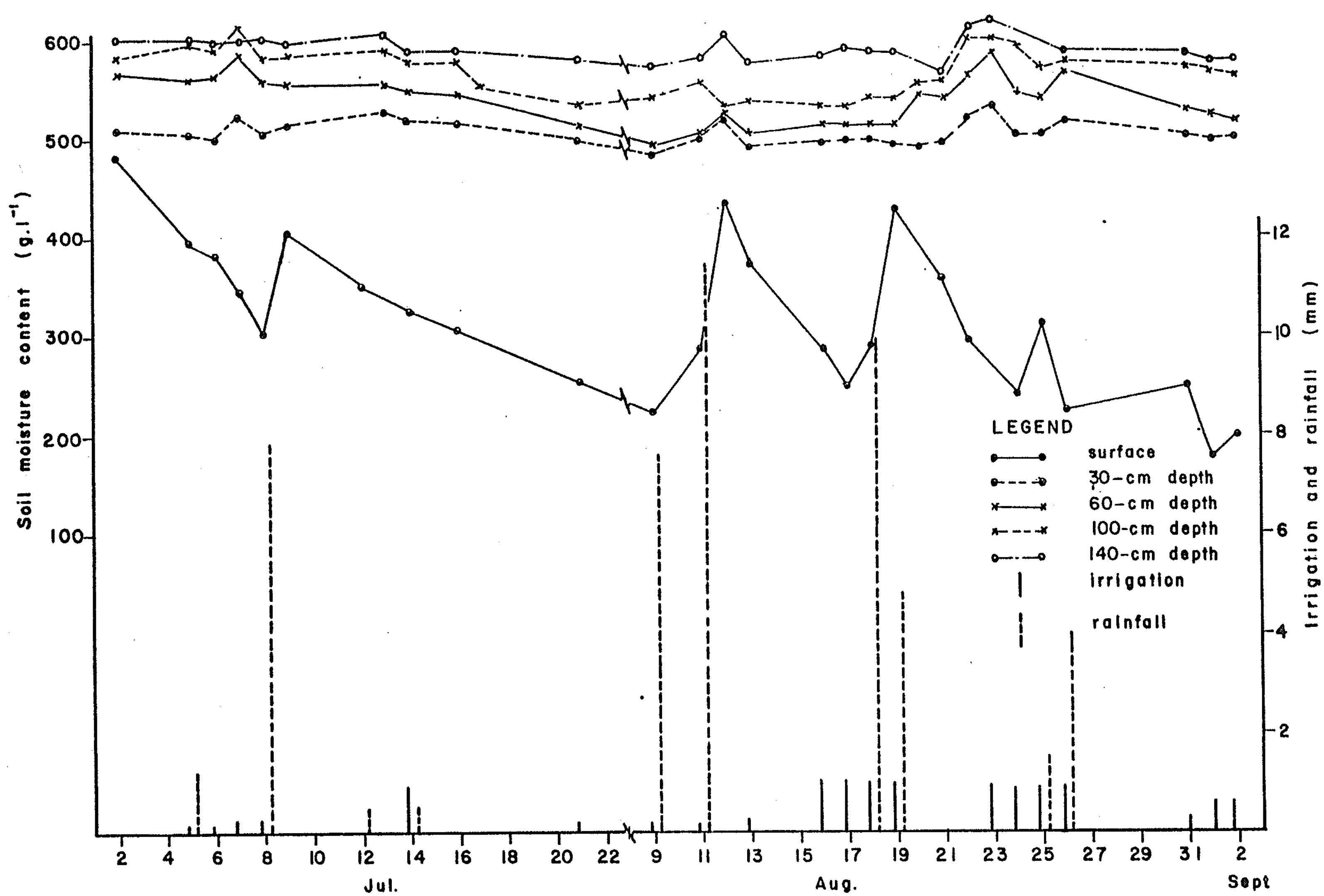

Figure 4.8 Soil moisture profile for access tube SUF - II - 4

At the 100-cm depth, the moisture was still practically the same at all locations and the fluctuations were very small in all cases. The moisture slightly decreased from approximately the 580 $g.l^{-1}$ to 590 $g.l^{-1}$ range at the beginning of the season to approximately the 540 $g.l^{-1}$ to 550 $g.l^{-1}$ range at the end of the season.

It is the same as SUF treatment, the moisture at the 60-cm depth was visibly different for all locations. In the buffer zone (access tube BUF-III-1) the moisture dropped from approximately 555 $g.l^{-1}$ at the beginning to approximately 460 $g.l^{-1}$ at the end of the season, access tube BUF-I-2 dropped from 535 $g.l^{-1}$ to 510 $g.l^{-1}$, access tube BUF-I-3 decreased from 535 $g.l^{-1}$ to 510 $g.l^{-1}$ and access tube BUF-II-4 dropped from 550 $g.l^{-1}$ to 505 $g.l^{-1}$. The maximum drop in moisture occurred at the buffer zone which it was farthest away from the drip line.

At the 30-cm depth, the moisture under the drip line at the end of the season was higher than at the beginning while at the other locations the moisture slightly decreased. The farther from the drip line, the greater the decrease in moisture content from the beginning to the end of the season.

The moisture conditions at the surface were similar to the 30-cm depth and showed even more fluctuation in response to irrigation and rainfall.

General observations for the BUF treatment were similar to those for the SUF treatment. The moisture conditions for all locations of this treatment are shown in Tables 4.9, 4.10, 4.11 and 4.12 and in Figures 4.9, 4.10, 4.11 and 4.12.

4.5.2 Previously unused Viaflo tubing.

4.5.2.1 The SNF treatment. The moisture content at the 140-cm depth was fairly constant in time and place (570 $g.l^{-1}$ to nearly 600 $g.l^{-1}$) except perhaps for the buffer zone for which it started at over 600 $g.l^{-1}$ and decreased very slightly.

At the 100-cm depth the moisture content was still fairly uniform and there was very little fluctuation. A slight moisture depletion was observed at all locations except at the drip line where there was a very slight increase.

At the 60-cm depth there was more fluctuation in the moisture content during the season at all locations and there were more differences between locations. There was no appreciable change in the moisture in the row and in the interrows but a substantial depletion occurred in the buffer zone. The moisture content certainly responded to irrigation and some impact of rain was observed everywhere.

At the 30-cm depth the moisture in the interrow increased and in the row itself it decreased between 1976 07 21 and 1976 08 09. Probably this was due to the coarser texture of the soil in the interrow location. A decrease

TABLE 4.9

Moisture content ($g.l^{-1}$) for access tube BUF-III-1

Date 1976	Soil depths (cm) surface	30	60	100	140
07 02	357	455	573	595	579
07 05	339	527	556	591	584
07 06	341	465	553	590	584
07 07	326	496	575	595	605
07 08	318	491	558	585	597
07 09	-	496	544	592	594
07 12	340	508	540	596	604
07 13	-	519	541	592	601
07 14	321	510	544	584	597
07 16	224	505	535	578	590
07 21	271	497	528	560	593
08 11	239	-	-	-	-
08 12	390	436	509	574	580
08 13	361	418	499	576	584
08 16	252	407	489	569	581
08 17	262	404	477	561	579
08 18	249	404	482	563	579
08 19	420	409	485	564	578
08 20	497	403	480	566	581
08 21	365	402	482	565	585
08 22	359	-	-	-	-
08 23	358	428	499	567	590
08 24	256	405	480	559	589
08 25	270	405	480	556	584
08 26	219	397	468	549	581
08 31	255	392	462	546	580
09 01	198	394	467	549	585
09 02	235	391	465	545	581

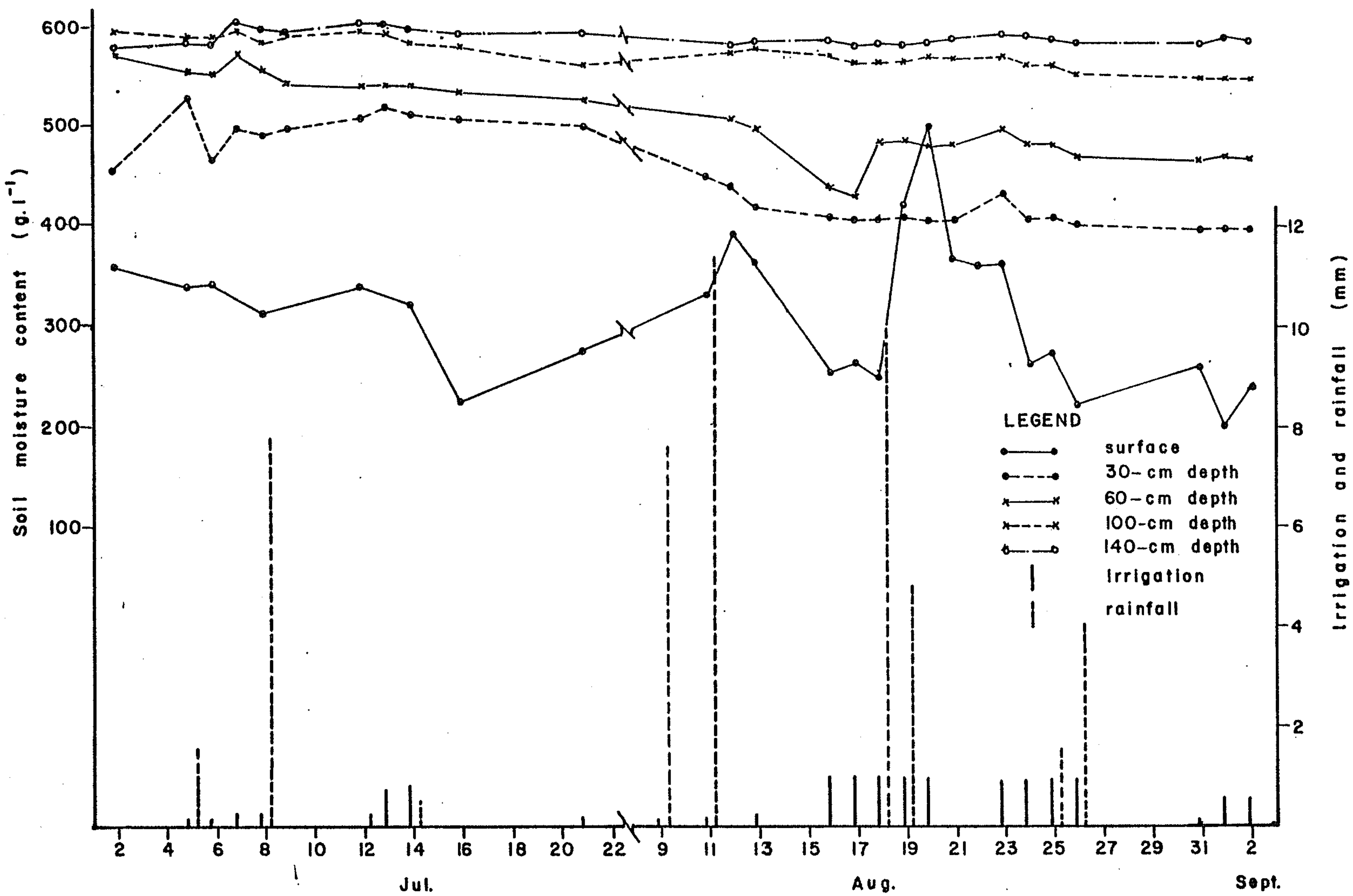

Figure 4.9 Soil moisture profile for access tube BUF - III - I

TABLE 4.10

Moisture content ($g.l^{-1}$) for access tube BUF-I-2

Date 1976	Soil depths (cm)				
	surface	30	60	100	140
07 02	446	485	535	580	590
07 05	429	526	546	594	605
07 06	391	514	555	582	603
07 07	329	523	555	594	605
07 08	386	513	545	579	590
07 09	448	510	539	580	601
07 12	341	510	536	584	599
07 13	-	510	531	578	605
07 14	297	504	525	572	594
07 16	297	504	534	575	589
07 21	247	489	528	569	594
08 09	246	462	525	560	588
08 11	259	461	525	563	580
08 12	420	463	527	574	586
08 13	386	456	520	573	592
08 16	215	434	523	574	592
08 17	239	428	528	565	590
08 18	244	431	516	569	589
08 19	401	437	520	570	589
08 20	462	424	518	566	583
08 21	356	432	522	563	587
08 22	226	436	524	557	591
08 23	333	455	523	558	589
08 24	242	429	519	557	585
08 25	303	425	510	550	580
08 26	317	429	511	549	587
08 31	233	418	513	545	584
09 01	211	417	510	545	587
09 02	181	440	510	545	585

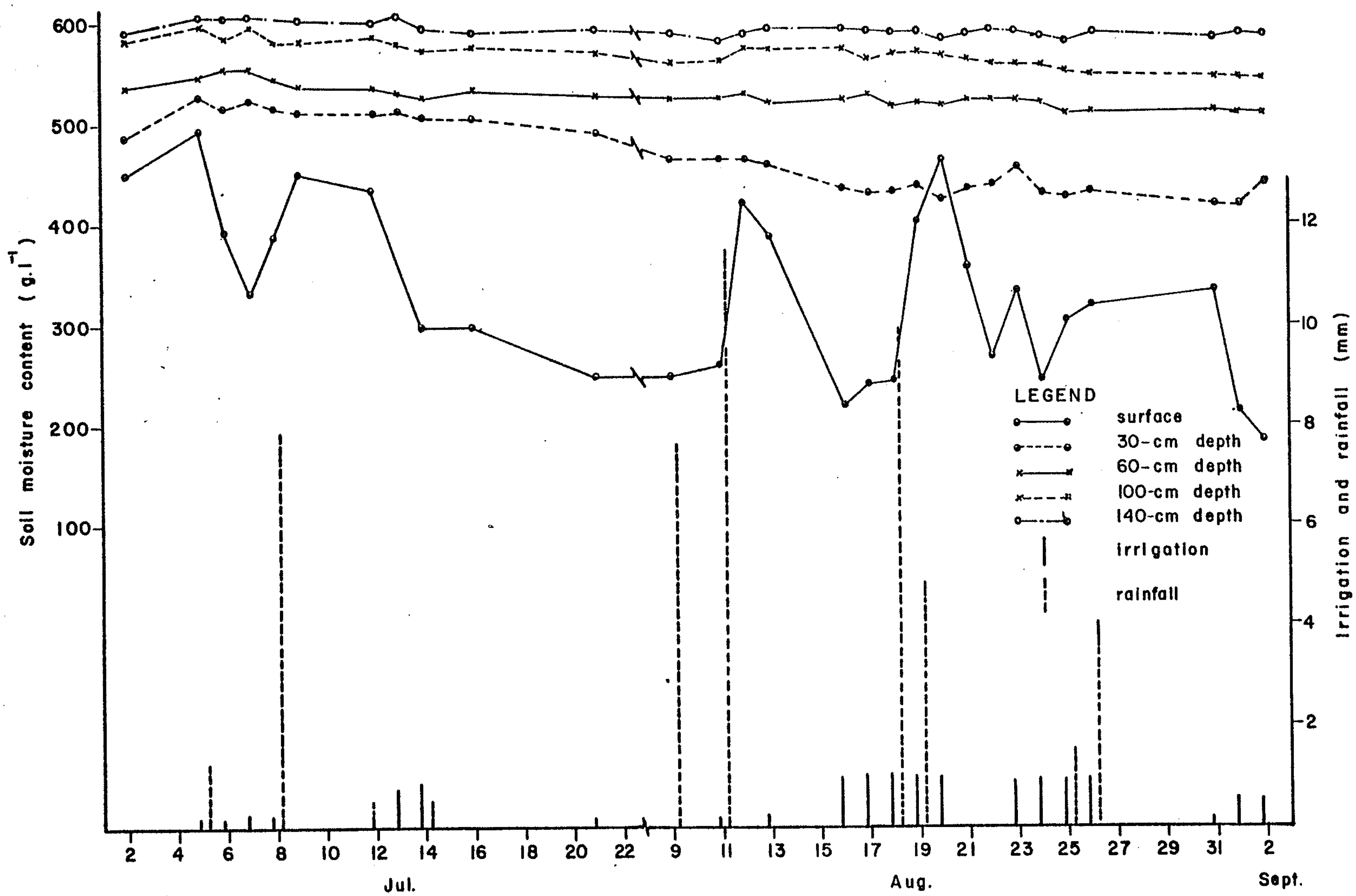

Figure 4.10 Soil moisture profile for access tube BUF - I - 2

TABLE 4.11

Moisture content ($g.l^{-1}$) for access tube BUF-I-3

Date 1976	Soil depths (cm)				
	surface	30	60	100	140
07 02	417	363	535	587	589
07 05	309	385	575	586	596
07 06	337	390	575	587	594
07 07	294	415	585	596	602
07 08	315	413	568	589	595
07 09	409	451	565	586	592
07 12	334	488	543	581	594
07 13	-	469	550	593	597
07 14	325	453	585	586	597
07 16	393	492	569	579	594
07 21	289	471	534	572	584
08 09	315	423	521	569	581
08 11	342	417	533	565	583
08 12	432	424	529	562	580
08 13	420	410	547	562	583
08 16	277	411	536	565	585
08 17	450	404	530	567	582
08 18	429	407	528	563	591
08 19	494	480	530	565	588
08 20	513	423	524	568	591
08 21	370	415	520	566	591
08 22	424	435	516	562	583
08 23	415	437	522	569	583
08 24	395	418	516	557	587
08 25	541	416	512	552	581
08 26	504	413	514	547	581
08 31	275	409	516	548	579
09 01	444	406	509	545	582
09 02	533	418	510	536	581

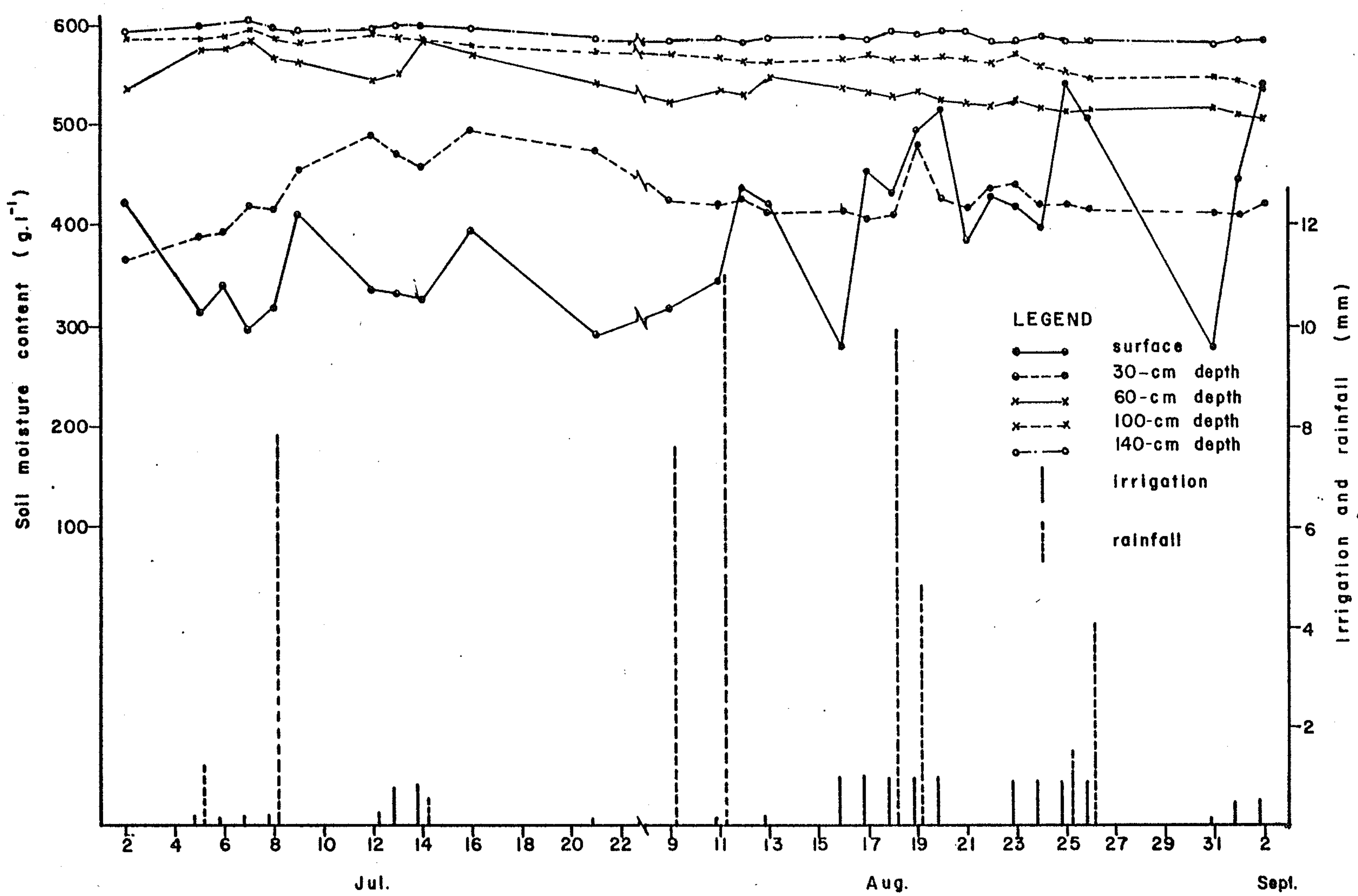

Figure 4.11 Soil moisture profile for access tube BUF-1-3

TABLE 4.12

Moisture content $(g.l^{-1})$ for access tube BUF-II-4

Date 1976	Soil depths (cm)				
	surface	30	60	100	140
07 02	436	472	565	567	586
07 05	389	469	555	570	587
07 06	325	471	551	578	585
07 07	345	500	565	574	593
07 08	281	496	544	571	588
07 09	412	509	542	567	585
07 12	375	523	545	580	592
07 14	201	507	535	574	586
07 16	214	505	529	570	582
07 21	237	495	523	569	579
08 09	209	477	520	560	583
08 11	229	460	510	556	584
08 12	366	432	528	555	584
08 13	336	410	510	552	580
08 16	224	422	506	551	585
08 17	198	418	517	549	582
08 18	189	421	523	551	586
08 19	418	429	520	549	585
08 20	514	425	516	546	586
08 21	359	413	518	552	587
08 22	258	449	531	555	584
08 23	258	454	545	560	585
08 24	275	431	526	562	579
08 25	258	421	512	557	581
08 26	222	428	522	554	581
08 31	261	427	519	547	579
09 01	195	423	510	544	575
09 02	193	424	505	545	572

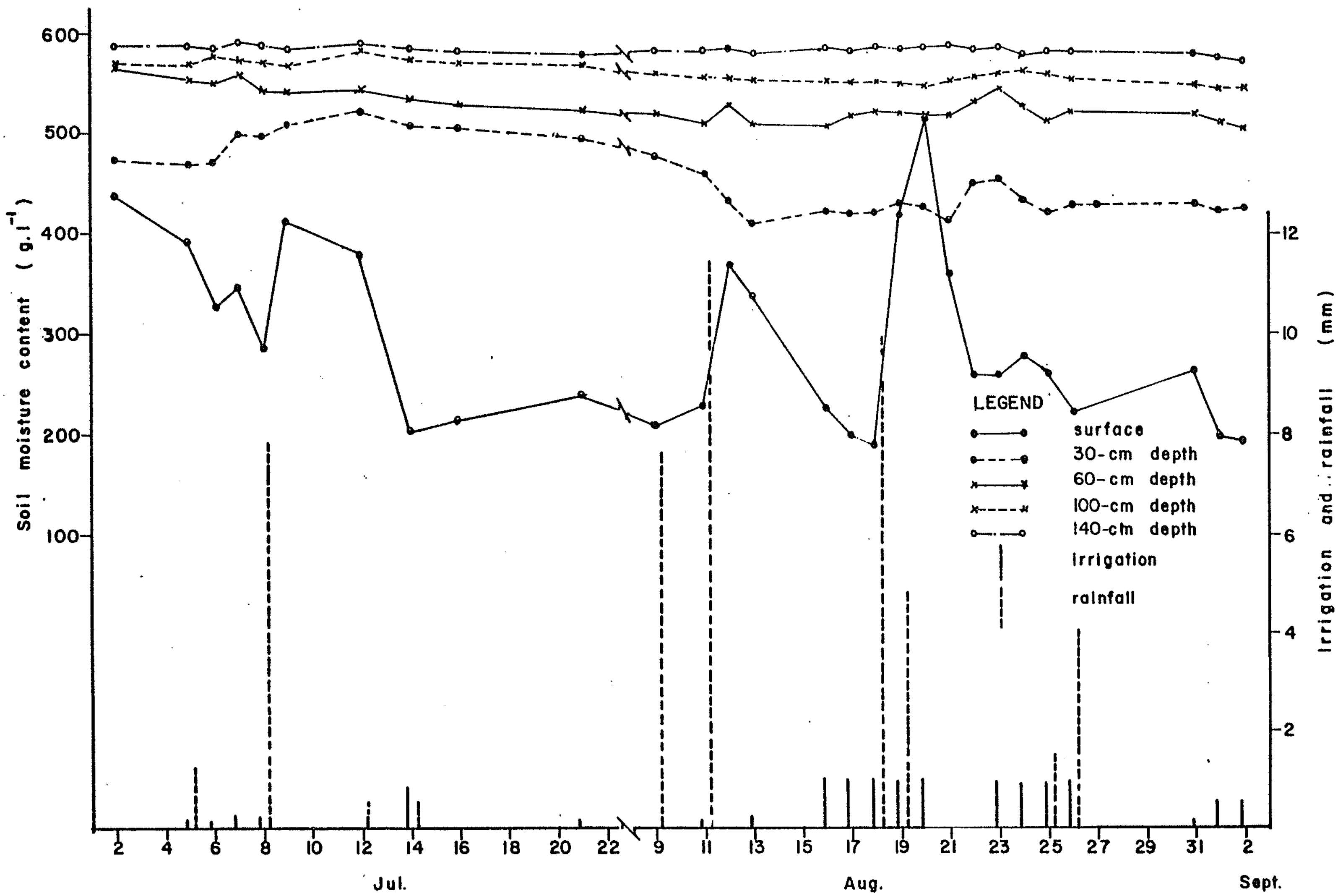

Figure 4.12 Soil moisture profile for access tube BUF - II - 4

in moisture content was observed in the buffer zone (access tube SNF-III-1).

At the surface there were large day-to-day fluctuations during the test period. Over the entire period there was a slight increase at the drip line, some decrease between the lines and a substantial decrease in the buffer zone.

General observations paralleled those for the SUF treatment.

4.5.2.2 The BNF treatment. At the 140-cm depth the soil moisture content was fairly constant in time and place, similar to other treatments.

The moisture conditions at the depth of 100 cm were the same as the 140-cm depth, except perhaps for access tube BNF-III-4 located between the two irrigated crop rows, where the moisture content decreased slightly (Table 4.20 and Figure 4.20) and for access tube BNF-I-2 where the moisture at this depth was very close to the moisture at 140 cm and even higher after the heavy rains in August (Table 4.18 and Figure 4.18).

At the 60-cm depth the moisture fluctuated more with time, and in some cases, with location but generally there was not much change.

At the 30-cm depth the moisture fluctuated even more decreasing in the buffer zone, increasing or remaining unchanged between rows and substantially increasing at the drip line.

TABLE 4.13

Moisture content $(g.l^{-1})$ for access tube SNF-III-1

Date 1976	Soil depths (cm)				
	surface	30	60	100	140
07 02	494	410	537	595	606
07 05	404	407	527	597	615
07 06	351	407	527	592	606
07 07	295	424	538	594	613
07 08	297	411	519	596	609
07 09	443	410	495	599	604
07 12	343	417	497	604	611
07 14	330	401	470	598	599
07 16	289	405	458	589	592
07 21	309	389	437	574	586
08 09	206	-	-	-	-
08 11	268	367	431	569	584
08 12	395	363	429	570	587
08 13	374	345	427	566	588
08 16	229	344	431	564	580
08 17	239	348	429	562	585
08 18	265	328	418	563	589
08 19	433	346	436	564	592
08 20	480	336	454	568	589
08 21	344	333	456	560	580
08 22	276	330	455	562	584
08 23	278	360	467	568	589
08 24	272	338	468	560	585
08 25	244	341	451	561	587
08 26	296	344	463	559	586
08 31	248	347	462	554	590
09 01	241	344	468	551	590
09 02	220	346	465	556	592

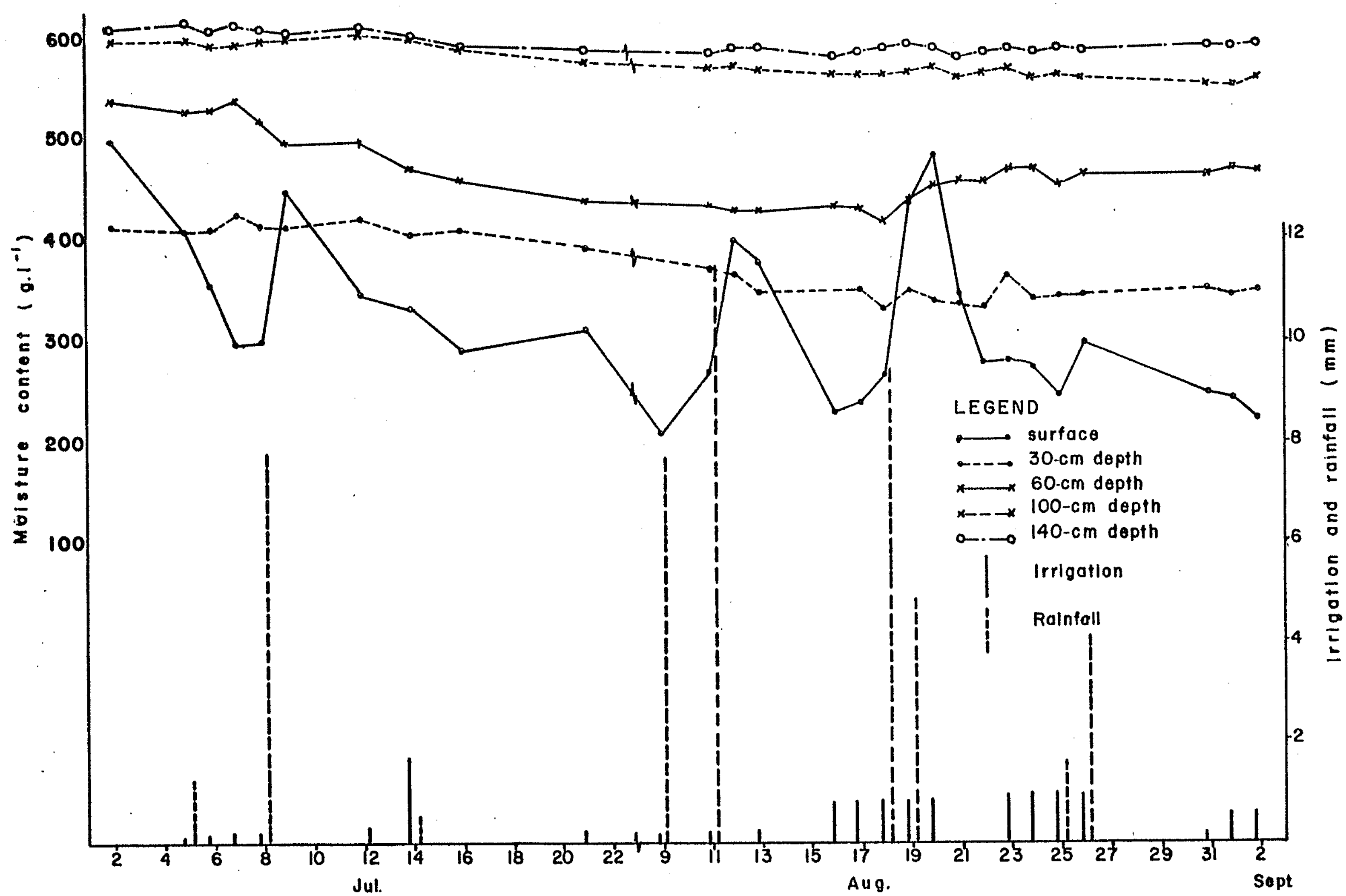

Figure 4.13 Soil moisture profile for access tube SNF - III - I

TABLE 4.14

Moisture content ($g.l^{-1}$) for access tube
SNF-I-2

Date 1976	Soil depths (cm)				
	surface	30	60	100	140
07 02	317	358	526	588	586
07 05	322	380	535	592	590
07 06	281	343	539	594	596
07 07	263	382	545	593	599
07 08	302	375	552	587	590
07 09	482	394	551	582	593
07 12	276	435	556	582	592
07 13	-	417	564	587	592
07 14	306	415	548	581	587
07 16	268	415	547	578	582
07 21	235	395	536	572	583
08 09	267	388	545	568	579
08 11	269	441	548	570	578
08 12	384	437	560	579	580
08 13	361	427	534	567	577
08 16	225	417	538	565	581
08 17	265	407	540	565	583
08 18	198	407	541	566	583
08 19	405	428	545	570	582
08 20	448	435	551	568	587
08 21	290	433	547	567	588
08 22	354	465	558	569	590
08 23	286	468	561	573	590
08 24	215	441	548	571	589
08 25	235	435	546	563	586
08 26	220	435	551	573	586
08 31	231	447	548	564	582
09 01	215	444	543	564	583
09 02	231	438	545	561	580

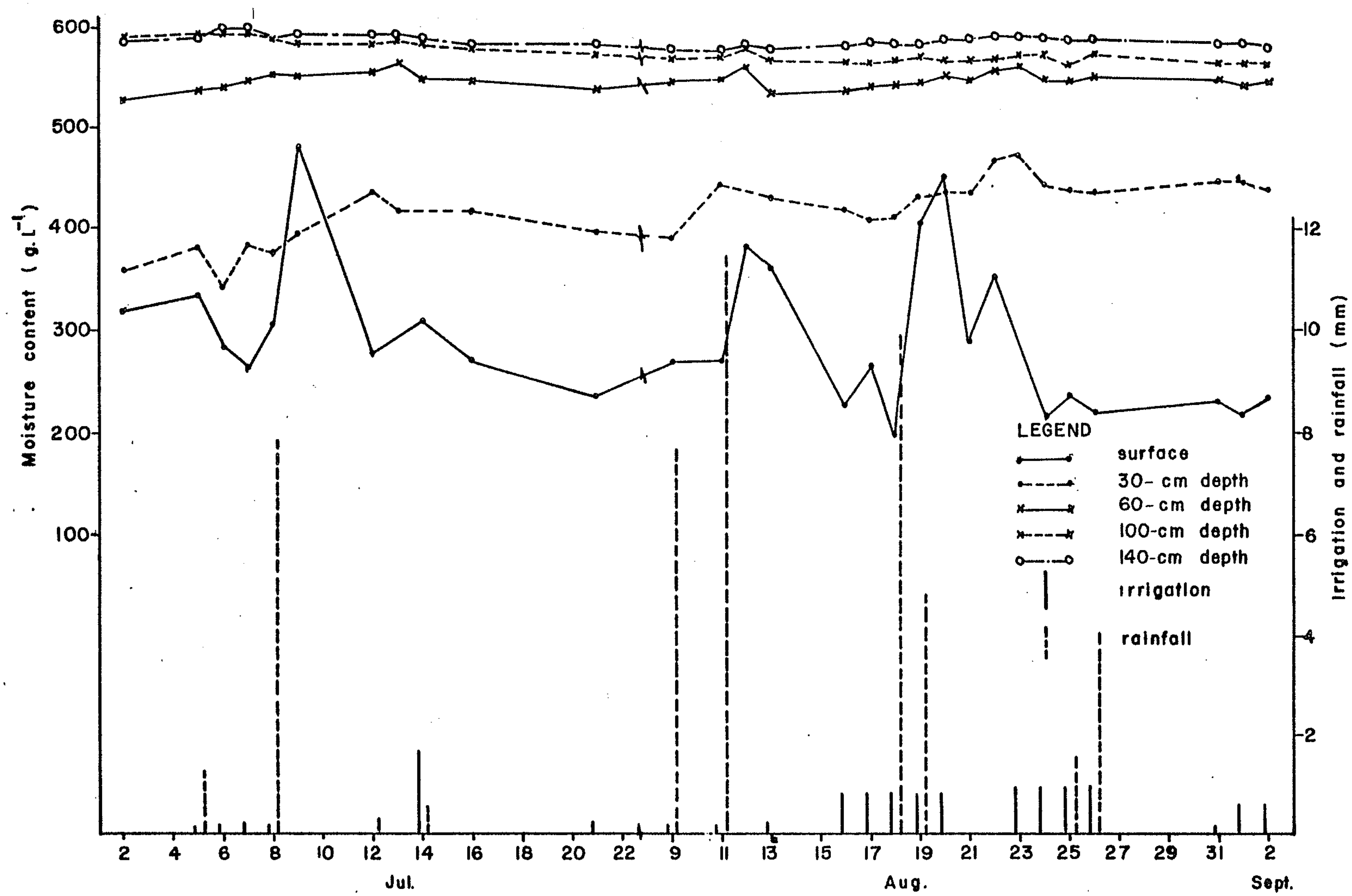

Figure 4.14 Soil moisture profile for access tube SNF-I-2

TABLE 4.15

Moisture content $(g.l^{-1})$ for access tube SNF-I-3

Date 1976	Soil depths (cm)				
	surface	30	60	100	140
07 02	426	460	497	558	572
07 05	340	494	519	571	583
07 06	310	473	520	575	588
07 07	326	496	523	580	594
07 08	292	465	520	584	596
07 09	410	476	522	575	591
07 12	356	494	543	580	597
07 13	-	478	555	589	589
07 14	362	486	541	584	593
07 16	425	489	540	580	596
07 21	265	475	534	585	599
08 09	269	398	516	582	596
08 11	394	401	526	579	594
08 12	430	420	546	575	588
08 13	394	403	530	572	581
08 16	271	412	505	575	584
08 17	255	402	505	571	585
08 18	422	405	549	568	584
08 19	494	413	519	564	586
08 20	485	413	516	572	584
08 21	371	411	516	567	589
08 22	498	426	531	570	593
08 23	430	438	536	578	605
08 24	462	417	507	576	592
08 25	482	415	505	573	592
08 26	501	422	506	579	590
08 31	331	434	502	575	586
09 01	301	432	510	575	581
09 02	422	427	493	578	581

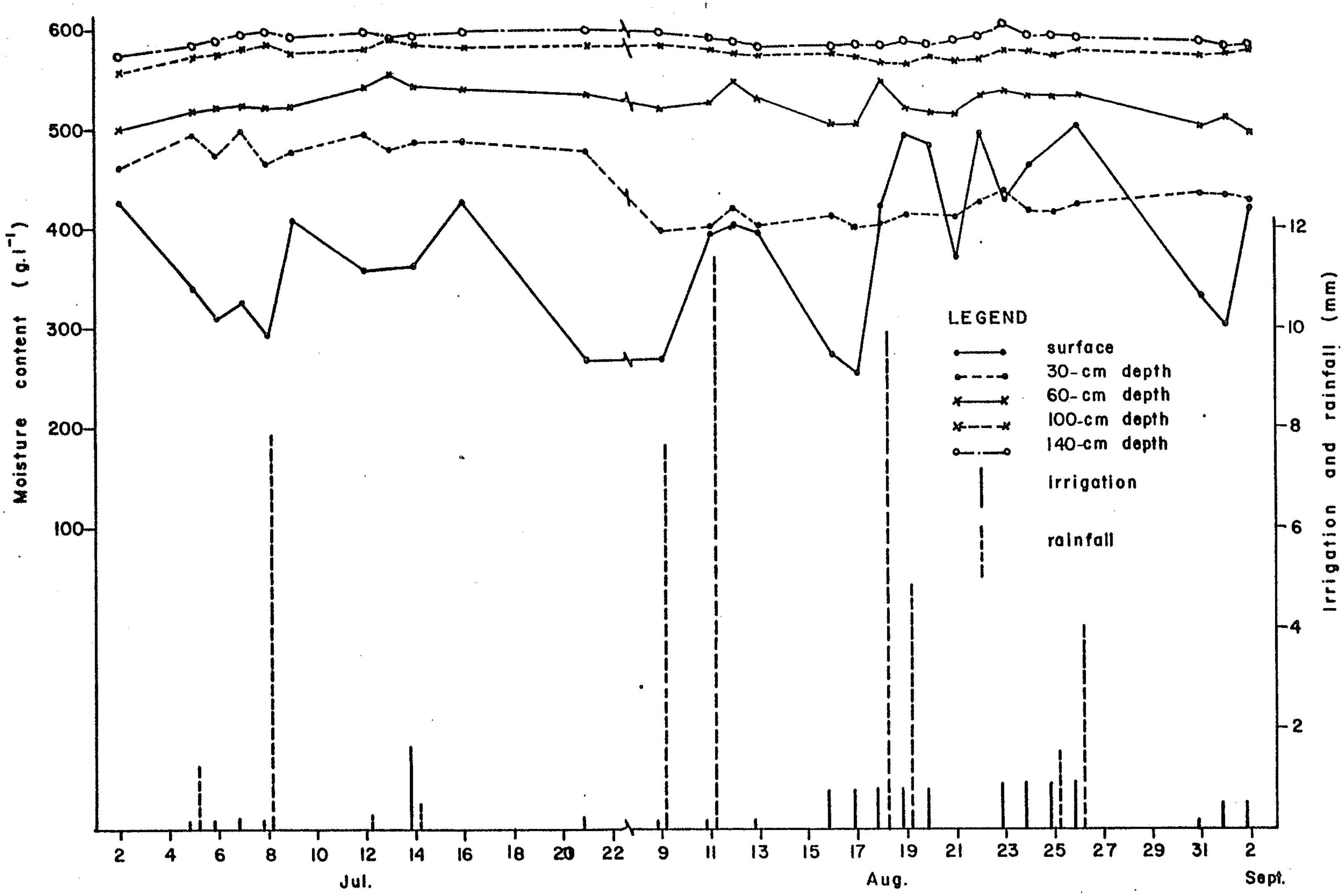

Figure 4.15 Soil moisture profile for access tube SNF-I-3

TABLE 4.16

Moisture content $(g.l^{-1})$ for access tube SNF-II-4

Date 1976	Soil depths (cm)				
	surface	30	60	100	140
07 02	388	434	574	591	578
07 05	375	432	564	594	580
07 06	374	431	565	603	589
07 07	316	445	570	607	604
07 08	275	436	561	590	590
07 09	405	428	563	592	593
07 12	318	475	565	605	596
07 14	263	471	549	595	601
07 16	380	488	557	583	597
07 21	322	472	546	596	595
08 09	232	480	531	585	599
08 11	230	489	531	581	598
08 12	359	511	560	578	595
08 13	308	514	553	572	596
08 16	288	492	552	572	594
08 17	284	483	552	572	590
08 18	208	487	537	568	596
08 19	432	480	535	574	590
08 20	470	494	546	565	587
08 21	283	488	547	560	581
08 22	333	528	549	570	587
08 23	305	513	561	565	592
08 24	211	497	547	560	589
08 25	231	499	559	566	593
08 26	186	496	546	562	589
08 31	214	490	548	566	587
09 01	205	484	550	563	583
09 02	213	491	550	559	582

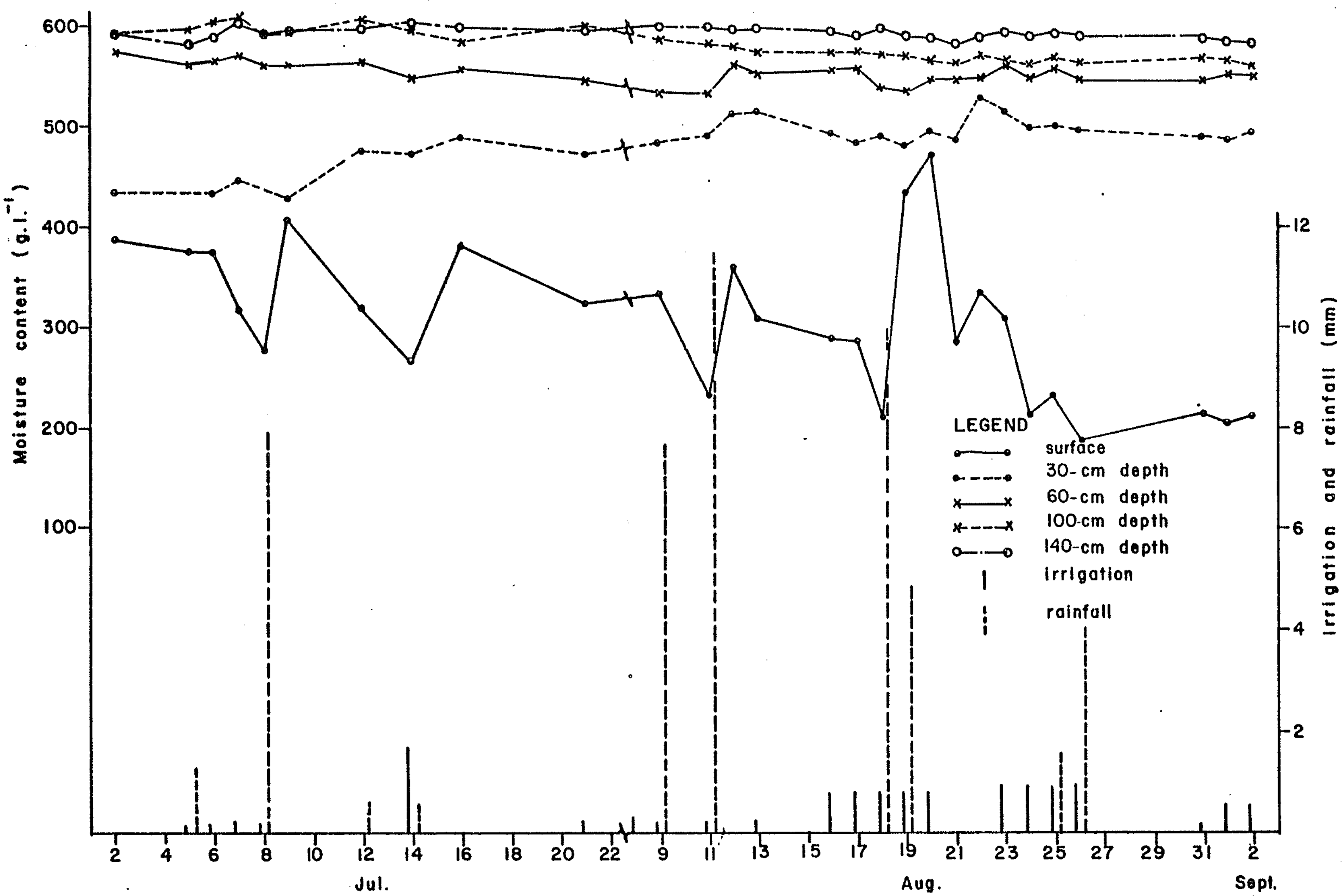

Figure 4.16 Soil moisture profile for access tube SNF - II - 4

The greatest short-term fluctuation in moisture took place at the soil surface. It was much decreased in the buffer zone but generally there was no change between rows and increasing trend on the drip line.

Generally moisture patterns and trends for the BNF treatment was the same as for the SUF, BUF and SNF treatments but the changes in moisture content with depth at the drip line were smaller at the end of the season than at the beginning.

4.5.3 General observation on drip-irrigation treatments.

The soil moisture regime at various depths for all treatments can be summarized as follows:

At 100 cm of depth and deeper the moisture content did not change much in time and place, it was not affected by irrigation and rain nor by crop consumption.

At the 60-cm depth over the long term (season), in most cases, there was some differences among locations where all access tubes showed a decreasing trend in moisture content. In the BUF treatment, for example the trend was less apparent closer to the drip line. For the SNF treatment, on the other hand, there was not much change in the row and between the rows, but there was some loss of moisture in the buffer zone. The 60-cm depth was in a transition zone between the deeper layer with its relatively constant moisture content and the shallower layer with its variable moisture content. On a short-term basis there

TABLE 4.17

Moisture content ($g.l^{-1}$) for access tube BNF-III-1

Date 1976	Soil depths (cm)				
	surface	30	60	100	140
07 02	391	525	594	579	579
07 05	407	523	591	582	585
07 06	338	517	595	584	589
07 07	373	526	599	587	592
07 08	312	536	581	586	588
07 09	403	531	588	580	590
07 12	359	542	587	580	593
07 14	340	539	576	582	590
07 16	251	524	562	576	583
07 21	243	515	550	571	582
08 09	224	-	-	-	-
08 11	425	532	551	570	585
08 12	468	540	552	576	590
08 13	458	502	547	573	585
08 16	302	493	542	573	583
08 17	349	492	531	571	579
08 18	302	490	542	575	577
08 19	448	488	545	568	574
08 20	513	500	550	566	572
08 21	414	500	540	558	572
08 22	412	504	540	558	572
08 23	410	504	546	561	580
08 24	397	495	550	570	589
08 25	371	490	552	571	589
08 26	309	496	557	572	588
08 31	333	501	555	579	584
09 01	249	505	543	569	581
09 02	240	525	550	573	585

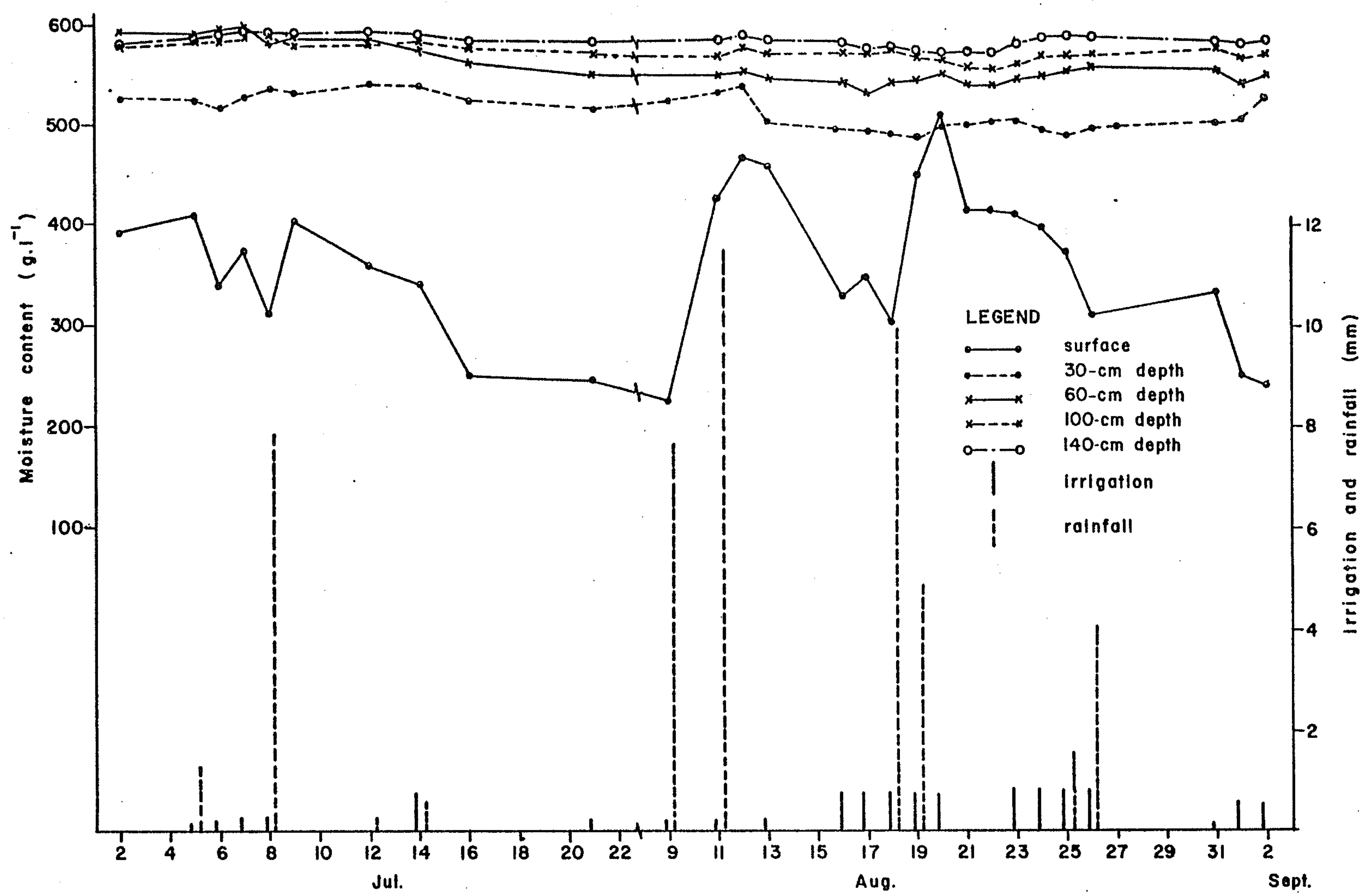

Figure 4.17 Soil moisture profile for access tube BNF-III-I

TABLE 4.18

Moisture content $(g.1^{-1})$ for access tube BNF-I-2

Date 1976	Soil depths (cm)				
	surgace	30	60	100	140
07 02	461	392	515	561	580
07 05	382	422	530	566	583
07 06	320	424	548	565	590
07 07	319	438	558	570	598
07 08	313	433	537	577	593
07 09	474	438	540	575	586
07 12	339	454	527	575	581
07 13	-	441	532	580	585
07 14	303	470	546	588	585
07 16	347	469	538	578	582
07 21	345	460	521	577	584
08 09	214	481	561	569	581
08 11	419	492	560	571	579
08 12	517	500	593	585	589
08 13	461	503	591	581	586
08 16	404	502	545	589	585
08 17	329	520	542	582	582
08 18	288	521	545	584	585
08 19	491	544	571	586	582
08 20	506	525	551	586	585
08 21	475	515	543	584	589
08 22	451	528	554	585	591
08 23	352	530	561	581	590
08 24	515	529	563	589	593
08 25	317	522	567	583	590
08 26	-	535	576	586	589
08 31	405	499	550	575	580
09 01	483	507	561	573	582
09 02	-	502	561	578	580

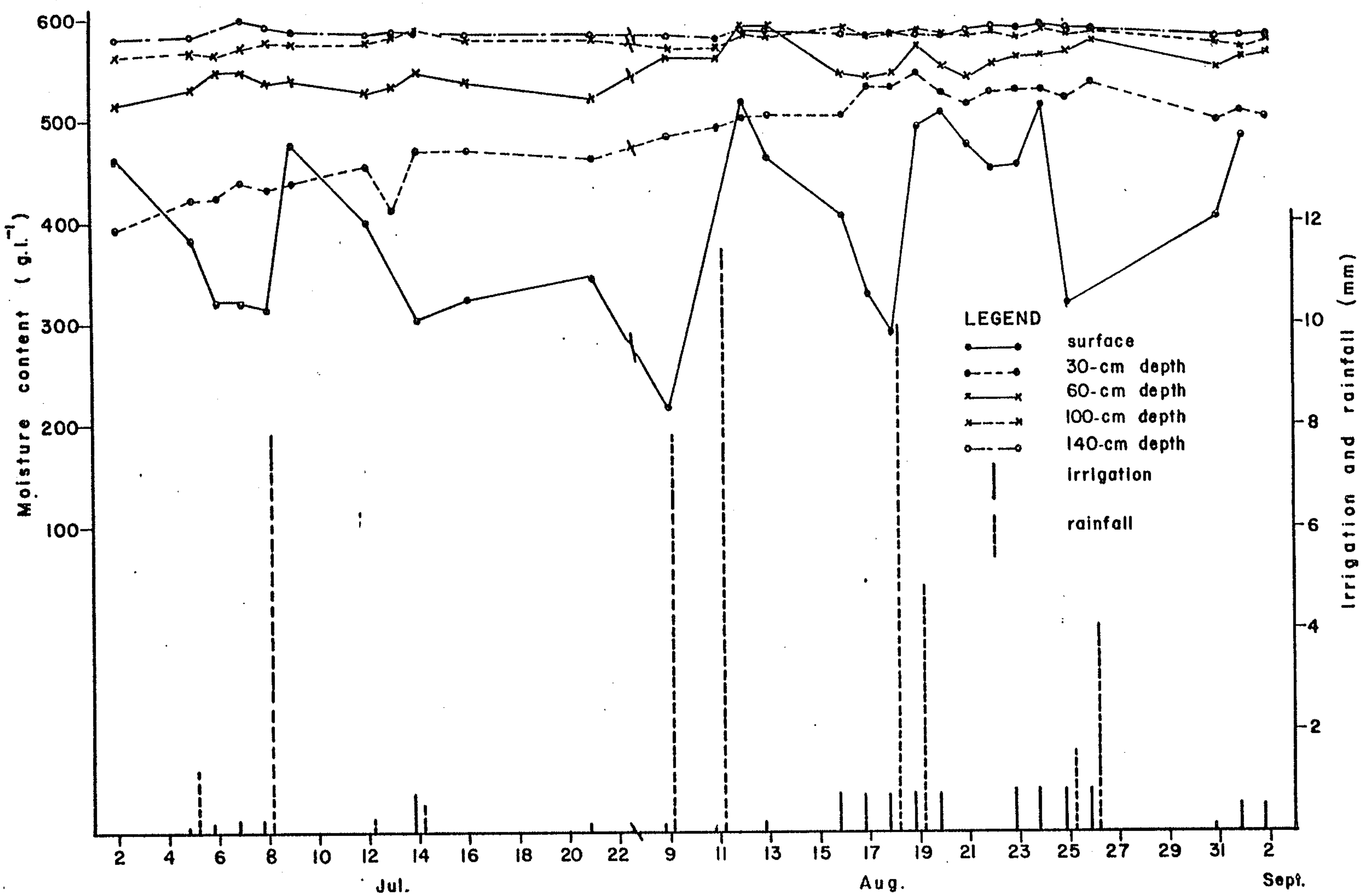

Figure 4.18 Soil moisture profile for access tube BNF-I-2

TABLE 4.19

Moisture content (g.l^{-1}) for access tube BNF-I-3

Date 1976	Soil depths (cm)				
	surface	30	60	100	140
07 02	468	394	580	591	594
07 05	410	429	599	600	610
07 06	350	414	580	595	595
07 07	336	454	590	600	605
07 08	495	451	577	591	596
07 09	494	465	562	585	600
07 12	417	485	557	581	596
07 13	-	466	556	584	604
07 14	594	495	579	585	593
07 16	532	472	571	585	590
07 21	342	446	562	580	594
08 09	507	467	572	577	589
08 11	498	480	570	574	584
08 12	615	495	579	584	590
08 13	543	486	569	586	594
08 16	448	500	565	582	589
08 17	484	516	575	581	588
08 18	492	529	575	587	595
08 19	520	535	571	585	590
08 20	575	555	568	586	590
08 21	551	535	557	580	587
08 22	556	545	568	572	583
08 23	548	538	575	584	591
08 24	544	546	569	581	586
08 25	454	531	554	585	591
08 26	542	527	541	589	587
08 31	505	527	531	580	585
09 01	579	539	546	578	589
09 02	484	541	557	578	584

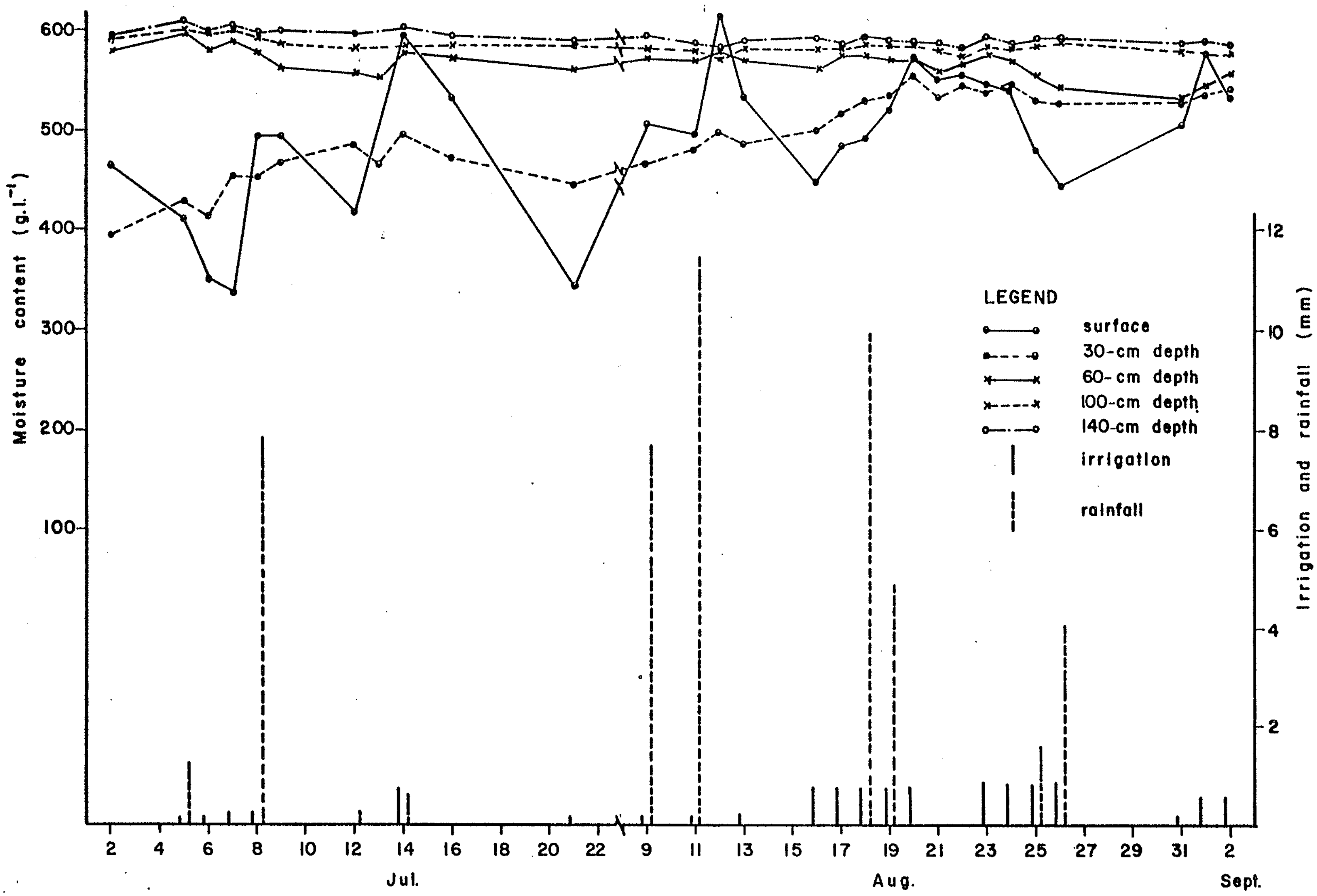

Figure 4.19 Soil moisture profile for access tube BNF - I - 3

TABLE 4.20

Moisture content $(g.l^{-1})$ for access tube BNF-II-4

Date 1976	Soil depths (cm)				
	surface	30	60	100	140
07 02	388	531	567	571	577
07 05	339	530	547	578	584
07 06	309	523	541	583	585
07 07	313	548	564	589	595
07 08	220	527	556	587	590
07 09	480	525	550	588	586
07 12	321	523	560	592	596
07 14	264	518	552	584	592
07 16	413	516	546	578	591
07 21	285	503	534	563	587
08 09	260	490	529	554	582
08 11	275	499	520	545	583
08 12	475	503	512	536	581
08 16	328	507	514	535	582
08 17	478	499	516	540	579
08 18	288	507	517	540	580
08 19	466	529	531	550	582
08 20	500	528	542	558	584
08 21	466	522	531	548	587
08 22	363	530	542	555	592
08 23	297	538	547	560	597
08 24	375	541	543	569	594
08 25	317	532	541	569	585
08 26	369	510	542	568	581
08 31	354	499	520	561	585
09 01	267	495	522	552	587
09 02	281	494	518	553	585

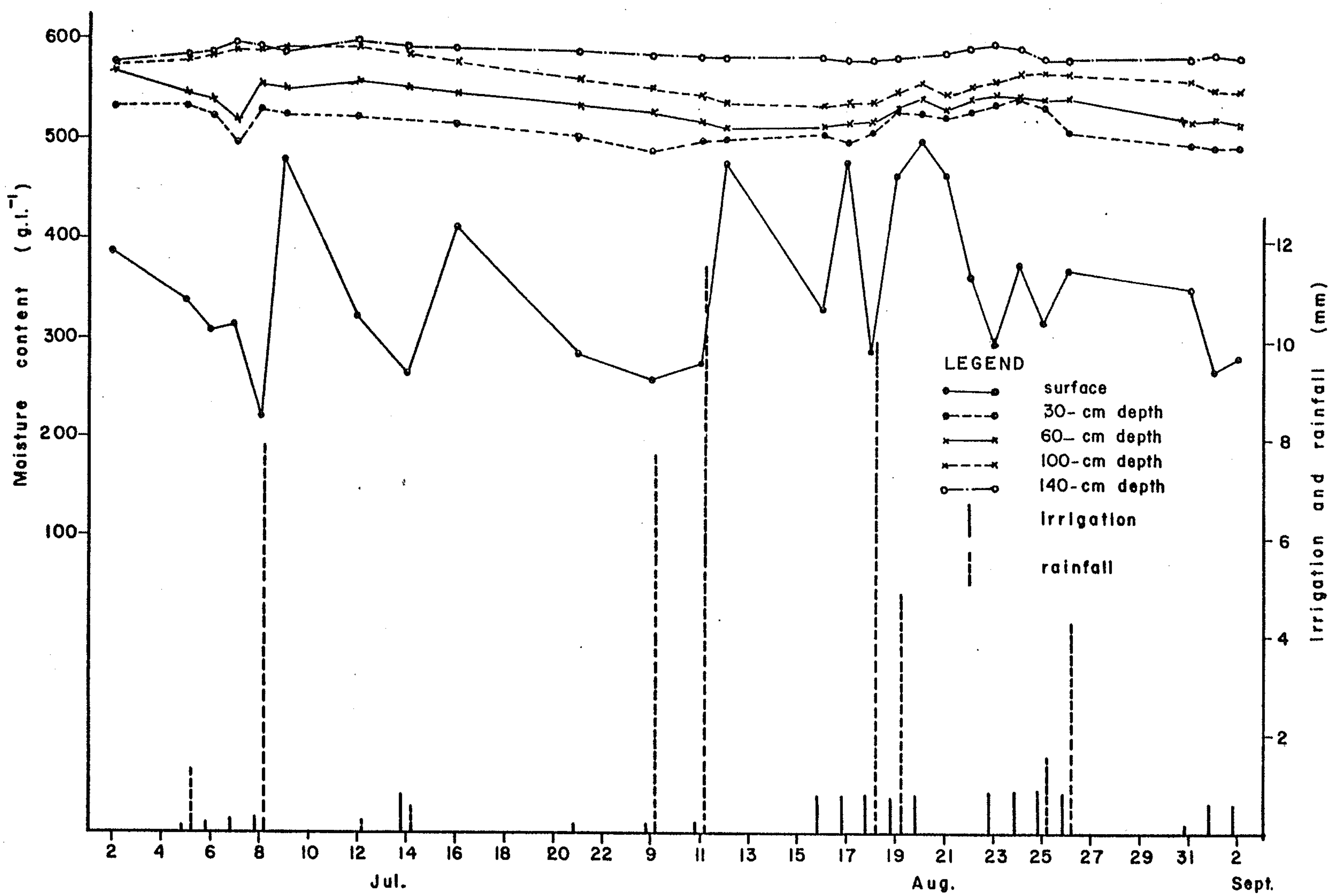

Figure 4.20 Soil moisture profile for access tube BNF - II - 4

seems to have been some moisture loss between rains in spite of the nearly continuous irrigation and an increase after rains. There were, however, many exceptions and irregularities and the short-term analysis also suggests that the 60-cm depth was a transition zone with a complex combination of all the factors involved (irrigation, rain, moisture consumption by crops, moisture migration and distance from the drip line).

At the 30-cm depth and the surface, the influence of the drip line was clearly visible and the short-term influence of irrigation and rain resulted in greater moisture fluctuations than it did at greater depths. Generally the moisture gradient (change of moisture with depth) farther from the lines increased through the season substantially while closer to the drip line and at the drip line it changed only a little and in some cases (BNF), it decreased during the season.

4.5.4 Furrow irrigation.

Soil moisture along the ridges below the crop rows increased consistently for depths up to the 100-cm depth after irrigations and rains. Moisture at the 140-cm depth, however, was almost constant throughout the season (Table 4.23 and Figure 4.24). The furrow irrigation also affected the moisture content in crop row in the buffer zone at a distance of 90 cm from the furrow (Table 4.22 and Figure 4.23). In station FF-I the influence of irrigation could be observed to a depth of 140 cm, because station FF-I was close to the point at which water was applied and due to the rather irregular water distribution connected with furrow irrigation, it received more water than the other stations.

4.6 Weed Control and Soil Tilth

There was no evidence that the drip irrigation system had any advantage in weed control. The rain and moisture moving laterally supported the weed growth even midway between the drip lines. On the other hand the broadleaved Plantain (Plantago Major L) which prefers moist soil, could grow better in the drip-irrigated treatments than in the non-irrigated treatments. In the subsurface drip irrigation treatments the root system of this weed developed around, and close to the drip tubes. It was so close and dense that it may have restricted the uniformity and the efficiency of the subsurface drip-irrigation system.

Under the drip-irrigation systems the soil tended to remain dry and powdery between rows while near the drip lines the soil remained muddy and saturated. In the furrow-irrigated plots the soil was muddy immediately after each irrigation but dried out and baked later.

4.7 Tensiometer Readings

In all irrigation systems the soil moisture tension did not exceed 50 KPa. This indicates that the crops suffered no moisture stress at any time.

TABLE 4.21

Irrigation frequency and quantity for furrow irrigation

Date 1976	Irrigation Volume (1)	Depth equivalent (mm)
06 02	536.01	1.99
06 22	487.26	1.80
07 05	684.53	2.54
07 14	935.40	3.46
07 26	1,151.34	4.26
08 05	1,140.74	4.23
08 18	1,069.44	3.96
09 03	965.35	3.57
Total	6,970.07	25.81

TABLE 4.22

Moisture content ($g.l^{-1}$) for access tube FF-I-1

Date 1976	Soil depths (cm)				
	surface	30	60	100	140
07 02	349	430	533	588	592
07 05	346	474	590	607	616
07 06	339	464	574	596	608
07 07	362	468	585	604	615
07 08	347	471	585	593	612
07 09	404	524	587	591	600
07 12	374	523	584	595	601
07 13	-	535	579	598	612
07 14	306	564	576	589	600
07 16	391	535	566	590	596
07 21	266	513	578	589	592
08 09	237	496	539	580	593
08 11	281	495	531	576	595
08 12	393	525	548	595	620
08 13	389	492	532	573	596
08 16	-	492	534	572	590
08 17	365	475	537	570	593
08 18	436	499	534	568	598
08 19	436	534	577	591	595
08 20	468	525	574	595	607
08 21	355	521	560	591	595
08 22	252	535	577	593	602
08 23	281	541	578	596	605
08 24	280	517	580	591	598
08 25	272	505	569	586	596
08 26	222	507	558	583	591
08 31	238	501	545	572	589
09 01	185	505	539	574	593
09 02	186	507	542	580	595

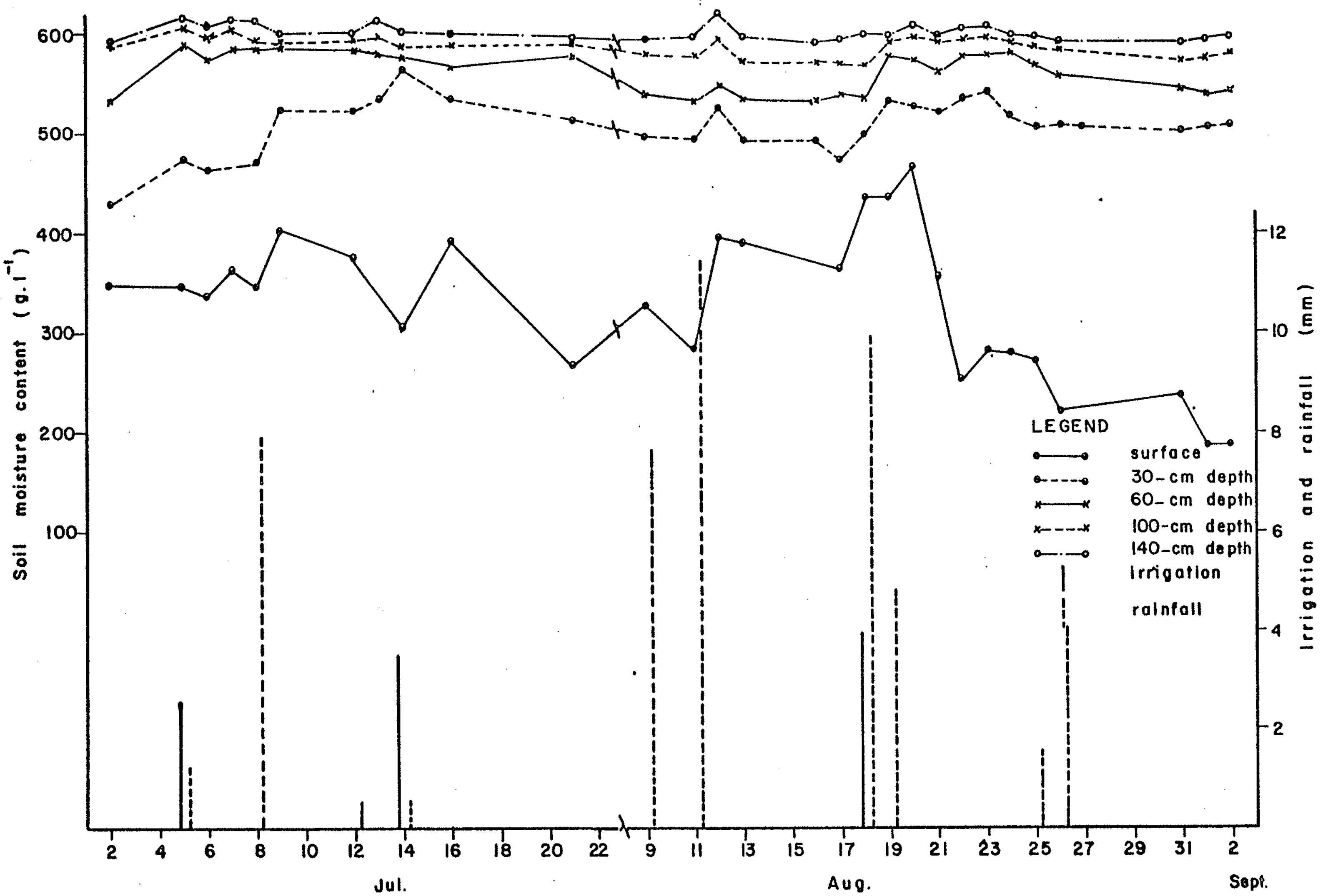

Figure 4.21 Soil moisture profile for access tube FF - I - I

TABLE 4.23

Moisture content ($g.l^{-1}$) for access tube FF-II-2

Date 1976	Soil depths (cm)				
	surface	30	60	100	140
07 02	396	503	543	571	601
07 05	396	513	552	593	603
07 06	337	506	546	592	612
07 07	387	532	546	596	615
07 08	314	518	539	592	600
07 09	414	513	529	588	597
07 13	380	518	533	595	606
07 14	406	507	544	590	600
07 16	397	506	545	587	598
07 21	322	495	521	560	583
08 09	335	509	512	540	587
08 11	321	502	508	536	585
08 12	474	531	526	561	600
08 13	419	509	529	558	600
08 16	362	508	531	568	596
08 17	256	501	528	568	590
08 18	295	499	511	562	586
08 19	434	534	569	575	590
08 20	442	523	570	584	594
08 21	440	509	566	580	595
08 22	371	513	567	579	601
08 23	392	519	570	586	600
08 24	284	500	554	577	592
08 25	284	497	549	562	590
08 26	317	502	546	572	588
08 31	269	497	530	560	591
09 01	250	501	535	570	583
09 02	234	490	524	562	587

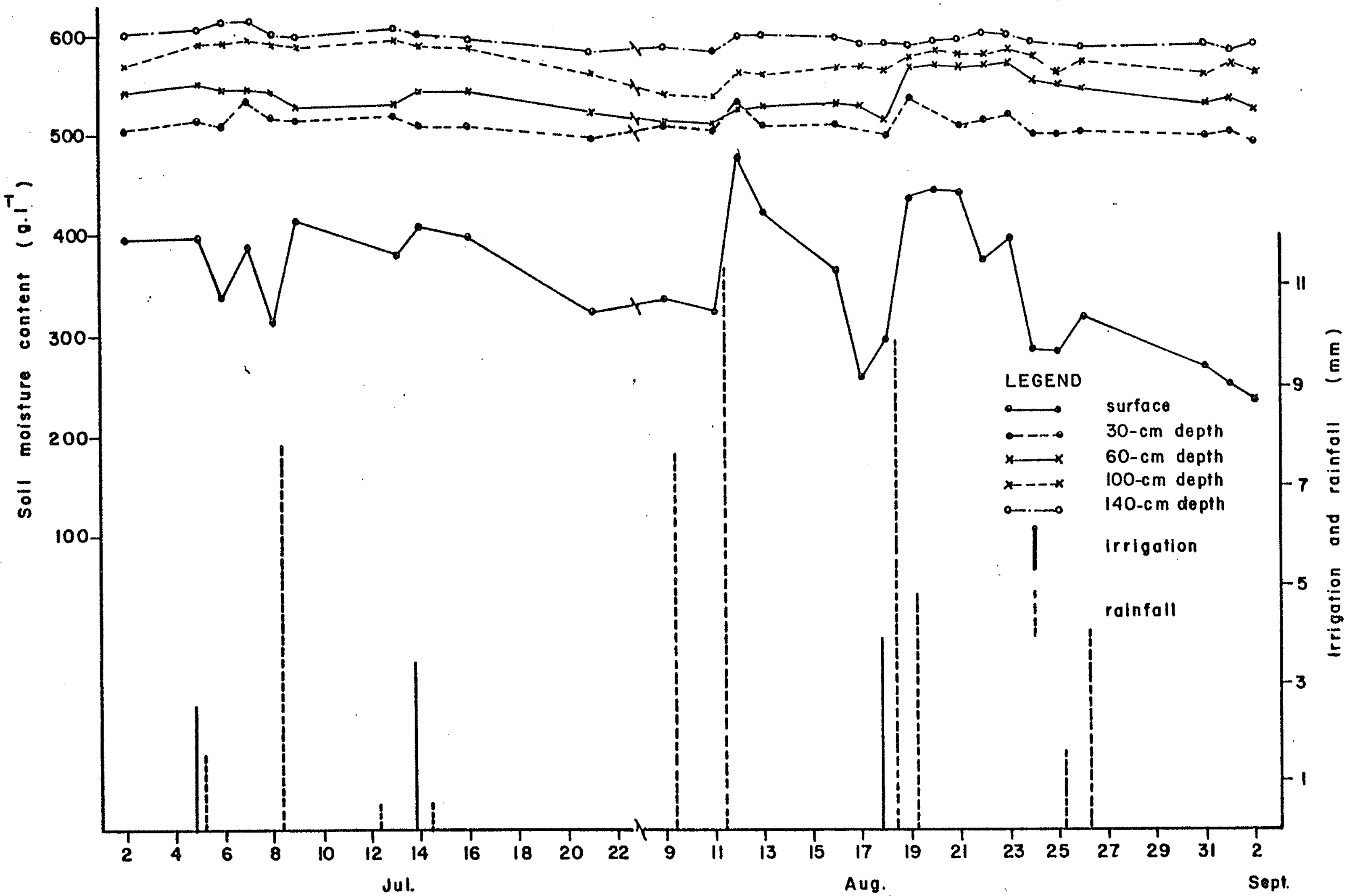

Figure 4.22 Soil moisture profile for access tube FF-II-2

4.8 Crop Response

There was no visible difference in germination among any of the irrigation treatments or the non-irrigated treatment. The germination in all subplots was non-uniform. It was concluded that this was caused by low temperatures during the germination stage and non-uniform depth of planting.

The furrow irrigation treatment gave the highest yield (green matter) but the highest water use efficiency was found in subsurface drip-irrigation method using new Viaflo tubes (the BNF treatment). Both the new surface installed tube treatment (SNF) and previously used surface installed tube treatment (SUF) gave yield higher than the subsurface drip-irrigation treatments (BNF and BUF) but their water use efficiency was lower. The crop yield (green matter), relative yield percentage and water use efficiency are shown in Table 4.24.

Yield results were strongly affected by nitrogen deficiency, erosion, non-uniform stands and weeds.

4.9 Other Observations

The following observations were also made in the field during the experiment:

1. the repair of damaged Viaflo tubes could not restore their previous properties and the water continued to leak and cause spot waterlogging problems;

TABLE 4.24

Crop yield, relative yield percentage and water use efficiency

Treatment	Total yield (green matter)[1] (kg)	Mass of 50 randomly collected cobs (kg)	Yield of green matter per 100 m row length (kg)	Total irrigation volume (l)	Applied water per 100 m row length (l)	Water use efficiency ($kg.l^{-1}$)	Relative yield percent of non-irrigated treatment[2]
SUF	575.87	12.89	191.96	5,753.55	1,917.85	0.100	134
BUF	557.04	11.53	185.68	5,241.14	1,747.05	0.106	120
SNF	641.33	12.08	213.78	4,573.98	1,524.66	0.140	125
BNF	558.02	13.12	186.01	4,369.30	1,456.43	0.128	136
FF	654.39	13.57	218.13	6,970.07	2,323.36	0.094	141
NF	437.14	9.61	145.71	-	-	-	100

[1] Cobs, stalks and leaves

[2] Based on the mass of 50 randomly collected cobs

2. Viaflo tube damage significantly increased with time. Unobserved damage caused non-uniform moisture distribution along the line and even crop loss due to waterlogging;
3. by visual observation, some damage to the surface-laid drip tubes seemed likely to have been caused by rodents;
4. the algae growth and ultraviolet degradation caused rapid deterioration of surface-laid Viaflo tubing.

CHAPTER V

CONCLUSION

Based on the results of this study a number of conclusions can be made.

1. Laboratory tests indicate that after one season of use, the bursting strength of surface-installed Viaflo tubes declined while no change in the bursting strength of Viaflo tubes used for the same period of time in a subsurface drip-irrigation installation could be observed.

2. In laboratory tests, water discharge from both types of previously used Viaflo tubes was substantially smaller than the discharge from new tubes.

3. In field tests, subsurface drip irrigation installations proved to be superior to surface drip-irrigation installations in terms of uniformity of water distribution, mechanical damage and material deterioration.

4. In surface drip-irrigation installations Viaflo tubes could not be used for more than two seasons, while the subsurface drip-irrigation tubes used for two seasons appeared to be in good condition and suitable for use in third season.

5. Drip irrigation failed to reduce weed growth in the interrow space; on the contrary, some weeds (especially the broadleaved Plantain (Plantago Major L) were more

abundant and stronger in the area near the drip lines.

6. Roots of some weeds (such as the broadleaved Plantain) which developed close to the subsurface drip lines may have adversely affected the discharge of water from the drip lines and the uniformity of water application.

7. All four drip-irrigation treatments increased yields substantially as compared with the non-irrigated plot; however, the yields from all drip-irrigation treatments were lower than the yield from the furrow-irrigated treatment.

8. In terms of water use efficiency all drip-irrigation treatments were better than furrow irrigation and both new tubing installations were substantially better than the old tubing installations.

9. Irrigation affected substantially the moisture regime of the root zone to approximately 60 cm with maximum impact at and around the depth of 30 cm.

10. Under drip irrigation, moisture levels below the depth of 100 cm remained fairly constant which indicates that there were no deep percolation losses. On the other hand moisture contents under furrow irrigation increased considerably up to the 140-cm depth after rainfall or irrigation.

11. Viaflo tubing is very susceptible to various kinds of damage, especially in surface installations.

12. Repairing damaged tubes according to the manufacturer's instructions failed to restore the uniformity

of water distribution.

13. The use of two filters proved more effective in improving water quality than the single filter.

CHAPTER VI

RECOMMENDATIONS

A number of recommendations for further studies are advanced arising from this experiment.

1. The possibility of the damage to surface-installed Viaflo tubing by rodents should be investigated.

2. Viaflo tubing with non-porous black polyethylene on one side should be used in surface installations instead of the conventional Viaflo tubing fabricated entirely of white porous polyethylene used in this investigation. This tubing would not be affected by ultraviolet light and would increase the life of the system.

3. The performance of the subsurface-installed Viaflo tubing in a third season should be studied.

4. Addition of a sediment tank and gravel or sand filters upstream from the 74- and 25-micron filters to provice more efficient filtration of irrigation water should be studied with a view to reduce the frequency of cleaning of the filters.

5. Automatic self-cleaning of the filter would be desirable for a system with a heavy sediment load. The automatic cleaning could be carried out on a time schedule or whenever the pressure drop across the filter reached a predetermined level.

6. The application of soluble fertilizers through a trickle-irrigation system should be studied. This would involve the study of reactions between fertilizers and irrigation water and the study of the impacts of the chemicals upon the properties of the tubing.

7. Because trickle irrigation wets only part of the potential soil rooting zone and the development of the root system is, therefore, limited the impact of this restriction upon the yield should be studied.

REFERENCES

1. Aggarwal, M. C., S. P. Dixit and K. Singh. 1973. Studies on drip method of irrigation for potato. Indian J. of Horticulture Vol. 30, Nos. 1 & 2, pp. 418-420.

2. Agriculture Canada. 1975. Irrigation on the prairies. Canada Department of Agriculture publication 1488, revised 1975.

3. Berstein, L. and L. E. Francois. 1973. Comparisons of drip, furrow and sprinkler irrigation. J. Amer. Soc. Agron. 35: 796-810.

4. Bester, D. H. 1974. Drip irrigation on citrus. Proc. Second International Drip Irrigation Congress. San Diego, California. July 1974, pp. 58-64.

5. Bush, C. D. and W. R. Kneebone. 1966. Sub-surface irrigation with perforated plastic pipe. Trans ASAE, pp. 100-101.

6. Edminster, T. W. 1974. Time of transition. Proc. Second International Drip Irrigation Congress. San Diego, California. July 1974, pp. 6-8.

7. Fraser, G. O. 1974. Drip irrigation inherent requisite- water quality. Proc. Second International Drip Irrigation Congress. San Diego, California. July 1974, pp. 81-85.

8. Furuta, T., R. Branson, W. C. Jones, R. Strohman, T. Mock and I. Ramadan. 1974. Irrigation for container growing. Proc. Second International Drip Irrigation Congress. San Diego, California. July 1974, pp. 155-158.

9. Goldberg, S. D. 1971. Modern concepts on irrigation. Paper presented to Israel National Committee of the ICID.

10. Goldberg, S. D. and M. Shmueli. 1970. Drip irrigation--a method used under arid and desert conditions of high water and soil salinity. Trans. ASAE, Vol. 13, No. 1.

11. Grobbelaar, H. L. and F. Lourens. 1974. Fertilizer applications with drip irrigation. Proc. Second International Drip Irrigation Congress. San Diego, California July 1974, pp. 411-415.

12. Grossi, P. 1974. Researches and applications on drip irrigation and similar methods in Italy. Proc. Second International Drip Irrigation Congress. San Diego, California. July 1974, pp. 46-51.

13. Gustafson, C. D., A. W. Marsh, R. L. Branson and S. Davis. 1974. Drip irrigation--worldwide. Proc. Second International Drip Irrigation Congress. San Diego, California. July 1974, pp. 17-22.

14. Hanson, E. G. and T. C. Patterson. 1974. Vegetable production and water-use efficiency as influenced by drip, sprinkler, subsurface and furrow irrigation methods. Proc. Second International Drip Irrigation Congress. San Diego, California. July 1974, pp. 97-102.

15. Harrison, D. S. and J. M. Myers. 1974. Drip irrigation design criteria for tree crops in Florida and other humid regions. Proc. Second International Drip Irrigation Congress. San Diego, California. July 1974, pp. 33-37.

16. Howell, T. A. and E. A. Hiller. 1974. Design trickle irrigation laterals for uniformity. J. of Irrigation and Drainage Division, ASCE, Vol. 100, No. IR4. Proc. Paper 10983, Dec. 1974, pp. 443-454.

17. Isobe, M. 1974. Investigations in sugarcane fertilization by drip irrigation in Hawaii. Proc. Second International Drip Irrigation Congress. San Diego, California. July 1974, pp. 405-410.

18. Karmeli, D. and J. Keller. 1975. Trickle Irrigation Design. Rain Bird Sprinkler Manufacturing Corporation, California.

19. Kenworthy, A. L. 1972. Trickle irrigation the concepts and guidelines for use. Research Report. Farm Science Michigan State University, pp. 2-3.

20. Lanham, F. B. 1976. Heritage and horizons--how It began. Agric. Eng., Dec. 1976. pp. 18-34.

21. Mehdizadeh, P. and S. T. Jahromi. 1974. An investigation on the use of drip irrigation for the establishment of multipurpose parks (green belts around the cities) in Iran. Proc. Second International Drip Irrigation Congress, San Diego, California. July 1974, pp. 462-467.

22. New, L. and R. Roberts. 1974. Automatic drip irrigation for greenhouse tomato production in West Texas. Proc. Second International Drip Irrigation Congress, San Diego, California. July 1974, pp. 159-164.

23. Paldi, H. 1974. Drip irrigation and automation tools in efficient use of water policy. Proc. Second International Drip Irrigation Congress, San Diego, California. July 1974, pp. 29-32.

24. Phene, C. J. 1974. High frequency porous tubing irrigation for water-nutrient management in humid regions. Proc. Second International Drip Irrigation Congress. San Diego, California. July 1974, pp. 166-171.

25. Rawitz, E. and D. Hillel. 1974. The progress and problems of drip irrigation in Israel. Proc. Second International Drip Irrigation Congress, San Diego, California. July 1974, pp. 23-28.

26. Read, A. L., M. F. Pietsch and W. E. Matheson. 1974. Australian vineyard used sewage effluent with trickle irrigation. Proc. Second International Drip Irrigation Congress. San Diego, California. July 1974, pp. 382-387.

27. Roberts, J. C. 1974. A farmer's opinion of trickle irrigation. Proc. Second International Drip Irrigation Congress. San Diego, California. July 1974, pp. 77-79.

28. Rolston, D. E., R. S. Rauschkolb and D. L. Hoffman. 1974. Use of glycerophosphate for fertilization through trickle irrigation system. Proc. Second International Drip Irrigation Congress. San Diego, California. July 1974, pp. 416-421.

29. Seifert, W. J., E. A. Hiler and T. A. Howell. 1975. Trickle Irrigation with Water of Different Salinity Levels. Trans. ASAE, Vol. 18 No. 1.

30. Spiess, L. B. 1973. Trickle irrigation projects 1973 report. Alberta Department of Agriculture, pp., 22.

31. Spiess, L. B. 1974. Trickle irrigation projects 1974 report. Alberta Department of Agriculture. p. 12.

32. Sterling, D. and W. J. Pugh. 1974. Drip irrigation: surface and subsurface compared with sprinkler and furrow. Proc. Second International Drip Irrigation Congress. San Diego, California. July 1974, pp. 109-112.

33. Tahnoon, S. and F. K. Aljibury. 1974. Afforestation with saline water in Abu Dhabi. Proc. Second International Drip Irrigation Congress. San Diego, California. July 1974, pp. 370-371.

34. Udeh, N. C. 1975. Evaluation of porous drip irrigation tubing 'Viaflo' for irrigation of row crops in Manitoba. MSc thesis, University of Manitoba.

35. Wilke, O. C. 1974. Mobile drip irrigation systems. Proc. Second International Drip Irrigation Congress. San Diego, California. July 1974, pp. 188-192.

36. Wolff, P. 1974. Use of drip irrigation in Germany. Proc. Second International Drip Irrigation Congress. San Diego, California. July 1974, pp. 71-76.

APPENDIX A

Precipitation at Glenlea Research Station

1976 05 01 - 1976 09 05

Precipitation at Glenlea Research Station

1976 05 01 - 1976 09 05

Date (1976)	Precipitation (mm)
05 12	3.56
05 14	4.32
05 26	2.29
06 05	5.59
06 06	34.29
06 07	1.02
06 08	3.05
06 09	32.51
06 12	14.99
06 14	0.76
06 16	5.84
06 20	0.25
06 21	0.51
06 24	34.80
06 25	2.54
06 26	8.64
06 28	3.56
07 05	1.27
07 08	7.87
07 12	0.25
07 14	0.51
07 15	1.52
07 18	1.27
07 19	1.02
07 24	4.32
07 27	0.25
07 29	2.29
08 08	0.51
08 09	7.62
08 11	11.43
08 18	9.91
08 19	4.83
08 25	1.52
08 26	4.06
08 27	0.25

APPENDIX B

Soil moisture contents for SUF treatment.

Moisture content ($g.l^{-1}$) for access tube SUF-I-1

Date 1976	Soil depths (cm)				
	surface	30	60	100	140
07 02	-	400	557	562	581
07 05	-	470	567	580	585
07 06	-	469	571	584	585
07 07	-	457	585	581	582
07 08	-	460	559	592	591
07 09	-	464	555	578	581
07 12	-	486	550	575	585
07 13	-	487	553	581	587
07 14	-	485	540	572	574
07 16	-	490	537	569	573
07 21	-	481	532	567	572
08 09	-	384	499	558	565
08 11	-	383	486	547	566
08 12	-	395	493	546	570
08 13	-	390	489	534	560
08 16	-	387	477	542	559
08 17	-	390	485	538	560
08 18	-	382	474	542	564
08 19	-	390	486	540	565
08 20	-	389	485	539	555
08 21	-	382	474	530	553
08 22	-	393	469	549	570
08 23	-	394	476	550	574
08 24	-	397	477	555	582
08 25	-	399	471	556	578
08 26	-	397	469	554	587
08 31	-	391	459	551	576
09 01	-	395	461	545	579
09 02	-	385	451	536	570

Moisture content $(g.l^{-1})$ for access tube SUF-I-2

Date 1976	Soil depths (cm) surface	30	60	100	140
07 02	395	423	536	576	581
07 05	368	476	580	596	595
07 06	329	477	571	600	594
07 07	363	504	573	600	601
07 08	322	503	558	592	596
07 09	447	510	560	593	598
07 12	304	524	566	591	591
07 13	-	487	553	581	587
07 14	366	512	564	588	592
07 16	315	518	560	585	590
07 21	229	481	532	577	582
08 09	142	460	520	560	577
08 11	255	467	527	568	585
08 12	385	496	530	562	586
08 13	363	462	515	565	587
08 16	233	464	520	565	585
08 17	262	463	515	559	588
08 18	255	468	516	558	586
08 19	383	479	527	549	589
08 20	448	475	515	546	583
08 21	372	473	512	546	588
08 22	355	491	524	563	582
08 23	289	517	526	572	587
08 24	367	502	512	560	584
08 25	310	484	509	559	584
08 26	345	489	512	545	582
08 31	327	478	501	546	581
09 01	250	468	503	543	587
09 02	232	479	518	558	585

Moisture content ($g.l^{-1}$) for access tube SUF-I-3

Date 1976	Soil depths (cm)				
	surface	30	60	100	140
07 02	418	441	546	587	590
07 05	358	484	590	600	602
07 06	331	465	592	600	600
07 07	398	478	588	597	593
07 08	477	460	584	590	590
07 09	459	456	571	588	591
07 12	436	474	556	586	588
07 13	-	478	571	595	592
07 14	434	485	558	586	591
07 16	509	515	553	582	592
07 21	308	473	552	578	594
08 09	378	441	537	576	586
08 11	478	473	540	584	592
08 12	543	484	544	585	592
08 13	528	471	546	585	589
08 16	349	472	545	570	589
08 17	349	506	543	575	584
08 18	454	510	550	579	591
08 19	495	518	554	581	590
08 20	626	533	551	583	596
08 21	514	494	545	585	595
08 22	563	539	556	580	597
08 23	574	557	570	590	606
08 24	600	530	550	584	593
08 25	510	532	549	580	594
08 26	528	515	547	580	594
08 31	362	499	530	578	585
09 01	457	485	534	570	588
09 02	542	509	540	575	588

Moisture content ($g.l^{-1}$) for access tube SUF-I-4

Date 1976	Soil depths (cm)				
	surface	30	60	100	140
07 02	-	441	546	575	566
07 05	-	367	585	588	584
07 06	-	372	576	601	585
07 07	-	359	525	599	588
07 08	-	399	502	585	583
07 09	-	411	499	593	580
07 12	-	432	535	585	580
07 13	-	427	534	595	584
07 14	-	410	508	584	583
07 16	-	430	529	580	577
07 21	-	415	519	560	573
08 09	-	352	506	553	579
08 11	-	350	494	545	577
08 12	-	389	517	535	567
08 13	-	374	499	528	568
08 16	-	358	495	530	561
08 17	-	360	503	528	560
08 18	-	359	513	525	558
08 19	-	387	521	528	555
08 20	-	406	517	528	558
08 21	-	395	505	530	550
08 22	-	415	528	536	570
08 23	-	409	541	556	589
08 24	-	466	520	540	576
08 25	-	390	525	541	565
08 26	-	400	525	554	566
08 31	-	402	526	541	565
09 01	-	400	520	540	559
09 02	-	415	543	551	562

Moisture content ($g.l^{-1}$) for access tube
SUF-II-1

Date 1976	Soil depths (cm)				
	surface	30	60	100	140
07 02	-	538	585	578	593
07 05	-	541	591	583	603
07 06	-	541	586	583	602
07 07	-	562	599	595	610
07 08	-	539	587	584	601
07 09	-	539	585	578	601
07 13	-	558	592	590	605
07 14	-	542	576	581	598
07 16	-	539	583	586	602
07 21	-	521	551	575	589
08 09	-	475	524	559	586
08 11	-	485	538	556	590
08 12	-	503	561	568	605
08 13	-	480	531	539	585
08 16	-	480	530	556	588
08 17	-	473	538	550	590
08 18	-	460	539	556	584
08 19	-	481	542	551	595
08 20	-	471	536	569	576
08 21	-	470	525	565	578
08 22	-	475	531	582	591
08 23	-	486	542	586	597
08 24	-	476	539	584	586
08 25	-	481	545	578	586
08 26	-	485	547	584	593
08 31	-	488	540	575	591
09 01	-	476	537	568	585
09 02	-	471	529	563	592

Moisture content ($g.l^{-1}$) for access tube SUF-II-2

Date 1976	Soil depths (cm)				
	surface	30	60	100	140
07 02	-	513	587	588	582
07 05	-	499	582	587	594
07 06	-	497	586	588	597
07 07	-	520	589	593	591
07 08	-	502	579	592	592
07 09	-	508	573	590	586
07 13	-	512	570	593	596
07 14	-	499	555	595	598
07 16	-	500	547	596	585
07 21	-	476	520	574	578
08 09	-	457	503	550	577
08 11	-	457	506	541	581
08 12	-	478	526	568	589
08 13	-	496	521	557	589
08 16	-	452	509	549	583
08 17	-	450	512	547	578
08 18	-	459	519	547	585
08 19	-	470	520	556	586
08 20	-	459	543	562	581
08 21	-	473	538	571	585
08 22	-	499	565	583	586
08 23	-	500	556	584	585
08 24	-	482	554	590	580
08 25	-	470	544	585	579
08 26	-	483	560	587	584
08 31	-	479	532	571	586
09 01	-	476	528	570	579
09 02	-	471	515	566	576

Moisture content ($g.l^{-1}$) for access tube SUF-II-3

Date 1976	Soil depths (cm)				
	surface	30	60	100	140
07 02	-	455	567	582	594
07 05	-	544	575	588	599
07 06	-	551	577	598	600
07 07	-	530	569	590	608
07 08	-	496	550	586	602
07 09	-	508	556	582	592
07 13	-	478	571	582	595
07 14	-	497	535	589	594
07 16	-	496	543	590	589
07 21	-	475	521	570	584
08 09	-	461	511	559	583
08 11	-	465	499	533	582
08 12	-	495	520	551	601
08 13	-	468	494	530	579
08 16	-	467	501	540	577
08 17	-	465	502	537	581
08 18	-	466	505	535	586
08 19	-	485	512	534	584
08 20	-	489	552	540	585
08 21	-	468	546	552	581
08 22	-	497	550	561	592
08 23	-	502	568	581	602
08 24	-	476	555	578	590
08 25	-	489	556	586	589
08 26	-	503	578	589	594
08 31	-	472	520	582	586
09 01	-	471	512	578	584
09 02	-	472	502	575	587

Moisture content $(g.l^{-1})$ for access tube SUF-II-4

Date 1976	Soil depths (cm)				
	surface	30	60	100	140
07 02	459	510	568	583	603
07 05	395	506	563	596	602
07 06	381	500	565	590	600
07 07	345	525	589	615	600
07 08	301	507	562	581	601
07 09	404	515	558	586	597
07 12	352	-	-	-	-
07 13	-	529	557	592	606
07 14	323	520	550	579	589
07 16	305	518	546	580	590
07 21	254	499	515	555	580
08 09	221	485	495	539	574
08 11	287	500	508	542	581
08 12	438	519	526	560	606
08 13	372	491	506	534	576
08 16	286	496	515	537	583
08 17	246	498	515	535	591
08 18	288	500	515	541	589
08 19	429	495	515	542	588
08 20	-	491	548	559	576
08 21	355	494	543	560	567
08 22	297	523	565	602	614
08 23	267	533	584	603	620
08 24	241	502	547	584	595
08 25	312	504	541	572	597
08 26	222	517	569	578	589
08 31	250	502	529	572	586
09 01	175	498	523	569	578
09 02	198	499	517	562	580

Moisture content $(g.l^{-1})$ for access tube SUF-III-1

Date 1976	Soil depths (cm) surface	30	60	100	140
07 02	399	432	543	589	591
07 05	359	438	545	594	594
07 06	355	438	550	590	592
07 07	329	497	551	593	595
07 08	327	462	541	592	595
07 09	401	482	565	595	598
07 12	286	476	515	592	598
07 14	275	464	518	592	596
07 16	268	455	516	589	596
07 21	252	449	500	589	598
08 09	157	424	498	582	597
08 11	-	-	-	-	-
08 12	413	440	513	588	597
08 13	412	427	507	586	595
08 16	309	428	532	582	588
08 17	343	425	534	580	592
08 18	291	430	535	580	590
08 19	456	448	542	585	596
08 20	472	450	545	586	590
08 21	444	462	565	591	595
08 22	388	468	570	588	600
08 23	346	466	571	589	600
08 24	290	461	569	585	590
08 25	376	465	567	581	592
08 26	195	457	556	581	590
08 31	343	439	549	579	584
09 01	241	435	542	572	590
09 02	249	428	541	576	596

Moisture content ($g.l^{-1}$) for access tube SUF-III-2

Date 1976	Soil depths (cm)				
	surface	30	60	100	140
07 02	-	463	596	599	600
07 05	-	473	600	600	602
07 06	-	497	586	597	598
07 07	-	480	579	597	599
07 08	-	447	578	588	598
07 09	-	481	584	595	604
07 13	-	491	592	597	604
07 14	-	505	588	597	605
07 16	-	490	566	587	593
07 21	-	482	557	583	587
08 09	-	486	549	580	595
08 12	-	514	584	575	592
08 13	-	562	584	575	588
08 16	-	560	584	578	591
08 17	-	561	584	575	585
08 18	-	545	582	579	590
08 19	-	557	578	576	587
08 20	-	559	571	575	589
08 21	-	547	580	574	585
08 23	-	541	573	577	591
08 24	-	533	587	579	595
08 25	-	525	581	580	598
08 26	-	515	580	586	593
08 31	-	504	555	576	593
09 01	-	498	544	565	587
09 02	-	525	568	578	586

Moisture content ($g.1^{-1}$) for access tube SUF-III-3

Date 1976	Soil depths (cm)				
	surface	30	60	100	140
07 02	-	467	594	605	605
07 05	-	523	579	597	607
07 06	-	557	572	590	608
07 07	-	575	579	597	608
07 08	-	541	558	589	600
07 09	-	539	569	595	606
07 13	-	535	559	595	607
07 14	-	536	571	598	603
07 16	-	516	551	588	601
07 21	-	521	537	586	604
08 12	-	557	576	589	605
08 13	-	565	574	587	598
08 16	-	573	575	583	601
08 17	-	579	583	588	606
08 18	-	575	586	590	608
08 19	-	581	586	588	602
08 20	-	564	576	582	594
08 21	-	547	562	583	600
08 23	-	597	582	586	603
08 24	-	538	575	591	602
08 25	-	542	579	592	607
08 26	-	535	568	587	598
08 31	-	500	538	577	591
09 01	-	485	528	571	596
09 02	-	496	546	580	600

Moisture content ($g.l^{-1}$) for access tube SUF-III-4

Date 1976	Soil depths (cm)				
	surface	30	60	100	140
07 02	-	436	584	590	595
07 05	-	525	587	597	596
07 06	-	528	574	593	597
07 07	-	539	582	592	604
07 08	-	516	565	584	593
07 09	-	534	582	596	597
07 13	-	523	556	596	605
07 14	-	522	580	592	598
07 16	-	516	556	589	595
07 21	-	496	507	580	593
08 12	-	589	587	597	600
08 13	-	570	588	585	590
08 16	-	573	575	583	601
08 17	-	569	572	589	596
08 18	-	575	582	585	604
08 19	-	572	588	584	600
08 20	-	564	589	586	594
08 21	-	572	586	587	595
08 23	-	585	591	592	602
08 24	-	503	591	586	590
08 25	-	501	595	584	598
08 26	-	512	580	576	590
08 31	-	494	565	582	588
09 01	-	472	540	574	588
09 02	-	480	555	584	594

APPENDIX C

Soil moisture contents for BUF treatment.

Moisture content ($g.l^{-1}$) for access tube
BUF-I-1

Date 1976	Soil depths (cm)				
	surface	30	60	100	140
07 02	-	472	526	578	586
07 05	-	513	543	584	590
07 06	-	500	551	579	587
07 07	-	513	552	581	596
07 08	-	493	532	569	585
07 09	-	500	530	573	583
07 12	-	500	533	565	582
07 13	-	495	543	577	586
07 14	-	485	528	576	582
07 16	-	485	540	569	583
07 21	-	462	519	563	580
08 09	-	435	512	560	578
08 11	-	435	513	556	576
08 12	-	537	525	563	580
08 13	-	438	503	558	581
08 16	-	440	525	566	582
08 17	-	435	510	556	578
08 18	-	432	553	550	572
08 19	-	436	520	548	566
08 20	-	427	505	537	570
08 21	-	437	513	541	570
08 22	-	467	541	553	575
08 23	-	459	546	559	586
08 24	-	438	511	545	584
08 25	-	433	515	538	575
08 26	-	430	512	547	569
08 31	-	430	510	542	564
09 01	-	425	507	538	563
09 02	-	415	513	531	562

Moisture content ($g.l^{-1}$) for access tube BUF-I-2

Date 1976	Soil depths (cm)				
	surface	30	60	100	140
07 02	446	485	535	580	590
07 05	429	526	546	594	605
07 06	391	514	555	582	603
07 07	329	523	555	594	605
07 08	386	513	545	579	590
07 09	448	510	539	580	601
07 12	341	510	536	584	599
07 13	-	510	531	578	605
07 14	297	504	525	572	594
07 16	297	504	534	575	589
07 21	247	489	528	569	594
08 09	246	462	525	560	588
08 11	259	461	525	563	580
08 12	420	463	527	574	586
08 13	386	456	520	573	592
08 16	215	434	523	574	592
08 17	239	428	528	565	590
08 18	244	431	516	569	589
08 19	401	437	520	570	589
08 20	462	424	518	566	583
08 21	356	432	522	563	587
08 22	226	436	524	557	591
08 23	333	455	523	558	589
08 24	242	429	519	557	585
08 25	303	425	510	550	580
08 26	317	429	511	549	587
08 31	233	418	513	545	584
09 01	211	417	510	545	587
09 02	181	440	510	545	585

Moisture content ($g.l^{-1}$) for access tube BUF-I-3

Date 1976	Soil depths (cm)				
	surface	30	60	100	140
07 02	417	363	535	587	589
07 05	309	385	575	586	596
07 06	337	390	575	587	594
07 07	294	415	585	596	602
07 08	315	413	568	589	595
07 09	409	451	565	586	592
07 12	334	488	543	581	594
07 13	-	469	550	593	597
07 14	325	453	585	586	597
07 16	393	492	569	579	594
07 21	289	471	534	572	584
08 09	315	423	521	569	581
08 11	342	417	533	565	583
08 12	432	424	529	562	580
08 13	420	410	547	562	583
08 16	277	411	536	565	585
08 17	450	404	530	567	582
08 18	429	407	528	563	591
08 19	494	480	530	565	588
08 20	513	423	524	568	591
08 21	370	415	520	566	591
08 22	424	435	516	562	583
08 23	415	437	522	569	583
08 24	395	418	516	557	587
08 25	541	416	512	552	581
08 26	504	413	514	547	581
08 31	275	409	516	548	579
09 01	444	406	509	545	582
09 02	533	418	510	536	581

Moisture content ($g.l^{-1}$) for access tube
BUF-I-4

Date 1976	Soil depths (cm)				
	surface	30	60	100	140
07 02	-	439	508	536	594
07 05	-	405	520	568	586
07 06	-	415	540	583	594
07 07	-	447	554	584	599
07 08	-	419	542	574	589
07 09	-	431	553	577	589
07 12	-	466	536	573	585
07 13	-	453	539	578	589
07 14	-	482	544	574	579
07 16	-	470	561	574	590
07 21	-	457	525	571	584
08 09	-	395	504	563	578
08 11	-	400	498	559	570
08 12	-	424	518	558	589
08 13	-	406	496	547	578
08 16	-	401	496	540	573
08 17	-	398	494	541	575
08 18	-	390	494	537	570
08 19	-	418	492	535	574
08 20	-	413	485	535	569
08 21	-	413	484	527	563
08 22	-	425	507	539	586
08 23	-	432	511	543	582
08 24	-	410	488	532	575
08 25	-	400	485	531	576
08 26	-	405	485	530	579
08 31	-	406	485	536	572
09 01	-	401	479	530	566
09 02	-	396	478	526	563

Moisture content ($g.l^{-1}$) for access tube BUF-II-1

Date 1976	Soil depths (cm)				
	surface	30	60	100	140
07 02	-	518	562	582	590
07 05	-	478	544	589	596
07 06	-	515	540	589	597
07 07	-	537	554	585	595
07 08	-	516	543	587	594
07 09	-	513	539	593	595
07 13	-	508	540	596	604
07 14	-	505	526	583	596
07 16	-	503	518	580	590
07 21	-	465	513	567	579
08 09	-	413	490	563	570
08 11	-	423	495	560	573
08 12	-	435	513	565	585
08 13	-	410	490	557	574
08 16	-	410	497	552	571
08 17	-	406	492	555	575
08 18	-	415	497	535	569
08 19	-	424	493	533	563
08 20	-	420	485	542	568
08 21	-	408	482	545	568
08 22	-	457	515	557	579
08 23	-	450	513	556	580
08 24	-	426	489	547	575
08 25	-	425	488	542	569
08 26	-	440	487	539	565
08 31	-	416	529	546	561
09 01	-	416	498	540	560
09 02	-	412	484	539	568

Moisture content ($g.l^{-1}$) for access tube BUF-II-2

Date 1976	Soil depths (cm)				
	surface	30	60	100	140
07 02	-	465	570	576	584
07 05	-	468	562	578	597
07 06	-	515	574	584	592
07 07	-	523	579	591	604
07 08	-	509	552	581	597
07 09	-	514	554	580	593
07 13	-	510	531	574	595
07 14	-	508	539	579	590
07 16	-	506	544	578	585
07 21	-	485	530	575	582
08 09	-	450	521	571	583
08 11	-	446	515	565	580
08 12	-	471	538	566	583
08 13	-	449	517	573	580
08 16	-	412	517	570	576
08 17	-	443	516	564	571
08 18	-	450	513	560	578
08 19	-	465	522	554	569
08 20	-	450	504	563	567
08 21	-	453	496	553	564
08 22	-	460	501	556	568
08 23	-	487	523	555	563
08 24	-	460	512	537	565
08 25	-	462	511	535	572
08 26	-	465	510	539	573
08 31	-	458	481	543	574
09 01	-	454	502	534	569
09 02	-	478	505	531	567

Moisture Content ($g.l^{-1}$) for access tube BUF-II-3

Date 1976	Soil depths (cm)				
	surface	30	60	100	140
07 02	-	449	555	562	571
07 05	-	505	557	575	578
07 06	-	471	551	578	585
07 07	-	539	572	581	590
07 08	-	499	546	575	580
07 09	-	517	547	570	580
07 13	-	528	550	581	585
07 14	-	513	529	576	586
07 16	-	515	531	571	579
07 21	-	484	513	561	574
08 09	-	414	500	558	569
08 11	-	415	501	556	565
08 12	-	438	511	540	571
08 13	-	418	495	540	568
08 16	-	417	505	532	563
08 17	-	415	503	530	560
08 18	-	421	523	531	564
08 19	-	428	513	528	565
08 20	-	417	499	536	565
08 21	-	418	497	532	560
08 22	-	429	511	535	564
08 23	-	448	512	544	560
08 24	-	426	507	535	555
08 25	-	426	508	534	554
08 26	-	422	503	534	548
08 31	-	423	501	527	547
09 01	-	421	499	521	543
09 02	-	425	494	517	545

Moisture content $(g.1^{-1})$ for access tube BUF-II-4

Date 1976	Soil depths (cm) surface	30	60	100	140
07 02	436	472	565	567	586
07 05	389	469	555	570	587
07 06	325	471	551	578	585
07 07	345	500	565	574	593
07 08	281	496	544	571	588
07 09	412	509	542	567	585
07 12	375	523	545	580	592
07 14	201	507	535	574	586
07 16	214	505	529	570	582
07 21	237	495	523	569	579
08 09	209	477	520	560	583
08 11	229	460	510	556	584
08 12	366	432	528	555	584
08 13	336	410	510	552	580
08 16	224	422	506	551	585
08 17	198	418	517	549	582
08 18	189	421	523	551	586
08 19	418	429	520	549	585
08 20	514	425	516	546	586
08 21	359	413	518	552	587
08 22	258	449	531	555	584
08 23	258	454	545	560	585
08 24	275	431	526	562	579
08 25	258	421	512	557	581
08 26	222	428	522	554	581
08 31	261	427	519	547	579
09 01	195	423	510	544	575
09 02	193	424	505	545	572

Moisture content ($g.l^{-1}$) for access tube BUF-III-1

Date 1976	Soil depths (cm)				
	surface	30	60	100	140
07 02	357	455	573	595	579
07 05	339	527	556	591	584
07 06	341	465	553	590	584
07 07	326	496	575	595	605
07 08	318	491	558	585	597
07 09	-	496	544	592	594
07 12	340	508	540	596	604
07 13	-	519	541	592	601
07 14	321	510	544	584	597
07 16	224	505	535	578	590
07 21	271	497	528	560	593
08 11	239	-	-	-	-
08 12	390	436	509	574	580
08 13	361	418	499	576	584
08 16	252	407	489	569	581
08 17	262	404	477	561	579
08 18	249	404	482	563	579
08 19	420	409	485	564	578
08 20	497	403	480	566	581
08 21	365	402	482	565	585
08 22	359	-	-	-	-
08 23	358	428	499	567	590
08 24	256	405	480	559	589
08 25	270	405	480	556	584
08 26	219	397	468	549	581
08 31	255	392	462	546	580
09 01	198	394	467	549	585
09 02	235	391	465	545	581

Moisture content ($g.l^{-1}$) for access tube BUF-III-2

Date 1976	Soil depths (cm)				
	surface	30	60	100	140
07 02	-	473	577	584	586
07 05	-	510	563	586	592
07 06	-	511	550	588	590
07 07	--	536	569	590	600
07 08	-	497	540	587	592
07 09	-	509	548	584	590
07 13	-	509	536	581	597
07 14	-	502	513	578	585
07 16	-	498	511	581	584
07 21	-	480	497	575	580
08 12	-	430	498	560	579
08 13	-	416	470	539	575
08 16	-	411	470	535	570
08 17	-	407	463	529	569
08 18	-	405	466	524	565
08 19	-	416	472	531	563
08 20	-	406	464	529	560
08 21	-	401	469	518	560
08 23	-	433	495	520	558
08 24	-	414	460	521	554
08 25	-	408	460	524	552
08 26	-	403	455	521	556
08 31	-	401	455	520	557
09 01	-	393	447	519	551
09 02	-	401	448	515	552

Moisture content ($g.l^{-1}$) for access tube
BUF-III-3

Date 1976	Soil depths (cm)				
	surface	30	60	100	140
07 02	-	480	573	580	588
07 05	-	523	577	580	590
07 06	-	515	578	580	582
07 07	-	538	592	590	597
07 08	-	512	565	583	589
07 09	-	535	564	584	586
07 13	-	524	540	590	590
07 14	-	510	521	588	589
07 16	-	500	516	578	587
07 21	-	500	504	567	580
08 12	-	450	499	541	571
08 13	-	429	483	538	571
08 16	-	411	478	536	564
08 17	-	416	468	534	561
08 18	-	414	478	528	557
08 19	-	422	478	528	555
08 20	-	413	463	521	550
08 21	-	416	471	517	550
08 23	-	443	488	522	546
08 24	-	413	462	519	553
08 25	-	416	462	519	560
08 26	-	419	460	519	559
08 31	-	411	466	516	554
09 01	-	401	466	511	559
09 02	-	408	461	520	556

Moisture content ($g.l^{-1}$) for access tube BUF-III-4

Date 1976	Soil depths (cm)				
	surface	30	60	100	140
07 02	-	476	579	583	588
07 05	-	516	566	580	590
07 06	-	507	563	585	589
07 07	-	533	573	586	592
07 08	-	510	550	579	590
07 09	-	517	553	587	586
07 13	-	514	525	589	591
07 14	-	496	513	575	583
07 16	-	500	512	574	580
07 21	-	482	500	561	577
08 12	-	459	499	554	572
08 13	-	432	478	547	570
08 16	-	429	479	538	567
08 17	-	424	477	531	567
08 18	-	425	486	528	561
08 19	-	437	482	525	556
08 20	-	427	473	518	549
08 21	-	435	472	518	541
08 23	-	462	504	515	542
08 24	-	434	485	509	541
08 25	-	434	480	499	542
08 26	-	429	484	498	536
08 31	-	445	488	498	535
09 01	-	441	477	487	543
09 02	-	470	504	490	548

APPENDIX D

Soil moisture contents for SNF treatment.

Moisture content ($g.l^{-1}$) for access tube SNF-I-2.

Date 1976	Soil depths (cm)				
	surface	30	60	100	140
07 02	317	358	526	588	586
07 05	322	380	535	592	590
07 06	281	343	539	594	596
07 07	263	382	545	593	599
07 08	302	375	552	587	590
07 09	482	394	551	582	593
07 12	276	435	556	582	592
07 13	-	417	564	587	592
07 14	306	415	548	581	587
07 16	268	415	547	578	582
07 21	235	395	536	572	583
08 09	267	388	545	568	579
08 11	269	441	548	570	578
08 12	384	437	560	579	580
08 13	361	427	534	567	577
08 16	225	417	538	565	581
08 17	265	407	540	565	583
08 18	198	407	541	566	583
08 19	405	428	545	570	582
08 20	448	435	551	568	587
08 21	290	433	547	567	588
08 22	354	465	558	569	590
08 23	286	468	561	573	590
08 24	215	441	548	571	589
08 25	235	435	546	563	586
08 26	220	435	551	573	586
08 31	231	447	548	564	582
09 01	215	444	543	564	583
09 02	231	438	545	561	580

Moisture content ($g.l^{-1}$) for access tube SNF-I-3

Date 1976	Soil depths (cm)				
	surface	30	60	100	140
07 02	426	460	497	558	572
07 05	340	494	519	571	583
07 06	310	473	520	575	588
07 07	326	496	523	580	594
07 08	292	465	520	584	596
07 09	410	476	522	575	591
07 12	356	494	543	580	597
07 13	-	478	555	589	589
07 14	362	486	541	584	593
07 16	425	489	540	580	596
07 21	265	475	534	585	599
08 09	269	398	516	582	596
08 11	394	401	526	579	594
08 12	430	420	546	575	588
08 13	394	403	530	572	581
08 16	271	412	505	575	584
08 17	255	402	505	571	585
08 18	422	405	549	568	584
08 19	494	413	519	564	586
08 20	485	413	516	572	584
08 21	371	411	516	567	589
08 22	498	426	531	570	593
08 23	430	438	536	578	605
08 24	462	417	507	576	592
08 25	482	415	505	573	592
08 26	501	422	506	579	590
08 31	331	434	502	575	586
09 01	301	432	510	575	581
09 02	422	427	493	578	581

Moisture content ($g.l^{-1}$) for access tube SNF-I-4

Date 1976	Soil depths (cm)				
	surface	30	60	100	140
07 02	-	460	530	545	587
07 05	-	494	553	574	600
07 06	-	485	550	581	591
07 07	-	496	564	589	601
07 08	-	465	545	582	587
07 09	-	476	548	576	585
07 12	-	494	537	575	580
07 13	-	478	545	583	598
07 14	-	486	537	579	591
07 16	-	489	536	575	587
07 21	-	475	520	578	586
08 09	-	398	505	573	582
08 11	-	401	505	565	583
08 12	-	420	522	561	593
08 13	-	403	495	560	586
08 16	-	412	494	557	586
08 17	-	402	493	567	581
08 18	-	405	488	570	582
08 19	-	413	493	579	580
08 20	-	413	505	574	581
08 21	-	411	485	568	574
08 22	-	426	528	569	580
08 23	-	438	525	565	581
08 24	-	417	496	562	579
08 25	-	415	505	557	578
08 26	-	422	511	548	585
08 31	-	434	496	544	574
09 01	-	432	508	539	576
09 02	-	427	485	549	576

Moisture content ($g.l^{-1}$) for access tube
SNF-II-1

Date 1976	Soil depths (cm) surface	30	60	100	140
07 02	-	409	547	575	592
07 05	-	450	564	582	592
07 06	-	451	563	582	592
07 07	-	461	591	589	604
07 08	-	460	535	581	604
07 09	-	478	550	577	597
07 13	-	502	547	587	601
07 14	-	486	533	587	601
07 16	-	505	533	573	599
07 21	-	484	521	571	592
08 09	-	431	521	560	587
08 11	-	428	517	552	581
08 12	-	460	536	546	588
08 13	-	429	516	542	580
08 16	-	430	520	542	585
08 17	-	422	520	539	577
08 18	-	423	520	534	576
08 19	-	438	515	527	574
08 20	-	426	501	517	564
08 21	-	424	497	514	567
08 22	-	450	543	521	568
08 23	-	447	548	537	570
08 24	-	447	535	530	578
08 25	-	420	532	535	575
08 26	-	424	516	532	576
08 31	-	424	513	534	564
09 01	-	418	510	525	562
09 02	-	440	525	530	568

Moisture content ($g.l^{-1}$) for access tube
SNF-II-2

Date 1976	Soil depths (cm) surface	30	60	100	140
07 02	-	460	570	578	578
07 05	-	450	564	580	582
07 06	-	451	563	582	582
07 07	-	461	591	595	594
07 08	-	444	565	585	591
07 09	-	448	581	587	588
07 13	-	471	569	586	598
07 14	-	474	560	578	601
07 16	-	472	559	574	591
07 21	-	462	549	567	589
08 09	-	474	541	561	579
08 11	-	481	540	560	574
08 12	-	505	562	570	579
08 13	-	473	529	562	576
08 16	-	485	541	560	570
08 17	-	470	538	553	572
08 18	-	480	543	551	575
08 19	-	494	539	557	570
08 20	-	478	526	546	565
08 21	-	481	533	546	563
08 22	-	481	527	550	571
08 23	-	503	535	555	573
08 24	-	493	546	551	569
08 25	-	492	530	550	568
08 26	-	493	533	551	573
08 31	-	488	532	554	572
09 01	-	476	528	552	570
09 02	-	479	523	545	566

Moisture content ($g.l^{-1}$) for access tube SNF-II-3

Date 1976	Soil depths (cm)				
	surface	30	60	100	140
07 02	-	411	504	589	576
07 05	-	435	547	596	591
07 06	-	425	546	591	594
07 07	-	445	576	590	605
07 08	-	430	546	590	597
07 09	-	425	548	584	594
07 13	-	449	543	592	595
07 14	-	441	533	585	593
07 16	-	456	524	585	590
07 21	-	447	513	580	584
08 09	-	436	506	574	585
08 11	-	454	507	573	586
08 12	-	471	528	565	580
08 13	-	460	507	559	580
08 16	-	451	536	556	575
08 17	-	439	519	553	570
08 18	-	441	519	549	563
08 19	-	464	516	553	559
08 20	-	450	501	546	553
08 21	-	451	509	541	550
08 22	-	480	530	545	554
08 23	-	488	543	558	564
08 24	-	502	552	559	563
08 25	-	450	544	552	564
08 26	-	452	532	543	560
08 31	-	445	530	542	554
09 01	-	435	528	532	550
09 02	-	430	499	529	548

Moisture content $(g.l^{-1})$ for access tube SNF-II-4

Date 1976	Soil depths (cm)				
	surface	30	60	100	140
07 02	388	434	574	591	578
07 05	375	432	564	594	580
07 06	374	431	565	603	589
07 07	316	445	570	607	604
07 08	275	436	561	590	590
07 09	405	428	563	592	593
07 12	318	475	565	605	596
07 14	263	471	549	595	601
07 16	380	488	557	583	597
07 21	322	472	546	596	595
08 09	232	480	531	585	599
08 11	230	489	531	581	598
08 12	359	511	560	578	595
08 13	308	514	553	572	596
08 16	288	492	552	572	594
08 17	284	483	552	572	590
08 18	208	487	537	568	596
08 19	432	480	535	574	590
08 20	470	494	546	565	587
08 21	283	488	547	560	581
08 22	333	528	549	570	587
08 23	305	513	561	565	592
08 24	211	497	547	560	589
08 25	231	499	559	566	593
08 26	186	496	546	562	589
08 31	214	490	548	566	587
09 01	205	484	550	563	583
09 02	213	491	550	559	582

Moisture content $(g.l^{-1})$ for access tube SNF-III-1

Date 1976	Soil depths (cm)				
	surface	30	60	100	140
07 02	494	410	537	595	606
07 05	404	407	527	597	615
07 06	351	407	527	592	606
07 07	295	424	538	594	613
07 08	297	411	519	596	609
07 09	443	410	495	599	604
07 12	343	417	497	604	611
07 14	330	401	470	598	599
07 16	289	405	458	589	592
07 21	309	389	437	574	586
08 09	206	-	-	-	-
08 11	268	367	431	569	584
08 12	395	363	429	570	587
08 13	374	345	427	566	588
08 16	229	344	431	564	580
08 17	239	348	429	562	585
08 18	265	328	418	563	589
08 19	433	346	436	564	592
08 20	480	336	454	568	589
08 21	344	333	456	560	580
08 22	276	330	455	562	584
08 23	278	360	467	568	589
08 24	272	338	468	560	585
08 25	244	341	451	561	587
08 26	296	344	463	559	586
08 31	248	347	462	554	590
09 01	241	344	468	551	590
09 02	220	346	465	556	592

Moisture content ($g.l^{-1}$) for access tube SNF-III-2

Date 1976	Soil depths (cm)				
	surface	30	60	100	140
07 02	-	462	524	620	594
07 05	-	407	513	620	595
07 06	-	409	516	619	595
07 07	-	428	506	614	600
07 08	-	412	460	591	600
07 09	-	419	448	586	597
07 13	-	411	447	588	599
07 14	-	400	450	596	590
07 16	-	401	444	591	591
07 21	-	394	437	585	590
08 12	-	382	441	574	591
08 13	-	352	432	561	584
08 16	-	364	446	554	580
08 17	-	364	451	553	569
08 18	-	356	464	549	563
08 19	-	364	476	542	566
08 20	-	357	474	543	562
08 21	-	363	466	536	563
08 23	-	384	507	546	573
08 24	-	362	487	543	565
08 25	-	357	484	544	570
08 26	-	363	490	550	570
08 31	-	358	495	542	574
09 01	-	355	487	540	571
09 02	-	351	579	535	577

Moisture content ($g.l^{-1}$) for access tube SNF-III-3

Date 1976	Soil depths (cm) surface	30	60	100	140
07 02	-	448	577	601	603
07 05	-	430	543	601	599
07 06	-	432	549	589	606
07 07	-	440	544	587	606
07 08	-	427	529	585	598
07 09	-	430	529	587	602
07 13	-	425	508	594	606
07 14	-	414	503	588	591
07 16	-	420	506	587	589
07 21	-	442	507	577	586
08 12	-	400	484	576	593
08 13	-	369	476	572	584
08 16	-	377	460	563	576
08 17	-	379	452	564	573
08 18	-	377	452	555	574
08 19	-	382	440	547	566
08 20	-	379	440	538	564
08 21	-	374	433	535	564
08 23	-	399	465	547	573
08 24	-	378	450	550	571
08 25	-	379	457	552	566
08 26	-	382	452	554	564
08 31	-	382	476	546	563
09 01	-	375	471	543	560
09 02	-	385	475	558	567

Moisture content ($g.l^{-1}$) for access tube
SNF-III-4

Date 1976	Soil depths (cm) surface	30	60	100	140
07 02	-	402	596	593	588
07 05	-	395	582	598	590
07 06	-	385	571	601	591
07 07	-	403	563	602	600
07 08	-	392	552	597	590
07 09	-	396	537	593	594
07 13	-	392	491	596	603
07 14	-	384	490	596	593
07 16	-	392	463	586	595
07 21	-	379	425	580	582
08 12	-	372	460	576	584
08 13	-	341	453	562	580
08 16	-	350	483	558	574
08 17	-	352	490	548	565
08 18	-	354	500	551	558
08 19	-	374	518	550	560
08 20	-	368	496	547	560
08 21	-	375	506	534	554
08 23	-	408	523	546	552
08 24	-	368	512	546	555
08 25	-	365	514	550	559
08 26	-	368	511	555	562
08 31	-	375	510	546	564
09 01	-	378	464	540	553
09 02	-	370	501	547	549

APPENDIX E

Soil moisture contents for BNF treatment.

Moisture content ($g.l^{-1}$) for access tube BNF-I-1

Date 1976	Soil depths (cm) surface	30	60	100	140
07 02	-	381	545	549	587
07 05	-	422	586	580	593
07 06	-	420	582	585	600
07 07	-	448	594	595	605
07 08	-	440	568	588	594
07 09	-	508	575	594	590
07 12	-	465	548	585	591
07 13	-	468	557	583	591
07 14	-	458	556	586	590
07 16	-	461	569	586	584
07 21	-	430	525	578	584
08 09	-	383	520	574	579
08 11	-	390	516	570	575
08 12	-	421	546	576	586
08 13	-	407	526	567	578
08 16	-	410	520	574	577
08 17	-	401	519	571	575
08 18	-	401	535	577	575
08 19	-	429	539	582	575
08 20	-	471	559	582	577
08 21	-	461	545	582	573
08 22	-	510	573	581	579
08 23	-	520	580	584	585
08 24	-	500	580	586	579
08 25	-	516	576	586	578
08 26	-	525	588	581	576
08 31	-	476	545	583	579
09 01	-	476	542	576	580
09 02	-	501	555	571	580

Moisture content $(g.l^{-1})$ for access tube BNF-I-2

Date 1976	Soil depths (cm)				
	surgace	30	60	100	140
07 02	461	392	515	561	580
07 05	382	422	530	566	583
07 06	320	424	548	565	590
07 07	319	438	558	570	598
07 08	313	433	537	577	593
07 09	474	438	540	575	586
07 12	339	454	527	575	581
07 13	-	441	532	580	585
07 14	303	470	546	588	585
07 16	347	469	538	578	582
07 21	345	460	521	577	584
08 09	214	481	561	569	581
08 11	419	492	560	571	579
08 12	517	500	593	585	589
08 13	461	503	591	581	586
08 16	404	502	545	589	585
08 17	329	520	542	582	582
08 18	288	521	545	584	585
08 19	491	544	571	586	582
08 20	506	525	551	586	585
08 21	475	515	543	584	589
08 22	451	528	554	585	591
08 23	352	530	561	581	590
08 24	515	529	563	589	593
08 25	317	522	567	583	590
08 26	-	535	576	586	589
08 31	405	499	550	575	580
09 01	483	507	561	573	582
09 02	-	502	561	578	580

Moisture content ($g.l^{-1}$) for access tube BNF-I-3

Date 1976	Soil depths (cm)				
	surface	30	60	100	140
07 02	468	394	580	591	594
07 05	410	429	599	600	610
07 06	350	414	580	595	595
07 07	336	454	590	600	605
07 08	495	451	577	591	596
07 09	494	465	562	585	600
07 12	417	485	557	581	596
07 13	-	466	556	584	604
07 14	594	495	579	585	593
07 16	532	472	571	585	590
07 21	342	446	562	580	594
08 09	507	467	572	577	589
08 11	498	480	570	574	584
08 12	615	495	579	584	590
08 13	543	486	569	586	594
08 16	448	500	565	582	589
08 17	484	516	575	581	588
08 18	492	529	575	587	595
08 19	520	535	571	585	590
08 20	575	555	568	586	590
08 21	551	535	557	580	587
08 22	556	545	568	572	583
08 23	548	538	575	584	591
08 24	544	546	569	581	586
08 25	454	531	554	585	591
08 26	542	527	541	589	587
08 31	505	527	531	580	585
09 01	579	539	546	578	589
09 02	484	541	557	578	584

Moisture content ($g.l^{-1}$) for access tube
BNF-I-4

Date	Soil depths (cm)				
1976	surface	30	60	100	140
07 02	-	401	535	535	574
07 05	-	450	554	573	592
07 06	-	436	563	575	589
07 07	-	447	569	579	591
07 08	-	556	544	573	591
07 09	-	466	544	577	589
07 12	-	460	537	575	581
07 13	-	473	545	580	590
07 14	-	461	536	582	591
07 16	-	454	530	572	586
07 21	-	441	517	562	584
08 09	-	403	509	558	584
08 11	-	409	507	557	582
08 12	-	446	528	569	591
08 13	-	412	537	552	583
08 16	-	422	504	553	579
08 17	-	418	507	556	587
08 18	-	420	520	560	587
08 19	-	451	536	568	586
08 20	-	455	526	576	578
08 21	-	450	526	571	578
08 22	-	479	544	575	585
08 23	-	483	549	575	582
08 24	-	470	526	570	578
08 25	-	470	523	571	576
08 26	-	465	541	576	575
08 31	-	476	520	572	572
09 01	-	499	533	567	570
09 02	-	450	533	567	576

Moisture content ($g.l^{-1}$) for access tube
BNF-II-1

Date 1976	Soil depths (cm) surface	30	60	100	140
07 02	-	447	579	589	596
07 05	-	451	578	590	594
07 06	-	452	576	597	600
07 07	-	475	579	591	603
07 08	-	474	579	597	601
07 09	-	494	569	595	605
07 13	-	514	583	599	610
07 14	-	505	572	598	600
07 16	-	507	564	590	601
07 21	-	485	554	582	590
08 09	-	437	538	579	588
08 11	-	445	537	576	581
08 12	-	467	560	571	587
08 13	-	452	541	566	582
08 16	-	452	540	565	580
08 17	-	442	545	559	583
08 18	-	444	546	558	592
08 19	-	480	548	565	596
08 20	-	470	539	571	587
08 21	-	475	532	570	588
08 22	-	483	562	576	583
08 23	-	485	567	579	594
08 24	-	481	544	578	597
08 25	-	490	547	569	590
08 26	-	496	555	572	598
08 31	-	492	542	565	591
09 01	-	480	540	568	586
09 02	-	486	551	573	584

Moisture content ($g.l^{-1}$) for access tube
BNF-II-2

Date	Soil depths (cm)				
1976	surface	30	60	100	140
07 02	-	454	585	572	575
07 05	-	464	575	578	581
07 06	-	460	573	577	581
07 07	-	484	586	579	587
07 08	-	505	572	581	589
07 09	-	515	575	587	589
07 13	-	522	575	589	595
07 14	-	514	556	580	597
07 16	-	514	554	576	590
07 21	-	487	537	572	595
08 09	-	486	527	568	586
08 11	-	503	536	562	576
08 12	-	504	559	568	583
08 13	-	500	537	556	581
08 16	-	502	544	560	582
08 17	-	535	556	568	580
08 18	-	533	559	570	576
08 19	-	560	574	577	579
08 20	-	550	562	573	575
08 21	-	550	564	575	576
08 22	-	560	573	587	583
08 23	-	565	580	589	590
08 24	-	534	556	577	587
08 25	-	520	559	570	581
08 26	-	569	573	579	588
08 31	-	517	552	569	580
09 01	-	515	540	565	582
09 02	-	518	547	566	579

Moisture content ($g.l^{-1}$) for access tube
BNF-II-3

Date 1976	Soil depths (cm) surface	30	60	100	140
07 02	-	531	567	571	576
07 05	-	530	547	578	584
07 06	-	523	541	583	585
07 07	-	548	564	586	591
07 08	-	516	550	585	599
07 09	-	521	545	588	596
07 12	-	525	545	595	595
07 14	-	509	534	597	597
07 16	-	514	530	597	597
07 21	-	504	514	585	593
08 09	-	511	513	576	585
08 11	-	500	510	571	580
08 12	-	544	551	579	586
08 13	-	503	512	568	581
08 16	-	492	517	552	582
08 17	-	525	543	553	580
08 18	-	526	537	550	581
08 19	-	535	542	551	584
08 20	-	526	561	564	582
08 21	-	489	516	565	587
08 22	-	534	528	567	585
08 23	-	541	523	565	585
08 24	-	537	524	569	584
08 25	-	501	527	570	582
08 26	-	520	551	578	583
08 31	-	490	548	563	581
09 01	-	492	536	574	582
09 02	-	485	525	562	579

Moisture content $(g.l^{-1})$ for access tube BNF-II-4

Date 1976	Soil depths (cm)				
	surface	30	60	100	140
07 02	388	531	567	571	577
07 05	339	530	547	578	584
07 06	309	523	541	583	585
07 07	313	548	564	589	595
07 08	220	527	556	587	590
07 09	480	525	550	588	586
07 12	321	523	560	592	596
07 14	264	518	552	584	592
07 16	413	516	546	578	591
07 21	285	503	534	563	587
08 09	260	490	529	554	582
08 11	275	499	520	545	583
08 12	475	503	512	536	581
08 16	328	507	514	535	582
08 17	478	499	516	540	579
08 18	288	507	517	540	580
08 19	466	529	531	550	582
08 20	500	528	542	558	584
08 21	466	522	531	548	587
08 22	363	530	542	555	592
08 23	297	538	547	560	597
08 24	375	541	543	569	594
08 25	317	532	541	569	585
08 26	369	510	542	568	581
08 31	354	499	520	561	585
09 01	267	495	522	552	587
09 02	281	494	518	553	585

Moisture content $(g.l^{-1})$ for access tube BNF-III-1

Date 1976	Soil depths (cm) surface	30	60	100	140
07 02	391	525	594	579	579
07 05	407	523	591	582	585
07 06	338	517	595	584	589
07 07	373	526	599	587	592
07 08	312	536	581	586	588
07 09	403	531	588	580	590
07 12	359	542	587	580	593
07 14	340	539	576	582	590
07 16	251	524	562	576	583
07 21	243	515	550	571	582
08 09	224	-	-	-	-
08 11	425	532	551	570	585
08 12	468	540	552	576	590
08 13	458	502	547	573	585
08 16	302	493	542	573	583
08 17	349	492	531	571	579
08 18	302	490	542	575	577
08 19	448	488	545	568	574
08 20	513	500	550	566	572
08 21	414	500	540	558	572
08 22	412	504	540	558	572
08 23	410	504	546	561	580
08 24	397	495	550	570	589
08 25	371	490	552	571	589
08 26	309	496	557	572	588
08 31	333	501	555	579	584
09 01	249	505	543	569	581
09 02	240	525	550	573	585

Moisture content ($g.l^{-1}$) for access tube BNF-III-2

Date 1976	Soil depths (cm) surface	30	60	100	140
07 02	-	456	592	599	600
07 05	-	465	596	593	602
07 06	-	462	597	596	600
07 07	-	496	591	590	597
07 08	-	504	582	587	595
07 09	-	519	585	590	595
07 13	-	525	566	593	601
07 14	-	517	551	587	590
07 16	-	520	557	584	595
07 21	-	501	525	577	583
08 12	-	528	535	563	585
08 13	-	501	529	557	580
08 16	-	498	512	550	585
08 17	-	492	510	548	585
08 18	-	495	513	541	584
08 19	-	496	522	539	576
08 20	-	508	526	541	574
08 21	-	496	517	532	570
08 23	-	518	542	540	581
08 24	-	516	577	560	589
08 25	-	535	579	570	591
08 26	-	542	578	584	589
08 31	-	514	541	572	584
09 01	-	505	529	563	580
09 02	-	503	521	558	574

APPENDIX F

Soil moisture contents for FF treatment.

Moisture content ($g.l^{-1}$) for access tube FF-I-1

Date 1976	Soil depths (cm) surface	30	60	100	140
07 02	349	430	533	588	592
07 05	346	474	590	607	616
07 06	339	464	574	596	608
07 07	362	468	585	604	615
07 08	347	471	585	593	612
07 09	404	524	587	591	600
07 12	374	523	584	595	601
07 13	-	535	579	598	612
07 14	306	564	576	589	600
07 16	391	535	566	590	596
07 21	266	513	578	589	592
08 09	237	496	539	580	593
08 11	281	495	531	576	595
08 12	393	525	548	595	620
08 13	389	492	532	573	596
08 16	-	492	534	572	590
08 17	365	475	537	570	593
08 18	436	499	534	568	598
08 19	436	534	577	591	595
08 20	468	525	574	595	607
08 21	355	521	560	591	595
08 22	252	535	577	593	602
08 23	281	541	578	596	605
08 24	280	517	580	591	598
08 25	272	505	569	586	596
08 26	222	507	558	583	591
08 31	238	501	545	572	589
09 01	185	505	539	574	593
09 02	186	507	542	580	595

Moisture content ($g.l^{-1}$) for access tube FF-I-2

Date	Soil depths (cm)				
1976	surface	30	60	100	140
07 02	-	444	527	566	590
07 05	-	493	587	631	615
07 06	-	476	565	630	613
07 07	-	485	566	639	621
07 08	-	536	579	621	619
07 09	-	539	582	609	598
07 12	-	543	584	607	592
07 13	-	551	579	620	603
07 14	-	582	572	607	592
07 16	-	556	573	605	595
07 21	-	529	560	592	583
08 09	-	523	539	593	586
08 11	-	519	529	585	593
08 12	-	548	544	600	610
08 13	-	513	540	575	575
08 16	-	505	520	570	586
08 17	-	493	518	566	589
08 18	-	552	568	595	590
08 19	-	573	576	610	589
08 20	-	557	562	601	594
08 21	-	532	558	586	589
08 22	-	553	566	619	620
08 23	-	552	572	620	626
08 24	-	517	580	587	596
08 25	-	502	535	582	591
08 26	-	502	537	583	590
08 31	-	560	559	586	586
09 01	-	544	555	584	573
09 02	-	525	545	580	576

Moisture content ($g.l^{-1}$) for access tube
FF-I-3

Date 1976	Soil depths (cm) surface	30	60	100	140
07 02	-	428	540	554	578
07 05	-	483	596	603	600
07 06	-	464	590	606	599
07 07	-	470	576	612	616
07 08	-	524	592	594	593
07 09	-	539	586	595	591
07 12	-	528	577	589	582
07 13	-	532	580	593	590
07 14	-	603	605	598	592
07 16	-	565	586	595	599
07 21	-	521	540	585	581
08 09	-	532	545	590	586
08 11	-	530	540	580	588
08 12	-	559	565	598	611
08 13	-	522	533	585	586
08 16	-	523	537	568	585
08 17	-	531	546	561	589
08 18	-	603	596	599	589
08 19	-	620	615	595	600
08 20	-	604	610	587	588
08 21	-	586	592	588	589
08 22	-	528	595	614	608
08 23	-	523	614	617	614
08 24	-	493	562	584	598
08 25	-	490	555	584	590
08 26	-	495	554	585	594
08 31	-	532	584	587	571
09 01	-	604	584	579	577
09 02	-	545	625	608	599

Moisture content ($g.l^{-1}$) for access tube FF-II-1

Date 1976	Soil depths (cm) surface	30	60	100	140
07 02	-	507	525	609	591
07 05	-	506	524	607	598
07 06	-	513	532	606	604
07 07	-	525	558	635	625
07 08	-	513	532	606	598
07 09	-	509	514	602	598
07 13	-	535	559	601	612
07 14	-	495	524	595	610
07 16	-	496	509	599	598
07 21	-	469	498	572	585
08 09	-	470	493	547	598
08 11	-	466	490	549	600
08 12	-	488	507	567	612
08 13	-	461	490	545	586
08 16	-	463	493	550	584
08 17	-	462	497	548	584
08 18	-	462	501	548	592
08 19	-	474	497	555	596
08 20	-	488	505	547	593
08 21	-	475	483	550	583
08 22	-	480	500	570	590
08 23	-	501	531	590	596
08 24	-	468	502	585	590
08 25	-	464	493	548	585
08 26	-	465	495	560	588
08 31	-	461	490	569	593
09 01	-	460	485	552	588
09 02	-	445	503	562	589

Moisture content ($g.l^{-1}$) for access tube FF-II-2

Date 1976	Soil depths (cm)				
	surface	30	60	100	140
07 02	396	503	543	571	601
07 05	396	513	552	593	603
07 06	337	506	546	592	612
07 07	387	532	546	596	615
07 08	314	518	539	592	600
07 09	414	513	529	588	597
07 13	380	518	533	595	606
07 14	406	507	544	590	600
07 16	397	506	545	587	598
07 21	322	495	521	560	583
08 09	335	509	512	540	587
08 11	321	502	508	536	585
08 12	474	531	526	561	600
08 13	419	509	529	558	600
08 16	362	508	531	568	596
08 17	256	501	528	568	590
08 18	295	499	511	562	586
08 19	434	534	569	575	590
08 20	442	523	570	584	594
08 21	440	509	566	580	595
08 22	371	513	567	579	601
08 23	392	519	570	586	600
08 24	284	500	554	577	592
08 25	284	497	549	562	590
08 26	317	502	546	572	588
08 31	269	497	530	560	591
09 01	250	501	535	570	583
09 02	234	490	524	562	587

Moisture content ($g.l^{-1}$) for access tube FF-II-3

Date 1976	Soil depths (cm) surface	30	60	100	140
07 02	-	506	544	590	585
07 05	-	504	514	593	588
07 06	-	505	505	588	585
07 07	-	530	540	611	615
07 08	-	531	533	592	590
07 09	-	532	529	588	587
07 13	-	560	533	595	606
07 14	-	527	544	590	590
07 16	-	556	545	587	580
07 21	-	484	511	560	573
08 09	-	445	512	550	577
08 11	-	438	508	536	575
08 12	-	466	527	561	600
08 13	-	462	522	549	583
08 16	-	442	505	531	568
08 17	-	436	509	528	568
08 18	-	443	511	542	567
08 19	-	470	569	535	590
08 20	-	456	523	544	590
08 21	-	440	510	550	565
08 22	-	465	540	567	617
08 23	-	472	537	570	616
08 24	-	445	519	551	587
08 25	-	448	510	549	582
08 26	-	442	464	537	582
08 31	-	436	500	530	580
09 01	-	459	511	535	585
09 02	-	490	536	563	599

APPENDIX G

Average moisture content for SUF treatment.

Average moisture contents ($g.l^{-1}$) for access tubes SUF-I-1, SUF-II-1 and SUF-III-1

Date	Soil depths (cm)				
1976	surface	30	60	100	140
07 02	-	446	525	576	588
07 05	-	483	568	586	594
07 06	-	483	569	586	593
07 07	-	506	578	590	596
07 08	-	487	562	589	596
07 09	-	495	568	584	593
07 16	-	495	545	581	590
07 21	-	500	528	577	586
08 09	-	428	507	566	583
08 12	-	446	522	567	591
08 13	-	432	509	553	580
08 16	-	432	513	560	578
08 17	-	429	519	556	581
08 18	-	428	516	559	580
08 19	-	440	523	559	585
08 20	-	437	492	565	574
08 21	-	438	521	562	575
08 22	-	445	523	573	587
08 23	-	445	526	574	590
08 24	-	445	528	560	586
08 25	-	448	528	572	585
08 26	-	446	524	573	590
08 31	-	439	516	568	584
09 01	-	435	513	562	585
09 02	-	469	507	558	586

Average moisture contents ($g.l^{-1}$) for access tubes SUF-I-2, SUF-II-2 and SUF-III-2

Date 1976	Soil depths (cm) surface	30	60	100	140
07 02	-	466	573	588	588
07 05	-	483	587	594	597
07 06	-	490	581	595	596
07 07	-	501	580	597	597
07 08	-	484	572	591	595
07 09	-	500	572	593	596
07 13	-	497	572	590	596
07 14	-	505	569	593	598
07 16	-	503	558	589	589
07 21	-	480	536	578	582
08 09	-	468	524	563	583
08 12	-	496	547	568	589
08 13	-	507	540	566	588
08 16	-	492	538	564	586
08 17	-	491	537	560	584
08 18	-	491	539	561	587
08 19	-	526	542	553	587
08 20	-	498	543	561	584
08 21	-	498	543	564	586
08 23	-	519	552	578	588
08 24	-	506	551	576	586
08 25	-	493	545	575	587
08 26	-	496	551	573	586
08 31	-	487	529	564	587
09 01	-	481	525	559	584
09 02	-	492	534	567	582

Average moisture contents ($g.l^{-1}$) for access tubes SUF-I-3, SUF-II-3 and SUF-III-3

Date	Soil depths (cm)				
1976	surface	30	60	100	140
07 02	-	454	569	591	596
07 05	-	517	581	589	603
07 06	-	524	580	596	599
07 07	-	528	579	595	603
07 08	-	499	564	588	597
07 09	-	501	565	588	596
07 13	-	497	567	591	598
07 14	-	506	555	591	596
07 16	-	509	549	587	594
07 21	-	490	537	578	594
08 12	-	512	547	575	599
08 13	-	501	538	567	589
08 16	-	504	540	564	589
08 17	-	517	543	567	590
08 18	-	517	547	568	595
08 19	-	528	551	568	592
08 20	-	529	560	568	592
08 21	-	503	546	573	592
08 23	-	552	573	586	604
08 24	-	515	560	584	595
08 25	-	556	561	586	597
08 26	-	518	564	585	595
08 31	-	490	529	579	587
09 01	-	480	525	573	591
09 02	-	492	529	552	592

Average moisture contents ($g.l^{-1}$) for access tubes SUF-I-4, SUF-II-4 and SUF-III-4

Date 1976	Soil depths (cm) surface	30	60	100	140
07 02	-	462	566	583	588
07 05	-	466	578	594	594
07 06	-	467	572	595	594
07 07	-	474	565	602	597
07 08	-	474	543	583	592
07 09	-	487	546	592	591
07 13	-	493	549	594	598
07 14	-	484	527	585	590
07 16	-	488	544	583	587
07 21	-	470	514	565	582
08 12	-	499	543	564	591
08 13	-	478	531	549	578
08 16	-	476	528	550	582
08 17	-	476	530	551	582
08 18	-	478	537	550	584
08 19	-	485	541	551	581
08 20	-	487	551	558	576
08 21	-	487	545	559	571
08 23	-	509	572	584	604
08 24	-	490	553	570	587
08 25	-	465	554	566	587
08 26	-	476	558	569	582
08 31	-	466	540	565	580
09 01	-	457	528	561	575
09 02	-	465	538	566	579