SUBSURFACE IRRIGATION PERFORMANCE IN THE SOILS OF THE ARID REGIONS OF JORDAN

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highest upward water movement was around 0.35-0.40m, and the horizontal movement was around 0.45-0.55m.

No significant differences were observed in the horizontal and the downward water movement. The results confirm a direct relation between the moisture content around the tube with the discharge rate. Where high moisture contents reduced the difference in the hydraulic gradient between the water pressure inside the tube and outside of it, causing a reduction in the discharge rate.

In a general comparison between the results obtained by the neutron probe device and the results of the gravimetric method, the results of the N.P. where less accurate to predict the wetting pattern shapes in the soil profile, especially when close irrigation periods are practiced. In similar researches for studying water-movement in the soil, more advanced and accurate devices are recommended.

and by continuous researches in different fields of agriculture science. Without proper management more degradation will occur to these lands and may extend to the adjacent high lands.

There has been a special attention given to these lands in the recent years especially under the conditions of water scarcity in Jordan. Agricultural development in these areas depends on harvesting rainfall and utilizing it efficiently. Direct utilization can be made as on-farm water harvesting and indirect use through the irrigation systems. The special conditions of these areas impose different restrictions on the type of irrigation system to be used. Of these restrictions are:

a. the effect of natural occurring strong wind conditions on sprinkler system. b. high impermeable soil surface crust effect on the infiltration rate. and c. very low water holding capacity of the soil. Sprinkler irrigation causes run-off and erosion even under the lowest application rate, with very low distribution efficiency due to the windy conditions. Even with drip irrigation, surface run-off occurred due to the soil surface crust formation and very low infiltration rate (23).

Surface irrigation under these conditions yield a very low application efficiency which is not favorable with limited water resources. In addition, surface irrigation requires precise land leveling which is not feasible due to economic and soil factors. Subsurface irrigation has the potential to overcome the limitations of other systems caused by soil and climate restrictions. In fact such limitations as soil crust may under subsurface system turn to have an advantage in reducing evaporation from the surface.

Since the subsurface irrigation method have not been used under these conditions or the desert conditions of Jordan, studies are needed to evaluate this method, and to provide tools for proper design and management under these conditions.

This study was carried out at Al-Muwaqqar area, with the following objectives:

1) to study the water distribution patterns through the soil profile under different lateral burial depths, water application times, and initial moisture content;

2) to formulate an empirical relationships for horizontal and vertical water movement in the soil profile under various design parameters; and

3) to evaluate the performance of the neutron probe scattering method in detecting the wetting fronts under the subsurface irrigation system.

CHAPTER II

LITERATURE REVIEW

2.1 Theories of unsaturated flow and water movement from subsurface irrigation:

A subsurface irrigation system wets the soil by the capillary water movement from a buried perforated pipe. Rational design of a subsurface irrigation system requires an understanding of the unsaturated capillary soil-water movement in the soil profile(Fok and Willardson, 1972). Kirkham and Power(1972) developed a differential equation for unsaturated flow by using the derivation of Laplace's equation:

$$d\theta/dt = -(dv_x/dx + dv_y/dy + dv_z/dz) \quad .....(1)$$

by assuming the validity of Darcy's law for unsaturated flow, $\underline{v}$ is expressed as:

$$v_x = - K_x \; dh/dx \quad .....(2)$$

$$v_y = - K_y \; dh/dy \quad .....(3)$$

$$v_z = - K_z \; dh/dz \quad .....(4)$$

Then the differential equation of unsaturated flow in three dimensions will be :

$$d\theta/dt = d/dx\,(D_x\, d\theta/dx) + d/dy\,(D_y\, d\theta/dt) + d/dz\,(D_z\, d\theta/dz) + dK/dz \quad .....(5)$$

where

θ = volumetric water content (cm^3/cm^3)

t = time (second)

D = diffusivity in the x, y, and z directions (cm/sec)

= K $dh_t/d\theta$

x, y, and z = length of one dimensional system (cm)

In order to obtain such data that might serve as a basis for the formulation of the unsaturated flow working theories, Gardner et al.(1970) conducted a study in which approximate solutions of the unsaturated flow equations were derived to describe the water content above the initial wetting front as a function of time:

$$W = a\ t^{-b} \quad .....(6)$$

<u>where</u>

W = soil water content

t = time

a and b = are constants (related to the capillary conductivity and soil water diffusivity).

In this experiment the water content measurements were done by Gamma-ray attenuation in soil columns during water redistribution following irrigation. Also they reported that as the initial moisture content increases the range of soil water content will be narrowed so that the diffusivity will tend to be more nearly constant.

Young (1957) conducted an experiment to study the moisture profiles during the redistribution after vertical infiltration to various depths into two inter porous materials. His results indicated that the redistribution of moisture depends more critically on infiltration depth.

In order to solve the problem of vertical ground-water movement in unsaturated soils in the absence of evaporation and transpiration, Green et al.(1970) developed a mathematical model describing isothermal, two-phase flow in porous media. The model consists of differential equations and algorithms for their numerical solution, these equations are second order, none linear partial differential equations. Neutron logs were run to measure water saturation versus depth up to 22 feet. A computer model was then used to compare the computed results with the results obtained from the field. The data matching showed that the effect of hysteresis in the capillary pressure-water saturation relation-ship and the water permeability-water saturation relation-ship should be considered for the system studied.

A model and its numerical solution were developed by Hanks and Nimah in 1973. The model predicts the water content profiles, evapotranspiration, water flow from or to the water table, root extraction, and root water potential under transient field condition. By including the root extraction term [A(z,t)] in the general flow equation of Hanks(1969) they get :

$$d\theta/dt = d/dz\ [K(\theta)\ dh/dz] + A(z,t) \quad .....(7)$$

They reported that variations in the limiting root water potential has a small influence on estimated evapo-transpiration, drainage, and root extraction.

Ahuja (1973) examined the vertical infiltration of water through a crust of constant nonzero hydraulic resistance, in one dimension. He reported that a greater proportion of the flow takes place at intermediate to low water contents, without an appreciable effect of gravity, as the crust resistance increases.

Hachum et al.(1976) studied the effect of the soil type and water application rate from a trickle water line source on the two-dimensional water movement and distribution within a soil profile, and utilized the results for practical use, by developing equations and relationships for water movement in the horizontal (H) and the vertical (V) directions assuming the following exponential relationships:

$$V = a\ T^{c} \quad .....(8)$$

$$H = b\ T^{d} \quad .....(9)$$

in which a, b,c ,and d are empirical parameters dependent on the soil-water system characteristics. They found that for the loamy sand soil, the horizontal advance is very small when compared to the vertical. While for the silt loam (a fine textured soil), a uniform or equal water advance in both directions. For the same water applied, as the water application rate increases, the vertical advance of the wetting front decreases while the horizontal advance increases. Also they concluded that the approximation of the shape of the wetting front moving within a soil profile irrigated from a water line source by a semi-ellipse seems to be reasonable from a practical standpoint.

principles of Darcy-law flow and mass balance were applied to each element to obtain the soil moisture conditions at each time, without the utilization of the traditional differential equation of unsaturated flow.

Mostaghimi et al.(1982) conducted laboratory experiments to study the effect of trickle discharge rate on the distribution of soil water in a silty-clay loam soil. Moisture measurements were made, based on a mean of three counts (30s each) of the calibrated neutron scattering method. Their results indicated that increasing the trickle discharge rate resulted in an increase in the vertical component and a decrease in the horizontal component of the wetted zone.

The neutron scattering method was used again by Armstrong and Wilson (1983), in a research conducted to study the moisture distribution under a trickle source, and to use a computer simulation model to simulate irrigation in stratified soils. They reported that the shape and size of the wetted zone is more a function of the amount of water than of the rate of application, and the CSMP computer simulation results were similar to the field measurements at both application rates tested in the experiment.

Hawatmeh and Battikhi (1983) conducted an experiment to find relations from actual field data , between vertical and horizontal advances of wet fronts for two soils, three ranges of initial moisture contents, rates of water application and some different soil physical properties. To describe the horizontal and vertical advances of wetting fronts; they selected the equation of Kirkham and Feng for horizontal flow which is:

$$x = NT^{1/2} + a \quad .....(10)$$

where, x is the horizontal advances of wetting front (cm) ,t is the time of advance (hours) and N is the slope of the line. For vertical flow Philip's equation was used which is:

$$y = St^{1/2} + At \quad .....(11)$$

where, y is the vertical advance of wetting front (cm), t is the time of advance (hours), S is the sorptivity (cm/hr$^{1/2}$), and A is a parameter, which depends upon the ability of the soil to transmit water (cm/hr$^{1/2}$). Regression analysis technique was used to study the relation-ship between the advance movement of wetting fronts and the square root of time. They reported that horizontal and vertical advances of wetting fronts increase with increasing initial moisture content, and it is effected by some soil properties like texture. In addition; increasing water application rates had resulted in increasing horizontal water advance of wetting fronts, which is similar to the results of Hachum et al.(1976), and Mostaghimi et. al.(1982).

For soil moisture detection of the wetting fronts, Vellidis et al.(1989) evaluated the ground-penetrating radar (GPR),and reported that the radar images were reliable for the detection of the wetting front in the soil profile and the wetting fronts shapes markedly resembled the application uniformity curves.

Many researches have used either laboratory models or field plots in subsurface irrigation-studies, but few have considered a theoretical study of the fluid flow processes taking place because of the complexity of these processes. A study of two-dimensional infiltration was carried out by Fok (1970) and he concluded that two-dimensional infiltration from a point source may be expressed by a simple power equation and the shape of the wetting pattern in a uniform soil profile during infiltration can be approximated by a series of half ellipses having a common center where the point source of in-flowing water is located.

Allred and Gilley (1974) presented an analytical solution based upon steady state conditions for flow from a buried array of line sources and combined this solution with a model of plant soil-moisture extraction to obtain a model of subsurface irrigation. In this solution they used the simplified equation for steady flow in two dimensions of (Childs 1969):

$$dK(h)/dz = d/dz * (K(h) * dh/dz) + d/dx * (K(h) * dh/dx) \quad \ldots(12)$$

<u>where:</u>

x = the horizontal direction

z = the vertical direction (expressed positively upward)

h = the capillary pressure head (expressed negatively for capillary suction)

K(h) = the hydraulic conductivity.

In addition solutions describing the matrix flux potential and stream function were found and evaluated for several values of lateral spacing. And dimensionless forms of the variables were utilized to obtain curves describing the matrix flux potential and stream function which were independent of source strength.

Dirksen (1978) carried an experiments in which water content and pressure head distributions were measured during transient and steady flows from four equally spaced line sources maintained at constant hydraulic head in very fine sand in a large laboratory model. A two-dimensional automatic gamma ray attenuation scanner was used for water detection in this experiment. There results showed a major differences between upward flow and lateral flow below the source indicating that the soil column exhibited varying degrees of anisotropy, with the hydraulic conductivity being greater horizontally than vertically. And they found that at the same water content, the hydraulic conductivity during wetting was only about half of that during drying.

2.2 Subsurface Irrigation Design:

In the design of a subsurface delivery system it is important to predict how water will move in time and space so that the desired water content of root zone will be maintained without excessive loss by deep percolation. Fok and Willardson (1971) presented a theoretical analysis on subsurface irrigation system design, where soil water movement from a given source in the soil profile was expressed as a function of time (t). For example in a horizontal direction water movement (x) is equal to:

$$x = c * t^{d} \quad .....(13)$$

in the vertical direction (y and z):

$$y = a * t^{b} \quad .....(14)$$

$$z = f * t^{g} \quad .....(15)$$

where: a,b,c,d,e,f and are empirical constants. The volume of water (V) in the soil adjacent to a unit length of the subsurface irrigation pipe may expressed as:

$$V = 3.14/2 * (x*y*As_1*w_1 + x*z*As_2*w_2) \quad .....(16)$$

$$V=3.14/2 *(w_1*As_1*a*c*t^{b+d} + w_2*As_2*c*f*t^{d+g}) \quad ...(17)$$

In which As_1 and As_2 are the apparent specific gravities of the upper and lower soil layers, respectively and w_1 and w_2 are the net increase, respectively of soil water content (dry weight percent) after wetting. By differentiating equation 17 with respect to time (t) the discharge rate (q) from a unit length of subsurface irrigation pipe may be obtained as:

$$q = (3.14/2)*[w_1*As_1*a*c(b+d)*t^{b+d-1} + w_2*As_2*c*f*(d+g)*t^{d+g-1}] \quad .....(18)$$

The burial depth of subirrigation pipes is assumed to be selected at the maximum value of height (y) for which water movement upward follows the simple power equation:

$$y = a*t^{b} \quad .....(19)$$

For spacing determination the following equation could be used:

$$s = 1.57 * c * (D/a)^{d/b} \quad .....(20)$$

This equation might have a special importance when close spacing is required where spacing would be a limiting economic factor.

Before that a similar model was constructed by Busch and Kneebone (1966) to represent the cross-section profile transverse to a buried plastic pipe. The tests were made on air-dried soils, initial testing marked the position of the wetting front on the face of the model at time intervals as flow advanced out-ward in all directions from the soil. This model shows that the moisture movement in upward, downward and horizontal direction can be equated to time on an exponential basis over a range of pressure heads and hydraulic conductivities. Results for two hydraulic conductivities at different heads were given, and if these relationships could be confirmed in the field, they would provide a general basis for deciding on the depth and spacing of pipe and time required for an irrigation to serve a particular soil and crop rooting depth. Therefore these results can give rise to problems of uniformity and excess water application under certain conditions.

Thomas et al.(1977) studied the infiltration from buried sources in a specially designed soil bin placed in a greenhouse. They compared calculated capillary potentials with those measured in two soil systems with an evapotranspirative demand. Also they illustrate the range of capillary potential distributions developed in the root zone for two crops grown at a constant subsurface irrigation rate. A design evaluation based on steady-state analysis for subsurface irrigation systems was also presented. The authors stated that subsurface irrigation systems can not be rigorously designed with a steady-state analysis but can only provide guidelines for selecting the lateral parameters, i.e. discharge rate, lateral spacing, and lateral depth.

2.3 Subsurface Irrigation Development:

Until recent years subsurface irrigation has been limited to areas in which special conditions are found, either a high water table is present, or highly permeable soils within several feet of the surface are underlaid with slowly permeable material that prevents excessive seepage losses (Busch and kneebone 1966). Now with the development of plastic tubing, it became possible to rely on a burial perforated pipe as the water source and to distribute water underground with pressures above atmospheric, where the positive pressure increase moisture gradient from the water source toward the surface, as well as in a downward directions.

Bavel et al.(1973) were able to use an automated dynamic simulation of an S/360 CSMP computer program for subsurface irrigation systems. In which water delivery and distribution from a subsurface irrigation system were simulated for a simplified one dimensional case and the water content at a given depth would turn infiltration from the buried delivery system off and on.

Nelson and Davis (1974) compared the distribution of soil salinity when citrus trees were sprinkler and subsurface irrigated, in addition changes in root distribution due to subsurface irrigation were investigated. No significant difference in tree growth was observed between the sprinkler and subsurface-irrigated plots. They found that the soil salinity distribution produced by subsurface irrigation results in maximum salt concentrations at the perimeter of the wetting front mostly above the burial depth of the subsurface pipe. They suggested to maintain a high water content during the rainfall months in order to allow the precipitation to be used only for leaching and not for increasing the soil water content.

In a comparison between surface, subsurface, sprinkler and furrow irrigation methods Davis and Pugh (1974) found that when the amount of water applied is near the consumptive use requirement, subsurface irrigation has greater production and better water use efficiency. In addition less water was needed for subsurface irrigation than furrow or sprinkler irrigation because less water was lost to direct evaporation and deep percolation. In a similar experiment Sammis (1980) feasible, like CO_2 enrichment near the plant roots.

5- The useful economic life of a trickle system can be prolonged by installing the subsurface system on row crops. They recommended that with fine textured soils to use less frequent trickle irrigations for a deep rooted row crop than for a shallow rooted crop.

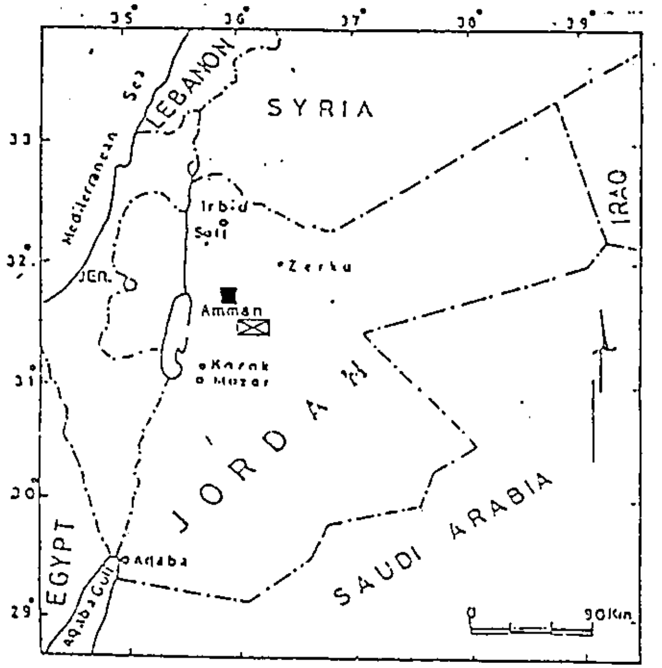
Hills et al.(1989) conducted a laboratory investigation to study the hydraulic effects of compression deformation of micro-irrigation subsurface drip-tape, they reported a reduction in average emitter flow rate corresponds to the degree of drip-tape deformation, resulting from soil compaction , and to the inlet flow rate. For soil characteristics and cultural practices conductive to soil compaction, the recommended maximum lateral length should be reduced, and times of irrigation lengthened, according to the drip-tape. Concerning the trickle subsurface irrigation systems, emitter clogging is a major problem. Drip pipes are buried below the ground surface causing additional problems, since the clogged orifices cannot be seen. Several studies have related emitter clogging to system hydraulics (Bralts et al.1982). Other studies have identified the major causes of clogging (physical, chemical, or biological), and recommendations have been provided by the researchers to control the problem. Chemical clogging through salt precipitation has been acknowledged to be the most difficult one (Hills et al.1989).

From the hydraulics point view, Vincent et al. (1982) reported that the rate of emitter plugging can be assessed by observing the changes in the total flow to the system, and they developed theoretical curves for predicting emitter plugging rates based on the changes in lateral line flow.

Hills et al.(1989) evaluated four management schemes for lessening the chemical clogging effects of high calcium content water in drip-tape. Of the management modes evaluated, reduction of water pH from 7.6 to 6.8, by sulfuric acid injection, provided the least clogging for all three water qualities used.

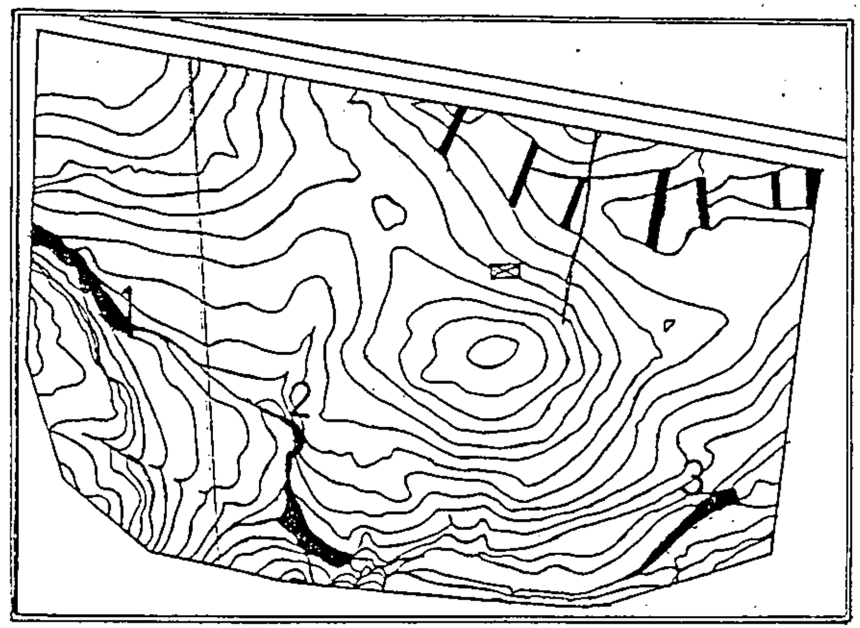
Schwanki and Prichard (1990) conducted an experiment to test an alternative to acid injection for dealing with chemical precipitate clogging in buried drip irrigation systems. They reported that injecting (ESI-35) a Phosphonate material was effective as acid against clogging in two field trials, and might cost less.

In order to evaluate subsurface trickle irrigation systems Kruse and Mizyed (1989) were able to use a computer model to analyze the performance of trickle irrigation sets. The program estimates the reduction in emitter flow rates caused by plugging and other deterioration of the systems by comparing the average pressure/discharge proportionality constants, K, determined by the computer from field measurements of inlet pressure head and flow rate with values of K determined in the laboratory for new hoses.



⊠ Project Area.

Fig.1: Location of the project area in Jordan.



⊠ Site of the experiment at the project area.

▬ Stone Terraces.

1,2,3 Surface reservoirs along the streamway.

Fig.2: Topographic map of the experimental site.

site is 1-2% . No previous irrigation practices has been experienced or conducted at the site and no soil disturbance has occurred. The location of the site was selected so that its soil represents most of the project soils as well as the region in terms of soil properties such as aggregation, surface crust, infiltration rate and vegetation cover.

Figure 2 shows the location of the experiment site. The soil of this site was classified by Taimeh (1989) as Fine,mixed,thermic,Typic Paleorthid (inclusion). The profile description is as follows:

Hor.	Depth/cm	Profile Description
A1	0-16	Light yellowish brown, 10 YR 6/4 (d) to brown-dark brown, 7.5 YR 4/4 (m),(SiCL), moderate medium subangular blocky, top 2cm is moderate platy structure, friable, s. hard, sticky, s. plastic, many fine roots, porous, gradual boundary.
BA	16-27	Strong brown, 7.5 YR 5/6 (d) to brown-dark brown to yellowish red 7.5 YR 4/4 (m), (SiCL), weak to moderate medium subangular blocky, few-many fine roots, crotovina, some gravels, friable, hard, sticky, plastic, clear boundary.
Bw	27-58	Yellowish red,5 YR 5/6 (d) to yellowish red, 5 YR 4/6 (m),(SiC), weak moderate medium subangular blocky, friable, hard,

sticky, plastic, few-common fine roots , decomposed roots, many root channels filled with ant exertion, clear boundary, stonline.

2BK	58-100	strong brown, 7.5 YR 5/6 (d) to yellowish red, 5 YR 5/6 (m), (SiCL), fine-medium moderate to subangular blocky and some medium granular, some tabules, friable, hard, v.sticky, v.plastic few fine roots, many decomposed roots, some dead insects, dark coating on ped faces, abundant (>50% by volume) of medium coarse carbonate concretions with many secondary carbonate accumulations, abrupt boundary.
2BKm	110+	The top 3cm is recrystallized cap of hard limestone, chert gravels, abundant secondary calcium carbonate, can be broken by hammer.
Cr		Compacted soft limestone.

Particle size distribution analysis were carried out by adopting "the international pipette method " as described by Day (1965) for the profile horizons. Apparent specific gravity was determined by core method described by Black (1965) for each depth, and other properties are presented in Table 1.

Moisture retention for each depth was conducted according to Richards (1948,1949,1952) as described by USDA

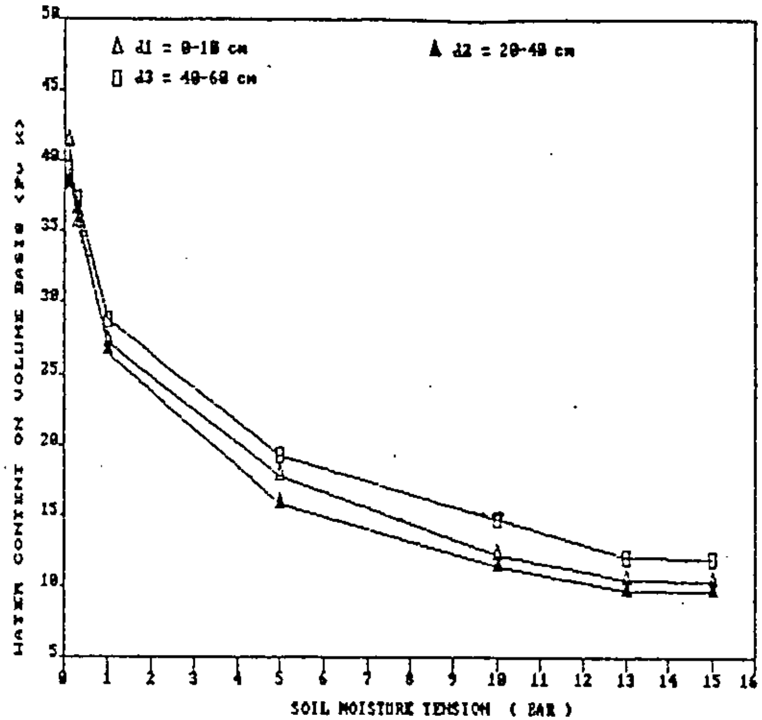


Fig.3: Soil moisture characteristic curves for depths of (d1) 10cm, (d2) 30cm ,and (d4) 50cm.

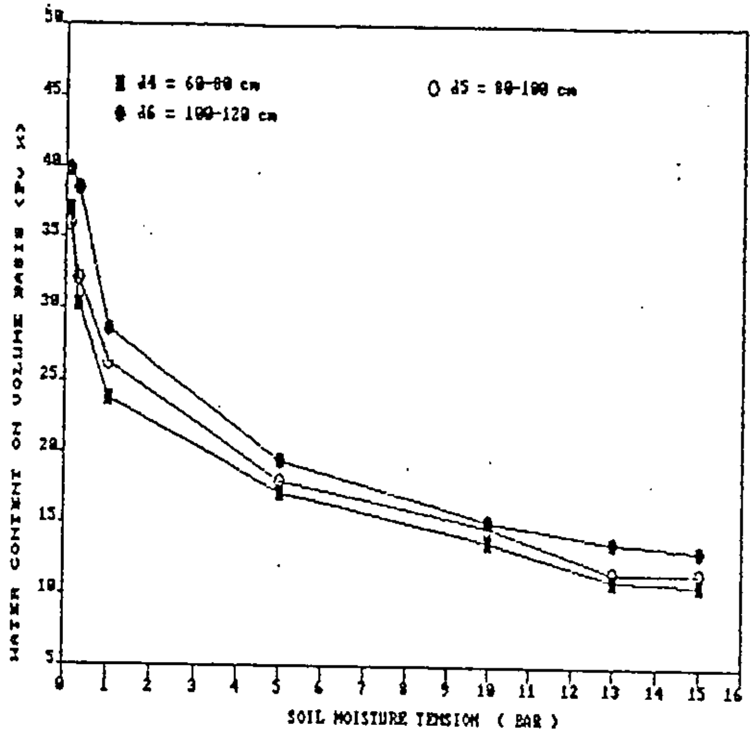
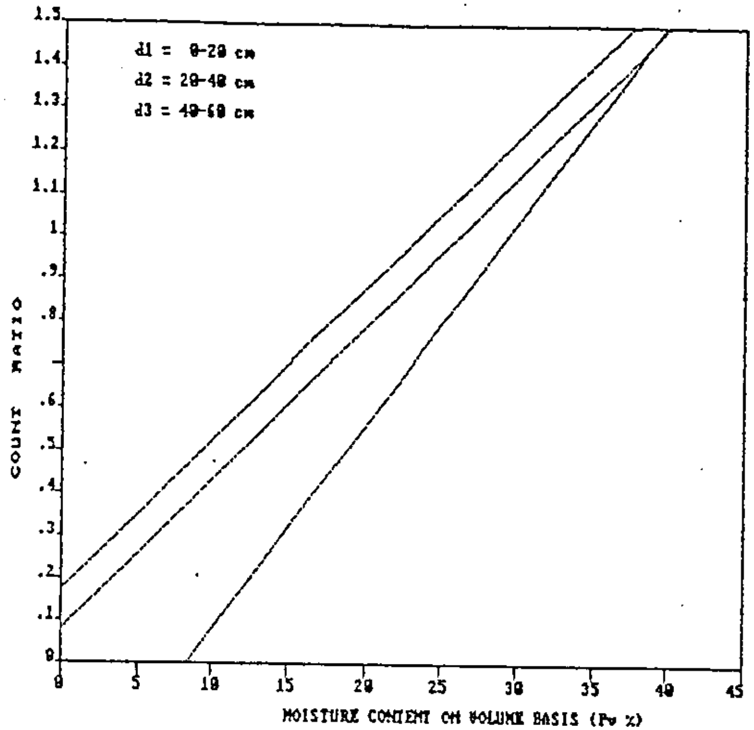


Fig.4: Soil moisture characteristic curves for depths of (d4) 70cm, (d5) 90cm, and (d6) 110cm.

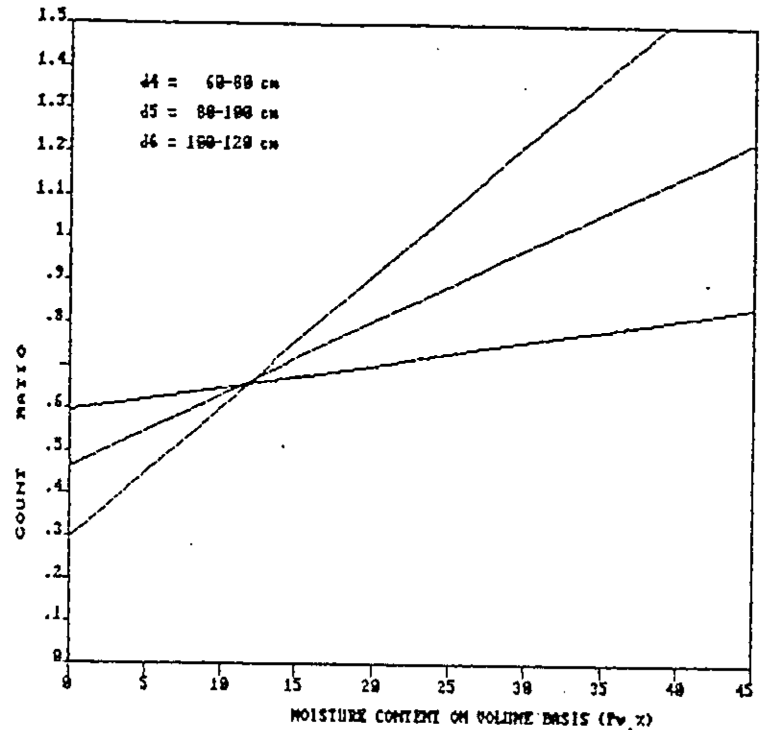


(d1) Pv. = 20.9864 * (C.R. + 0.39450) , r^2 = 0.92

(d2) Pv. = 28.9184 * (C.R. - 0.07838) , r^2 = 0.93

(d3) Pv. = 28.2885 * (C.R. - 0.11720) , r^2 = 0.92

Fig.5: Neutron Probe calibration curves for depths of (d1) 10cm, (d2) 30cm, and (d3) 50cm.



(d4) Pv. = 32.4569 * (C.R. - 0.2960) , r^2 = 0.96

(d5) Pv. = 58.4453 * (C.R. - 0.4611) , r^2 = 0.97

(d6) Pv. = 185.013 * (C.R. - 0.5934) , r^2 = 0.85

Fig.6: Neutron Probe calibration curves for depths of (d4) 70cm, (d5) 90cm, and (d6) 110cm.

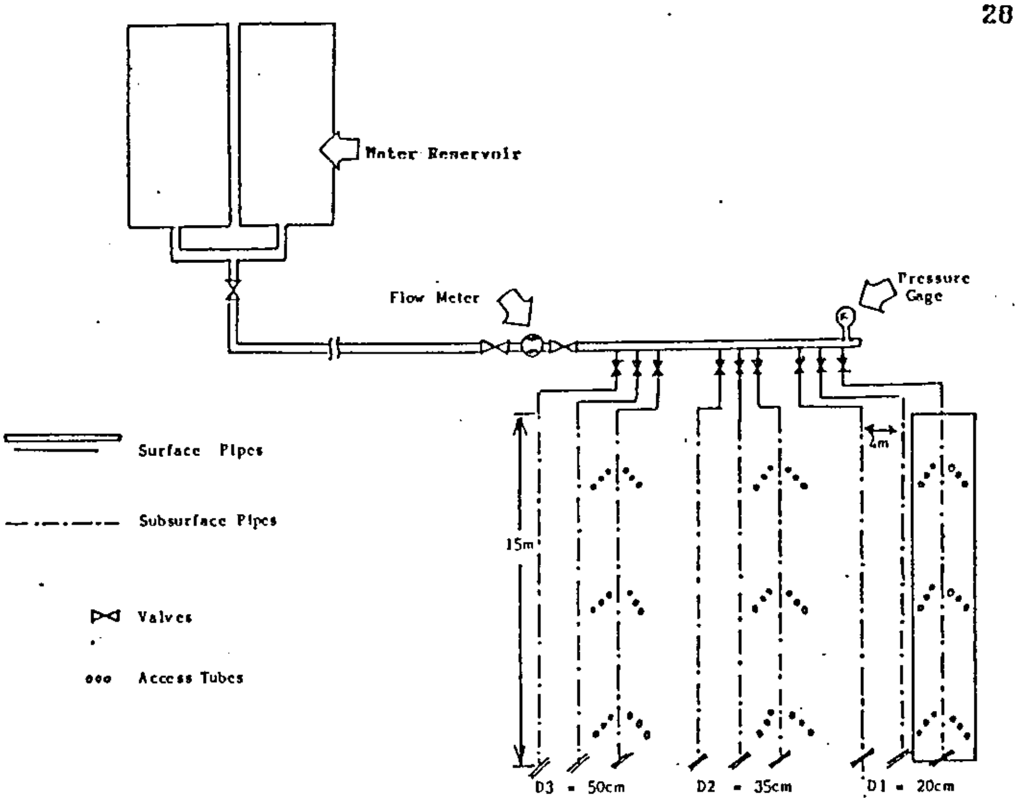


Fig.7: Layout of the experiment.

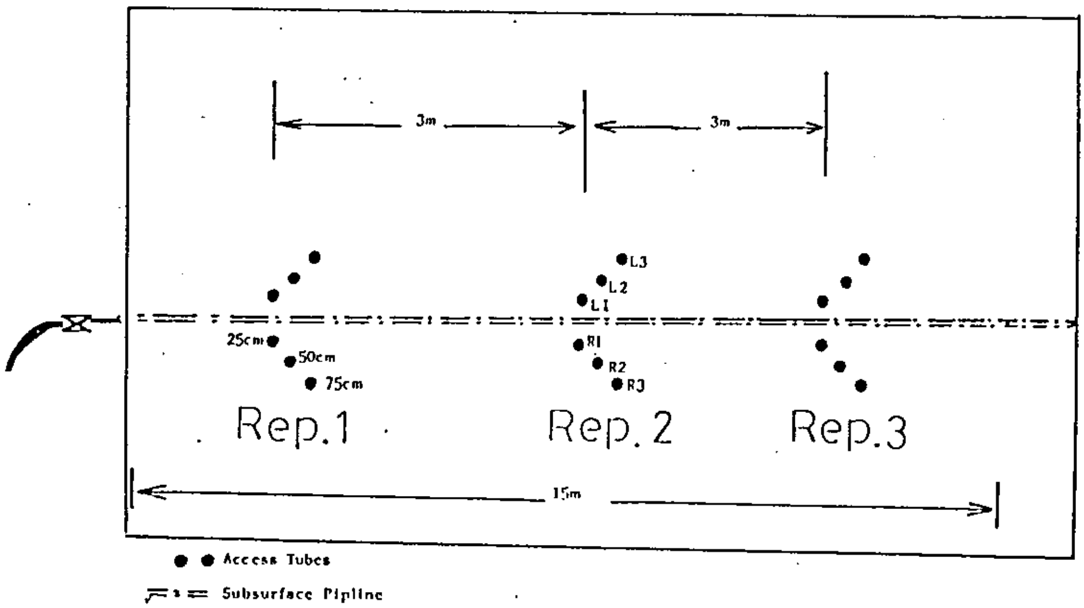


Fig.8: Position of the access tubes installed around the subsurface pipe line.

was delivered to this unit by a 63mm diameter polyethylene pipe from a $4m^3$ water supply reservoir up the hill. Water was pumped to the supply reservoir from the harvested water behind the earth dams that are built to collect run-off water resulted from the rainfall storms during winter.

For each required burial depth, a 15m long ditches were opened, and the pipes were installed straight ahead along the ditch. Since the used pipes are flat when empty, before back-filling the pipes are allowed to be filled with water to take the round shape. The same soil with the same sequence was used to refill the ditches, care was taken so as to prevent any physical damage or blockage to the pipes.

Three parallel lines of 15m long were installed for each burial depth with 4m spacing between each of them. The neutron probe access tubes were installed at the first line of each depth, and soil moisture samples were taken from the others (Figure 8).

The access tubes were installed around each lateral at a horizontal distance of 0.25m, 0.50m, and 0.75m away from both sides right (R), left (L), and three replicates of each set of these access tubes were installed at three places along the line (Rep.1 near the beginning, Rep.2 at the middle, and Rep.3 near the end) as shown in Figures 7 and 8.

3.2.2 Treatments:

Three burial depths were used as the major variable in this study, these are:

1. Shallow depth of 0.2m (D1),
2. Moderately deep one of 0.35m (D2), and
3. Deep depth of 0.5m (D3).

For each of the three burial depths three initial moisture contents were used, namely:
(I1) of Pv. = 5-10%, which is less than the PWP; (I2) of Pv. = 10-15%, which is nearly at the PWP; and (I3), which is between the PWP and the field capacity.

3.3 Water Analysis:

Two water samples were taken each run; one from the reservoir and one out of the water control unit. The pH was measured using glass electrode, the EC was determined by the use of the conductivity bridge and the total suspended solids were determined at the water research and study center in the University of Jordan by measuring the weight of the suspended solids in a measured volume,the results are shown in Table 2.

3.4 Experimental Procedure (Data collection):

Soil Moisture Measurements:

Before starting the experimental procedure, the tanks were filled with the water from the reservoir and the elevation in the tanks was recorded. The water gauge reading was taken to measure the exact amount of water that is used during the application time of irrigation. The pressure gauge was set at 2.5 Psi (the recommended head pressure), then two methods were used for the detection of the wetting fronts;

they are: gravimetric method and the neutron probe scattering method.

a. Gravimetric Method:

Wetting fronts were determined by taking soil moisture samples. The first is before starting the irrigation to know the initial moisture content, then soil moisture samples were taken at different horizontal and vertical distances away from the subsurface irrigation line for each treatment. Samples are taken after 1:00, 2:00, 4:00, 8:00, and 24:00 hours from the start of application time. It should be mentioned that at later stages some samples were taken from one side, and is considered to be symmetrical with the other side, due to the observed symmetry in the data taken from different soil samples. The wetting fronts were determined by extrapolation or interpolation between the two closest point to the initial moisture content.

b. Neutron Scattering Method:

Soil moisture was measured by the neutron probe at horizontal distances of 0.25, 0.50, and 0.75m on both sides of the subsurface line for the depth of the 0.1, 0.3, 0.5, 0.7, 0.9, and 1.10m depths. First before starting the irrigation to make sure of the desired initial moisture content; and then after 1:00, 2:00, 4:00, 8:00, 16:00, and 24:00 hours after irrigation started. The wetting fronts were then determined using the same procedure of the gravimetric method.

3.5 Data Analysis:

Wetting pattern advance figures were developed from the results obtained by gravimetric and neutron probe methods for each burial depth, at different initial moisture content. This reflects the horizontal and vertical water movement through out the cross sectional area of soil profile around subsurface irrigation line.

Statistical regression analysis was used to determine the relationship between the advance distance of the wetting front (x, y and z) and the time (t), as a simple power function (13). The best fit curves can be then used as design charts to predict the water movement in the soil as a function of time. They could be used for design purposes.

The measured specific discharge rate (SDR) was determined by dividing the total volume of irrigation water by the length of the subsurface line, and the hours of irrigation. In addition, charts were made to show the effect of the initial moisture content on the specific discharge rate.

The neutron probe measurements were used to locate the wetting front in the soil profile in the same manner of the gravimetric method. Simple power function equations were also developed and used to compare the two techniques.

CHAPTER IV

RESULTS AND DISCUSSION

4.1 Assumptions :

The wetting patterns under subsurface irrigation lines were determined by using the gravimetric method, based on The following assumptions :

1- The two-dimensional wetting pattern from a subsurface irrigation pipe in the soil profile at a given time can be approximated by two semi-ellipses equations as formulated by Fok and Willardson (1971).

2- Water movement from subsurface irrigation pipe obeys the principles of unsaturated flow.

3- Soil is homogeneous in the horizontal and vertical directions.

These assumptions were used in the early development and orientation of the wetting front advance figures, and for the establishment of the design charts and water movement equations of the soil profile.

4.2 Burial depth of (0.20 m) :

Figures 9,10 and 11 show the wetting front progress from subsurface line buried at 0.20m depth with initial Pv. of 5-10%, 10-15%, and 15-20% respectively, is shown at times 1:00, 2:00, 4:00, 8:00, and 24:00 hrs after irrigation started. These figures represents a cross sectional area in the soil profile, where the 0:00 hr point represents the

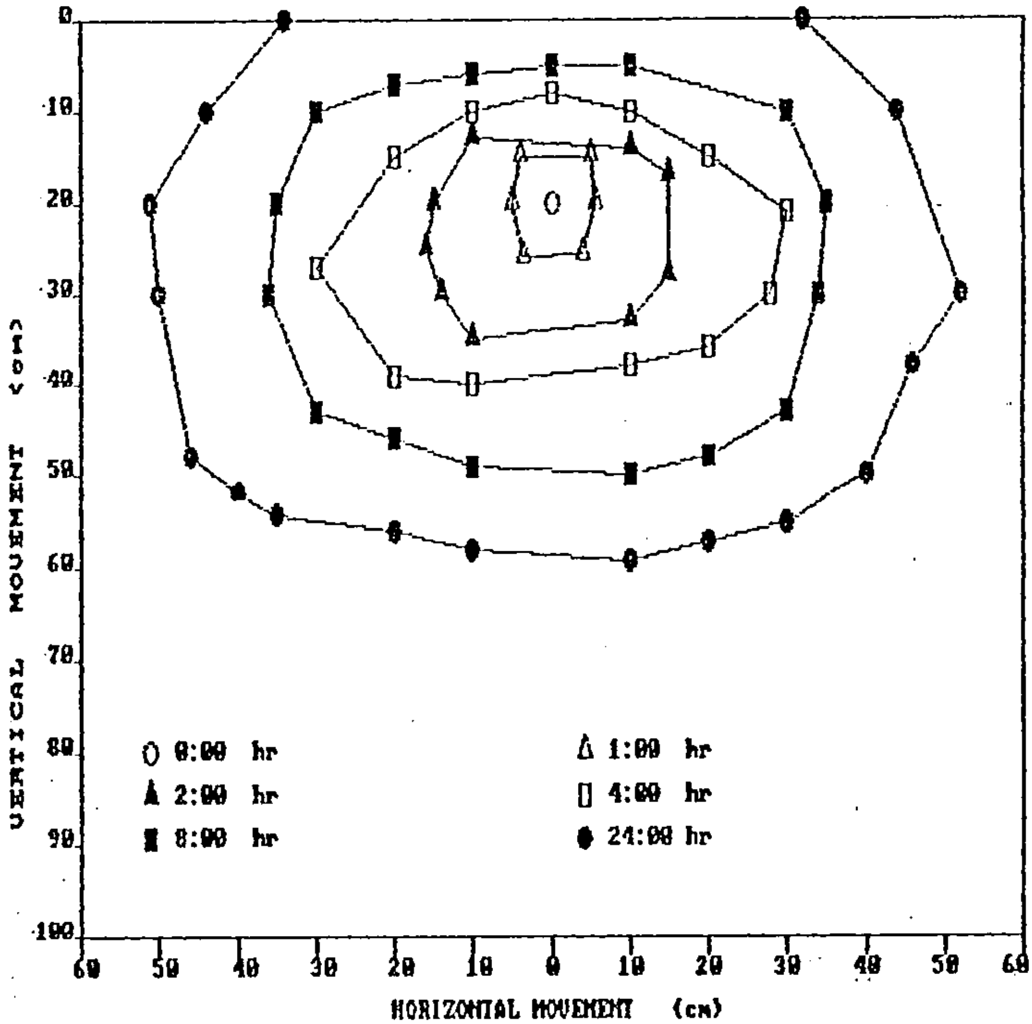


Fig.10: Location of the wetting front for the 20cm burial depth, after 1,2,4,8, and 24 hours from irrigation with initial Pv. of 10-15%.

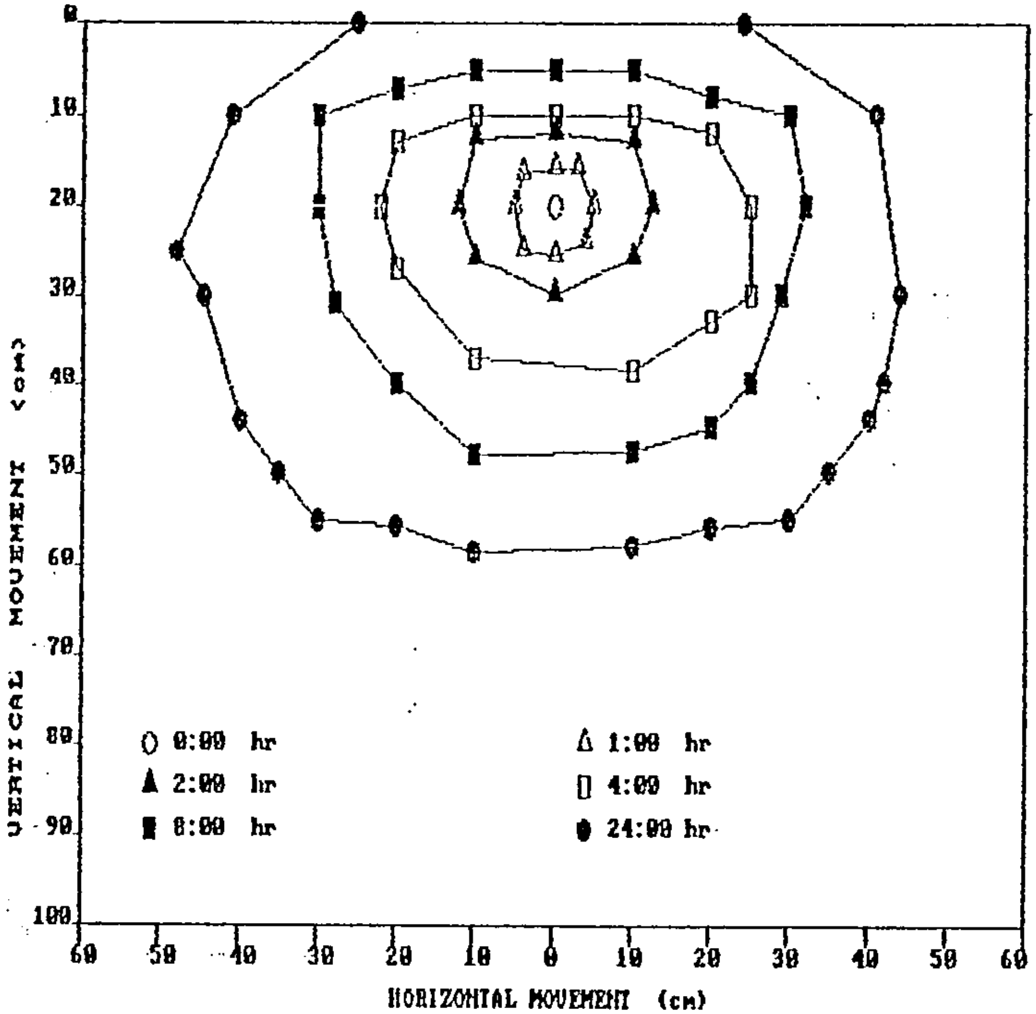


Fig.11: Location of the wetting front for the 20cm burial depth, after 1,2,4,8, and 24 hours from irrigation with initial Pv. of 15-20%.

location of the source of water (subsurface line), and the points 1:00hr through 24:00hr indicates the shape of the wetting front after each irrigation interval.

For the initial moisture content of 5-10%, as shown in Figure 9, the wetting front progress is symmetrical in the horizontal plane. This result applies for all the treatments of the experiment.

At this burial depth the water did reach the soil surface after a time of 8-16 hours of irrigation, depending on the initial moisture content. These results are clear as shown figures and as observed in the field. It suggests that using 0.20m burial depth may result in evaporation loses if irrigation duration exceeds 24:00 hours. This practice may not be recommended under the arid conditions since the main advantage of this system is to achieve high efficiency. But on the other hand these results indicate that at this depth the system may operate efficiently to soften the surface soil crust and facilitate seed germination and emergence.

On the other hand, comparing the effect of the initial moisture content at the 0.20m burial depth on the wetting front progress showed that the upward water movement is slower at higher initial moisture content. Previous researches in this area (Hawatmeh and Battikhi 1983, Karadsheh 1990, and Mostaghimi et al. 1982) studied the downward water movement only. This result could be attributed to the change in the soil compaction as a result of the installation procedure of the subsurface irrigation pipes.

4.3 Burial Depth of (0.35 m):

Figures 12,13 and 14 are similar to those under 0.20m depth; where they show the progress of the wetting front advance in a cross sectional area of the soil profile by using a source of water buried at 0.35m. In this case few spots of moisture were at the soil surface along the subsurface line after 24:00 hours of irrigation. Although the results in the figures show that the water reached the surface, but field observation showed that the water did not reach the soil surface all over along the irrigation line. This difference between the results shown in these figures and field observations is related to another concept that is called the water uniformity which reflects the water distribution pattern in the field. It was not possible to study this concept by using the gravimetric method for water detection. Such evaluation requires large numbers of soil samples in order to make more than one cross sectional area along the line at one time. This could be done by using other tools such as the Ground-Penetrating Radar (Vellidis et al 1989), or the Gamma ray attenuation (Dirksen 1978). Concerning the effect of the initial moisture content on the development of the wetting front, similar results to the 0.20-m depth were found. Wetting front reached the soil surface faster at lower initial moisture content. Slight differences were observed in the horizontal direction.

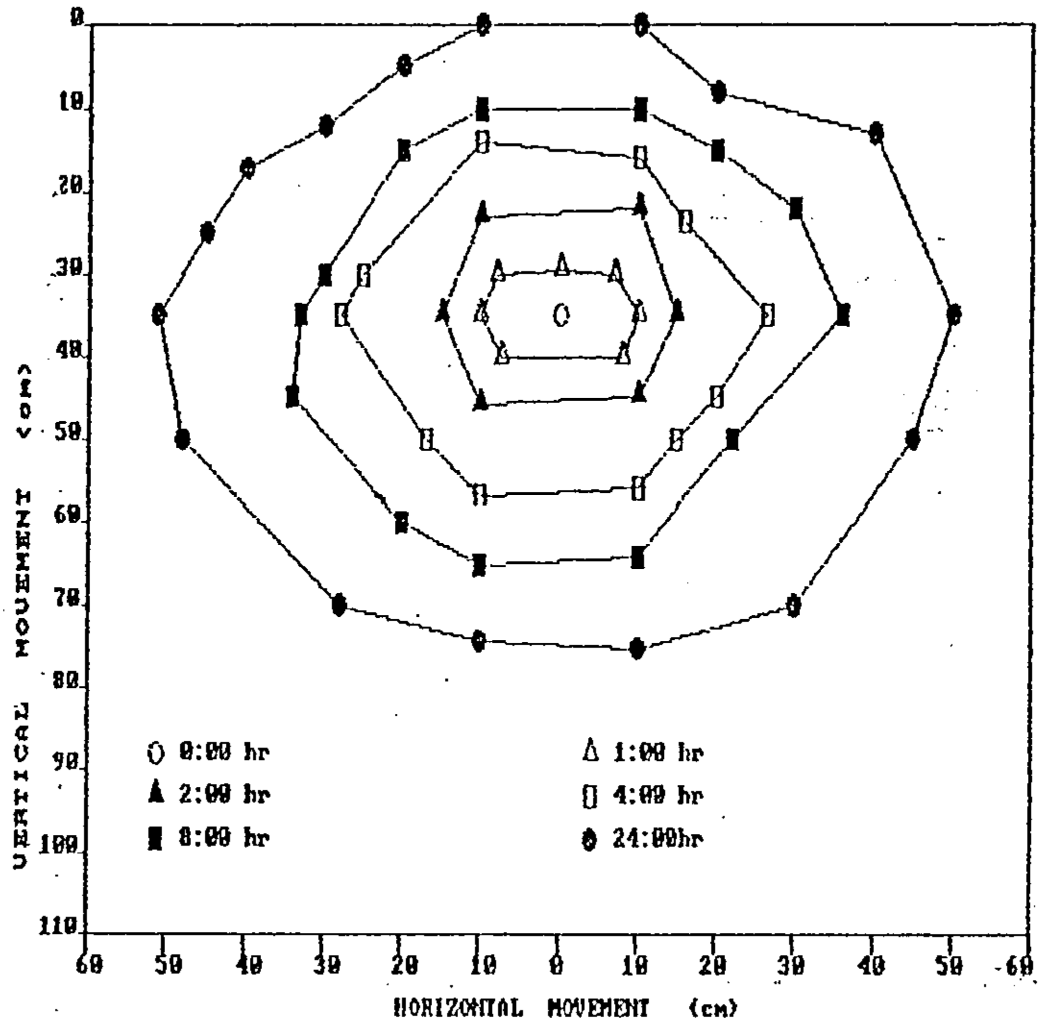


Fig.12: Location of the wetting front for the 35cm burial depth, after 1,2,4,8, and 24 hours from irrigation with initial Pv. of 5-10% .

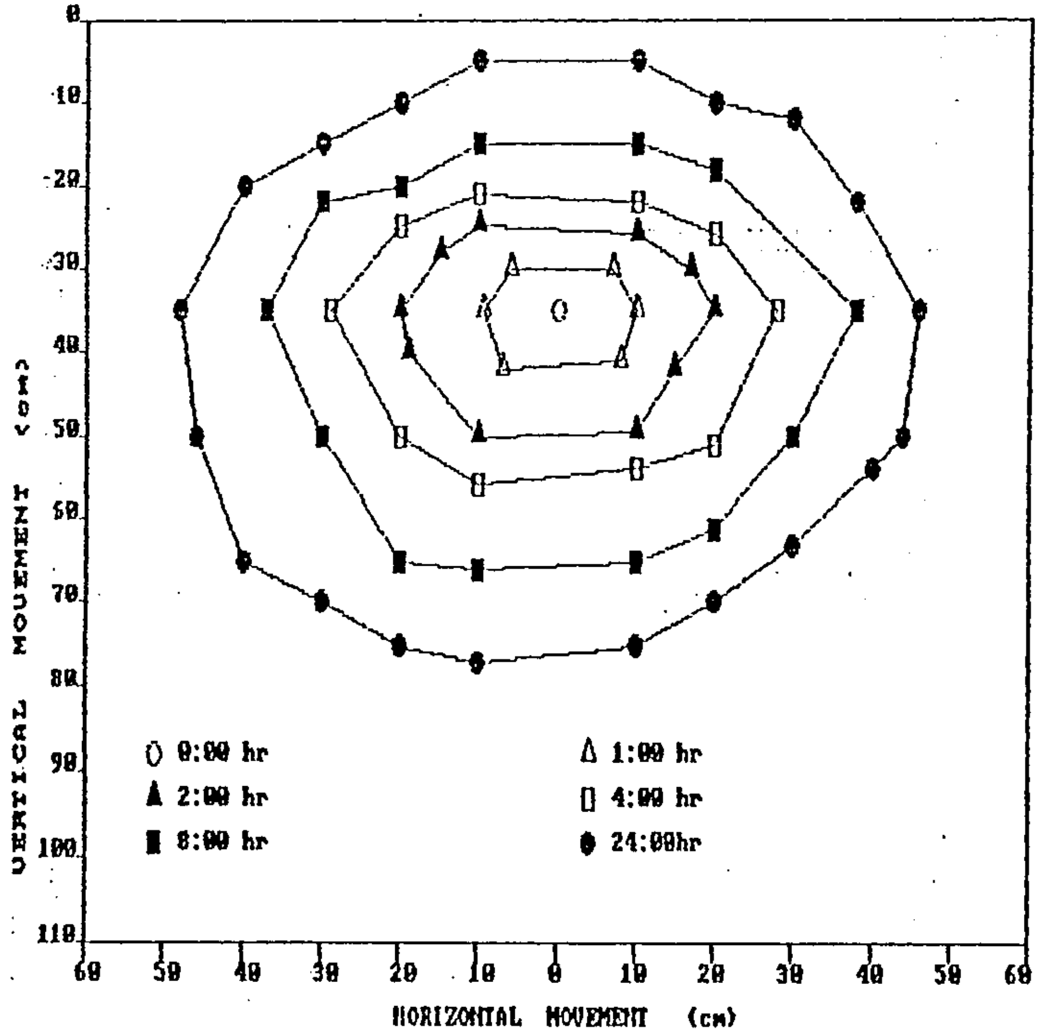


Fig.13: Location of the wetting front for the 35cm burial depth, after 1,2,4,8, and 24 hours from irrigation with initial Pv. of 10-15%.

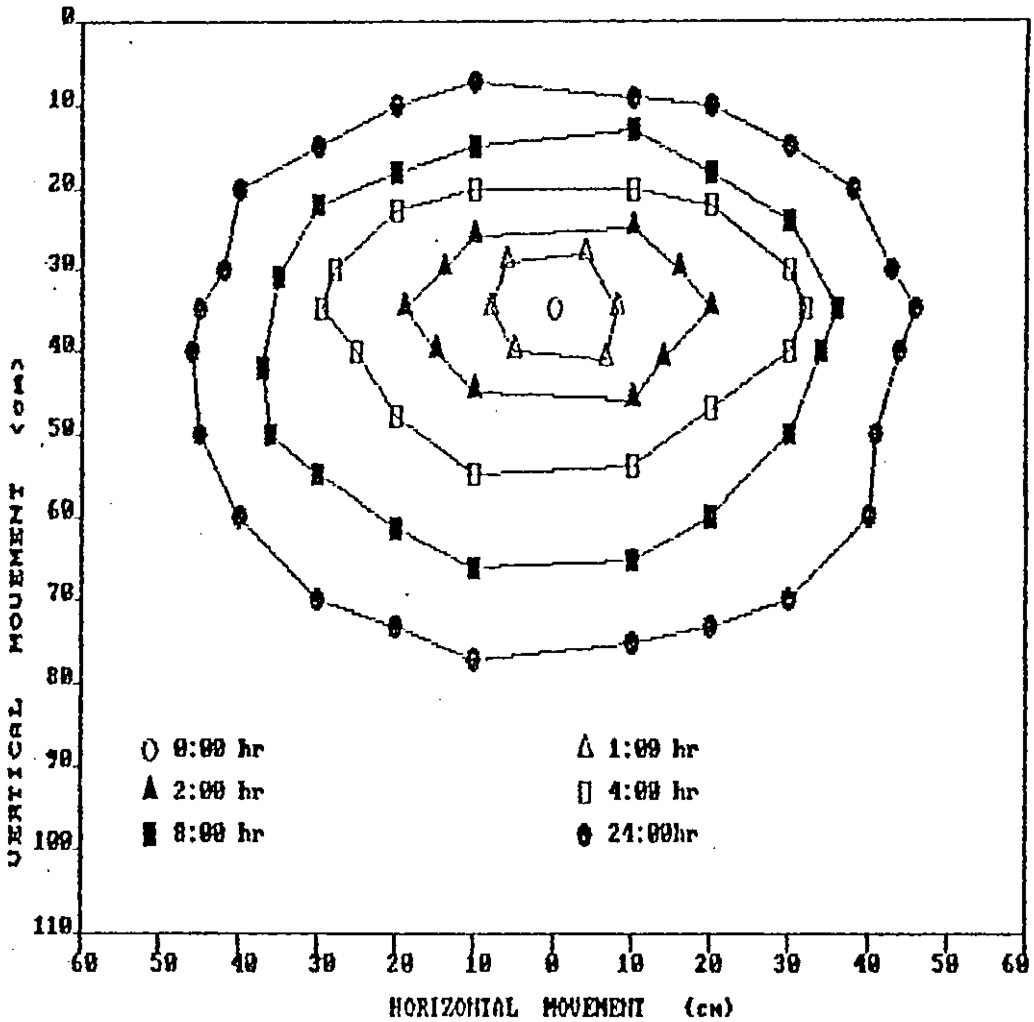


Fig.14: Location of the wetting front for the 35cm burial depth, after 1,2,4,8, and 24 hours from irrigation with initial Pv. of 15-20% .

4.4 Burial Depth of (0.50 m):

Figures 15, 16, and 17 shows the wetting patterns under 0.50m burial depth, for the three initial moisture contents used. These figures show a semi-ellipse shape of the wetting front progress, where the horizontal water advance was slightly more than the vertical one. This result is noticed clearly at this deep burial depth may be due to the affect of soil compaction at the lower depths of the soil profile, in addition to the presence of a compacted soft limestone layer at the bottom. The highest upward water movement was about 0.44 m above the subsurface irrigation line after 24:00 hours of irrigation at the 1st initial moisture content.

4.5 Water movement relationships :

Simple power equations (Table 3) were developed by studying the horizontal (x), the upward (y), and the downward (z) water movement for different burial depths, and different initial moisture contents. In each case an equation was derived by using the time as independent variable to predict the distance of water advance (dependent variable). These equations were used to produce the charts of Figures 18 to 26 which shows the water advance as a function of time.

It should be mentioned that the effect of the discharge rate was not considered as a variable in these design charts because in the case of the perforated subsurface irrigation

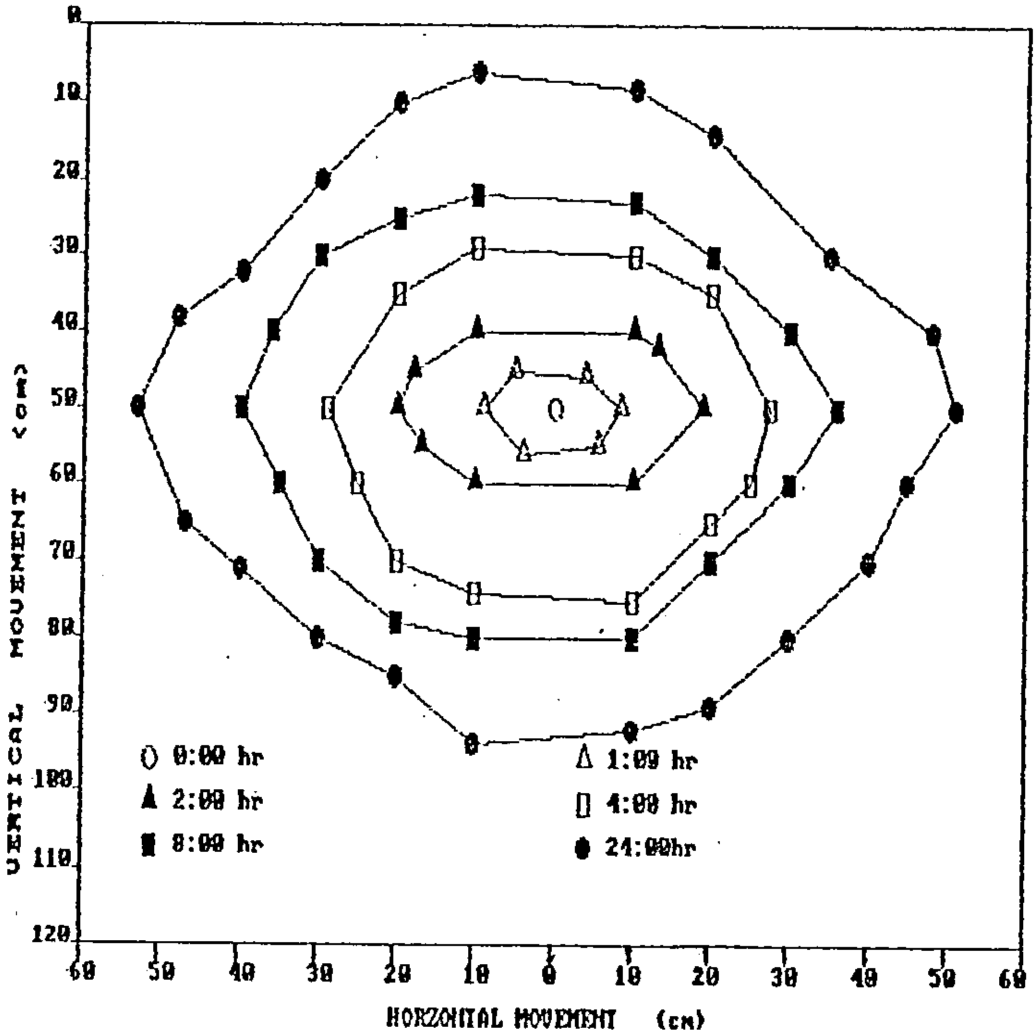


Fig.15: Location of the wetting front for the 50cm burial depth, after 1,2,4,8, and 24 hours from irrigation with initial Pv. of 5-10% .

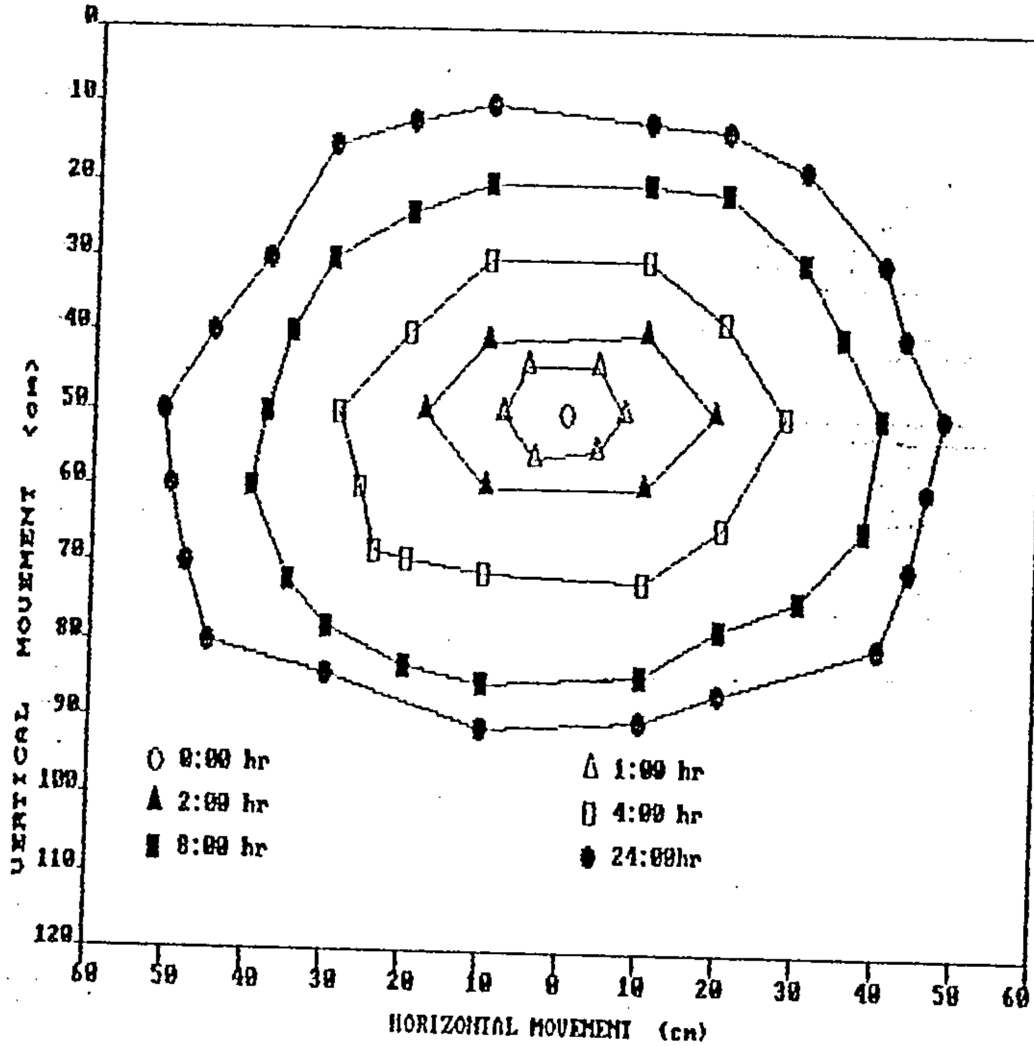


Fig.16: Location of the wetting front for the 50cm burial depth, after 1,2,4,8, and 24 hours from irrigation with initial Pv. of 10-15% .

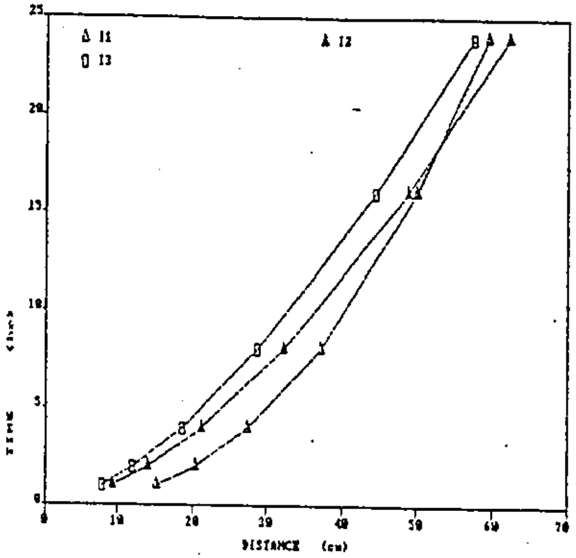


Fig.18: Horizontal water advance for subsurface lines buried at 20cm depth after different initial moisture content.

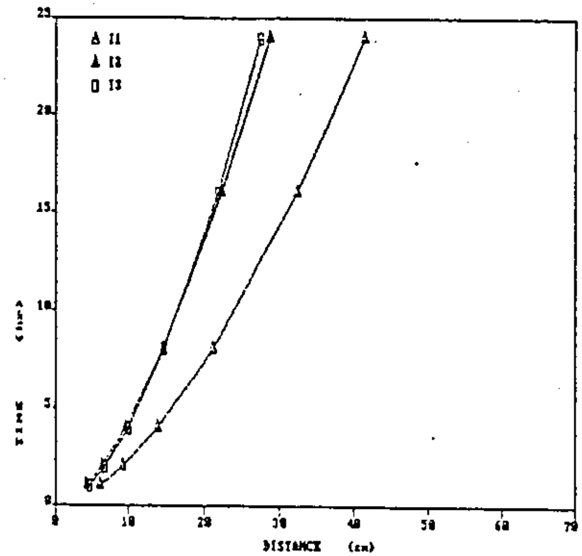


Fig.19: Upward water advance for subsurface lines buried at 20cm depth after different initial moisture content.

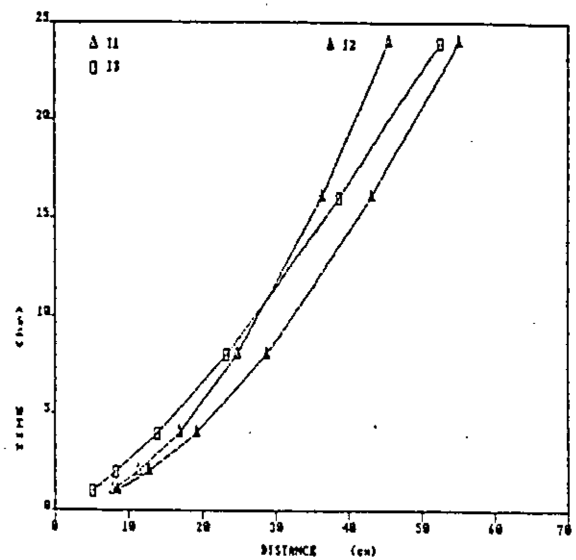


Fig.20: Downward water advance for subsurface lines buried at 20cm depth after different initial moisture content.

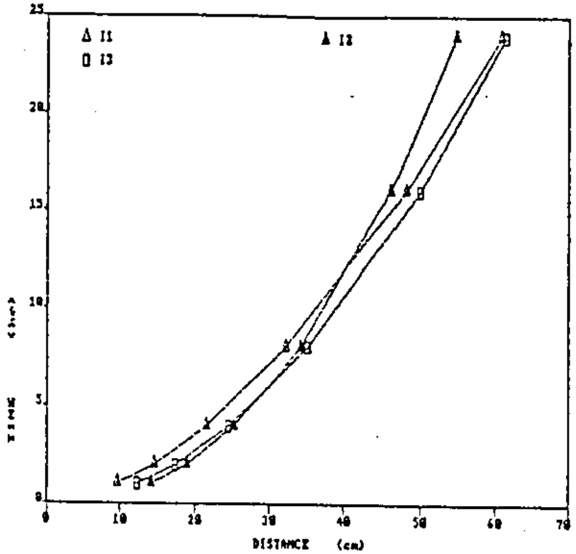


Fig.21: Horizontal water advance for subsurface lines buried at 35cm depth after different initial moisture content.

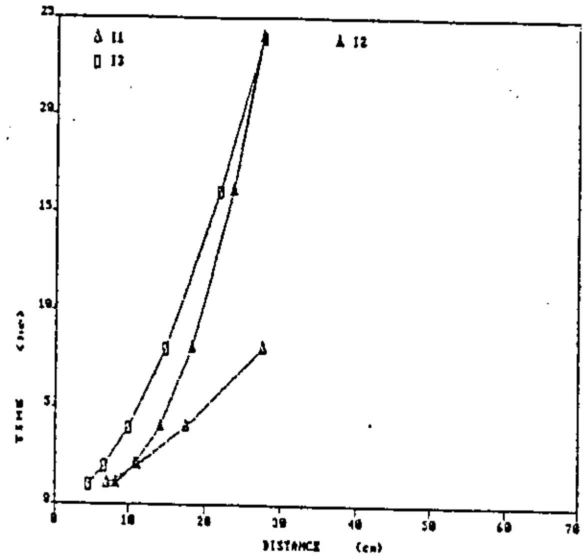


Fig.22: Upward water advance for subsurface lines buried at 35cm depth after different initial moisture content.

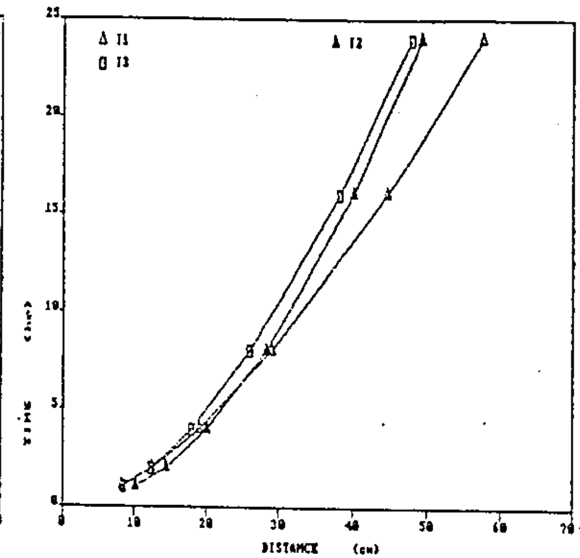


Fig.23: Downward water advance for subsurface lines buried at 35cm depth after different initial moisture content.

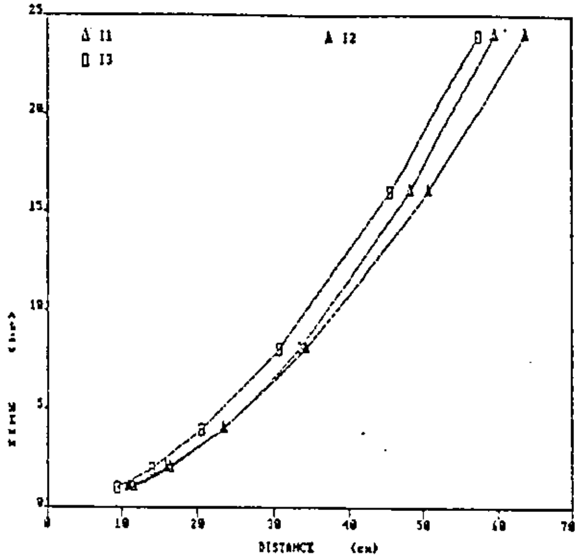


Fig.24: Horizontal water advance for subsurface lines buried at 50cm depth after different initial moisture content.

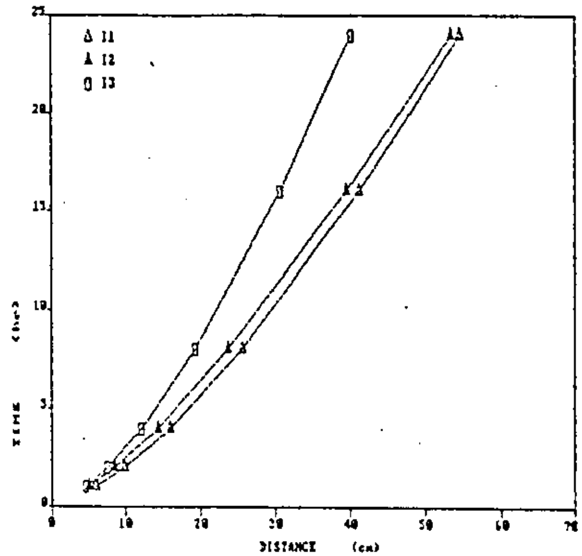


Fig.25: Upward water advance for subsurface lines buried at 50cm depth after different initial moisture content.

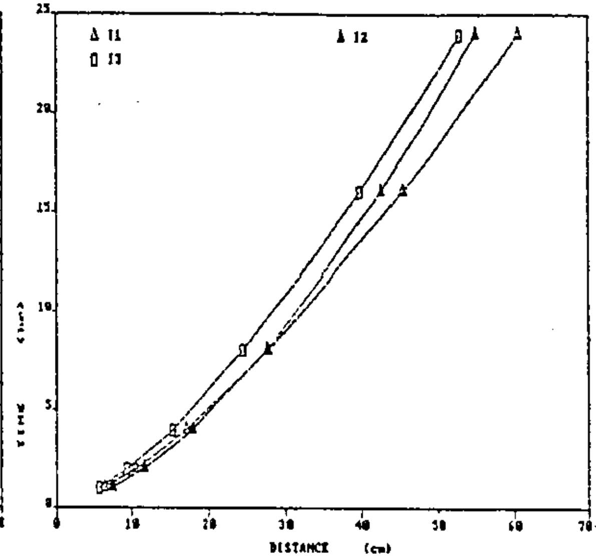


Fig.26: Downward water advance for subsurface lines buried at 50cm depth after different initial moisture content.

pipe lines the water movement out of the pipes is related to the difference in the hydraulic gradient between the pipe and the moisture content around it, i.e. the discharge rate is related to the soil moisture content and cannot be controlled in this case.

The same applies for the operating pressure head, which is related to the tube manufacturing. The recommended operating pressure range is 2-5psi.

In a comparison between the relationships under each depth, the effect of the initial moisture content was more on the vertical upward direction. Increasing the initial moisture content a considerable decrease in the upward front advance rate was found. A small reduction was observed in the horizontal water movement, which could be explained due to increasing the initial moisture content. Reduction in the difference in the hydraulic gradient will occur which will decrease the discharge rate (Table 4). This will lead to a reduction in the horizontal movement (Hachum et al. 1976, Hawatmeh and Battikhi 1983, and Karadsheh 1990). This reduction is attributed to the decrease in the discharge rate which is related to the indirect effect of the initial moisture content.

The effect of the initial moisture content on the wetting fronts in the cases of the surface line sources (Hawatmeh and Battikhi) cannot be applied in the case of subsurface water application specifically for the upward and

Table.4: DISCHARGE RATE.

B.depth (cm)	Initial moisture Pv.%	Applicat. Time (hr)	Total Volume liter	Pipe length (meter)	Measured Specific discharge rate liter/hour/meter
D1=20cm	5-10%	0 - 1	155.00	14.00	11.07
		1 - 2	145.00	14.00	10.36
		2 - 4	210.00	14.00	7.50
		4 - 8	340.00	14.00	6.07
		8 -24	1305.00	14.00	5.83
D1=20cm	10-15%	0 - 1	130.00	14.00	9.29
		1 - 2	125.00	14.00	8.93
		2 - 4	190.00	14.00	6.79
		4 - 8	315.00	14.00	5.63
		8 -24	1215.00	14.00	5.42
D1=20cm	15-20%	0 - 1	120.00	14.00	8.57
		1 - 2	115.00	14.00	8.21
		2 - 4	185.00	14.00	6.61
		4 - 8	305.00	14.00	5.45
		8 -24	1195.00	14.00	5.33
D2=35cm	5-10%	0 - 1	145.00	13.00	11.15
		1 - 2	130.00	13.00	10.00
		2 - 4	220.00	13.00	8.46
		4 - 8	325.00	13.00	6.25
		8 -24	1315.00	13.00	6.32
D2=35cm	10-15%	0 - 1	135.00	13.00	10.38
		1 - 2	125.00	13.00	9.62
		2 - 4	215.00	13.00	8.27
		4 - 8	320.00	13.00	6.15
		8 -24	1295.00	13.00	6.23
D2=35cm	15-20%	0 - 1	110.00	13.00	8.46
		1 - 2	120.00	13.00	9.23
		2 - 4	195.00	13.00	7.50
		4 - 8	295.00	13.00	5.67
		8 -24	1250.00	13.00	6.01

.../53

Table. 4: Continued

B.depth (cm)	Initial moisture Pv.%	Applicat. Time (hr)	Total Volume liter	Pipe length (meter)	Specific discharge rate liter/hour/meter
d3=50cm	5-10%	0 - 1	155.00	15.00	10.33
		1 - 2	160.00	15.00	10.67
		2 - 4	245.00	15.00	8.17
		4 - 8	375.00	15.00	6.25
		8 -24	1420.00	15.00	5.92
d3=50cm	10-15%	0 - 1	145.00	15.00	9.67
		1 - 2	150.00	15.00	10.00
		2 - 4	230.00	15.00	7.67
		4 - 8	355.00	15.00	5.92
		8 -24	1400.00	15.00	5.83
d3=50cm	15-20%	0 - 1	140.00	15.00	9.33
		1 - 2	135.00	15.00	9.00
		2 - 4	215.00	15.00	7.17
		4 - 8	340.00	15.00	5.67
		8 -24	1380.00	15.00	5.75

horizontal water movements.

Application of Kirkham and Power (1972) formula to unsaturated flow may explain the reduction in the upward movement, their equations:

$$q_w = -k_\theta \, [\, d\Psi h/dz \,]$$

$$d\Psi h/dz = (\, d\Psi m/dz + d\Psi z/dz \,)$$

$$q_w = -k_\theta \, [d\Psi m/dz + d\Psi z/dz]$$

by increasing the moisture content, the matric potential gradient ($d\Psi m/dz$) will be reduced until it approach zero at the saturation point. At this point the hydraulic term will be reduced to the only effect of the gravity ($d\Psi z/dz$). After the soil reaches the saturation point the only factor for water movement is the gravitational effect; and in the case of subsurface irrigation, the water movement after a certain time of irrigation, or after increasing the initial moisture content will be mostly effected by the gravitational force.

Figures 27,28, and 29 were developed to study the water advance as a function of time for each initial moisture content regardless of the burial depth used.

In the horizontal movement (Fig 27) a slight deferences were observed due to the effect of the initial moisture, while in the downward movement (Fig 28) the average values were not as expected to be more with high initial moisture. This may be attributed to the fact that the soil profile in this sight has a compacted soft lime stone in the lower parts with high apparent specific gravity of 1.583, and a

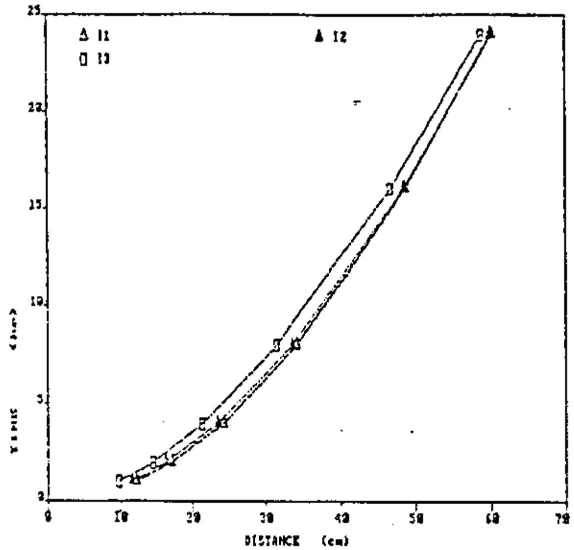


Fig.27: Best fit curves for horizontal water advance in the soil profile at different initial moisture content regardless of the burial depth of the subsurface pipe.

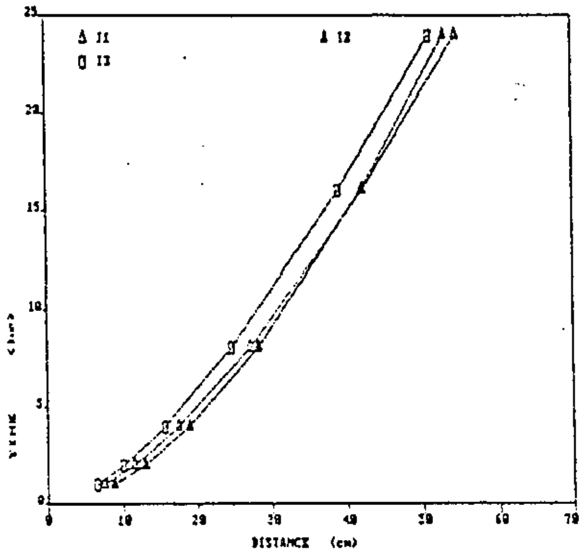


Fig.28: Best fit curves for downward water advance in the soil profile at different initial moisture content regardless of the burial depth of the subsurface pipe.

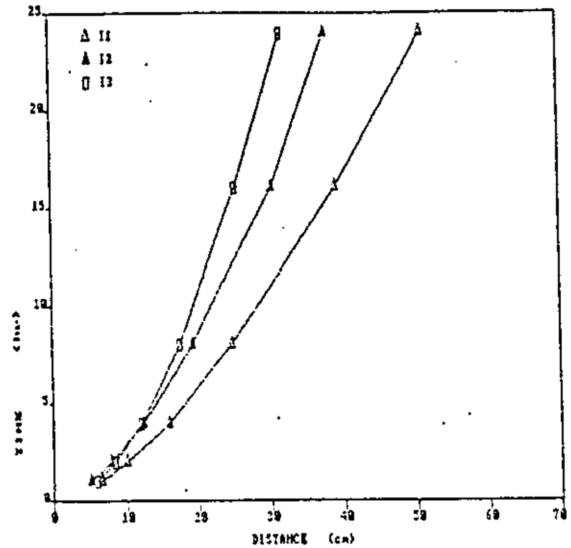


Fig.29: Best fit curves for upward water advance in the soil profile at different initial moisture content regardless of the burial depth of the subsurface pipe.

porosity value of 40%. This very low porosity would reduce the downward water penetration.

Comparing the results between the three burial depths, no significant differences in water movement were observed due to the burial depth, but using the equations of the 0.5m burial for the upward water movement prediction was more precise than the others because the water did not reach soil surface. This give a good idea of how far would the water advance in all directions in the soil.

Figure 30 was produced as a simple and general chart to predict the water movement in the three directions x,y and z, as a function of time regardless of the initial moisture content and the burial depth, with the following assumption: a. no significant differences were observed in water movements due to the initial moisture content. b. also no differences were observed due to the effect of the burial depth. c. one location (soil profile) was used in this experiment. The values obtained from this figure were used to develop the following equations for the water advances at this site (silty clay loam soil) as a function of time :

Horizontal movement : $X = 11.129\ T^{0.5306}$

Up-ward movement : $Y = 5.665\ T^{0.6196}$

Down-ward movement : $Z = 7.405\ T^{0.6172}$

In which the units for X,Y, and Z are expressed in centimeters (cm) and the unit of T (time) is expressed in hours. This figure may be used as a general guide line for

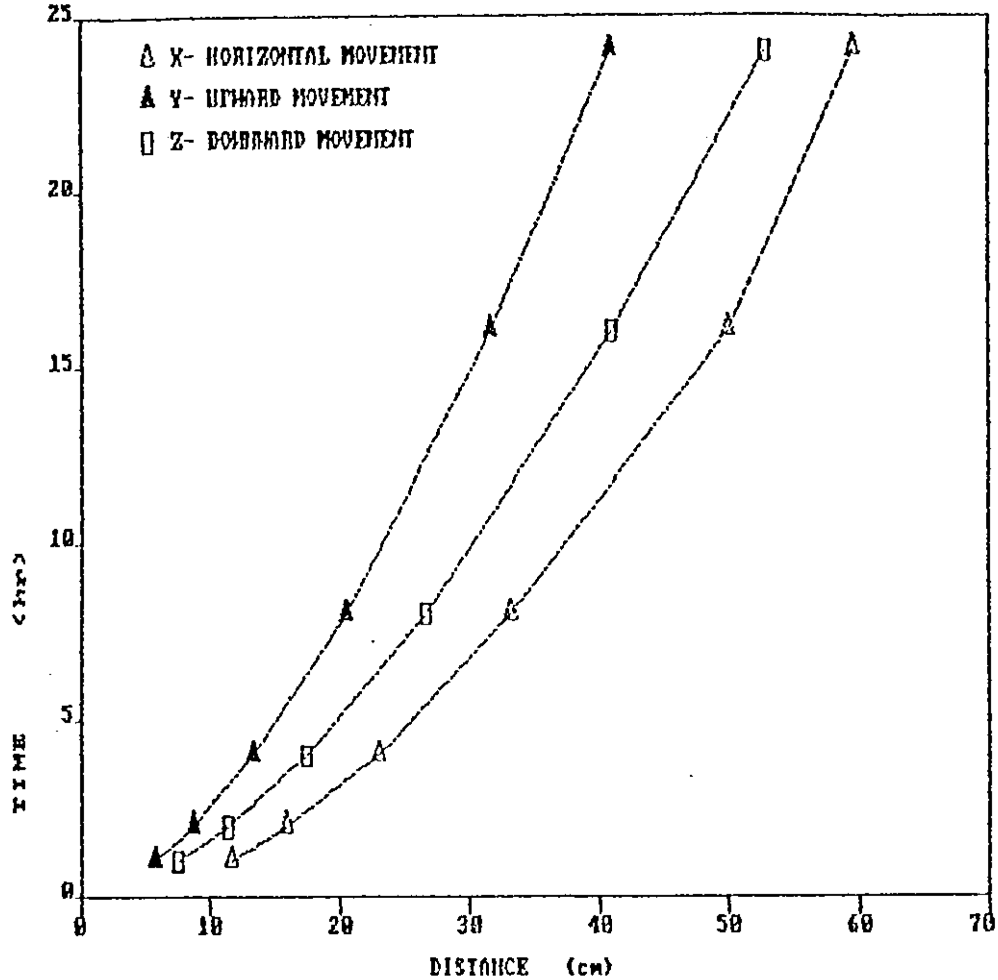


Fig.30: Best fit curves for horizontal, upward, and downward water advance in the soil profile regardless of the initial moisture content and the burial depth of subsurface pipe.

the design of such a system at similar locations. The maximum Y-value (upward water advance) is about 0.45m indicates the recommended burial depth for this site, and the maximum X-value (horizontal water advance) is around 0.55 cm, should be the maximum spacing between laterals if complete wetting of soil volume in the root zone is required.

4.6 Discharge rate and water analysis :

4.6.1 The effect of the initial moisture content and the application time on the specific discharge rate (SDR):

It was possible to measure the discharge at pressure head range of 2.5-5 psi for each run by using a water gage reading before and after each time of irrigation. Since the subsurface irrigation pipes are porous and not of emitter type, it was necessary to consider the length of each line in order to calculate the specific discharge rate (SDR) for each case by dividing the total volume of applied water by the length of each lateral (Table 4).

Figures 31 ,32 and 33 show the relations between the application time and the measured specific discharge obtained from Table 4.

These results indicate that the application time has a great effect on the discharge. The discharge rate starts high because the initial moisture around the subsurface pipe is lower and the hydraulic gradient is very high. When the soil moisture increases after some time the hydraulic

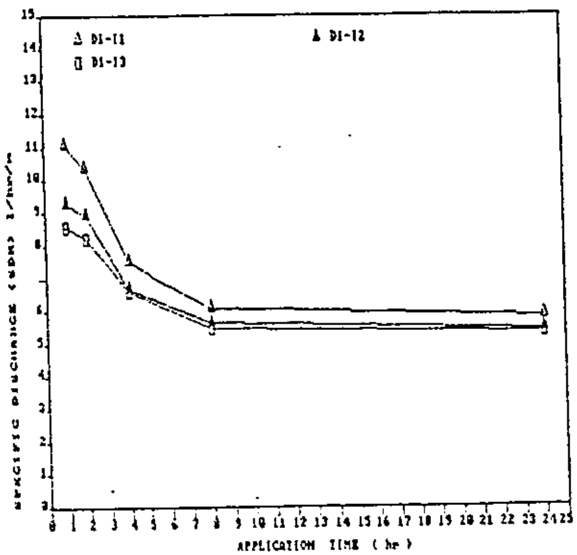


Fig.31: Measured specific discharge rate of the subsurface pipe laid at 20cm depth, at different application times and initial moisture levels.

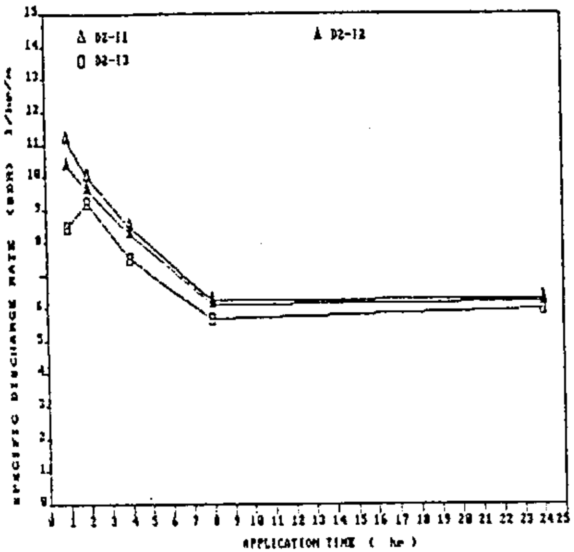


Fig.32: Measured specific discharge rate of the subsurface pipe laid at 35cm depth, at different application times and initial moisture levels.

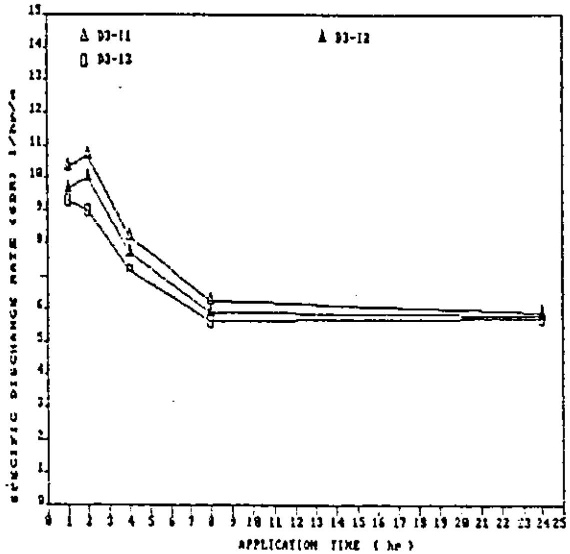


Fig.33: Measured specific discharge rate of the subsurface pipe laid at 50cm depth, at different application times and initial moisture levels.

gradient will be reduced which will cause a drop in the discharge rate values. The maximum specific discharge rate was 11 l/hr/m. This indicates the capability of this system to give high amount of irrigation water in a limited time without problems of surface run-off.

By increasing the initial moisture content a slight decrease is observed in the SDR due to reduction in the hydraulic gradient. This can be observed from figures 34,35 and 36,where they show the percentage of the SDR at each depth for each initial moisture content. For example at 0.20 m burial depth; by increasing the moisture from 10% to 20% the SDR was reduced from 11 to 8.5 l/hr/m after the first hour of irrigation.

4.6.2 The effect of the pressure head and water quality on the specific discharge rate (SDR) :

Table 5 shows a comparison made in the field between SDR for lateral before and after installation under different operating pressures. The results show that increasing the pressure head has a direct effect on the free SDR. The discharge under burial condition is related more to the head outside the pipe since no change is observed in the discharge rate by increasing the head inside the pipe (for a certain range).

These free specific discharge rate values were more than those obtained for burial pipes. This fact may be attributed to the reduction in the hydraulic gradient in the soil which

Table (5-a): Free specific discharge rate before installation in the soil.

Q: discharge = liter/hour/1.00 meter

Head (psi)	Q.1	Q.2	Q.3	Q.4	Q.5	Average
2.5	24.0	19.8	20.4	22.2	21.0	21.48
5.0	30.0	33.0	33.6	36.0	30.6	32.64
7.5	63.0	60.0	66.0	63.6	69.0	64.32
10.0	96.0	93.0	90.0	96.0	96.6	94.32
12.5	129.0	120.0	120.0	117.0	114.0	120.00

Table (5-b): Free specific discharge rate after installation in the soil.

Q: discharge = liter/hour/1.00 meter

Head (psi)	Q.1	Q.2	Q.3	Q.4	Q.5	Average
2.5	21.0	24.6	20.4	18.0	24.0	21.60
5.0	36.0	39.0	33.6	30.0	31.8	34.08
7.5	54.6	60.0	57.0	54.0	63.0	57.72
10.0	75.0	81.0	72.0	66.0	78.0	74.40
12.5	90.0	90.6	93.0	87.0	88.8	89.88

is created few minutes after irrigation due to the formation of a saturated soil layer around the subsurface pipe especially in silty clay loam soils.

In order to compare the effect of using the pipe after a while on the free specific discharge rate, which would reflect the effect of the inside clogging problem, no differences was observed at a pressure head less than 5psi, and a slight drop in the free discharge rate was observed at higher pressure heads, this result agrees with the manufacturer recommendations.

4.7 Neutron Probe Scattering technique performance in detecting the wetting front :

Water detection under subsurface irrigation by using the Gravimetric method was very tedious and not practical for the following reasons:

1- Large numbers of soil samples are required to get accurate results. This cannot be done when close irrigation intervals is used since sampling needs more than one hour.

2- Taking soil samples at close distances to the pipe line was not possible by the augers since it might damage the pipe and may cause undesired leaking.

3- Taking samples from more than one point (replicate) for measuring the water distribution efficiency is not possible because by the time needed to take soil samples from the first replicate redistribution of the water will occur at the other replicates.

Therefore the neutron probe scattering method was tested and compared with the gravimetric method. It was used after developing a calibration curve at the site consisting of 25 points for each depth (Figures 5 and 6). Three replicates of access tubes were installed around the subsurface line (Figure 8). The soil water content were taken every 0.20 m interval depth by a 16 seconds count readings at each point.

The difference in the volumetric moisture content at each point was used as a guide for detecting the wetting front using the same procedure and assumptions for the gravimetric method (Figures 37 to 45). These figures were used to derive a simple power function equations to predict the water advance in the soil in the three directions as a function of time (Table 6).

The results of the N.P. were less accurate for all the treatments (comparing Table 3 with Table 6). This may be due to the fact that the access tubes cannot be installed at a distance less than 0.25 m interval, since the range of the detected area is 0.30m in diameter. It is not accurate to detect water movements after 1 and 2 hours from irrigation where the water advance is less than 0.25m.

In addition the results gave only the amount of changes in the moisture within relatively large area which approximated the changes in each depth interval (0.20m) with a circle of 0.3m diameter. Thus this method cannot produce

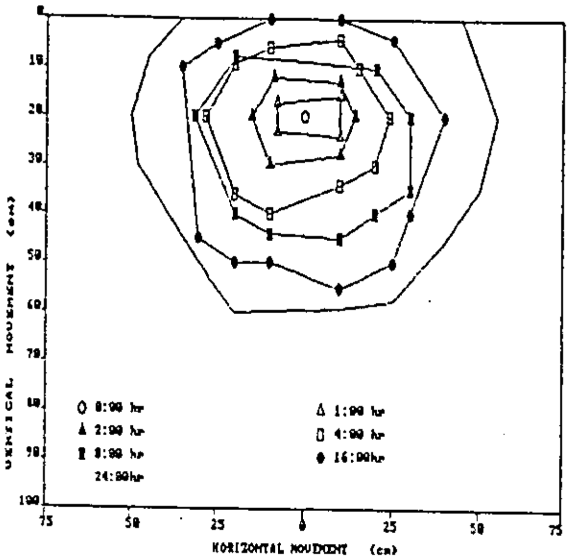


Fig.37: Neutron Probe results for the location of the wetting front for the 20cm burial with initial Pv. of 5-10% .

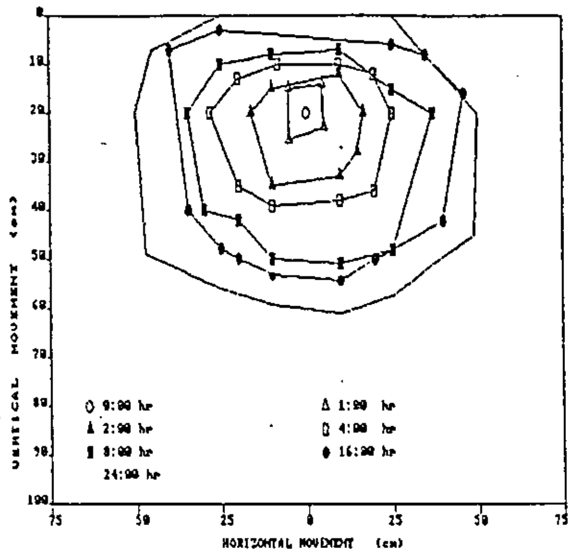


Fig.38: Neutron Probe results for the location of the wetting front for the 20cm burial with initial Pv. of 10-15% .

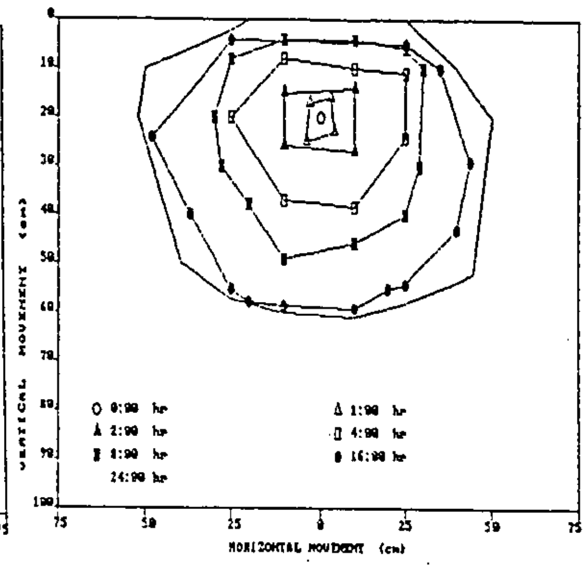


Fig.39: Neutron Probe results for the location of the wetting front for the 20cm burial with initial Pv. of 15-20% .

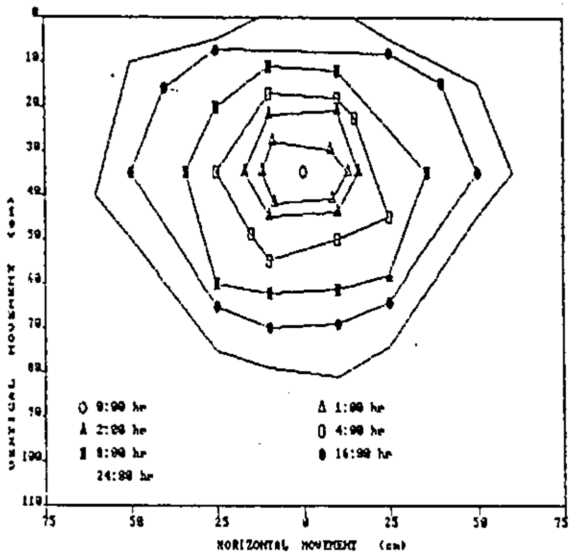


Fig.40: Neutron Probe results for the location of the wetting front for the 35cm burial with initial Pv. of 5-10% .

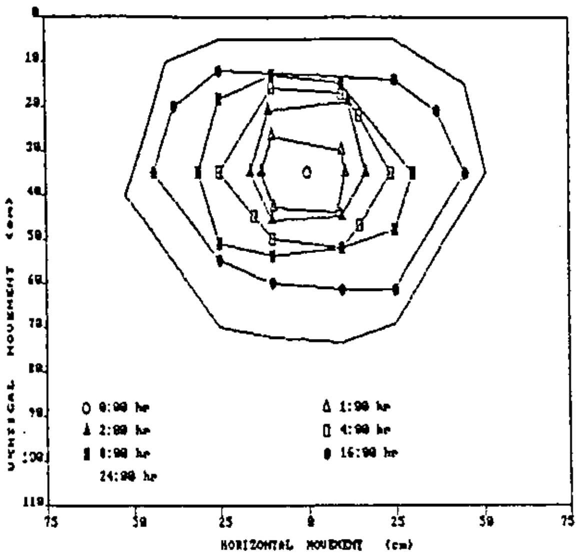


Fig.41: Neutron Probe results for the location of the wetting front for the 35cm burial with initial Pv. of 10-15% .

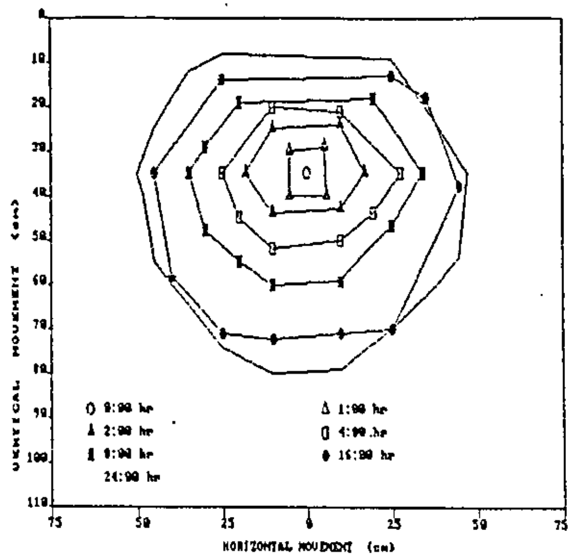


Fig.42: Neutron Probe results for the location of the wetting front for the 35cm burial with initial Pv. of 15-20% .

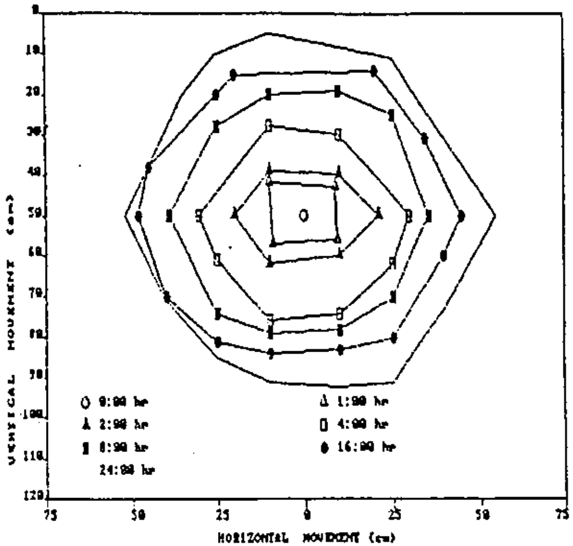


Fig.43: Neutron Probe results for the location of the wetting front for the 50cm burial with initial Pv. of 5-10% .

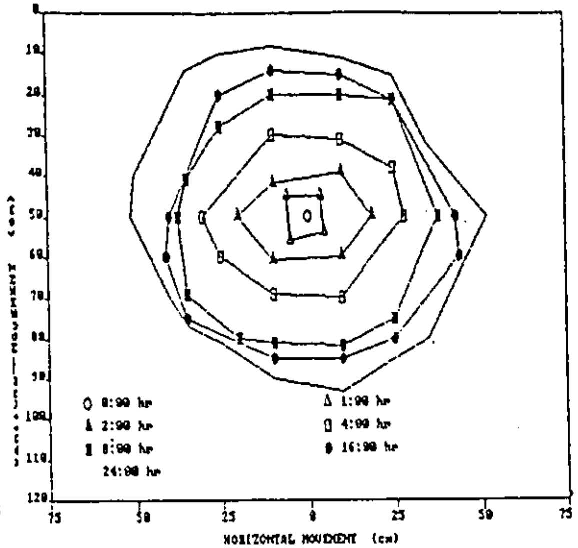


Fig.44: Neutron Probe results for the location of the wetting front for the 50cm burial with initial Pv. of 10-15% .

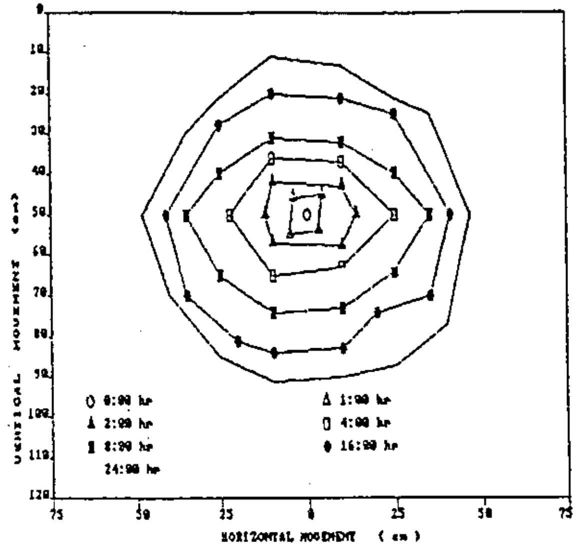


Fig.45: Neutron Probe results. for the location of the wetting front for the 50cm burial depth with initial Pv. of 15-20%.

Table .6 : The empirical soil-water movement equations in the x,y, and z directions derived from soil sampling data using the Neutron probe method.

Burial depth	Initial moisture	The empirical simple power equations	r^2
20cm	I-1	$x = 9.25\ t^{0.54}$	0.86
		$y = 5.19\ t^{0.51}$	0.88
		$z = 6.40\ t^{0.61}$	0.89
20cm	I-2	$x = 6.89\ t^{0.70}$	0.84
		$y = 5.16\ t^{0.38}$	0.89
		$z = 8.78\ t^{0.57}$	0.92
20cm	I-3	$x = 6.97\ t^{0.68}$	0.90
		$y = 4.41\ t^{0.37}$	0.85
		$z = 5.06\ t^{0.70}$	0.89
35cm	I-1	$x = 9.34\ t^{0.51}$	0.81
		$y = 5.71\ t^{0.56}$	0.86
		$z = 6.18\ t^{0.65}$	0.89
35cm	I-2	$x = 11.35\ t^{0.46}$	0.90
		$y = 5.83\ t^{0.48}$	0.93
		$z = 5.02\ t^{0.56}$	0.84
35cm	I-3	$x = 7.51\ t^{0.63}$	0.88
		$y = 4.16\ t^{0.58}$	0.89
		$z = 5.21\ t^{0.70}$	0.89

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Table .6 : continued

50cm	I-1	$x = 11.51\ t^{0.48}$	0.86
		$y = 6.35\ t^{0.61}$	0.89
		$z = 7.92\ t^{0.56}$	0.85
50cm	I-2	$x = 7.18\ t^{0.68}$	0.84
		$y = 5.13\ t^{0.64}$	0.84
		$z = 6.47\ t^{0.64}$	0.83
50cm	I-3	$x = 6.15\ t^{0.71}$	0.88
		$y = 6.17\ t^{0.54}$	0.94
		$z = 6.37\ t^{0.61}$	0.89

x = horizontal movement (cm).
y = upward movement (cm).
z = downward movement (cm).
t = time (hour).

accurate results to predict the water movement after small time interval. On the other hand the results obtained at 4,8,16 and 24 hours of application were more acceptable when compared with the results of the gravimetric method.

No specific relation was found between the results of the gravimetric method and the neutron probe scattering Technique.

CHAPTER V

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

The performance of subsurface irrigation method was studied at Al-Muwaqqar area of Jordan. This area is characterized as an arid region suffering from desertification. This system is seen to overcome problems related to water deficiency, evaporation losses and soil infiltration. The major objective of this study was to evaluate the performance of the subsurface irrigation method under the condition of arid land soils, and to develop the relationships that govern the water movement in the horizontal and vertical directions. These would be important for the design of subsurface systems in the arid regions for similar conditions.

Three subsurface burial depths of porous subsurface pipes were tested at depths of 0.20, 0.35, and 0.50 m and the resulting wetting front development were detected using thee initial moisture contents (Pv. = 5-10% ,10-15%, and 15-20%), after 1,2,4,8,16,and 24 hours from the application time.

The gravimetric method of moisture determination was used to detect the wetting front advance, neutron probe scattering technique was also used in parallel with the gravimetric method to detect moisture wetting front and to investigate its applicability in such circumstances.

Simple power equations were developed that describe wetting front advance in the horizontal and vertical directions. The results of the study showed that the subsurface irrigation method can overcome many of water application problems in arid soils especially problem associated with very low infiltration and high evaporation rates.

The following conclusions and recommendations could be reported:

1. Using 0.20m burial depth indicated the capability of this system to overcome the surface crust formation, where the water had reached the surface along the whole line.

2. Using 0.50m burial depth was associated with some disadvantages such as difficult installation procedure and the inability to solve the problem of surface crust formation.

3. Increasing the application time caused a large reduction in the discharge rate, which is attributed to the reduction in the hydraulic gradient due to the increase in the moisture content.

4. No difference in the horizontal water advance was noticed among the different treatments while a slight difference in the downward movement was observed, both were at a range of 0.45-0.55m. Therefore it is recommended that such spacing be considered as the maximum spacing for the conditions of arid regions.

5. The results of the neutron probe were less accurate than the gravimetric method, and were insufficient to predict the water advances after short time of application. They were only capable of estimating the water content and shape after 8,16 and 24 hours of water application.

Since no problems were observed in the water application to the root zone in this method, and even with a high application rate and efficiency, this confirms the capability of such system to overcome all the problems facing the other irrigation methods, and therefore is recommended under the arid regions. The only problems that was noticed in the field was due installation and this could be solved if careful installation is done by avoiding stones to be near the line during the burying, using good quality or thick perforated pipe lines with the end being curved up for flushing procedures, and using filtered water.

For further studies, or similar in other regions, other water detection methods is recommended if available, and if not the gravimetric method is recommended over the neutron probe method by taking as many samples as possible to get an accurate shape of the wetting patterns. In addition since this is the first type of research in this region, a field comparison with other irrigation systems is recommended to study the water uniformity, water application efficiency, water use efficiency and other economical factors that needs to be done with more specific researches.

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APPEDICES

Table (7.a):Moisture content,on volume basis at different horizontal and vertical distance from the subsurface line.
initial moisture content no.1 = 5 -10 % Pv.
burial depth no. 1 = 20 cm.

Time (hr)	Depth (cm)	Horizontal distance from the right (cm). 10	20	30	40	50	60
1:00	0-20	9.56	6.39	3.78			
	20-40	15.20	8.55	7.03			
	40-60	7.23	6.85	5.22			
2:00	0-20	10.24	10.13	2.89			
	20-40	16.33	11.01	6.22			
	40-60	8.32	7.65	4.35			
4:00	0-20	12.25	9.11	8.65	5.36		
	20-40	21.71	19.35	9.33	7.41		
	40-60	4.89	3.65	6.50	6.88		
8:00	0-20	30.11	22.12	17.13	3.69		
	20-40	32.72	24.58	15.44	6.84		
	40-60	13.30	8.40	5.80	7.80		
	60-80	6.67	5.36	8.40	4.11		
24:00	0-20	30.25	25.25	22.11	13.50	10.12	7.10
	20-40	34.95	31.66	39.65	15.36	13.10	6.85
	40-60	27.55	25.67	24.00	8.65	8.96	5.44
	60-80	8.50	7.19	8.01	5.65	6.35	4.58

Table(7.b): Moisture content on volume basis at different horizontal and vertical distance from the subsurface line.
initial moisture content no.1 = 5 -10% Pv.
burial depth no. 1 = 20 cm.

Time (hr)	Depth (cm)	Horizontal distance from the left (cm). 10	20	30	40	50	60
1:00	0-20	10.42	6.97	4.12			
	20-40	16.57	9.32	7.66			
	40-60	7.88	7.47	5.69			
2:00	0-20	9.98	9.88	2.82			
	20-40	15.92	10.73	6.06			
	40-60	8.11	7.46	4.24			
4:00	0-20	15.31	11.39	10.81	6.70		
	20-40	27.14	24.19	11.66	9.26		
	40-60	6.11	4.56	8.13	8.60		
8:00	0-20	21.21	26.32	20.38	4.39		
	20-40	38.94	29.25	18.37	8.14		
	40-60	15.83	10.00	6.90	9.28		
	60-80	7.94	6.38	10.00	4.89		
24:00	0-20	29.66	24.66	21.52	12.91	9.53	6.51
	20-40	34.36	31.07	39.06	14.77	12.51	6.26
	40-60	26.96	25.08	23.41	8.06	8.37	4.85
	60-80	7.91	6.60	7.42	5.06	5.76	3.99

Table(8.a): Moisture content on volume basis at different horizontal and vertical distance from the subsurface line.
initial moisture content no.2= 10-15% Pv.
burial depth no. 1 = 20 cm.

Time (hr)	Depth (cm)	Horizontal distance from the right (cm) 10	20	30	40	50	60
1:00	0-20	15.29	11.96	9.22			
	20-40	21.21	14.23	12.63			
	40-60	12.84	12.44	10.73			
2:00	0-20	16.00	15.89	8.28			
	20-40	22.40	16.81	11.78			
	40-60	13.99	13.28	9.82			
4:00	0-20	18.11	14.82	14.33	10.88		
	20-40	28.05	25.57	15.05	13.03		
	40-60	10.38	9.08	12.08	12.47		
8:00	0-20	36.87	28.48	23.24	9.12		
	20-40	39.61	31.06	21.46	12.43		
	40-60	19.22	14.07	11.34	13.44		
	60-80	12.25	10.88	14.07	9.57		
24:00	0-20	37.01	31.76	28.47	19.43	15.88	12.71
	20-40	41.95	38.49	35.89	21.38	19.01	12.44
	40-60	34.18	32.20	30.45	14.33	14.66	10.96
	60-80	14.18	12.80	13.66	11.18	11.92	10.06

Table(8.b): Moisture content on volume basis at different horizontal and vertical distance from the subsurface line.
initial moisture content no.2 = 10-15% Pv.
burial depth no. 1 = 20 cm.

Time (hr)	Depth (cm)	Horizontal distance from the left (cm) 10	20	30	40	50	60
1:00	0-20	16.19	12.56	9.58			
	20-40	22.65	15.04	13.30			
	40-60	13.52	13.09	11.22			
2:00	0-20	15.73	15.62	8.21			
	20-40	21.97	16.52	11.62			
	40-60	13.77	13.08	9.70			
4:00	0-20	21.33	17.21	16.60	12.29		
	20-40	33.74	30.65	17.50	14.78		
	40-60	11.67	10.04	13.78	14.28		
8:00	0-20	27.52	32.87	26.65	9.86		
	20-40	36.13	35.96	24.54	13.80		
	40-60	21.87	15.75	12.50	15.00		
	60-80	13.58	11.95	15.75	10.39		
24:00	0-20	36.39	31.14	27.85	18.81	15.26	12.07
	20-40	41.33	37.87	46.26	20.76	18.39	11.82
	40-60	33.56	31.58	29.83	13.71	14.04	10.34
	60-80	13.56	12.18	13.04	10.56	11.30	9.44

Table(9.b): Moisture content on volume basis at different horizontal and vertical distance from the subsurface line.
initial moisture content no.3 = 15-20% Pv.
burial depth no. 1 = 20 cm.

Time (hr)	Depth (cm)	Horizontal distance from the right (cm). 10	20	30	40	50	60
1:00	0-20	23.86	19.58	16.06			
	20-40	31.48	22.50	20.44			
	40-60	20.71	20.20	18.00			
2:00	0-20	23.32	23.19	14.44			
	20-40	30.68	24.25	18.46			
	40-60	21.00	20.19	16.21			
4:00	0-20	29.92	25.06	24.35	19.25		
	20-40	34.55	40.92	25.40	22.43		
	40-60	18.52	16.60	21.02	21.61		
8:00	0-20	21.22	25.32	16.52	16.39		
	20-40	38.32	37.25	33.72	21.04		
	40-60	30.56	23.34	19.50	22.45		
	60-80	20.78	18.85	23.34	17.01		
24:00	0-20	31.12	33.22	26.15	18.19	20.10	19.02
	20-40	35.68	39.24	34.22	29.25	26.45	18.71
	40-60	40.11	42.02	39.96	20.94	21.32	16.96
	60-80	20.75	19.13	20.14	17.22	18.09	15.89

Table(10.a): Moisture content on volume basis at different horizontal and vertical movement from the subsurface line.
initial moisture content no.1 = 5-10% Pv.
burial depth no.2 = 35 cm

Time (hr)	Depth (cm)	Horizontal distance from the right (cm). 10	20	30	40	50	60
1:00	0-20	4.32	6.39	4.65			
	20-40	17.56	9.86	6.68			
	40-60	12.30	6.85	7.35			
	60-80	5.32	6.15	3.33			
2:00	0-20	8.53	8.39	7.50			
	20-40	22.11	14.56	5.40			
	40-60	20.31	8.56	2.11			
	60-80	6.50	5.40	8.35			
4:00	0-20	16.38	7.35	4.32	8.08		
	20-40	30.68	18.52	8.88	3.68		
	40-60	22.36	3.86	3.05	5.02		
	60-80	5.36	1.98	2.68	6.73		
8:00	0-20	15.23	10.82	1.23	4.36	5.12	
	20-40	36.85	31.58	13.68	8.11	3.15	
	40-60	26.33	9.11	8.70	9.36	5.41	
	60-80	9.85	6.81	3.56	5.89	3.68	
	80-100	3.69	5.74	4.44	8.60	1.03	
24:00	0-20	25.68	13.98	8.66	6.15	8.65	7.10
	20-40	31.35	30.95	39.65	-28.11	17.17	6.85
	40-60	28.53	25.88	24.00	9.11	10.15	5.44
	60-80	27.12	19.45	8.01	3.25	5.66	3.09
	80-100	5.61	6.88	5.44	1.88	8.38	7.66

Table(10.b): Moisture content on volume basis at differnt horizontal and vertical distance from the subsurface line.
initial moisture content no.1 = 5 -10% Pv.
burial depth no. 2 = 35 cm

Time (hr)	Depth (cm)	Horizontal distance from the left (cm). 10	20	30	40	50	60
1:00	0-20	4.76	7.05	5.12			
	20-40	19.45	10.90	7.37			
	40-60	13.61	7.56	8.12			
	60-80	5.87	6.79	3.66			
2:00	0-20	9.43	9.27	8.29			
	20-40	24.50	16.12	5.95			
	40-60	22.50	9.46	2.30			
	60-80	7.18	5.95	9.23			
4:00	0-20	18.14	8.12	4.76	8.93		
	20-40	34.01	20.52	9.82	4.04		
	40-60	24.78	4.24	3.35	5.53		
	60-80	5.91	2.16	2.93	7.43		
8:00	0-20	16.87	11.97	1.33	4.80	5.64	
	20-40	40.86	35.01	15.14	8.96	3.46	
	40-60	29.19	10.07	9.62	10.35	5.97	
	60-80	10.89	7.52	3.91	6.50	4.04	
	80-100	4.06	6.33	4.89	9.51	1.10	
24:00	0-20	28.46	15.48	9.57	6.79	9.56	7.84
	20-40	34.76	34.31	43.97	31.16	19.02	7.56
	40-60	31.63	28.69	26.60	10.07	11.23	6.00
	60-80	30.06	21.55	8.85	3.57	6.24	3.39
	80-100	6.19	7.60	6.00	2.05	9.26	8.46

Table(11.a): Moisture content on volume basis at different horizontal and vertical distance from the subsurface line.
initial moisture content no.2 = 10-15% Pv.
burial depth no. 2 = 35 cm

Time (hr)	Depth (cm)	Horizontal distance from the right (cm). 10	20	30	40	50	60
1:00	0-20	9.79	11.96	10.13			
	20-40	23.69	15.60	12.26			
	40-60	18.17	12.44	12.97			
	60-80	10.84	11.71	8.75			
2:00	0-20	14.21	14.06	13.13			
	20-40	28.47	20.54	10.92			
	40-60	26.58	14.24	7.47			
	60-80	12.08	10.92	14.02			
4:00	0-20	14.25	12.97	9.79	13.73		
	20-40	37.46	24.70	14.57	9.11		
	40-60	28.73	9.30	8.45	10.52		
	60-80	10.88	7.33	8.06	12.32		
8:00	0-20	21.24	16.61	6.54	9.83	10.63	
	20-40	38.95	38.41	19.61	13.77	8.56	
	40-60	32.90	14.82	14.39	15.08	10.93	
	60-80	15.59	12.40	8.99	11.43	9.11	
	80-100	9.12	11.28	9.91	14.28	6.33	
24:00	0-20	32.21	19.93	14.34	11.71	14.33	12.71
	20-40	38.17	37.75	31.25	34.77	23.28	12.44
	40-60	35.21	32.42	30.45	14.82	15.91	10.96
	60-80	33.73	25.67	13.66	8.66	11.19	8.49
	80-100	11.14	12.47	10.96	7.22	14.05	13.29

Table(11.b): Moisture content on volume basis at different horizontal and vertical distance from the subsurface line.
initial moisture content no.2 = 10-15% Pv.
burial depth no.2 = 35 cm.

Time (hr)	Depth (cm)	Horizontal distance from the left (cm). 10	20	30	40	50	60
1:00	0-20	10.24	12.66	10.63			
	20-40	25.67	16.70	12.99			
	40-60	19.54	13.19	13.77			
	60-80	11.41	12.38	9.09			
2:00	0-20	15.93	15.76	14.64			
	20-40	32.96	23.49	12.01			
	40-60	30.71	15.97	7.88			
	60-80	13.38	12.01	15.71			
4:00	0-20	25.78	14.45	10.65	15.37		
	20-40	33.71	28.46	16.37	9.85		
	40-60	33.28	10.07	9.06	11.53		
	60-80	11.95	7.72	8.59	13.67		
8:00	0-20	24.33	18.80	6.77	10.70	11.65	
	20-40	31.25	24.25	22.39	15.40	9.18	
	40-60	38.26	16.66	16.14	16.97	12.02	
	60-80	17.59	13.77	9.70	12.62	9.85	
	80-100	9.86	12.43	10.80	16.02	6.52	
24:00	0-20	25.21	19.81	16.09	12.95	16.08	14.14
	20-40	39.55	35.65	34.11	36.24	26.77	13.82
	40-60	41.02	37.69	35.34	16.66	17.96	12.06
	60-80	39.25	29.63	15.28	9.31	12.33	9.11
	80-100	12.27	13.86	12.06	7.59	15.74	14.84

Table(12.a): Moisture content on volume basis at different horizontal and vertical distance from the subsurface line.
initial moisture content no. 3 = 15-20% Pv.
burial depth no. 2 = 35 cm.

Time (hr)	Depth (cm)	Horizontal distance from the right (cm). 10	20	30	40	50	60
1:00	0-20	16.30	18.87	16.71			
	20-40	32.71	23.17	19.23			
	40-60	26.19	19.44	20.06			
	60-80	17.54	18.57	15.08			
2:00	0-20	23.36	23.17	21.96			
	20-40	41.75	31.53	19.12			
	40-60	39.31	23.40	14.66			
	60-80	20.61	19.12	23.11			
4:00	0-20	23.41	21.76	17.65	22.75		
	20-40	37.52	36.89	23.83	16.79		
	40-60	32.52	17.03	15.93	18.60		
	60-80	19.06	14.49	15.43	20.92		
8:00	0-20	32.43	26.46	13.47	17.71	18.74	
	20-40	35.27	34.56	30.33	22.79	16.07	
	40-60	37.22	24.14	23.59	24.48	19.13	
	60-80	25.15	21.03	16.63	19.78	16.79	
	80-100	16.80	19.58	17.82	23.45	13.20	
24:00	0-20	36.25	30.74	23.53	20.13	23.52	21.42
	20-40	35.45	33.30	35.58	39.25	35.06	21.08
	40-60	31.02	26.25	34.25	24.14	25.55	19.17
	60-80	39.39	38.15	22.65	16.21	19.47	15.99
	80-100	19.40	21.12	19.17	14.35	23.15	22.18

Table(12.b): Moisture content on volume basis at different horizontal and vertical movement from the subsurface line.
initial moisture content no.3 = 15-20% Pv.
burial depth no. 2 = 35 cm

Time (hr)	Depth (cm)	Horizontal distance from the right (cm). 10	20	30	40	50	60
1:00	0-20	16.84	19.69	17.30			
	20-40	35.05	24.46	20.09			
	40-60	27.82	20.32	21.01			
	60-80	18.22	19.36	15.48			
2:00	0-20	23.55	23.35	22.03			
	20-40	33.65	32.48	18.92			
	40-60	30.98	23.60	14.05			
	60-80	20.55	18.72	23.27			
4:00	0-20	35.17	21.81	17.32	22.89		
	20-40	34.53	38.34	24.07	16.38		
	40-60	33.25	16.64	15.44	18.36		
	60-80	18.86	13.86	14.90	20.89		
8:00	0-20	33.47	26.94	12.75	17.38	18.51	
	20-40	41.63	33.37	31.18	22.93	15.59	
	40-60	39.25	24.41	23.81	24.78	18.94	
	60-80	25.51	21.01	16.20	19.65	16.38	
	80-100	16.39	19.42	17.50	23.66	12.45	
24:00	0-20	34.50	28.13	23.75	20.03	23.73	21.44
	20-40	41.42	36.82	35.00	37.24	36.34	21.07
	40-60	33.15	39.00	36.22	24.41	25.95	18.98
	60-80	21.06	29.71	22.78	15.74	19.31	15.50
	80-100	19.23	21.11	18.98	13.71	23.33	22.27

Table(13.a): Moisture content on volume basis at different horizontal and vertical distance from the subsurface line.
initial moisture content no.1 = 5-10% Pv.
burial depth no. 3 = 50 cm

Time (hr)	Depth (cm)	Horizontal distance from the right (cm). 10	20	30	40	50	60
1:00	0-20	6.98	6.39	2.60			
	20-40	7.28	1.25	8.50			
	40-60	13.81	6.85	3.75			
	60-80	6.45	6.15	6.85			
2:00	0-20	6.26	3.98	4.32			
	20-40	17.56	9.40	7.85			
	40-60	18.80	16.25	1.22			
	60-80	19.78	5.40	6.42			
	80-100	1.25	5.24	3.01			
4:00	0-20	3.69	7.35	5.98	3.69		
	20-40	15.24	8.36	7.66	8.50		
	40-60	22.36	28.22	9.69	6.87		
	60-80	23.21	5.42	3.69	2.01		
	80-100	7.80	6.99	7.36	3.02		
8:00	0-20	8.24	6.66	5.39	3.69	6.13	
	20-40	24.68	16.81	11.02	8.56	5.11	
	40-60	38.07	28.08	13.16	5.68	1.11	
	60-80	16.80	7.81	13.13	7.69	5.87	
	80-100	7.31	8.18	3.65	6.88	5.55	
24:00	0-20	12.65	8.55	4.65	2.11	8.63	3.11
	20-40	31.65	24.25	12.36	4.35	5.44	2.10
	40-60	33.86	30.65	29.50	12.58	10.15	1.03
	60-80	33.55	28.25	13.15	6.80	8.11	5.12
	80-100	11.12	7.85	6.11	5.69	6.53	4.99
	100-120	4.56	5.64	5.11	1.35	3.65	7.69

Table(13.b): Moisture content on volume basis at different horizontal and vertical distance from the subsurface line.
initial moisture content no.1 = 5-10% Pv.
burial depth no. 3 = 50 cm

Time (hr)	Depth (cm)	Horizontal distance from the left (cm). 10	20	30	40	50	60
1:00	0-20	6.91	6.33	2.58			
	20-40	7.20	1.25	8.41			
	40-60	13.65	6.78	3.72			
	60-80	6.38	6.09	6.78			
2:00	0-20	6.20	3.95	4.28			
	20-40	17.35	9.30	7.77			
	40-60	18.57	16.06	1.22			
	60-80	19.54	5.35	6.36			
	80-100	1.25	5.19	2.99			
4:00	0-20	3.98	8.05	6.53	3.98		
	20-40	16.80	9.17	8.39	9.32		
	40-60	24.71	31.21	10.64	7.54		
	60-80	25.65	5.90	3.98	2.12		
	80-100	8.55	7.65	8.06	3.24		
8:00	0-20	9.03	7.28	5.87	3.98	6.69	
	20-40	27.28	18.55	12.12	9.39	5.56	
	40-60	33.14	31.06	14.50	6.19	1.12	
	60-80	18.54	8.56	14.46	8.42	6.43	
	80-100	8.00	8.97	3.94	7.52	6.05	
24:00	0-20	13.93	9.38	5.05	2.23	9.47	3.34
	20-40	35.02	26.81	13.61	4.72	5.93	2.21
	40-60	37.47	33.91	32.63	13.85	11.15	1.03
	60-80	37.13	31.25	14.48	7.44	8.89	5.57
	80-100	12.23	8.60	6.67	6.20	7.14	5.43
	100-120	4.95	6.15	5.56	1.39	3.94	8.42

Table(14.a): Moisture content on volume basis at deffernt horizontal and vertical distance from the subsurface line. initial moisture content no. 2 = 10-15% Pv. burial depth no. 3 = 50 cm.

Time (hr)	Depth (cm)	Horizontal distance from the right (cm). 10	20	30	40	50	60
1:00	0-20	12.58	11.96	7.98			
	20-40	12.89	6.56	14.18			
	40-60	19.75	12.44	9.19			
	60-80	12.02	11.71	12.44			
2:00	0-20	11.82	9.43	9.79			
	20-40	23.69	15.12	13.49			
	40-60	24.99	22.31	6.53			
	60-80	26.02	10.92	11.99			
	80-100	6.56	10.75	8.41			
4:00	0-20	9.12	12.97	11.53	9.12		
	20-40	21.25	14.03	13.29	14.18		
	40-60	28.73	34.88	15.42	12.48		
	60-80	29.62	10.94	9.12	7.36		
	80-100	13.44	12.59	12.98	8.42		
8:00	0-20	13.90	12.24	10.91	9.12	11.69	
	20-40	31.16	22.90	16.82	14.24	10.62	
	40-60	35.23	34.73	19.07	11.21	6.42	
	60-80	22.89	13.45	19.04	13.32	11.43	
	80-100	12.93	13.84	9.08	12.47	11.08	
24:00	0-20	18.53	14.23	10.13	7.47	14.31	8.52
	20-40	38.48	30.71	18.23	9.82	10.96	7.45
	40-60	40.80	37.43	36.23	18.46	15.91	6.33
	60-80	40.48	34.91	19.06	12.39	13.77	10.63
	80-100	16.93	13.49	11.67	11.22	12.11	10.49
	100-120	10.04	11.17	10.62	6.67	9.08	13.32

Table(15.a): Moisture content on volume-basis at different horizontal and vertical distance from the subsurface line.
initial moisture content no. 3 = 15-20% Pv.
burial depth no. 3 = 50 cm.

Time (hr)	Depth (cm)	Horizontal distance from the right (cm).					
		10	20	30	40	50	60
1:00	0-20	19.60	18.87	14.17			
	20-40	19.97	12.50	21.48			
	40-60	28.06	19.44	15.60			
	60-80	18.94	18.57	19.44			
2:00	0-20	20.28	17.19	17.65			
	20-40	21.21	22.00	18.25			
	40-60	37.27	33.81	13.46			
	60-80	28.15	19.12	20.50			
	80-100	13.50	18.90	15.88			
4:00	0-20	16.80	21.76	19.90	16.80		
	20-40	27.13	23.13	22.18	23.32		
	40-60	42.09	30.03	24.93	21.14		
	60-80	23.24	19.14	16.80	14.53		
	80-100	12.36	14.35	17.15	15.89		
8:00	0-20	22.96	20.82	19.10	16.80	20.11	
	20-40	35.23	34.57	26.73	23.40	18.72	
	40-60	40.47	39.83	29.63	19.50	13.31	
	60-80	34.56	22.38	29.59	22.22	19.78	
	80-100	21.70	22.88	16.75	21.12	19.32	
24:00	0-20	28.94	23.38	18.10	14.66	23.49	16.02
	20-40	44.67	34.65	28.55	17.70	19.17	14.64
	40-60	38.66	38.31	51.76	28.84	25.55	13.19
	60-80	37.24	30.07	29.62	21.01	22.79	18.74
	80-100	26.87	22.44	20.08	19.51	20.65	18.56
	100-120	13.98	15.11	14.56	10.61	13.02	17.26

Table(15.b): Moisture content on volume basis at different horizontal and vertical distance from the subsurface line.
initial moisture content no. 3 = 15-20% Pv.
burial depth no.3 = 50 cm.

Time (hr)	Depth (cm)	Horizontal distance from the right (cm). 10	20	30	40	50	60
1:00	0-20	19.51	18.79	14.15			
	20-40	19.88	12.50	21.37			
	40-60	27.86	19.35	15.56			
	60-80	18.86	18.49	19.35			
2:00	0-20	19.25	16.25	16.69			
	20-40	20.12	18.15	21.34			
	40-60	35.75	32.39	12.61			
	60-80	21.25	18.11	19.46			
	80-100	12.65	17.90	14.97			
4:00	0-20	16.29	21.71	19.68	16.29		
	20-40	23.39	23.21	22.17	23.41		
	40-60	39.87	32.60	25.17	21.03		
	60-80	31.10	18.85	16.29	13.81		
	80-100	18.98	17.96	18.43	12.98		
8:00	0-20	18.11	20.69	18.81	16.29	19.91	
	20-40	23.85	35.71	27.14	23.50	18.40	
	40-60	41.63	32.40	30.31	19.24	12.48	
	60-80	35.70	22.39	30.27	22.21	19.55	
	80-100	18.36	19.45	13.77	17.82	16.15	
24:00	0-20	29.56	23.49	17.72	13.96	23.61	15.44
	20-40	38.89	39.61	29.13	17.27	18.88	13.93
	40-60	34.26	37.63	54.50	29.45	25.86	12.35
	60-80	31.27	34.16	30.30	20.90	22.84	18.41
	80-100	27.29	22.45	19.88	19.25	20.50	18.22
	100-120	13.89	15.25	14.58	9.86	12.75	17.82

Table(15.b): Moisture content on volume basis at different horizontal and vertical distance from the subsurface line.
initial moisture content no. 3 = 15-20% Pv.
burial depth no.3 = 50 cm.

Time (hr)	Depth (cm)	Horizontal distance from the right (cm). 10	20	30	40	50	60
1:00	0-20	19.51	18.79	14.15			
	20-40	19.88	12.50	21.37			
	40-60	27.86	19.35	15.56			
	60-80	18.86	18.49	19.35			
2:00	0-20	19.25	16.25	16.69			
	20-40	20.12	18.15	21.34			
	40-60	35.75	32.39	12.61			
	60-80	21.25	18.11	19.46			
	80-100	12.65	17.90	14.97			
4:00	0-20	16.29	21.71	19.68	16.29		
	20-40	23.39	23.21	22.17	23.41		
	40-60	39.87	32.60	25.17	21.03		
	60-80	31.10	18.85	16.29	13.81		
	80-100	18.98	17.96	18.43	12.98		
8:00	0-20	18.11	20.69	18.81	16.29	19.91	
	20-40	23.85	35.71	27.14	23.50	18.40	
	40-60	41.63	32.40	30.31	19.24	12.48	
	60-80	35.70	22.39	30.27	22.21	19.55	
	80-100	18.36	19.45	13.77	17.82	16.15	
24:00	0-20	29.56	23.49	17.72	13.96	23.61	15.44
	20-40	38.89	39.61	29.13	17.27	18.88	13.93
	40-60	34.26	37.63	54.50	29.45	25.86	12.35
	60-80	31.27	34.16	30.30	20.90	22.84	18.41
	80-100	27.29	22.45	19.88	19.25	20.50	18.22
	100-120	13.89	15.25	14.58	9.86	12.75	17.82

Table (16):Moisture content on volume basis obtained by the Neutron Probe method at different horizontal and vertical distances at 20cm burial depth . Initial moisture content = 5-10% Pv.

0:00 hr Application time		d1 0-20	d2 20-40	d3 40-60	d4 60-80	d5 80-100
REP.1	L1	6.98	16.32	17.17	12.55	13.00
	L2	4.31	3.85	7.04	7.87	5.58
	L3	7.32	7.41	12.71	12.81	10.25
	R1	6.65	13.38	16.11	15.28	23.83
	R2	4.13	6.20	7.17	8.13	12.38
	R3	3.82	8.48	10.71	10.51	14.90
REP.2	L1	4.57	7.78	10.87	13.05	12.58
	L2	8.65	9.33	9.95	7.47	5.39
	L3	9.01	10.15	12.34	15.01	21.05
	R1	6.46	15.12	14.36	13.86	11.02
	R2	8.82	8.18	9.68	7.13	5.15
	R3	5.87	12.32	13.79	12.51	14.18
REP.3	L1	9.00	15.53	13.46	12.21	15.02
	L2	9.57	8.28	8.65	8.03	4.46
	L3	9.12	7.25	11.69	8.66	5.88
	R1	10.53	19.13	17.64	14.07	15.53
	R2	9.86	8.71	9.63	9.54	9.90
	R3	5.82	6.53	9.63	9.46	8.09

1:00 hr Application time		d1 0-20	d2 20-40	d3 40-60	d4 60-80	d5 80-100
REP.1	L1	10.90	15.75	16.94	12.42	14.73
	L2	5.18	5.95	7.34	7.75	5.94
	L3	9.84	8.13	12.09	13.85	11.47
	R1	9.99	13.46	16.21	15.54	24.47
	R2	7.08	6.21	7.81	8.92	10.83
	R3	5.76	7.37	10.22	10.19	15.17
REP.2	L1	6.73	14.68	11.07	13.63	13.40
	L2	8.47	10.64	10.91	8.16	7.41
	L3	7.67	8.38	11.73	13.17	18.01
	R1	14.28	16.55	14.09	12.54	10.07
	R2	10.62	8.31	9.52	6.73	5.37
	R3	7.94	11.65	11.35	11.31	14.84
REP.3	L1	12.61	15.43	13.47	11.84	15.07
	L2	9.20	7.81	9.10	7.97	6.18
	L3	6.77	6.72	10.16	8.26	4.72
	R1	10.79	18.33	17.65	13.11	15.93
	R2	9.60	8.35	9.80	9.24	10.06
	R3	5.16	6.46	8.72	8.94	9.86

Table (16) : Continued.

2:00 hr Application time		d1 0-20	d2 20-40	d3 40-60	d4 60-80	d5 80-100
REP.1	L1	11.47	16.45	15.44	12.50	13.83
	L2	5.74	5.49	7.05	7.32	5.48
	L3	9.51	7.59	13.31	13.07	9.64
	R1	11.96	14.10	16.48	15.73	23.90
	R2	7.35	5.72	7.97	8.92	10.57
	R3	5.04	7.49	9.84	9.40	12.17
REP.2	L1	7.36	7.86	11.20	13.03	12.79
	L2	9.24	9.48	9.97	7.08	5.37
	L3	6.97	8.73	11.38	13.39	18.09
	R1	14.93	16.74	13.86	12.57	10.72
	R2	10.53	8.20	9.30	6.83	5.90
	R3	5.64	11.27	11.04	11.11	11.79
REP.3	L1	10.74	15.98	13.55	11.44	13.90
	L2	7.81	7.49	8.64	7.61	6.16
	L3	6.20	6.43	10.09	8.12	4.97
	R1	23.40	25.20	17.95	14.53	12.94
	R2	9.71	8.92	10.89	9.18	9.92
	R3	4.79	5.68	9.10	9.23	6.77

4:00 hr Application time		d1 0-20	d2 20-40	d3 40-60	d4 60-80	d5 80-100
REP.1	L1	11.83	16.82	16.61	12.43	14.03
	L2	5.92	6.29	7.21	7.04	6.65
	L3	10.05	7.81	13.29	13.43	12.84
	R1	12.41	13.79	16.01	15.24	24.59
	R2	7.30	6.21	8.08	9.35	10.57
	R3	4.73	7.85	9.10	10.53	13.17
REP.2	L1	7.16	7.77	11.08	13.42	13.72
	L2	8.89	9.62	9.67	7.46	6.48
	L3	6.78	8.09	11.90	12.98	17.35
	R1	18.29	16.96	13.42	12.31	11.97
	R2	10.88	8.27	9.64	6.69	5.31
	R3	5.62	12.64	12.56	11.99	12.26
REP.3	L1	11.36	15.71	13.20	11.54	13.72
	L2	8.07	7.90	7.96	7.61	6.11
	L3	6.43	6.71	10.87	8.17	6.11
	R1	23.46	23.42	16.31	13.08	13.66
	R2	9.41	7.95	10.68	8.98	10.06
	R3	6.78	2.74	4.44	8.51	8.68

Table (16) : Continued.

8:00 hr Application time		d1 0-20	d2 20-40	d3 40-60	d4 60-80	d5 80-100
REP.1	L1	12.37	16.26	16.69	12.93	15.50
	L2	5.69	4.68	6.72	7.96	5.43
	L3	9.45	7.03	13.05	12.65	9.40
	R1	13.20	13.62	15.19	15.47	23.40
	R2	7.90	6.50	8.03	9.23	10.48
	R3	22.19	8.10	10.83	9.02	10.83
REP.2	L1	7.01	8.93	11.05	13.81	12.83
	L2	8.50	9.16	9.85	6.67	4.65
	L3	8.06	8.96	10.64	12.06	17.78
	R1	20.45	18.38	14.35	12.64	9.34
	R2	11.75	7.59	9.83	7.49	5.01
	R3	6.32	10.83	13.11	10.49	10.21
REP.3	L1	11.37	16.24	13.66	11.60	16.25
	L2	8.93	8.37	8.66	7.72	4.32
	L3	6.44	5.87	10.51	9.03	4.92
	R1	23.20	23.86	15.92	13.28	14.42
	R2	8.37	7.50	9.60	9.99	10.27
	R3	4.88	7.02	7.70	9.33	8.62

16:00 hr Application time		d1 0-20	d2 20-40	d3 40-60	d4 60-80	d5 80-100
REP.1	L1	14.54	21.07	14.53	9.51	12.31
	L2	5.47	4.70	7.66	6.26	4.76
	L3	8.37	7.52	13.97	13.37	8.23
	R1	14.65	13.98	15.45	14.80	22.86
	R2	6.49	5.67	8.57	9.01	9.97
	R3	3.91	7.60	8.91	9.04	12.10
REP.2	L1	7.37	10.25	10.56	13.33	14.66
	L2	8.17	8.62	8.38	7.13	4.76
	L3	7.64	8.38	11.17	13.31	18.63
	R1	20.67	18.19	13.13	10.49	10.57
	R2	10.10	7.51	8.34	4.61	4.56
	R3	5.81	10.30	11.69	10.66	10.78
REP.3	L1	14.75	16.37	13.53	10.66	13.26
	L2	7.96	7.61	8.45	11.32	4.41
	L3	5.83	4.75	9.97	7.10	5.96
	R1	22.78	21.38	28.74	12.67	24.19
	R2	9.11	8.88	10.00	8.04	10.89
	R3	4.90	10.78	9.27	7.72	7.06

Table (16) : Continued.

24:00 hr Application time		d1 0-20	d2 20-40	d3 40-60	d4 60-80	d5 80-100
REP.1	L1	14.88	18.61	17.19	12.29	13.96
	L2	5.62	4.46	7.65	7.76	5.27
	L3	9.03	8.10	13.76	14.83	9.21
	R1	14.83	14.54	15.64	15.31	23.44
	R2	6.43	6.24	8.36	9.21	10.39
	R3	4.15	7.48	9.17	9.31	12.74
REP.2	L1	7.63	10.21	11.04	13.07	15.33
	L2	8.60	9.57	9.47	7.11	5.61
	L3	7.88	8.32	11.33	13.08	17.98
	R1	21.27	20.56	13.41	11.88	11.45
	R2	12.06	8.04	9.05	4.97	5.98
	R3	16.84	15.51	11.22	4.98	11.72
REP.3	L1	15.07	19.16	13.91	10.56	13.91
	L2	8.25	7.70	8.73	11.28	4.82
	L3	6.16	6.57	10.28	7.59	5.07
	R1	22.79	24.14	29.00	12.69	13.32
	R2	9.46	9.18	10.30	8.65	11.67
	R3	4.85	10.96	9.54	7.57	7.96

Table (18) : Continued.

24:00 hr Application time		d1 0-20	d2 20-40	d3 40-60	d4 60-80	d5 80-100
REP.1	L1	38.85	36.26	25.78	19.37	19.20
	L2	16.10	14.53	17.45	15.02	11.49
	L3	16.68	15.11	18.35	18.04	18.34
	R1	26.16	23.88	22.59	20.02	27.46
	R2	16.01	13.61	15.23	15.35	18.69
	R3	11.34	14.55	16.97	16.24	18.70
REP.2	L1	17.56	19.69	20.34	20.31	20.49
	L2	16.04	16.65	17.45	14.70	12.63
	L3	15.60	16.24	18.70	19.07	21.59
	R1	29.63	25.28	22.03	18.65	17.94
	R2	21.86	16.69	15.48	15.01	11.95
	R3	15.19	20.00	20.03	16.97	16.94
REP.3	L1	28.90	28.33	22.38	18.64	21.02
	L2	17.08	15.92	16.35	15.25	11.76
	L3	29.02	13.25	17.12	14.64	13.45
	R1	30.21	31.23	26.69	19.26	18.69
	R2	21.80	18.81	17.53	16.93	16.19
	R3	13.48	14.77	18.17	16.19	15.84

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Table(19) : Moisture content on volume basis obtained by the Neutron Probe method, at different horizontal and vertical distances, at 35cm burial depth. Initial moisture content = 5-10% Pv.

0:00 hr Application time		d1 0-20	d2 20-40	d3 40-60	d4 60-80	d5 80-100
REP.1	L1	4.20	5.84	6.48	6.33	4.13
	L2	6.55	6.70	7.33	6.11	4.40
	L3	5.57	7.43	7.95	7.53	10.48
	R1	7.05	6.61	8.75	6.45	3.33
	R2	10.93	9.34	8.26	5.75	2.62
	R3	11.67	11.90	8.89	7.79	6.18
REP.2	L1	8.19	7.52	7.52	6.80	9.67
	L2	7.27	6.58	7.58	7.31	7.42
	L3	6.81	7.26	8.14	9.01	10.62
	R1	7.47	5.92	5.57	2.68	2.37
	R2	7.45	7.28	7.58	5.60	2.96
	R3	14.75	15.55	10.00	4.17	1.99
REP.3	L1	11.96	9.07	8.08	6.34	3.34
	L2	9.69	7.19	8.55	6.50	3.91
	L3	9.48	7.49	5.44	2.87	5.02
	R1	11.16	10.14	8.64	5.30	3.63
	R2	9.90	6.90	7.72	5.46	3.21
	R3	9.80	6.80	7.75	5.35	4.56

1:00 hr Application time		d1 0-20	d2 20-40	d3 40-60	d4 60-80	d5 80-100
REP.1	L1	5.49	6.04	6.48	5.97	4.00
	L2	7.90	6.56	7.20	6.63	3.90
	L3	7.67	7.10	7.24	7.65	8.89
	R1	8.19	8.53	6.99	5.12	1.13
	R2	13.55	10.36	10.42	7.50	2.64
	R3	12.87	13.30	9.01	7.36	7.21
REP.2	L1	9.98	7.88	7.99	6.70	12.28
	L2	8.13	7.01	7.87	7.36	7.96
	L3	10.64	10.69	11.72	12.00	17.38
	R1	9.27	5.76	6.19	2.66	3.50
	R2	8.79	7.63	7.56	5.96	2.91
	R3	15.87	15.01	10.07	4.18	0.04
REP.3	L1	12.39	10.77	9.48	7.20	6.84
	L2	10.53	7.18	8.46	5.32	3.03
	L3	10.12	7.70	6.33	2.53	0.31
	R1	13.84	10.92	8.66	4.42	2.89
	R2	10.78	7.73	9.00	6.23	4.17
	R3	11.35	7.24	8.89	6.49	5.56

Table (19) : Continued.

2:00 hr Application time		d1 0-20	d2 20-40	d3 40-60	d4 60-80	d5 80-100
REP.1	L1	6.30	6.82	7.60	6.74	4.20
	L2	9.25	7.23	7.31	6.34	5.11
	L3	9.25	8.36	8.18	7.68	9.75
	R1	8.50	8.82	6.67	4.45	0.50
	R2	12.19	9.90	7.60	5.42	3.10
	R3	14.55	12.90	10.10	8.38	7.41
REP.2	L1	8.90	8.14	7.56	6.79	7.33
	L2	8.57	7.09	8.43	7.27	6.74
	L3	8.88	7.80	7.85	9.45	10.16
	R1	8.57	7.57	6.13	2.67	3.30
	R2	9.02	7.37	9.51	6.15	2.55
	R3	16.89	15.38	9.59	4.00	2.02
REP.3	L1	12.44	9.63	8.19	8.82	5.75
	L2	10.62	7.82	8.62	5.51	3.11
	L3	10.19	7.56	5.76	2.39	3.55
	R1	16.64	12.03	8.25	4.39	3.69
	R2	10.68	8.29	8.50	6.52	1.76
	R3	11.29	8.02	8.10	6.33	5.60

4:00 hr Application time		d1 0-20	d2 20-40	d3 40-60	d4 60-80	d5 80-100
REP.1	L1	5.77	5.72	6.41	6.39	3.10
	L2	8.57	6.65	7.36	6.16	4.42
	L3	7.75	7.09	7.19	7.92	8.81
	R1	10.01	11.51	6.92	5.11	4.45
	R2	12.33	9.82	7.70	5.31	3.16
	R3	13.93	12.15	9.01	8.39	6.56
REP.2	L1	8.91	8.77	7.60	7.10	8.50
	L2	8.55	6.71	8.72	8.44	7.75
	L3	8.74	7.18	8.19	9.55	9.97
	R1	13.65	9.21	5.39	2.11	2.66
	R2	9.56	7.60	8.64	5.62	2.31
	R3	15.80	14.88	9.97	4.12	0.25
REP.3	L1	11.71	9.76	8.43	5.73	3.82
	L2	10.63	7.31	8.87	5.41	3.41
	L3	10.43	7.72	5.78	2.73	5.65
	R1	17.96	11.97	7.47	5.02	3.33
	R2	10.44	6.47	8.04	4.98	3.63
	R3	10.46	7.05	7.67	5.25	4.05

Table (19) : Continued.

8:00 hr Application time		d1 0-20	d2 20-40	d3 40-60	d4 60-80	d5 80-100
REP.1	L1	6.57	9.36	9.58	7.02	5.45
	L2	8.92	7.21	7.58	5.75	4.01
	L3	7.92	7.28	6.66	7.51	7.67
	R1	14.68	19.26	12.22	5.17	0.38
	R2	12.82	10.01	7.65	5.70	2.86
	R3	13.53	11.92	8.78	7.71	6.56
REP.2	L1	10.33	10.90	8.36	7.27	7.58
	L2	8.53	6.98	7.82	7.23	7.63
	L3	8.85	7.74	8.16	9.36	10.08
	R1	16.15	13.50	5.66	2.56	2.66
	R2	9.12	7.61	7.38	4.89	2.49
	R3	15.53	14.26	9.67	4.05	0.34
REP.3	L1	13.52	10.42	8.61	6.16	4.32
	L2	10.78	6.80	8.65	5.61	3.96
	L3	10.55	7.85	5.57	2.45	5.32
	R1	20.13	14.90	8.70	4.77	3.17
	R2	10.39	6.82	7.39	5.08	2.52
	R3	10.36	6.74	7.98	4.76	3.78

16:00 hr Application time		d1 0-20	d2 20-40	d3 40-60	d4 60-80	d5 80-100
REP.1	L1	9.19	16.79	16.94	9.21	6.15
	L2	8.60	7.18	7.36	6.57	4.30
	L3	8.22	7.20	7.45	7.65	8.68
	R1	22.47	26.06	24.81	17.41	1.06
	R2	17.67	16.61	8.74	5.47	2.53
	R3	14.48	11.88	9.30	7.86	7.65
REP.2	L1	17.61	22.11	12.28	7.34	7.81
	L2	8.82	6.92	8.67	8.09	6.88
	L3	8.92	7.70	7.99	9.02	10.23
	R1	22.69	23.47	12.26	3.08	3.25
	R2	9.54	7.86	7.51	5.57	4.88
	R3	16.49	14.34	9.47	4.05	5.56
REP.3	L1	19.55	17.72	9.48	5.69	3.98
	L2	10.87	7.49	8.28	5.66	3.34
	L3	10.72	7.91	6.11	2.74	3.25
	R1	25.35	39.44	9.28	4.60	2.53
	R2	10.44	6.86	7.41	4.95	2.97
	R3	10.47	7.28	7.96	5.07	3.15

Table (19) : Continued.

24:00 hr Application time		d1 0-20	d2 20-40	d3 40-60	d4 60-80	d5 80-100
REP.1	L1	9.84	18.10	18.04	8.79	4.51
	L2	8.63	6.61	7.40	6.30	4.32
	L3	8.31	7.37	6.91	7.56	7.92
	R1	23.93	26.56	25.32	18.32	2.19
	R2	18.83	18.81	9.42	5.63	2.71
	R3	13.98	12.52	8.61	7.52	7.76
REP.2	L1	18.69	24.00	13.15	7.39	7.51
	L2	8.86	7.49	8.06	7.68	7.72
	L3	8.84	7.73	8.67	9.35	8.83
	R1	23.39	23.68	13.58	2.80	2.15
	R2	9.66	7.96	7.67	5.20	2.86
	R3	15.94	14.61	10.32	4.08	0.15
REP.3	L1	19.55	19.27	9.78	5.93	3.03
	L2	10.74	7.10	8.04	5.40	3.32
	L3	10.73	7.48	5.71	3.19	3.24
	R1	25.90	22.46	9.38	4.82	3.28
	R2	10.74	6.95	7.89	4.84	3.61
	R3	11.28	7.10	8.79	4.93	3.78

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Table(20) : Moisture content on volume basis, obtained by the Neutron Probe method, at different horizontal and vertical distances, at 35cm burial depth. Initial moisture content = 10 - 15% Pv.

0:00 hr Application time		d1 0-20	d2 20-40	d3 40-60	d4 60-80	d5 80-100
REP.1	L1	9.75	18.63	16.70	16.44	15.40
	L2	10.18	11.54	12.94	10.12	9.48
	L3	9.35	11.37	10.64	11.51	11.92
	R1	30.11	26.28	23.73	20.23	21.03
	R2	17.29	17.86	16.95	11.15	9.12
	R3	13.50	13.04	12.62	10.77	10.31
REP.2	L1	14.96	13.49	13.64	13.17	10.66
	L2	7.75	9.56	12.78	10.02	9.50
	L3	7.48	8.95	10.96	11.91	11.82
	R1	20.92	17.27	16.90	11.09	5.10
	R2	12.53	14.33	13.13	10.05	7.12
	R3	13.63	15.31	14.83	11.50	5.96
REP.3	L1	14.78	16.22	15.07	9.51	8.28
	L2	11.75	9.92	10.85	8.25	4.91
	L3	12.28	10.71	9.49	6.74	0.77
	R1	15.23	15.68	15.21	9.88	6.26
	R2	11.62	9.93	10.72	7.88	4.62
	R3	11.38	9.31	9.97	7.47	6.17

1:00 hr Application time		d1 0-20	d2 20-40	d3 40-60	d4 60-80	d5 80-100
REP.1	L1	11.23	19.30	16.56	16.04	14.99
	L2	10.33	11.79	13.26	8.36	7.21
	L3	10.31	9.51	10.33	11.07	13.17
	R1	29.26	28.46	22.87	19.51	20.15
	R2	18.34	18.20	14.95	11.14	8.88
	R3	13.74	13.37	12.09	11.22	10.66
REP.2	L1	15.54	14.91	14.56	12.02	13.20
	L2	9.41	9.48	12.21	10.73	8.22
	L3	9.39	9.52	12.66	11.50	11.56
	R1	21.38	16.84	18.00	10.92	5.69
	R2	13.93	14.76	12.17	9.91	5.54
	R3	15.66	15.72	14.09	11.21	9.00
REP.3	L1	16.32	15.82	14.60	8.18	7.27
	L2	13.34	10.67	11.21	8.66	7.98
	L3	13.11	10.36	9.43	6.05	1.34
	R1	18.88	17.78	14.92	8.01	5.87
	R2	12.43	10.97	11.55	7.74	5.99
	R3	12.03	9.62	10.49	8.03	6.32

Table (20) : Continued.

2:00 hr Application time		d1 0-20	d2 20-40	d3 40-60	d4 60-80	d5 80-100
REP.1	L1	10.65	18.79	17.11	15.19	16.72
	L2	10.15	12.13	12.21	9.64	7.30
	L3	8.46	10.49	10.58	9.67	11.53
	R1	30.72	28.57	24.19	19.92	18.50
	R2	16.12	18.35	15.10	11.24	7.59
	R3	12.68	13.13	11.55	10.08	10.97
REP.2	L1	17.49	14.03	14.43	12.36	13.67
	L2	9.21	10.39	12.78	10.09	9.68
	L3	9.27	10.56	11.23	11.81	11.47
	R1	20.99	16.71	16.83	10.62	6.01
	R2	14.68	14.87	13.57	9.54	5.72
	R3	14.88	14.83	13.54	10.38	7.33
REP.3	L1	16.80	17.07	11.41	7.86	8.65
	L2	13.05	11.76	11.67	7.66	8.22
	L3	14.72	11.14	9.06	5.24	0.86
	R1	19.76	18.22	14.31	7.11	7.48
	R2	12.70	9.48	9.64	7.26	6.40
	R3	13.75	10.16	10.56	9.39	7.54
4:00 hr Application time		**d1 0-20**	**d2 20-40**	**d3 40-60**	**d4 60-80**	**d5 80-100**
REP.1	L1	13.88	23.05	17.88	14.80	17.79
	L2	11.51	12.46	13.35	9.90	10.55
	L3	8.33	11.05	10.48	9.81	12.31
	R1	33.16	30.48	23.65	19.10	19.76
	R2	18.09	18.87	16.28	11.12	10.60
	R3	13.02	14.08	11.25	11.17	9.29
REP.2	L1	15.78	15.61	14.86	12.54	15.47
	L2	8.03	9.88	11.47	10.68	10.04
	L3	8.35	10.26	10.99	11.75	13.50
	R1	19.65	15.78	15.80	11.51	4.85
	R2	13.55	15.04	12.74	8.68	6.61
	R3	14.12	14.87	14.43	10.74	8.46
REP.3	L1	14.55	16.09	15.02	8.12	7.78
	L2	12.97	11.42	12.78	8.51	7.69
	L3	13.17	10.44	8.77	5.42	1.99
	R1	19.64	18.37	15.13	7.89	7.15
	R2	13.59	11.05	12.01	9.05	8.43
	R3	12.09	10.23	10.74	8.99	5.36

Table (20) : Continued.

8:00 hr Application time		d1 0-20	d2 20-40	d3 40-60	d4 60-80	d5 80-100
REP.1	L1	11.91	22.54	21.38	16.14	15.38
	L2	10.74	12.35	13.49	10.91	10.76
	L3	10.68	9.75	10.93	9.60	11.77
	R1	31.47	29.21	23.89	18.86	18.12
	R2	18.03	20.96	15.91	12.10	7.98
	R3	13.12	13.21	12.22	11.22	11.95
REP.2	L1	17.67	15.50	14.66	12.13	11.56
	L2	10.72	10.94	12.76	9.91	9.86
	L3	11.03	10.22	12.17	11.35	10.76
	R1	22.54	17.51	16.03	9.76	7.72
	R2	16.98	15.20	12.95	8.44	5.78
	R3	15.63	14.64	14.40	11.66	7.86
REP.3	L1	16.45	16.67	15.14	9.35	7.36
	L2	14.12	11.38	12.15	8.10	5.99
	L3	14.92	10.40	8.36	5.25	1.94
	R1	21.31	19.07	14.85	8.40	5.57
	R2	14.50	10.44	10.14	7.74	5.99
	R3	13.07	10.47	9.85	6.25	6.22
16:00 hr Application time		**d1 0-20**	**d2 20-40**	**d3 40-60**	**d4 60-80**	**d5 80-100**
REP.1	L1	12.09	19.68	19.83	12.10	9.05
	L2	11.49	10.07	10.25	9.46	7.19
	L3	11.11	10.10	10.34	10.54	11.58
	R1	25.36	28.95	27.70	20.30	3.96
	R2	20.57	19.50	11.63	8.36	5.43
	R3	17.37	14.78	12.19	10.75	10.55
REP.2	L1	20.51	25.00	15.17	10.23	10.70
	L2	11.71	9.82	11.57	10.98	9.77
	L3	11.81	10.59	10.88	11.92	13.12
	R1	25.58	26.36	15.15	5.97	0.59
	R2	12.44	10.76	10.40	8.47	7.77
	R3	19.38	17.23	12.37	6.94	2.34
REP.3	L1	22.45	20.61	12.37	8.58	6.87
	L2	13.77	10.38	11.17	8.55	6.24
	L3	13.61	10.80	9.01	5.63	2.16
	R1	28.24	42.34	12.17	7.49	5.42
	R2	13.34	9.75	10.31	7.84	5.86
	R3	13.36	10.18	10.85	7.96	6.04

Table (20) : Continued.

24:00 hr Application time		d1 0-20	d2 20-40	d3 40-60	d4 60-80	d5 80-100
REP.1	L1	11.06	24.02	22.76	16.01	16.93
	L2	9.06	12.65	13.35	10.05	6.95
	L3	7.90	9.98	11.62	10.45	13.14
	R1	29.98	28.92	25.68	20.88	18.25
	R2	18.69	23.40	17.23	10.48	8.83
	R3	12.51	13.15	13.09	11.39	10.98
REP.2	L1	15.49	17.93	15.06	11.65	12.57
	L2	8.97	9.98	11.92	11.01	8.89
	L3	9.31	10.84	10.92	12.22	11.97
	R1	22.67	19.85	17.20	11.68	7.25
	R2	16.79	16.15	12.78	8.99	7.43
	R3	16.39	15.19	14.23	12.19	7.10
REP.3	L1	15.34	17.20	15.05	8.64	7.64
	L2	13.17	11.39	12.22	7.79	5.63
	L3	14.06	10.57	8.66	6.17	1.03
	R1	23.01	20.82	14.56	8.83	6.29
	R2	12.85	10.48	11.22	8.29	7.10
	R3	12.55	9.66	11.46	7.68	7.22

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Table(21): Moisture content on volume basis, obtained by the Neutron Probe method, at different horizontal and vertical distances, at 35cm burial depth.
Initial moisture content = 15-20% Pv.

0:00 hr Application time		d1 0-20	d2 20-40	d3 40-60	d4 60-80	d5 80-100
REP.1	L1	14.99	27.82	26.73	19.94	20.85
	L2	12.85	16.60	17.36	14.05	10.94
	L3	11.77	13.99	15.50	14.02	17.16
	R1	33.91	32.76	28.15	24.79	21.98
	R2	22.65	27.35	21.18	14.44	12.70
	R3	16.30	17.12	17.04	15.35	14.91
REP.2	L1	19.46	21.88	19.01	15.63	16.47
	L2	12.95	13.91	13.38	15.00	12.81
	L3	13.31	14.85	14.88	16.18	15.89
	R1	26.61	23.64	20.94	15.41	11.16
	R2	20.75	20.16	16.50	12.99	11.30
	R3	20.15	19.30	18.82	15.48	9.94
REP.3	L1	19.21	21.18	18.98	12.30	11.61
	L2	17.12	15.35	16.20	11.65	9.68
	L3	18.04	14.56	12.61	10.17	5.14
	R1	26.97	24.75	18.55	12.78	10.25
	R2	16.83	14.44	14.94	12.29	10.97
	R3	16.56	13.63	15.42	11.66	11.17

1:00 hr Application time		d1 0-20	d2 20-40	d3 40-60	d4 60-80	d5 80-100
REP.1	L1	17.02	28.43	27.01	20.20	20.87
	L2	13.83	15.93	16.68	13.05	10.46
	L3	12.03	14.41	15.64	13.99	16.18
	R1	34.13	33.13	28.50	24.52	22.77
	R2	22.87	27.58	21.51	14.74	12.91
	R3	16.13	17.12	17.07	15.64	15.09
REP.2	L1	19.69	22.10	19.11	15.40	16.43
	L2	12.85	14.03	13.69	14.65	12.85
	L3	13.12	14.86	14.88	16.20	15.94
	R1	27.25	23.95	20.96	15.64	11.59
	R2	20.95	20.38	16.74	12.70	11.90
	R3	20.30	19.28	17.70	16.32	10.95
REP.3	L1	17.39	21.24	17.11	12.52	11.61
	L2	18.20	15.32	16.42	11.70	10.95
	L3	18.06	14.41	12.02	10.47	9.27
	R1	28.75	24.81	19.92	12.46	10.26
	R2	16.78	14.59	15.17	11.36	10.96
	R3	16.97	13.61	15.14	12.00	11.11

Table (21) : Continued.

2:00 hr Application time		d1 0-20	d2 20-40	d3 40-60	d4 60-80	d5 80-100
REP.1	L1	18.68	29.02	27.81	20.45	21.07
	L2	14.94	15.71	15.92	12.95	10.42
	L3	14.39	14.40	13.63	14.26	14.46
	R1	34.07	31.47	30.67	24.47	22.98
	R2	23.24	27.11	20.77	14.44	12.16
	R3	17.11	18.36	15.93	14.35	13.18
REP.2	L1	21.36	20.99	18.80	16.12	18.65
	L2	13.55	14.60	16.74	13.73	13.77
	L3	14.22	13.65	16.94	16.04	16.55
	R1	27.60	23.48	20.13	15.66	10.19
	R2	19.85	20.31	17.25	13.69	9.23
	R3	19.60	18.89	17.13	14.79	13.21
REP.3	L1	20.17	20.98	18.86	11.62	9.85
	L2	17.70	15.43	16.12	12.32	11.59
	L3	18.29	14.60	13.90	9.37	5.19
	R1	25.32	25.02	20.29	13.48	10.37
	R2	16.63	15.77	14.75	11.29	9.80
	R3	16.26	14.83	14.85	11.46	10.01

4:00 hr Application time		d1 0-20	d2 20-40	d3 40-60	d4 60-80	d5 80-100
REP.1	L1	17.93	28.58	26.99	19.07	20.11
	L2	14.71	16.61	16.08	14.00	12.49
	L3	14.19	14.73	14.72	14.44	18.11
	R1	33.74	29.79	29.61	24.49	22.83
	R2	25.08	27.65	20.39	14.66	13.35
	R3	18.97	17.46	17.01	14.57	14.82
REP.2	L1	22.34	21.22	18.15	16.78	16.86
	L2	12.95	13.66	15.93	14.86	14.46
	L3	13.09	13.52	14.91	16.72	15.12
	R1	25.57	23.77	20.79	15.19	8.90
	R2	20.34	19.43	17.89	13.39	10.57
	R3	19.18	19.44	18.99	14.76	12.54
REP.3	L1	20.14	22.25	19.09	13.27	11.02
	L2	16.88	15.92	15.83	12.33	10.55
	L3	18.29	14.34	13.02	9.55	7.70
	R1	25.98	26.07	19.28	11.67	10.55
	R2	17.29	14.25	14.28	11.64	10.01
	R3	15.75	14.25	14.67	11.77	9.98

Table (21) : Continued.

8:00 hr Application time		d1 0-20	d2 20-40	d3 40-60	d4 60-80	d5 80-100
REP.1	L1	19.27	29.62	28.60	21.16	19.93
	L2	15.42	16.69	16.06	14.31	13.21
	L3	12.93	14.30	14.37	13.89	17.45
	R1	33.51	32.66	27.66	23.88	22.71
	R2	24.81	26.98	21.33	14.09	14.34
	R3	17.91	17.55	16.17	15.03	12.93
REP.2	L1	21.22	21.86	18.39	16.42	16.82
	L2	14.02	14.76	16.46	15.42	15.21
	L3	13.37	13.71	15.52	15.22	17.33
	R1	27.57	25.02	20.80	14.88	9.41
	R2	21.16	21.86	17.45	13.71	10.96
	R3	20.06	18.95	17.60	15.25	12.31
REP.3	L1	20.04	22.63	19.08	13.21	9.17
	L2	17.84	15.78	16.96	12.76	11.98
	L3	18.99	15.30	11.65	9.58	5.73
	R1	27.46	25.06	19.56	11.46	11.83
	R2	16.34	15.20	14.73	11.31	11.32
	R3	15.83	14.67	14.15	12.02	10.75

16:00 hr Application time		d1 0-20	d2 20-40	d3 40-60	d4 60-80	d5 80-100
REP.1	L1	19.56	30.10	28.77	21.41	19.89
	L2	15.46	16.42	16.31	14.35	13.56
	L3	12.75	14.58	14.09	14.19	17.72
	R1	33.75	32.86	31.37	23.87	22.72
	R2	25.02	26.96	21.24	14.35	14.24
	R3	18.13	16.90	16.39	15.17	12.74
REP.2	L1	21.42	23.09	18.52	16.19	16.93
	L2	14.20	14.86	16.03	15.11	15.48
	L3	13.54	15.71	15.55	15.19	17.40
	R1	27.72	25.31	21.25	15.19	9.44
	R2	21.14	21.83	17.68	13.71	11.33
	R3	20.21	18.86	17.70	15.53	12.92
REP.3	L1	20.24	22.35	19.38	13.52	9.56
	L2	18.06	15.74	17.10	12.82	11.99
	L3	19.21	15.55	11.37	9.87	5.78
	R1	27.96	25.33	20.19	11.08	12.34
	R2	16.82	15.42	14.86	10.63	11.32
	R3	15.85	14.05	14.46	12.58	10.31

Table (21) : Continued.

24:00 hr Application time		d1 0-20	d2 20-40	d3 40-60	d4 60-80	d5 80-100
REP.1	L1	19.77	30.35	26.50	21.35	19.47
	L2	15.26	16.53	16.49	14.41	13.92
	L3	12.89	14.31	14.23	14.48	17.73
	R1	34.51	33.39	31.67	23.84	22.38
	R2	25.04	26.74	21.38	14.35	14.78
	R3	17.20	17.06	16.17	15.13	12.75
REP.2	L1	21.67	23.73	19.39	16.21	17.13
	L2	14.61	14.91	16.26	15.19	14.84
	L3	13.72	13.52	15.48	15.49	16.55
	R1	28.32	27.33	22.16	15.46	9.61
	R2	21.38	23.09	19.10	13.47	11.87
	R3	19.99	18.73	17.40	14.02	12.87
REP.3	L1	20.75	23.73	19.66	13.71	9.48
	L2	18.09	15.88	19.39	12.94	12.02
	L3	19.21	15.79	11.25	9.61	4.94
	R1	28.75	27.08	21.31	11.65	12.34
	R2	16.54	15.71	15.31	10.19	10.26
	R3	15.91	13.77	14.83	11.88	10.74

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Table(22): Moisture content on volume basis obtained by the Neutron Probe method, at different horizontal and Vertical distances, at 50cm burial depth. Initial moisture content = 5- 10% Pv.

0:00 hr Application time		d1 0-20	d2 20-40	d3 40-60	d4 60-80	d5 80-10	d6 100-120
REP.1	L1	7.60	12.04	16.02	11.15	9.38	8.33
	L2	4.30	4.51	5.56	5.49	3.23	2.35
	L3	10.08	10.52	9.38	6.46	4.24	4.44
	R1	8.28	6.74	9.96	6.25	0.76	3.22
	R2	7.44	5.30	6.28	7.23	1.48	2.16
	R3	14.04	14.41	11.62	6.08	2.71	3.67
REP.2	L1	6.53	6.80	3.68	3.11	0.73	4.37
	L2	8.28	4.87	5.74	3.02	4.02	4.56
	L3	9.88	6.77	8.88	4.56	1.60	5.66
	R1	8.30	9.30	6.63	2.65	0.85	5.10
	R2	12.90	7.94	6.62	2.49	0.64	3.66
	R3	10.24	14.25	12.34	8.74	3.94	2.36
REP.3	L1	9.45	4.71	9.55	4.21	2.35	5.02
	L2	7.60	4.39	8.80	3.89	2.50	2.36
	L3	15.71	14.06	12.50	4.84	6.03	3.23
	R1	7.20	4.30	16.59	13.99	4.62	4.35
	R2	4.97	2.84	4.61	3.55	2.01	6.53
	R3	11.76	6.54	3.33	1.63	1.56	3.66

1:00 hr Application time		d1 0-20	d2 20-40	d3 40-60	d4 60-80	d5 80-10	d6 100-120
REP.1	L1	7.93	13.73	17.12	11.24	10.10	8.36
	L2	5.35	4.03	5.47	4.49	4.35	2.36
	L3	10.23	10.00	9.80	6.42	0.24	4.46
	R1	8.57	6.96	9.21	5.89	0.33	3.23
	R2	10.27	11.83	11.84	8.04	3.70	2.17
	R3	16.58	15.28	12.05	4.65	1.93	3.68
REP.2	L1	7.79	7.43	4.47	2.06	2.36	4.38
	L2	9.62	5.44	6.16	2.94	1.75	4.57
	L3	11.35	8.06	9.89	5.81	4.30	5.68
	R1	8.83	9.56	7.28	3.12	0.88	5.12
	R2	14.12	8.50	6.27	2.86	5.22	3.67
	R3	12.88	13.25	12.65	8.44	3.43	2.36
REP.3	L1	10.05	4.96	9.92	4.53	5.70	5.04
	L2	8.03	4.67	9.44	4.21	2.15	2.36
	L3	15.69	13.84	12.72	4.88	4.88	3.24
	R1	8.06	6.82	16.40	15.65	8.13	4.37
	R2	5.78	4.13	5.11	3.04	1.96	6.55
	R3	11.46	6.05	3.47	1.32	2.12	3.67

Table (22): Continued.

2:00 hr Application time		d1 0-20	d2 20-40	d3 40-60	d4 60-80	d5 80-10	d6 100-120
REP.1	L1	8.50	19.07	17.76	11.45	9.19	8.57
	L2	5.73	4.84	5.35	4.37	2.66	2.42
	L3	11.34	11.83	10.46	7.48	2.33	4.57
	R1	7.88	6.94	9.46	5.52	1.68	3.31
	R2	9.14	11.79	12.52	8.37	4.18	2.22
	R3	7.15	14.70	12.20	4.92	0.92	3.77
REP.2	L1	7.15	7.92	5.03	3.42	1.68	4.49
	L2	10.40	6.37	7.06	4.07	1.60	4.69
	L3	11.01	8.19	9.79	5.19	1.18	5.82
	R1	7.99	10.49	7.26	3.31	0.79	5.25
	R2	13.76	8.30	6.13	2.77	3.34	3.76
	R3	9.62	12.62	12.43	8.26	4.52	2.42
REP.3	L1	10.05	5.18	9.94	4.83	8.00	5.17
	L2	8.24	5.88	9.74	5.01	1.51	2.42
	L3	15.94	13.80	12.69	4.83	5.19	3.32
	R1	7.11	5.52	16.10	15.12	19.04	4.48
	R2	5.56	4.38	5.78	3.69	0.13	6.71
	R3	11.15	7.37	4.29	2.37	1.58	3.76

4:00 hr Application time		d1 0-20	d2 20-40	d3 40-60	d4 60-80	d5 80-10	d6 100-120
REP.1	L1	8.18	18.70	19.45	11.01	9.75	8.79
	L2	4.29	4.34	4.65	5.19	2.34	2.48
	L3	10.21	11.82	10.68	6.67	1.20	4.69
	R1	9.84	8.16	10.68	6.80	4.75	3.39
	R2	11.52	12.86	13.39	9.60	6.09	2.28
	R3	16.96	16.10	13.52	6.01	1.62	3.87
REP.2	L1	8.61	10.54	6.10	1.79	1.89	4.61
	L2	9.17	5.18	6.16	2.15	1.73	4.81
	L3	11.70	8.17	10.07	5.04	3.77	5.97
	R1	9.69	10.88	6.69	3.11	0.35	5.38
	R2	14.95	9.59	6.98	3.69	2.33	3.86
	R3	13.13	13.88	13.56	10.03	6.04	2.48
REP.3	L1	10.23	5.48	10.29	5.07	7.57	5.30
	L2	8.72	6.16	10.23	5.77	0.90	2.48
	L3	16.35	14.06	13.65	5.35	5.52	3.41
	R1	7.57	7.61	17.73	14.57	19.39	4.59
	R2	5.96	5.17	4.75	2.70	2.94	6.88
	R3	11.74	7.39	5.47	2.25	1.95	3.86

Table (22): Continued.

8:00 hr Application time		d1 0-20	d2 20-40	d3 40-60	d4 60-80	d5 80-10	d6 100-120
REP.1	L1	10.10	24.42	21.92	11.72	9.99	8.60
	L2	4.60	4.45	5.23	4.35	2.74	2.43
	L3	9.58	11.13	9.69	6.12	0.13	4.59
	R1	10.17	9.31	10.63	7.03	3.70	3.32
	R2	11.70	13.07	12.90	8.64	4.85	2.23
	R3	17.17	15.33	12.36	5.09	1.27	3.79
REP.2	L1	7.89	15.30	6.91	3.28	9.57	4.51
	L2	8.53	5.79	6.75	3.50	3.25	4.70
	L3	8.01	6.62	8.95	3.94	3.57	5.84
	R1	9.99	14.87	6.80	3.12	0.30	5.27
	R2	14.75	10.02	7.79	4.45	1.92	3.78
	R3	12.68	13.34	14.21	9.12	2.07	2.43
REP.3	L1	9.17	8.06	11.38	5.31	5.65	5.19
	L2	8.05	5.43	10.57	5.79	1.52	2.43
	L3	16.55	14.36	13.94	5.30	5.49	3.33
	R1	8.38	8.81	19.85	16.66	19.36	4.50
	R2	5.19	3.70	5.30	3.66	2.66	6.74
	R3	10.30	6.21	3.36	1.63	8.66	3.78

16:00 hr Application time		d1 0-20	d2 20-40	d3 40-60	d4 60-80	d5 80-10	d6 100-120
REP.1	L1	10.49	21.10	21.71	14.76	10.79	7.68
	L2	3.90	5.35	7.69	3.59	2.66	2.17
	L3	7.73	9.08	8.95	5.03	7.57	4.10
	R1	9.46	13.87	10.71	5.66	1.39	2.97
	R2	9.68	11.21	11.72	7.47	3.65	1.99
	R3	17.17	15.64	12.24	4.12	1.98	3.38
REP.2	L1	9.62	17.06	11.52	1.77	5.78	4.03
	L2	8.17	4.07	5.40	2.88	5.70	4.20
	L3	10.31	6.30	7.38	4.38	2.44	5.22
	R1	13.27	16.85	7.33	1.79	1.29	4.71
	R2	14.63	9.25	5.77	2.23	0.94	3.37
	R3	12.99	13.74	12.56	9.88	4.47	2.17
REP.3	L1	11.82	13.62	11.74	5.38	9.57	4.63
	L2	8.33	5.24	10.85	5.90	1.75	2.17
	L3	16.52	14.37	13.67	5.37	5.39	2.98
	R1	7.52	11.49	15.42	14.47	17.66	4.02
	R2	3.91	3.84	5.74	4.18	3.38	6.02
	R3	12.00	7.42	4.83	2.35	6.60	3.37

Table (22): Continued.

24:00 hr Application time		d1 0-20	d2 20-40	d3 40-60	d4 60-80	d5 80-10	d6 100-120
REP.1	L1	10.52	24.42	24.53	14.47	10.68	6.86
	L2	4.54	5.47	8.13	5.45	9.85	1.94
	L3	7.64	9.47	8.87	4.99	8.65	3.66
	R1	9.83	14.13	11.01	6.07	1.38	2.65
	R2	10.07	11.23	12.03	7.17	3.65	1.78
	R3	17.13	15.65	12.69	4.32	2.07	3.02
REP.2	L1	10.10	20.21	12.35	2.38	10.35	3.60
	L2	8.78	4.76	5.70	2.85	9.66	3.76
	L3	10.74	6.65	7.99	4.37	2.43	4.66
	R1	13.36	18.36	7.55	3.03	7.65	4.20
	R2	14.35	9.47	6.21	2.50	5.65	3.01
	R3	13.29	13.99	12.61	9.85	4.46	1.94
REP.3	L1	12.05	13.55	15.07	5.71	10.63	4.14
	L2	9.12	5.14	15.46	5.96	2.09	1.94
	L3	16.52	14.28	13.70	5.42	4.81	2.66
	R1	7.43	11.80	21.89	16.13	17.94	3.57
	R2	4.26	4.10	5.93	4.22	3.27	5.38
	R3	12.02	7.23	4.64	2.67	5.66	3.01

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Table (23) : Moisture content on volume basis obtained by the Neutron Probe method, at different horizontal and vertical distances, at 50cm burial depth. Initial moisture content = 10-15 % Pv.

0:00 hr Application time		d1 0-20	d2 20-40	d3 40-60	d4 60-80	d5 80-10	d6 100-120
REP.1	L1	16.62	24.50	33.35	20.17	13.04	2.94
	L2	7.20	9.85	12.25	7.65	1.50	2.23
	L3	12.19	13.27	12.54	9.14	1.83	8.89
	R1	15.80	20.53	14.91	7.82	3.50	8.66
	R2	14.00	13.15	14.86	10.94	7.79	9.37
	R3	20.31	17.47	14.05	7.21	6.00	10.25
REP.2	L1	17.16	24.56	22.50	7.54	0.61	9.65
	L2	12.74	9.30	9.27	5.69	1.21	11.23
	L3	13.77	9.83	11.04	6.96	3.23	5.37
	R1	17.40	23.14	13.22	5.74	4.09	6.58
	R2	13.00	11.08	8.89	4.42	1.86	4.37
	R3	14.48	15.69	15.58	11.77	6.60	9.00
REP.3	L1	15.91	17.88	19.34	11.49	2.30	4.66
	L2	11.68	8.65	21.66	8.88	5.46	9.23
	L3	19.64	16.90	16.29	8.82	8.17	6.60
	R1	10.92	17.11	20.33	22.45	32.86	9.37
	R2	7.68	5.56	7.56	5.52	0.13	4.35
	R3	14.25	9.24	6.53	4.36	1.71	8.66

1:00 hr Application time		d1 0-20	d2 20-40	d3 40-60	d4 60-80	d5 80-10	d6 100-120
REP.1	L1	16.23	24.70	25.17	20.23	11.22	3.68
	L2	8.35	9.39	12.53	8.60	1.56	2.79
	L3	13.03	12.54	12.24	8.68	2.13	11.15
	R1	11.45	9.84	12.08	8.77	5.80	10.86
	R2	14.11	14.09	15.14	11.16	5.31	11.75
	R3	19.23	18.01	15.59	7.29	3.77	12.86
REP.2	L1	16.09	22.35	20.49	7.34	2.33	12.11
	L2	12.38	8.98	8.67	5.66	0.91	14.08
	L3	6.97	6.32	8.00	9.91	4.54	6.73
	R1	15.92	22.20	13.67	6.50	4.09	8.26
	R2	17.02	11.49	9.34	5.60	2.69	5.48
	R3	14.86	15.17	14.70	11.65	3.97	11.29
REP.3	L1	15.74	17.83	19.63	11.49	2.31	5.84
	L2	11.85	8.86	21.97	8.94	5.71	11.57
	L3	19.94	16.95	16.00	8.77	7.90	8.28
	R1	10.87	16.61	23.48	18.98	19.77	11.75
	R2	8.31	7.34	6.92	4.47	1.26	5.46
	R3	14.39	8.46	7.50	5.11	0.01	10.86

Table (23): Continued.

2:00 hr Application time		d1 0-20	d2 20-40	d3 40-60	d4 60-80	d5 80-10	d6 100-120
REP.1	L1	17.16	25.23	24.97	21.11	12.71	3.63
	L2	8.15	10.02	11.02	8.15	0.61	2.75
	L3	13.00	14.12	11.83	8.76	3.00	11.00
	R1	15.42	19.92	14.32	7.01	4.16	10.72
	R2	14.08	14.93	14.78	10.86	7.02	11.57
	R3	19.19	17.78	15.58	6.84	3.35	12.67
REP.2	L1	17.60	21.73	20.89	8.87	3.62	11.94
	L2	13.38	8.85	8.68	5.66	3.08	13.87
	L3	13.89	10.90	10.68	6.11	4.04	6.64
	R1	19.36	22.73	12.20	6.76	3.50	8.15
	R2	16.73	11.14	9.21	5.66	1.05	5.40
	R3	17.59	15.65	15.15	11.39	6.39	11.14
REP.3	L1	15.72	18.05	19.93	11.82	2.65	5.77
	L2	11.86	8.81	22.20	8.96	5.03	11.42
	L3	19.87	16.73	17.09	8.05	8.50	8.17
	R1	11.40	19.81	24.97	20.19	22.43	11.57
	R2	8.82	7.18	7.71	5.72	6.58	5.38
	R3	14.62	9.34	6.79	3.77	0.82	10.72

4:00 hr Application time		d1 0-20	d2 20-40	d3 40-60	d4 60-80	d5 80-10	d6 100-120
REP.1	L1	18.53	26.37	26.95	19.04	12.41	3.59
	L2	8.67	9.89	12.05	8.89	1.65	2.72
	L3	20.31	12.95	12.68	8.45	3.11	10.85
	R1	14.55	21.07	14.76	8.74	5.38	10.57
	R2	13.81	15.39	13.65	11.41	6.09	11.44
	R3	19.09	17.25	14.12	7.09	3.71	12.52
REP.2	L1	15.35	23.57	20.56	6.94	3.83	11.78
	L2	12.43	8.71	7.63	5.60	1.38	13.71
	L3	13.92	11.15	11.54	6.71	5.76	6.55
	R1	18.18	21.52	13.42	6.14	2.66	8.04
	R2	18.07	12.43	9.98	6.25	2.55	5.33
	R3	15.06	15.31	14.53	11.16	5.28	10.99
REP.3	L1	15.64	18.93	22.40	44.02	2.66	5.69
	L2	11.77	8.78	22.21	8.99	4.99	11.26
	L3	20.06	16.95	17.38	7.65	8.34	8.06
	R1	12.09	10.34	24.21	19.28	17.98	11.44
	R2	9.49	7.01	8.76	5.83	7.64	5.31
	R3	14.81	9.30	5.81	4.51	6.48	10.57

Table (23): Continued.

8:00 hr Application time		d1 0-20	d2 20-40	d3 40-60	d4 60-80	d5 80-10	d6 100-120
REP.1	L1	19.14	27.27	24.35	21.61	13.01	3.54
	L2	8.45	9.93	12.68	7.73	7.24	2.68
	L3	13.38	12.66	12.53	9.39	1.65	10.70
	R1	15.84	21.30	15.88	8.45	3.76	10.43
	R2	13.55	15.35	16.17	12.76	8.50	11.28
	R3	23.53	22.96	19.72	12.98	12.83	12.35
REP.2	L1	18.88	26.94	22.02	8.12	6.21	11.62
	L2	12.59	9.51	7.69	5.85	1.17	13.52
	L3	13.54	10.77	10.40	6.32	4.19	6.46
	R1	19.47	23.31	13.64	5.36	1.68	7.93
	R2	16.71	12.39	8.11	4.72	1.92	5.26
	R3	17.28	15.13	14.82	11.44	6.30	10.84
REP.3	L1	15.60	19.21	22.43	14.91	2.76	5.61
	L2	13.93	8.79	22.14	8.98	5.61	11.11
	L3	19.85	16.68	17.31	7.73	7.70	7.95
	R1	11.36	21.24	23.97	20.25	22.30	11.28
	R2	9.18	7.10	7.53	5.48	0.64	5.24
	R3	14.49	9.48	6.83	4.11	2.40	10.43

16:00 hr Application time		d1 0-20	d2 20-40	d3 40-60	d4 60-80	d5 80-10	d6 100-120
REP.1	L1	19.14	27.56	26.48	27.17	13.01	3.98
	L2	8.90	9.94	12.74	7.65	11.19	3.02
	L3	13.41	12.65	12.55	9.39	1.64	12.05
	R1	15.56	21.72	17.11	8.67	3.34	11.74
	R2	13.47	15.75	16.75	12.71	8.48	12.70
	R3	23.77	22.69	19.70	12.99	13.13	13.91
REP.2	L1	19.22	27.22	22.21	8.40	6.25	13.09
	L2	12.80	9.75	8.00	5.94	1.14	15.22
	L3	13.45	10.76	10.40	6.53	4.41	7.28
	R1	19.23	23.58	13.89	5.59	1.62	8.93
	R2	16.67	12.39	8.11	4.76	1.94	5.92
	R3	17.31	15.06	15.10	11.76	13.72	12.20
REP.3	L1	15.76	18.71	22.57	14.94	2.88	6.32
	L2	12.37	8.86	22.20	8.96	5.71	12.51
	L3	19.90	19.08	17.32	7.70	12.96	8.95
	R1	11.34	21.47	23.63	20.22	22.87	12.70
	R2	9.14	6.72	8.62	7.05	6.26	5.90
	R3	14.70	9.74	6.84	4.14	2.36	11.74

Table (23): Continued.

24:00 hr Application time		d1 0-20	d2 20-40	d3 40-60	d4 60-80	d5 80-10	d6 100-120
REP.1	L1	19.71	27.10	26.70	21.40	14.32	4.48
	L2	8.58	8.35	13.45	8.26	2.23	3.40
	L3	13.75	12.18	11.74	9.00	2.63	13.57
	R1	14.91	22.23	16.20	8.65	3.40	13.22
	R2	15.27	14.49	15.92	10.03	6.48	14.30
	R3	19.54	17.90	14.11	7.29	4.04	15.66
REP.2	L1	18.23	25.76	23.09	8.18	5.49	14.74
	L2	13.21	10.42	8.48	5.69	2.93	17.14
	L3	14.33	9.92	12.08	6.76	4.33	8.19
	R1	20.56	24.18	14.86	5.81	3.31	10.05
	R2	16.49	12.21	8.58	5.85	2.15	6.67
	R3	16.16	16.87	15.49	12.73	8.67	13.74
REP.3	L1	15.98	19.01	24.53	16.70	2.55	7.11
	L2	12.84	11.52	24.82	8.99	5.03	14.09
	L3	18.82	19.16	17.38	7.99	6.74	10.08
	R1	12.78	18.97	25.93	22.09	21.27	14.30
	R2	9.07	6.52	6.95	5.34	5.90	6.64
	R3	14.06	8.75	7.35	4.31	7.98	13.22

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Table(24): Moisture content on volume basis obtained by the Neutron Probe method, at different horizontal and vertical distances, at 50cm burial depth.
Initial moisture content = 15-20% Pv.

0:00 hr Application time		d1 0-20	d2 20-40	d3 40-60	d4 60-80	d5 80-10	d6 100-120
REP.1	L1	20.70	28.09	27.69	22.37	15.27	8.94
	L2	9.60	9.34	14.45	9.29	3.25	3.58
	L3	14.10	13.15	12.73	10.01	3.64	1.91
	R1	15.95	23.19	17.17	9.41	4.34	8.66
	R2	16.28	15.49	16.66	10.99	7.01	10.23
	R3	20.53	18.89	15.10	8.29	4.98	6.36
REP.2	L1	19.00	26.74	23.89	8.90	6.42	5.37
	L2	14.03	11.26	9.24	6.43	3.51	4.66
	L3	15.31	11.02	13.07	7.76	5.26	5.37
	R1	21.47	25.22	16.17	6.79	4.23	9.66
	R2	17.49	13.23	9.61	6.79	3.08	12.35
	R3	15.02	16.92	16.22	12.08	9.11	9.36
REP.3	L1	17.07	20.81	18.38	6.89	3.30	6.37
	L2	14.19	12.79	25.44	7.67	6.03	7.90
	L3	19.61	18.88	18.95	8.08	7.74	8.70
	R1	13.79	19.66	26.65	28.58	22.44	4.34
	R2	10.05	7.49	7.92	6.34	10.24	3.58
	R3	14.98	9.78	8.31	5.26	3.70	8.65

1:00 hr Application time		d1 0-20	d2 20-40	d3 40-60	d4 60-80	d5 80-10	d6 100-120
REP.1	L1	20.68	28.18	27.99	22.51	14.69	11.04
	L2	9.48	9.66	15.01	9.35	3.19	4.43
	L3	14.85	13.13	12.46	10.02	4.06	2.35
	R1	15.73	24.22	18.38	9.73	5.11	10.70
	R2	16.33	15.97	17.29	10.70	7.54	12.63
	R3	20.54	19.19	14.70	8.64	7.74	7.85
REP.2	L1	19.02	26.47	23.04	9.38	8.90	6.63
	L2	13.78	12.43	9.64	6.11	3.00	5.75
	L3	15.30	11.05	11.86	8.07	5.08	6.63
	R1	21.65	24.88	16.63	7.11	4.93	11.93
	R2	17.48	13.26	9.62	6.82	3.12	15.26
	R3	15.02	16.58	16.01	12.48	7.74	11.56
REP.3	L1	17.15	20.44	28.88	17.77	3.07	7.86
	L2	14.20	12.42	26.05	7.78	6.67	9.75
	L3	19.63	19.06	19.23	8.06	5.04	10.74
	R1	13.97	20.01	26.05	28.34	22.47	5.36
	R2	10.03	7.43	7.91	6.01	1.00	4.43
	R3	14.87	9.38	8.56	5.41	0.22	10.69

كان تأثير الرطوبة ملحوظاً على الحركة العمودية إلى أعلى، ولم تلاحظ أية فروق كبيرة في حركة الماء الأفقية كذلك فقد بيّنت النتائج علاقة مباشرة ما بين تصرف الأنبوب وكمية الرطوبة في التربة المحيطة به، والتي كان من شأنها تحديد كمية مياه الري المُعطاه بغض النظر عن ضغط الماء في الأنبوب، حيث وجد أن زيادة كمية الرطوبة في التربة خارج الأنبوب تؤدي الى تقليل الفرق في الضغط ما بين داخل الأنبوب وخارجه، وبالتالي إلى التقليل من تصّرف الأنبوب بشكل ملحوظ.

في مقارنة أجمالية ما بين النتائج المشتقة من أستخدام جهاز المِجّس النيوتروني و نتائج عينات الرطوبة وجد أن هذا الجهاز أقل دقة في تحديد شكل وموضع المياه في قطاع التربة وخاصة عندما تكون فترات الري محدودة الزمن. ومن المقترح في الدراسات المتخصصة في هذا المجال (تتبع الرطوبة) أن يتم استخدام أجهزة متطورة وأكثر دقة.

حيث أن هذا البحث الأول من نوعه في المنطقة، لا تزال عدة أمور أخرى بحاجة الى دراسات متخصصة، والتي لم يتم بحثها في هذه الدراسة، مثل دراسة الجدوى الإقتصادية لهذا النظام، ومقارنة كفاءته في ري المحاصيل (Water Use Efficiency) مع الأنظمة الأخرى.