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"A Study on irrigation systems" Developing of furrow irrigation method for corn crop under local conditions

By

Tariq Mahmmoud Attaffey Morsi
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APPROVAL SHEET

"A Study on Irrigation Systems"
Developing of Furrow Irrigation Method for Corn Crop under Local Conditions

By

Tariq Mahmmoud Attaffey Morsi

This Thesis for M. Sc. Degree in
Agricultural Sciences (Agricultural Mechanization)

Thesis has been approved by:

Prof. Dr. Mamduh A. Helmy ....
Professor of Ag. Eng. and
Head of Ag. Mech. Dept.,
Faculty of Agriculture, Kafr El-Sheikh,
Tanta University.

Prof. Dr. Mohamed A. El-Sheikha ....
Professor of Ag. Eng.,
Ag. Eng. Dept.,
Faculty of Agriculture,
Mansoura University.

Dr. Samir M. Gomaa ....
Associate Prof. of Ag. Eng.,
Ag. Mech. Dept.,
Faculty of Agriculture, Kafr El-Sheikh,
Tanta University.

Dr. El-Said Mohamed Khalifa ....
Associate Prof. of Ag. Eng.,
Ag. Mech. Dept.,
Faculty of Agriculture, Kafr El-Sheikh,
Tanta University.

Date: 8 / 5 / 2001

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SUPERVISION COMMITTEE

Dr. Samir M. Gomaa
Associate Prof. of Ag. Eng.,
Ag. Mech. Dept.,
Faculty of Ag., Kafr El-Sheikh,
Tanta Univ.

Dr. El-Said Mohamed Ahmed Khalifa
Associate Prof. of Ag. Eng.,
Ag. Mech. Dept.,
Faculty of Ag., Kafr El-Sheikh,
Tanta Univ.

Dr. Zakaria Mohamed Ismail Emara
Researcher of Agric. Eng. Res. Inst.,
Agric. Res. Center; El-Dokki; Cairo,
Egypt.

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1. Introduction

Irrigation was initially introduced in Egypt as surface irrigation, about more than 6000 B.C. ***(Nakayama and Bucks 1986)***. Surface irrigation is practiced as flooding the soil surface by basin or border irrigation or running the water in small ditchers of furrows despite the fact that, sprinkler and drip irrigation are used maximize the crop yield for unit water, the surface irrigation is still the most common method for distributing the water to the cultivated fields but lower irrigation efficiencies is one of its disadvantages where it is not more than 50%, developing surface irrigation aims to increase irrigation efficiencies by the following means; Improving water application efficiency, providing good water distribution uniformity, reducing drainage problems "run off and deep percolation" and developing surface irrigation with an appropriate mechanized or automized system.

The water losses under such system are mainly due to deep percolation particularly in the upper part of the fields, this causing several acute problems, consequently this problems have negatively affecting crop yield and reducing fertilizer.

Increasing the efficiencies of surface irrigation to saving irrigation water is considered a strategically target of Egypt.

Under the Egyptian old land circumstances the Alternative and Surge irrigation techniques may be more applicable and less cost manners to improve surface irrigation efficiencies and increase water application efficiency and water use efficiency.

As fore Alternative irrigation technique water can be saved when maize and cotton were irrigated using alternate row flow technique

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(Milligan 1973), for surge irrigation the latest improved surface irrigation methods through surge flow irrigation ***(James, 1988).***

It is important knowing the possibility of using the third irrigation system which collect surge and alternative irrigation systems in a new system called *(Surge-alternative)* irrigation system and known the effectiveness of this system on surface irrigation efficiencies and the yield.

The selected field crop is maize as a summer crop cultivated on furrows. On the other hand, maize is considered as a very important crop for human, animal and industry.

The aim of the present work was to develop furrow surface irrigation by using alternative and Surge-alternative irrigation methods, and compared them with continuous furrow irrigation and study the effect of developed irrigation methods on corn production and irrigation efficiency.

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2. REVIEW OF LITERATURE

2-1 irrigation systems: -

Johl (1980) classified the irrigation systems as shown,

1- Surface

A. Flooding "uncontrolled"

1. Ponding or basin
   a) contour
   b) rectangular
2. Flowing water
   a) free flooding
   b) border or strip check

B. Furrow "controlled"

1. Conventional
2. Modified
   a) corrugation
   b) zig-zag
   c) check back
   d) cluster
   e) basin

2- Subsurface

A. Ditch system

1. Field
2. Spud

B. Ditch and mole

C. Underground conduit

D. Uncontrolled

3- Sprinkler

A. Stationary

1. Hand moved
2. Mechanical
   a) side-roll
   b) end-two
      i- drag type
      ii- pull type

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c) side-move

d) boom

B. Continuously moving

1. Circular center-pivot
2. Straight moving lateral
3. Travelers

4- trickle

A. Hand operated

B. Automatic

1. Partial automation
2. Sequential operation
3. Fully automatic operation

He added that every irrigation method has advantages and disadvantages and has a definite place in the irrigation system. Wrong selection of an irrigation method or poor design of the system would affect the water use-efficiency adversely. The low infiltration rate of heavy clay soil prevents the use of sprinkler irrigation. In this case gated pipes and tailwater systems are suggested used to increase water efficiency

Hill and Keller (1980) indicated that an optimization of irrigation system design is a complicated task and most often it is done by intuition. It involves the physical system, crop growth patterns, crop response to water and fertility and on-farm management practices. The many interactions existing in agriculture production process create a very complex system. They added that the design and operation of an irrigation system is for express purpose of modifying the soil water status to be more favorable for plant growth and thus increased yield.

Eduardo et al. (1985) said that, there are two steps to select irrigation method, the first one is analytical- technical and the second is technical-economic.The procedure is developed on the basis of indices that show the acceptability of the irrigation method to the selection parameters (crop density, type of planting or sowing, slope of the field, infiltration rate of the soil, etc.), cost, and financial feasibility.

Vazirani and Chandola (1985) summarized the various methods of irrigation used in the modern time as fallow:

A) Surface Irrigation

1) Wild flooding,
2) Free flooding,
3) Check flooding,

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4) Border strip method,

5) Zig-zag method,

6) Basin method,

7) Furrow method.

B) Sub-surface Irrigation

C) Sprinkler irrigation

Hillel (1986) stated that there are, three main ways to apply water to plants:

(1) Surface irrigation where the water run over the surface of the soil and allow it to infiltrate,

(2) Sprinkler irrigation where the water spray into air and allow it to fall onto plants and soil as simulation rainfall,

(3) Drip or sub- irrigation where the water applies directly to the root zone.

Punmia and Lal (1990) opined that irrigation water may be applied to the crops by three basic methods:

I) Surface irrigation

a) Furrow method,

b) Contour farming,

c) Flooding

1) Wild flooding

2) Controlled flooding

i) Free Flooding

ii) Contour Laterals

iii) Border Strips

iv) Check or Levels

v) Basin Flooding

vi) Zigzag Method

2) Sub- Surface irrigation.

3) Sprinkler irrigation.

Garge (1993) claimed that irrigation may broadly be classified as follow:

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A) Surface irrigation

a) Lift irrigation

b) Flow irrigation

i) Perennial irrigation

ii) Flood irrigation

B) Sub-Surface irrigation

a) Natural sub irrigation,

b) Artificial sub irrigation.

He also added that, there are various ways in which the irrigation water can be applied to the field. as follows:

1. Free flooding
2. Border flooding
3. Check flooding
4. Basin flooding
5. Furrow irrigation method
6. Sprinkler irrigation method
7. Drip irrigation method.

2.2 <u>Management and scheduling of irrigation :</u>

Amir et al. (1980) demonstrated that there are many factors affect construction of the irrigation scheduling; most of them are unforeseen and , thus require a rapid response and frequent change. In the construction of an irrigation time-table the planner has to consider these factors and to meet, at every point in time. weather, pump failures and other unforeseen interruptions introduce a considrable uncertainty requeiring rapid response and frequent changes.

Hillel (1983) postulated that many factors influence the decision – making process of determining when to apply irrigation water. Among them are climatic setting (arid, semiarid, etc.), water supply (constraints on availablity), crop (flowering habit, harvest index, stress sensitivity of the current stage), irrigation system (degree of mechanization and control over application rate amount), soils (profile textures, spatial variability), weather (current and short term expected), and economics (profit-maximizing level of irrigation). Additional considerations may include electric load management, salinity control, crop quality at harvest, and the cultural or labor scheduling aspects of farming operations.

Eduardo et al. (1986) pointed out that there are many criterion should be selected that permits the irrigation scheduling of the crop in a particular field to be determined beforehand on the basis of historical data. The criterion used in this investigation to determine the irrigation schedule was the meteorological approach, which the following.

1) The physical characteristics of the soil, .

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2) Allowable soil water depletion until the next irrigation,

3) The dynamics of rooting depth, and

4) The evapotranspiration rate of crop at stages between planting and maturity.

Moigne et al. (1988) reported that there are many factors responsible fore the poor performance of irrigation projects in Sub-Saharn African (SSA) countries. Lake of good project management and proper maintaenance have reduced yields and increased crop losses. At the farme level , the success of irrigation schemes could be influenced by social organization of procedures, and farmes participation in the operation and maintenance of irrigation. They added that for improving irrigation schemes there are improvements also required in project design, in particular water delivery systems and storage structures.

El-Zeiny et al. (1989) **studied the effect of three irrigation interavals 6,** 12, and 18 days on vegetative growth ,yields and its components of maize. They cocluded that, Maize plants can be irrigate every 12 days under the enviromental conditions of this study or any other similar conditions.

Tuijl (1993) summarized techniques for achieving high irrigation efficiencies include:

1) land leveling by using LASER techniques;

2) syphoning irrigation water from a head ditch into the furrow;

3) flexible or rigid PVC pipe to distribute water into the furrows; and

4) buried PVC pipe with riser. He added that, it can be obtained an irrigation efficiencies of more than 80% with modern surface irrigation methods if design and management are reliable.

El-Amir (1996) studied the effect of irrigation intervals on root system characteristics of maize crop. A micro lysimeter of 45 Liters volume was used to calculated the water requirement (daily, two and three days intervals). His results showed that, increasing irrigation interval tended to increase the root fresh weight, volume adsorbing and absorbing surface area.

Miiller et al. (1996) mentioned that irrigation management practices can affect application uniformity, run off, the amount of water that will be leached bellow the root zone, and the amount of water that is effectively used by the crop as evapotranspiration. Good irrigation management requires consideration of soil moisture conditions, rainfall, and crop water requirements to decide when to irrigate. They added that in Nebraska, 80 percent of the irrigators reported using every other row irrigation and only 15 percent reported using Surge irrigation.

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Hess (1996a) observed that irrigation scheduling involves determing when, and how much to irrigate. Poor scheduling may lead to a waste of water, energy and labour, low yields and enviromental problemes. Good scheduling should optimise yield and quality of produce whilst making efficient use of resources.

Hess (1996b) studied the effect of evapotranspiration estimation method on irrigation scheduling. He reported that water balance method was used to determine the irrigation water. This method measures the water input into the soil (rainfall and irrigation) and water output (evapotranspiration and drainage) on a daily basis. Most water balance irrigation scheduling methods are based on a daily estimate of the reference evapotranspiration (ET_O), which is then modified according to the crop being grown.

Hess (1999) reported that irrigation scheduling involves, firstly, deciding the most appropriate irrigation plan (i.e.what soil water deficit to allow and how much to apply at that deficit) and secondary, deciding what is the soil water deficit on any particular day. Good scheduling will aim to meet the goals of irrigation (optimise production, quality and aesthetics) whilst minimizing the water used and other adverse environmental impacts. Bad scheduling will mean that either too little water is applied or it is applied too late resulting in under-watering, or too much is applied or it is applied too soon resulting in over-watering. Under or over- watering will lead to reduced yields, lower quality and inefficient use of nutrients. Poor scheduling also leads to adverse environmental impacts.

2. 3. Management and evaluation of irrigation system:

2.3.1.Surge irrigation system:

Stringham and Keller (1979) reported that surge flow is the intermittent application of irrigation water to irrigation pathways, creating a series of on and off periods of constant or variable duration. The sum of these cycle applications termed "Hydraulic surges". They added that, according to the abvious definition surge irrigation is an old modern technique. That is ancient egyptian used shadouf to irrigate their lands (in shadouf irrigation technique, watering resembles surge flow).

Allan (1980) studied continuous and surge irrigation. He found that significantly reducation in advance time and infiltration rates with surge irrigation than for continuous irrigation.

Bishop et al. (1981) came to conclusion that in a surge irrigation experiment with a cycle time of 2, 5, 10 and 20 minut and with cycle ratio of 0.5 and discharge of 1.26 L/S, surge flow irrigation was more effecitve during the first irrigation than in the second one. They also showed that surge flow alters the basic intake characteristics of the furrows by developing a thin surface seal in bottom which is compacted by tension face that build up in the

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furrow during the drainage period between surges. They also found that the surge advantages increased with cycle time and decreased with cycle ratio.

Podmore and Duke (1982) claimed that the surge advantage decreased with furrow length for a given cycle time. They concluded that longer cycle times were more effective on longer furrow at cycle ratio of 0.5.

Bassett and Evans (1983) opined that the excessive cutback during the post-advance phase imparis uniformity at the tail of the field.

Izuno and Podmore (1984) presented a technique for managing surge irrigation to achieve effective and efficient results. They pointed out that surge irrigation produce best results when surging is increased after completion of advance and continuous application at a reduced inflow rate is applied.

Manges et al. (1985) studied the effect of variable cycle time in surge irrigation. Advantage times in furrows were measured for surge flow with 3 fixed cycle time, and one variable pluse continuous flow, on 287 m long furrows spaced at 76 cm with an average slope of 0.15%. Three cycle times (40, 120.and 240 min) were compared with continuous flow and a variable cycle time (64, 86, 108, 128, 150 and 184 min.), cycle ratio was fixed at 0.5 . Their obtained results showed that, advance time for variable cycle times were similar to those for fixed cycle times.

Goldhamer et al. (1987) compared surge and continuous flow irrigation methods in 1200 feet (450m) long field on two different soils, with sloping furrows during preplanting and first postplanting irrigation when infiltration rate was high Advance and recession time were measured by recording the arrival and disappearance of water at 50 or 100 feet interval across the field. Their results showed that surge irrigation accelerated water advance rates due to the effect of the wetting and drying cycles on soil infiltration characteristics. The full (end of the field) advance volume ratio of surge to continuous flow averaged 0.59.

Stringham (1988) outlined a general guidelines to determine the optimal surge flow management based on surge flow modeling:

1-The combination of inflow and cycle time should be such that the advance phase is competed in about 4-6 surges. More surges may results in poor uniformity, while fewer ones may apply too much water or cause too much tail water.

2-The intake opportunity time should be maximized at the end of the field under dry infiltration conditions. This suggests that the next to last advance phase surge should stop just short of the field end.

3- If the root zone depletion at the end of the field cannot be satisfied except through continual surging beyond the time required to completely wet the furrow, the system should be configured for a cutback regime to avoid tail-water losses and erosion.

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4- Inflow rates should be near the maximum non-erosive value where cutback provisions have been included in the system. Finally, cycle times should be such that individual surge do not overlap or coalesce during advance and do coalesce during the post advance phase. He also added that, in general, stream sizes and surge on-times should be larger for light textured soils as well as long and clogged furrows. For heavy soils and short canals, clean furrows, smaller sizes and shorter surge on-times should be used.

Farahani et al. (1990) concluded from their study in different soil types that, as suction increased to 100 cm water, over-all buck density increased, this increased bulk density was due to both vertical and lateral consolidation surge flow irrigation has shown to be more effective in coarse-textured soils than in fine one.

Izadi et al. (1990) indicate that, it can be increase surge irrigation possible as follows:

(i) decrease furrow roughness and a more stable cross-section during infiltration of water between pulses,

(ii) redistribution of water during the time that water is turned off, which causes a decrease in the hydraulic gradient in the top soil layer for the next surge.

(iii) hystersis in the soil water vs. pressure relationship,

(iv) air entry and entrapment occuring between pulses,

(v) surface sealing and consolidation of the soil matrix near the soil surface which decreases the hydraulic conductivity of the top soil layer,

(vi) changes in the hydraulic properties of the soil profile between pulses.

Osman (1991) found that the advance time was reduced by about 51% at Sakha region and 53 % at Abis region by using surge irrigation with cycle ratio of 0.33, and compared with continuous irrigation. His results indicated that, the surge irrigation saved about of 41.8 % and 35 % at Sakha and Abis respectively compared with continuous irrigation method.

Moustafa (1992) found that the advance time was reduced by about 51.9 % at Sakha region and 53 % at Abis region by using surge irrigation with cycle ratio of 0.33and compared with continuous irrigation. The results indicated that , the surge irrigation saved amount of irrigation water by about of 41.8 % and 35 % at Sakha and Abis region respectively compared with continuous irrigation.

Popova et al. (1994) stated that, a highly uniform soil moisture distribution could be achieved by delivering water into the furrows by short overlapping pulses. They also added that, about of 10-15 % reduction in surface run-off can be obtained. The deep percolation losses were reduced to a

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minimum, with furrows of 100 to 400 m. length The duration of the overlapping pulses is recommended to be approximately 3-4 min and 12-15 min respectively.

Osman et al. (1996) compared continuous irrigation and surge irrigation with three cycles times 10 , 15 , and 20 with the same on-times in calcareous soil. The average value of advance time of water applied to reach the end of furrow (75 m) was 73.8, 62.2, 47.7, 34.8 min. For continuous, surge 10 min cycle time, surge 20 min cycle time and surge 10 min cycle time, respectively, at El-Kaher Sandy loam soil. These values were 72.0, 49.8, 39.0 and 29.5 min. for the previous treatments at El-Nasser Sandy clay soil . The total amount of applied water at El-Nasser region were 82.8, 76.5 and 61.4 % for surge irrigation 10 min cycle time, surge irrigation 15 min cycle time and surge irrigation 20 min cycle time respectively, compared with continuous irrigation. The values were 86.0, 80.3 and 68.7 % for the same treatments at El-Kaher region

EL-Saadawy (1997) studied the effect of cycle time, irrigation method and discharge on advance time and total amount of applied water. He found that the values of advance time and total applied water were higher in case of continuous irrigation compared with surge irrigation. Also, he indicated that, both of advance time and applied water were decreased by increasing cycle time in case of surge irrigation.

Eid (1998) continuous irrigation was compared with four different cycle times of 25 min, 30 min, 35 min and 40 min with 0.8, 0.67, 0.57 and 0.5 cycle ratio respectively, also it was used traditional and dead levelling and 5.4 l/s. inflow rate. He found that the values of advance time and total applied water were higher in case of continuous irrigation compared with surge irrigation under dead and traditional leveling. Also, he indicated that, increasing cycle time in case of surge irrigation decreased both of advance time and applied water under dead and traditional leveling.

Mattar (2001) studied the effect of surge furrow irrigation comparing with continuous irrigation on water management at different ploughing methods. The results showed that, surge flow treatments required less time completion of the advance phase than in those continuous flow treatments at different ploughing treatments.

2.3.2 Alternative irrigation system:

Michael et al. (1972) mentioned that in the method of alternate furrow irrigation water is allowed to flow in alternate furrow keeping the in-between furrows dry, in the subsequent irrigation, water is allowed to pass through these middle furrow which are not covered in the previous irrigation. They added that wide bottom furrows having increased wetted perimeter are used to

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improve even distribution of water, this method is common when water is limited and where salt accumulation is a problem.

Fischbach and Mulliner (1974) evaluated every-other furrow irrigation by using 12, 5 and 2.75 h irrigation sets. They used seven soil types in their study at Eastern Nebraska. For 12 h irrigation sets the furrow length varied from 182 m on the loamy sandy to 395 m on the silty clay loam. To evalute every-other furrow irrigation with 2.75 and 5 h irrigation stes, the furrows had 380 m length and 0.25% slope. They found that, alternate- furrow irrigation tended to decrease the average size of irrigation by about 29%. They added that water moved lateraly from the irrigated furrow to the dry furrow in 5 h and 2.75 h irrigation time for the first and third irrigation respectivelly.

Musick and Dusek (1974) irrigation of alternate furrows was compared with irrigation of every furrow on Pullman silty clay loam soil with Potato. Their results showed that, the soil water storage under alternate-furrow irrigated beds was only slightly lower than under every furrow.

Khater (1992) studied the water consumptive use and some agronomic traits for some maize varieties under three different irrigation methods. All furrows were irrigated by plastic siphon tubes of 2 inches diameter, irrigated furrows by siphon tubes of 2 inches diameter and skipping other without irrigation and traditional surface irrigation as control. His results showed that, under three varieties of maize the other-row irrigation method reduces the water applied compared with to the traditional surface irrigation.

Abdel-Maksoud and Khater (1997) studied the effect of Alternate furrow irrigation on some soil water relations and yield for cotton and maize. The discharge average was 6 l/s. They reported that, applying the water to either cotton or maize crops through the other-row technique tended to reduce the total water applied for cotton and maize crops comparable to the traditional irrigation method.

EL-Sherbeny et al. (1997) compared between traditional furrow irrigation and alternate irrigation in clay soils. Three lengths of furrows (15, 30 and 45) m and three different distances between furrow 50, 60 and 70 cm were used. Their results showed that, the values of advance time were higher in case of traditional furrow irrigation than alternate furrow irrigation. Recession time values had the same trend. They also added that there is no effect for width of furrow on the amount of water. The lowest amount value of water irrigation was 2729m^3/fed/season for 15m furrow length under alternate irrigation. The highest amount value of irrigation water was 2861 m^3/fed/season for 45 m furrow length under traditional irrigation.

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2.4. Impact of irrigation system on some soil water relations (infiltration rate and irrigation efficiencies):

2.4.1. Surge irrigation system:

Izuno et al. (1984) used the advanced infiltration data to characterize infiltration under surge irrigation. They reported that the benefits of surge irrigation include less advance time and water.

Ismail et al. (1985) compared surge flow border irrigation using an automatic drop gate. With conventional continuous flow. They reported that the surge flow treatments gave higher distribution uniformity. It means that that, the depth of infiltrated water was more uniform in case of surge flow than for continuous flow. Surge irrigation also had a higher potential application efficiency than cotinuous irrigation under the same inflow, by using the same amount of water.

Samani et al. (1985) said that there are two basic phenomina, which affect infiltration during the intermittent off time of surge irrigation. The two basic phenomena were redistribution of the infiltrated water in soil profile and partial sealing of the wetted soil surface. The redistribution of the infiltrated water in the soil profile during the off time was caused by the unbalanced capillary and gravity forces acting on the water that has infiltrated. The redistribution process continuous until hydraulic equilibrium is achieved. The redistribution process results in advance of the wetting front within the soil profile and the development of negative capillary pressure near the soil surface. This negative pressure will create a higher hydraulic gradient for the infiltration of water during the succeding on-time of surge flow irrigation. The second phenomenon which take place during the off-time is the consolidation of the previously wetted soil due to the development of negative pressure in the soil. During surface irrigation, the soil aggregates are weakened or partially broken due to the mechanical force of water or the slaking of the soil aggregates during the period when water is flowing.

Ghalleb (1987) found that, the value of application efficiency were higher in case of surge irrigation compared with continuous irrigation under faba bean and maize. He added that under surge irrigation, decreasing cycle ratio tended to increase application efficiency.

Testezlaf et al. (1987) investigated the infiltration behavior for continuous flow and three different surge flow regimes (20, 40, and 60 min cycle times). With each of these surge treatments, the quasi-steady infiltration rate was reduced significantly below that measured for continuous flow conditions. A rebound effect was evident with the surge treatments, where the initial infiltration rate following the off-time was higher than that the infiltration rate measured at the end of the preceding surge.

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Guirguis (1988) reported that, increasing water application efficiency for surge flow than continuous flow can be attributed to the surface seal that is caused by the intermitted wetting and the surface hydraulic roughness of the wet advance.

Zein El-Abedin (1988) stated that the application efficiency was over 80 percent by using the surge flow, while it was 40 percent for continuous irrigation.

Kemper et al.(1988) postulated that the reduction degree of infiltration is variable and difficult to predict. Mechanisms that help surge irrigation reduces infiltration rate include the following

a) consolidation of the furrow perimeter due to increased soil water

b) tension during flow interruptions,

c) filling of cracks which develop during flow interruption with bed

d) load during the following surge ,

e) forced sediment of suspended sediment on the furrow parameter when the water supply is interrupted, and

f) greater sediment detachment and movement caused by more advance of the surged stream front.

Hymphreys (1989) showed that surge flow generally results to reduce soil infiltration rate and this enables the wetting front to advance more quickly than conventional irrigation technique. He, also, added that the greatest effect on infiltration rates occurs during the advance phase on light-textured soils and during the first irrigation of the seasons, or after tillage.

Shin and Chang (1990) compared surge flow furrow irrigation efficiency with continuous flow furrow irrigation efficiency for up land crops in Taiwan. They found that surge flow irrigation was more efficient than continuous flow irrigation. It reduced irrigation time by about of 30% and also the amount of water reduced by about of 30% in a silt loam soil.

Unger and Musick. (1990) reported that on moderately permeable soils, furrow compaction, surge irrigation, and precision water application practices help to reduce water losses resulting from high infiltration rates and deep percolation.

Broner (1991) compared surge irrigation and cabligation (the automation of gated pipe irrigation and automatic application of continuous stream size cutback). He reported that surge irrigation was found to be affordable for developing countries. Cabligation needed considerable adjustments and fine tubing.

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El-Amir (1991) demonstrated that mechanisms by which surge flow irrigation reduces infiltration rate in a sandy loam soil include:

i) consolidation of the soil surface due to increased soil water tension during flow interruption, and

ii) air entrapment between successive rewetting (pulses).

The dominance of one mechanism or the other depends on the history of the soil. In recently tilled soil, both mechanisms are effective, whereas in soil partially consolidated or compacted, air entrapment becomes the dominant mechanism in reducing infiltration rates under surge flow irrigation.

Moustafa (1992) he reported that, the surge flow technique has a highly significant effect on water application efficiency than the continuous irrigation system because less water is nedded to fill the effective root zone, and less water is lost by run-off and percolation. Also he found that, the surge flow technique has a highly significant effect on water distribution uniformity than the continuous irrigation system because most of water used can be distriputed with high uniformity in the effective root zone.

Monserrat et al. (1993) compared between surge and continuous irrigation by using six furrows trials and two border trials. They mentioned that a significant reduction in infiltration rate was measured with surges.

Varlev et al. (1995) reported that surge irrigation had more uniformity streams advance than continuous flow. Extremely unifom water distribution over the furrow length was obtained by overlapping surges. Their results indicated that, surge irrigation decreased deep percolation losses, run off and water applied than continuous irrigation.

El-Zaher et al. (1996) studied the effect of surge flow irrigation on water application efficiency of faba bean under calcareous soil condition in two different sites (EL-Kaher and EL-Nasser farms).They showed that, the average values of application efficiency were increased by increasing the cycle time in both two sites. Also , the application efficiency was higher in case of surge irrigation than continuous irrigation.

Amali et al.(1997) studied soil water variability under surge furrow and continuous furrow irrigation in a clay loam soil. they concluded that, the spatial variabilities in soil water contents of the top 0.9 m of fieled with clay loam soil were very similar when irrigated with the surge furrow and continuous furrow methods, the non-uniformities in the infiltration rates along the furrows have not been appreciably reduced by surging.This lack of appreciable difference is a result of

1-random distribution of surface cracks along the furrows aftre each irrigatiom,

2- random movement and settling of surface particles during each irrigation

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They added that , the data indicate that an advantage of surge on fine soils may be a reducation in the volume of run off water.

Zein El-Abedin and Ismail (1998) they used a laboratory infiltrometer to measure the infiltration rate under both surge and continuous flow. They found that the quasi-steady infiltration rate was reduced significantly below surge than that measured for continuous flow conditions.

Mattar (2001) reported that surge irrigation with 4 surges (6-11-15-18) min on and 15 min off between the surges, increased the value of water application efficiency when compared with continuous flow at the same ploughing methods.

2.4.2.Alternative irrigation system:

Milligan (1973) stated that about 50 % of water applied for cotton, sorghum and corn could be saved using the alternate flow irrigation.

Ley and Clyma (1981) examined both every furrow irrigation and alternative furrow irrigation practices in Northern Colorado. They found that deep percolation losses from these yields were frome 0 to 57 % of the water applied. They also added that the amount of overirrigation increased as the length of furrow increased. Better knowledge of two-dimensional water infiltration and water-holding capacities for different soil types would help minimize overirrigation yet provide optimum water supplies to the crop.

Benjamin et al. (1994) analyzed water flow patterns and soil recharge for every furrow irrigation and alternate furrow irrigation , for loamy sand and clay loam soils. They reported that, every-furrow irrigation gave more uniform water content distribution than alternate furrow irrigation for the loamy sand. Much of the infiltration water moved directly downword rather than across the row for alternate furrow irrigation. They also added that for the clay loam soil, the water content differences between every furrow irrigation and alternate furrow irrigation were smaller than for the loamy sand.

EL-Sherbeny et al. (1997) revealed that alternate furrow method saved about 22-28 % of irrigation water. The water application efficiency of alternate method were higher than traditional method. They added that soil water movement in lateral directions were higher than in vertical direction under alternate furrow method and vise versa for traditional furrow method.

Abdel-Maksoud and Khater (1997) compared alternate irrigation system with continuous furrow irrigation. They showed that water distribution efficiency under alternate irrigation did not greatly influence. However this result could be considered an advantage for the tested irrigation technique particularlly under conditions of less irrigation water applied.

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2.5. Effect of irrigation methods on yield and water relations of crop:

2.5.1. Surge irrigation system:

Musick et al. (1987) showed that both of seasonal water use and maize yields were reduced by using surge flow irrigation in clay loam soil

Ghalleb (1987) compared between continuous flow irrigation and surge irrigation with different cycle rates 1/2, 1/3 and 1/4 for different field crops.His results indicated that, surge irrigation increased grain yield and water use efficiency than continuous irrigation. He also added that, increasing cycle rate tended to increase grain yield and water use efficiency.

Zaghloul (1988) found that in surge flow method the average value of water use was increased by about of 20% while the average value of grain yield was increased by about of 21% by using surge irrigation method. He also added that the grain increased by increasing the cycle ratio,soil slope and inflow rate.He found that, the maximum value of grain yield was obtained at 0.8 cycle ratio.

Osman (1991) proposed that the corn yield increased by about of 0.46 ton/fed. at Sakha and by 0.8 ton/fed. at Abis by using surge furrow irrigation with a cycle rate of 1/3 comparing with continuous flow. He also, added that surge irrigation leads to increase water use efficiency.

El-Zaher et al. (1996) studied the effect of surge flow irrigation on water use efficiently and productivity of faba bean under calcareous soil conditions in two different sites (El-Kaher and El-Nasser) farmes. They showed that the surge treatment 20 min. cycle with 5 min.on and 15 min. off gave 1.506 and 0.859 ton/fed as seed yield. at El-Kaher and El-Nasser respectively while the continuous treatment gave 1.026 and 0.703 ton/fed. as a seed yield at the same sites.

Eid (1998) compared continuous flow irrigation with surge irrigation. He showed that grain yield of corn that obtained under surge flow treatment was higer that obtained with continuous method. The overall average water use efficiency under the continuous flow irrigation were 0.79 and 0.61 kg/m^3 for dead and traditional levelling respectively, the corresponding values for surge flow treatments were with an average of 1 and 0.72 kg/m^3 under dead and traditional levelling respectively.

Mattar (2001) claimed that surge irrigation had the highest value of maize grain yield when compared with continuous flow. Also it recorded the highest value of field water use efficiency.

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2.5.2.Alternative irrigation system:

New (1971) compared every furrow irrigation and every-other furrow irrigation with 91.5cm spacing and 80.4 m furrow length. His results indicated that, every-other furrow irrigation reduced water intake by one-third, while grain sorghum decreased from 3.71 to 3.26 Mg/fed. He also added that, every-other furrow irrigation increased yields slightly when the amount of water applied during five irrigation to every-other furrow irrigation equaled the amount applied during four irrigation to every furrow irrigation.

Fischbach and Mulliner (1974) showed that the effect of every furrow irrigation system and every-other furrow irrigation system on corn grain yield, They added that there is no significant difference at the 5% level in corn grain yields between every-other furrow irrigation when the water is run in the same furrow and every-other furrow irrigation when the water was alternated between adjacent furrows.

Crabtree et al. (1985) stated that for alternate furrow irrigation when compared with every furrow irrigation but irrigation water use decreased by 40%, the greatest yield losses for alternate furrow irrigation were at locations farthest from water source, which indicates that inadequate water was being applied.

Camp et al. (1989) an experiment was conducted for a three year period (1985-1987) to evaluate three micro-irrigation lateral placements and two irrigation application modes for corn in a coarse-textured southeastern coastal plain soil. Tubing placements were surface in-row, subsurface in-row, and surface alternate middle. Irrigation application modes were continuous and pulsed. The results showed that, yields were significantly lower for the surface alternate middle treatments in 1986 and for the surface alternate middle pulsed application mode treatment in 1987. They added that, in 1986 the reducation in yield caused by extreme drough during the early part of the growing season when the corn root system was not large enough to reach the irrigated area.

Khater (1992) claimed that traditional furrow irrigation had the highest value of water use efficiency and corn grain yield as a compared with the other-row irrigation for the same irrigation intervales (15 days).

Zongsou et al. (1997) studied the effect of controlled roots-divided alternative irrigation on water use efficiency in maize. They reported that in maize irrigation of roots to 60% of field water capacity, saved 35.6% of irrigation water with a biomass decreased only 9%.

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3- MATERIALS AND METHODS

The field experiments were carried out in the Farm of Rice Mechanization Center (RMC), Meet El-Deepa, Kafr El-Sheikh Governorate during the successive season of 1999-2000. The aim of the present work was to improve and increase the efficiency of surface irrigation method.The soil texture was clayey and Table 1 indicates the mechanical analysis of the soil.

Table 1: Some physical analysis of experimental site: -

Soil depth	Particle size distribution			Texture	Bulk density	Field capacity, %
	Sand,%	Silt, %	Clay,%			
0 - 15	15.6	19.35	64.97	Clay	1.1	44.80
15 - 30	20.4	14.3	65.3	Clay	1.21	41.45
30 - 45	17.09	17.0	65.01	Clay	1.28	39.27
45 - 60	13.05	15.73	66.13	Clay	1.3	37.20

3.1. Infiltration rate:

Infiltration rate was determined using double cylinder infiltrometer as decreased by ***Michael et al (1929).*** The measurements were taken at different sites along the furrows in three replicates for each treatment. Table 2 and Figure 1 presented the soil infiltration rate before soil preparation.

3.2.3. Experimental layout:

Maize TWC310 variety was sown in June 7, 2000. All agricultural practices were the same as recommended for the area except the furrow length and the irrigation treatments under study. The experiment was arranged in split-split plot design with three replicates as shown in Fig 2. The main plot was assigned as three methods of irrigation, while the sub plot treatments were the furrow length practices, and sub sub plot treatments were the discharge practices. The field was ploughed by a seven mounted shares chisel plough which mounted on Naser tractor 48.49 Kw (65hp); the ploughing depths were 20 cm .Traditional leveling was used. The furrow spacing was designed to be 0.7 meter in order to suit the flow rates used for testing. Planting was practiced manually in the middle of the furrows with one plant per hill, spacing between hills were 25 cm to present 24000 plant/fed. 100kg/fed. Calcium super phosphate 16% P_2O_5 was added before sowing. Ammonium nitrate (33.5% N) was added with a rate of 90 kg N/fed, divided in two equal doses before El-Mohaya and first irrigation as recommend by

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Table 2: Average of accumulative infiltration (Cum.I.) and infiltration rate (I.R.) before soil preparation

Elapsed Time (min.)	R_1		R_2		R_3		Average	
	Cum. I mm	IR mm/h	Cum. I mm	IR mm/h	Cum. I mm	IR mm/h	Cum. I mm	IR mm/h
0.0	0.0	341	0.0	375	0.0	352	0.0	356
5	28.4	315	31.25	362	29.3	340	.29.65	339
10	54.65	226	61.45	278	57.6	250	57.9	251.3
20	92.35	130	107.75	152	99.3	170	99.8	150.7
30	114.05	92	133	101	127.8	112	124.95	101.6
45	137.05	54	149.25	65	155.8	65	147.36	61.33
60	150.55	42	165.5	43	172.05	41	162.7	42
90	171.55	35	187	33	192.55	28	183.7	32
120	189.05	29	203.5	30	206.55	28	199.7	29
180	218.05	29	233.5	30	234.55	28	228.7	29

R = replicate.

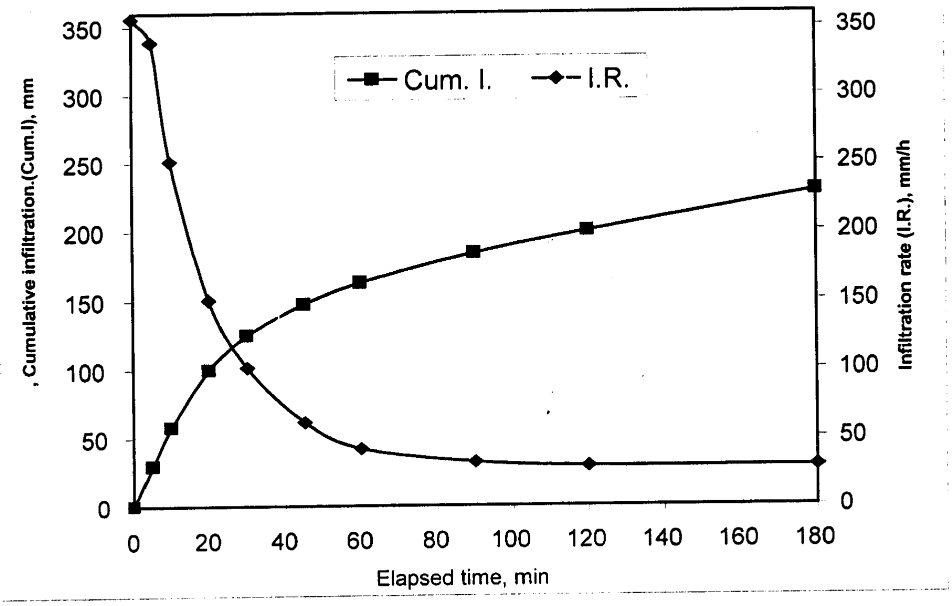


Fig. 1: Average of accumulative infiltration and infiltration rate before soil preparation

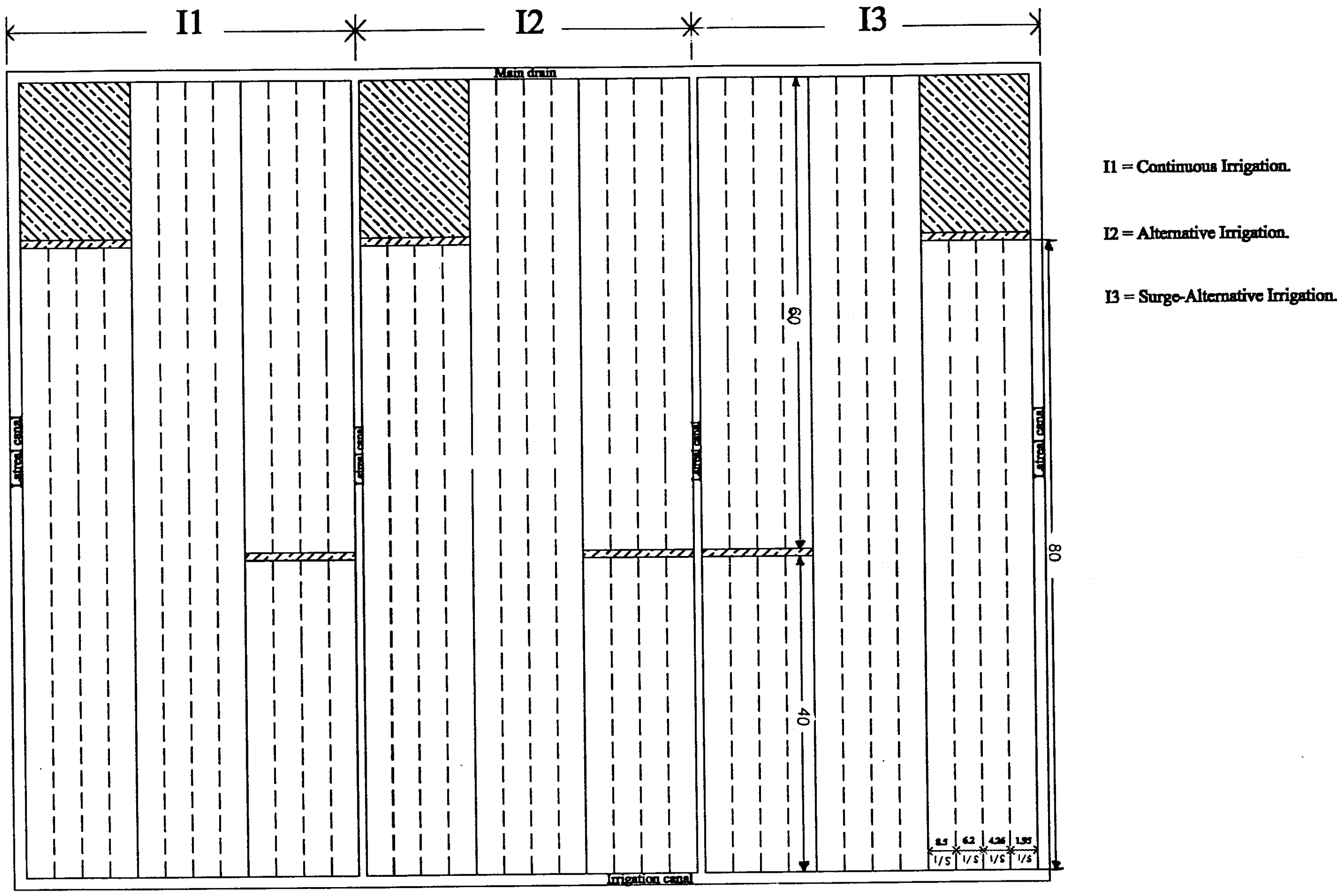


Fig. 2 : Schematic diagram showing the irrigation treatments

El-Zeiny et al. (1989). Hoeing, thinning and weed control was practiced manually after El-Mohaya irrigation.

3.3 Treatments: -

3.3.1 Main treatment:

The main treatment included on three of irrigation methods as follows:-

a) Continuous furrow irrigation **(c),**

b) Alternative furrow irrigation **(A),** and

c) Surge-Alternative furrow irrigation **(S-A)** with cycle ratio of 0.3 (3 min. on and 7 min. off).

3.3.2 Sub treatments:

It had four different furrow lengths of, 40, 60, 80 and 100 m, respectively.

3.3.3 Sub sub treatments :

The present study had four different of discharges, 1.95, 4.26, 6.2 and 8.5 l/s, respectively.

For continuous irrigation, the irrigation intervals were 15 days after the post irrigation (El-Mohaya). But, in case of alternative and surge-alternative irrigation methods, the irrigation intervals were 10 days. Plastic pipe 50 cm length each sub emerged in the upper end of the furrows was used to convey the irrigation water according to the required flow rate. These pipes had four different of inner diameter 5.0, 7.5, 10.0 and 12.5 cm, respectively .The temporary dam was used to keep the water level constant, which measured several times during irrigation. The crop was harvested at 20th of Oct. 2000.

3.4.Statistical analysis:-

Split-split plot design was used in statistical analysis where main plot was irrigation systems. Sub plot was furrow length and sub sub plot was flow rate. The mean values were compared by L.S.D. test and Duncan multiple range test.

3.5. The previous factors were effected on the following:

3.5.1. Soil moisture:

Soil moisture content was measured by using gebsum block, its dimensions were 5x2.5x1 cm , before and 2 days after each irrigation ,Fig3a. The gebsum block were put at different of soil depths (0-15, 15-30, 30-45 and 45-60) cm to measure the soil moisture distribution. Soil moisture meter (Model J-3) Fig 3b was used to measure the electrical resistance for the gebsum block, after that soil samples were taken and dried at 105°C for 24 h at the same time .The soil moisture meter was used to measure the electrical resistance. Excel program was used to drive the relationship between moisture content (Y) and electrical resistance (X) .

$$Y = -0.099\, x^2 - 2.3\, X + 47.2 \qquad \textbf{3.1}$$

Where:-

Y = Moisture content, ranged from (25-43 %)

X = Electrical resistance. ranged from (1.5-7.5 ?)

3.5.2. The advance time :

The advance time of the water flow for each treatment was recorded when the water front was reached at station along the furrow. The number of surges in case of surge - alternative were recorded when the irrigation water reached at about of 95 %of the furrow length.

3.5.3. Applied irrigation water (Q):

The volume of water applied for each plot was calculated by the following equation:

$$Q = q \times T \times n \qquad \textbf{3.2}$$

Where:

Q = Water volume l/plot,

q = Irrigation flow rate per furrow, l / min ,

T = Total time irrigation per furrow that calculated by using stop watch, min., and

n = Number of furrow per each plot.

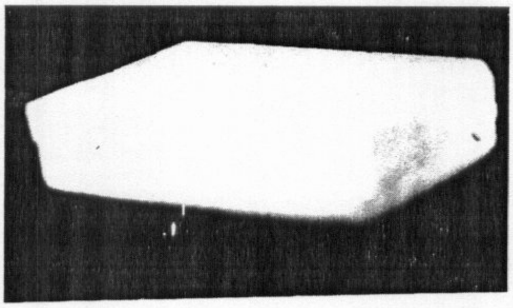
The irrigation flow rate per furrow was calculated by using following ***Israelson and Hansen equation (1962):***

$$q = 0.0226 \;\; D^2 \;\; h^{\frac{1}{2}} \qquad 3.3$$

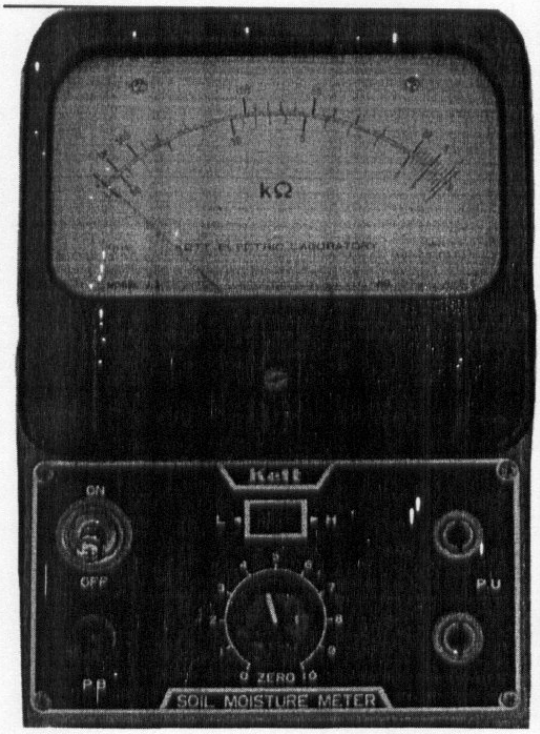
Where: -

h = Average effective head, cm, and

D = Inside diameter of the pipe,cm.



(a) Gebsum block



(b) Soil moisture meter (J-3).

Fig 3 : (a) Gebsum block and (b) Soil moisture meter (J-3).

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3.5.4. Application efficiency (Ea):

Application efficiency is the ratio of the average depth of irrigation water infiltrated and stored in the root zone to the average depth of irrigation applied water. It was calculated for the 60 cm soil depth according to ***Michael (1978) and James (1988)*** as follow:

$$Ea = \frac{Ws}{Wf} \times 100 \qquad 3.4$$

Where:

Ea = Water application efficiency, %;

Ws = Amount of water stored in the root zone, m^3 and

Wf = Amount of water added to each plot, m^3 .

Application efficiency was calculated after El- Mohaya irrigation for 1^{st}, 3^{rd} and 5^{th} irrigation for continuous irrigation and for 1^{st}, 4^{th} and 7^{th} irrigation for alternative and surge alternate furrow irrigation.

3.5.5. Water distribution efficiency (E_d):

It was calculated according to **James (1988)** as follow: -

$$E_d = (1 - \frac{y}{d}) X 100 \qquad 3.5$$

Where: -

d = Average of soil water depth stored along the furrow during the Irrigation.It was calculated from three points a long the furrow run, cm and

y = Average numerical deviation from d, cm.

3.5.6. Water use efficiency (WUE)

It was measured according to **James (1988)** as follow: -

$$WUE = \frac{y}{W_a} \times 100 \qquad 3.6$$

Where: -

WUE = Water use efficiency (kg/m^3).

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y = Total grain yield (kg/fed.).

W_a = Total applied water (m^3/fed*.)

3.5.7.Inclination lines:

Traditional method of land leveling was used , furrow slope was 0.0%.

3.5.8.Yield and its components: -

3.5.8.1. Leaf area: -

It was measured for five plant leaves at 90 days from sowing by using leaf area meter model (LI-3100) Fig. 4. The theory of operation of area meter is described as follow:-

Samples are placed between the guides on the lower transparent belt and allowed to pass through the LI-3100. As a sample travels under the fluorescent light source, the projected image is reflected by a system of three mirrors to a solid state-scanning camera within the rear housing. This state-of-the-art optics design results in high accuracy and dependability. As the sample passes under the light source, accumulating area in cm^2 is shown on the LED display. Any adjustment in calibration is easily accomplished by measuring a standard area disk and turning the CAL screw located near the display.

3.5.8.2. Leaf area index (L.A.I): -

Leaf area index was calculated according to **El-Zeiney et al. (1989)**

$$L.A.I. = \frac{Leaf\ area\ per\ plant, cm^2}{Spacing\ area\ per\ plant, cm^2} \qquad 3.7$$

3.5.8.3. Plant height.

Plant height was measured for five plants per plot, from the ground surface to the base at 100 days from sowing date .

3.5.8.4. Root volume:-

Root volume was determined from the volume of water displaced by immersing the root sample in the graduated cylindrical beaker filled with tap water ***Suliman et al (1998).*** It was measured at 60 days, after 1st irrigation.

3.5.8.5. Grain yield: -

Five plants from the central furrow at each treatment were randomly chosen to determine the yield for plant; the average of plant yield was multiplied by number of plants in feddan (24000 plant/fed.).

* One feddan (fed.) = 4200.83 m^2

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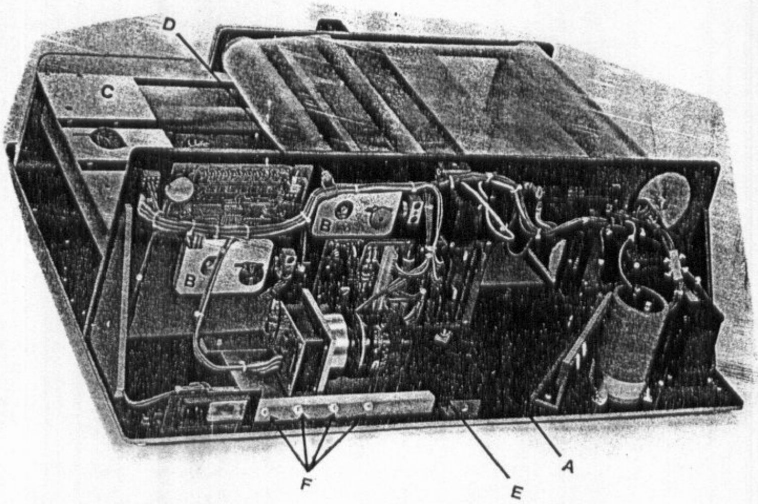

a. Main printed circuit board (paragraph 1-1c.)
b. Rear sliding bearing blocks (paragraph 2-3a.).
c. Sample guides (7.5 cm) for 0.1 mm^2 resolution.
d. Decimal selector switch to the 0.1 mm^2 position.
e. The 105 mm lens in place for 0.1 mm^2 operation.
f. Screws on outer camera pressure rail.

Fig 4: Leaf area meter

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4.RESULTS AND DISCUSSION

4.1. Advance time:

The advance rate was recorded at four stations along the furrow. The advance time is related to distance under different of irrigation methods. Figs 5,6,7 and 8 and table 3 indicated the relationship between the advance time and distance from water inlet for continuous, alternative and surge-alternative irrigation methods.

Data revealed that, the continuous irrigation required more time to complete the advance phase followed by alternative irrigation method, but surge-alternative irrigation method needed the shortest advance time. The shortest advance time was obtained by surge-alternative irrigation method with 40m furrow length and 8.5l/s discharge, where it was 4.5 min.

The results indicated that, the total irrigation time per feddan was decreased by about 9.75% under alternative irrigation method and by about of 37.22% under surge-alternative irrigation method compared to continuous irrigation method, where the average of total irrigation time for continuous irrigation method was 23.11 min/fed. This is due to the higher soil moisture content in case of alternative and surge-alternative irrigation method before the next irrigation than that in case of continuous irrigation method.

Decreasing advance time for surge-alternative can be attributed to infiltration rate reduction which results from the surface sealing and soil consolidation was happen. Increasing furrow length lead to increase advance time while increasing discharge lead to decrease advance time.

Generally the required time for water to reach the end of the furrow was longer during the first irrigation than the subsequent ones because the soil surface was still distributed and semi rough as indicated in Tables 1, 2 and 3 in appendix. These results are in agreement with **Eid (1998)**. It must be mentioned to that generally faster advance rate which was considered to help surface irrigation efficiencies.

The analysis of variance Table 13,14,15,16 and 17 in appendix indicated that, the irrigation system, furrow length and discharge had a highly significant effect on advance rate.

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Table 3: Effect of irrigation method, furrow length and discharge on advance time (min).

L	D	Continuous flow (C)				Alternative flow (A)				Surge-Alternative flow (S – A)			
		Discharge, l/s*				Discharge, l/s				Discharge, l/s			
		1.95	4.26	6.2	8.5	1.95	4.26	6.2	8.5	1.95	4.26	6.2	8.5
40	10	6.2	3.3	2.5	1.8	6	3.3	2.3	1.7	5	2.5	1.83	1.5
	20	11.8	6	4.3	3.7	11.3	6.67	4.17	3.3	9.17	4.83	3.5	2.67
	30	18.8	8.8	6.5	4.9	16.4	8.67	5.67	4.83	13.3	6.47	4.5	3.77
	40	22.8	11.1	8.2	6.5	20.7	10	7.13	6	16.3	8.06	5.6	4.47
60	15	9.67	4.8	3.5	2.67	9	4.67	3.33	2.67	6.67	3.33	2.5	1.87
	30	18.6	9	8	5.2	18	9.33	6.4	5	13.3	6.67	4.67	3.5
	45	28.6	13.8	10	7.5	25.6	11.6	9.07	6.7	19.2	9.8	6.33	5.17
	60	36	17.6	12.8	9.7	35.2	15.5	11.1	8.8	24	11.8	8.2	8.27
80	20	13.6	7.17	4.67	3.83	12.6	6.67	4.67	4	8.33	4.83	3.33	2.17
	40	26.7	13.6	9.17	7.5	24.6	13	9	7.67	16	8.67	6	4.17
	60	38.3	20.5	13.6	9.3	36	18.3	12.6	11	23.3	12	8.4	6.43
	80	49.1	24.6	17.2	13.1	43.6	22	15.8	13	29.3	14.9	10.3	8.1
100	25	18	8.83	6.67	5	17.3	8.3	6.33	4.67	13.3	6.3	4.33	3.33
	50	35.1	17.3	13	10	35	16.7	11	9.33	23.3	11.6	7.67	6.17
	75	53.1	25.3	18	13.8	52.1	23.7	16.3	14	32.6	16.1	11.2	8.67
	100	68.1	32.6	23.1	17.3	63.8	30.6	20	16.5	39.3	19.7	13.6	10.3

L = Furrow length,m.
D = Distance from water inlet,m
* = The average of discharge for five replicates.

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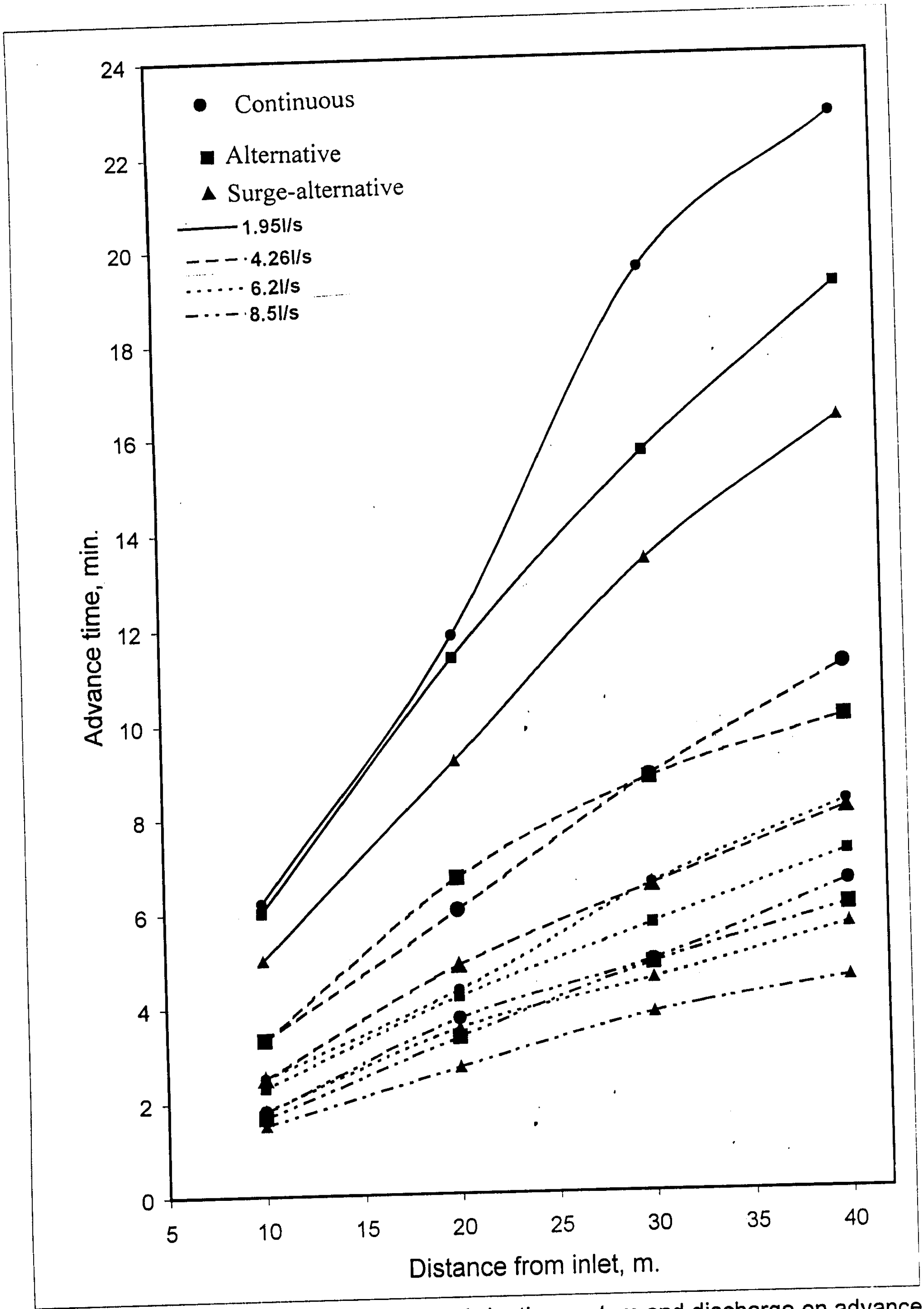

Fig. 5 :Effect of distance from water inlet, irrigation system and discharge on advance rate at 40 m furrow length

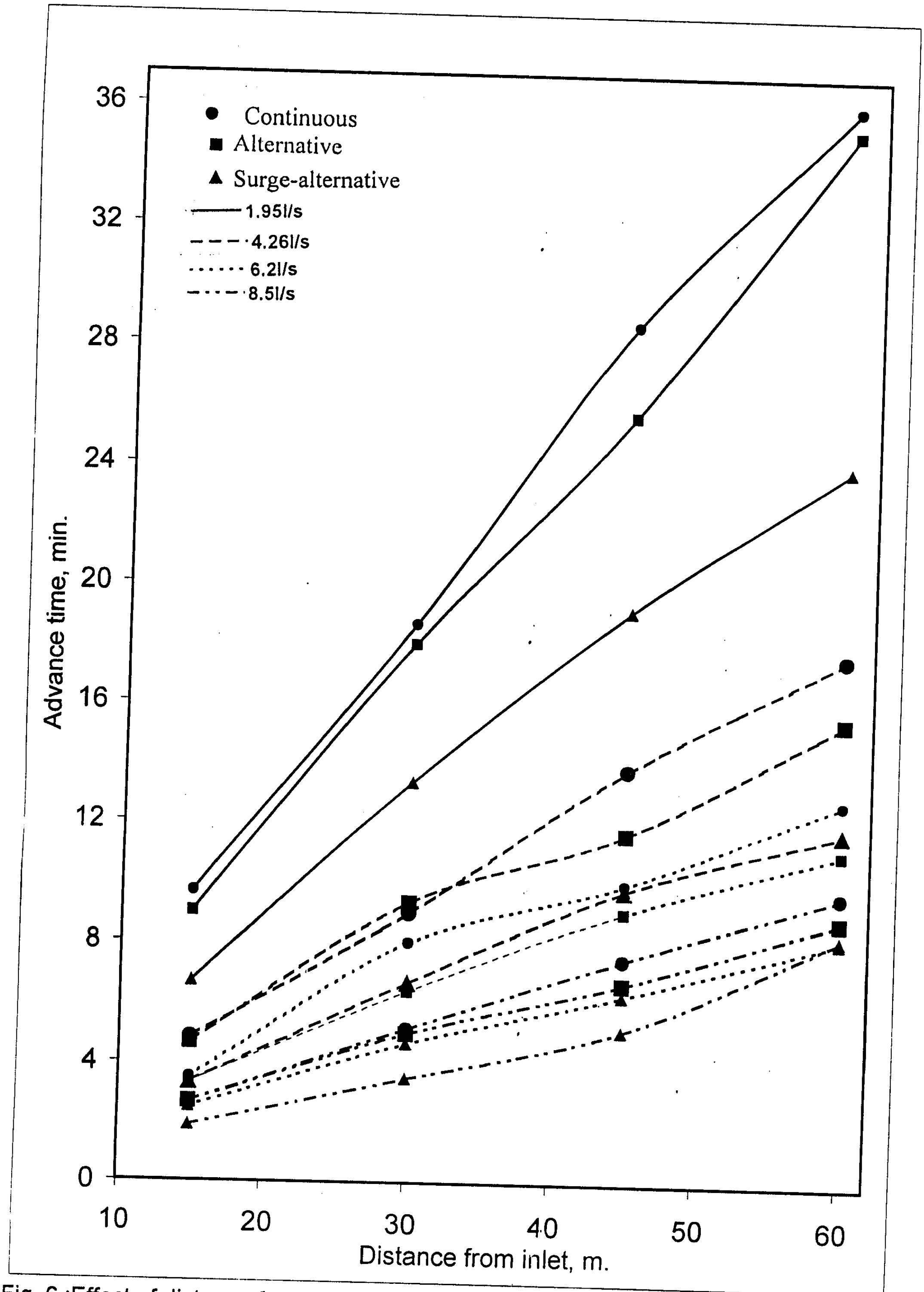

Fig. 6 :Effect of distance from water inlet, irrigation system and discharge on advance rate at 60 m furrow length

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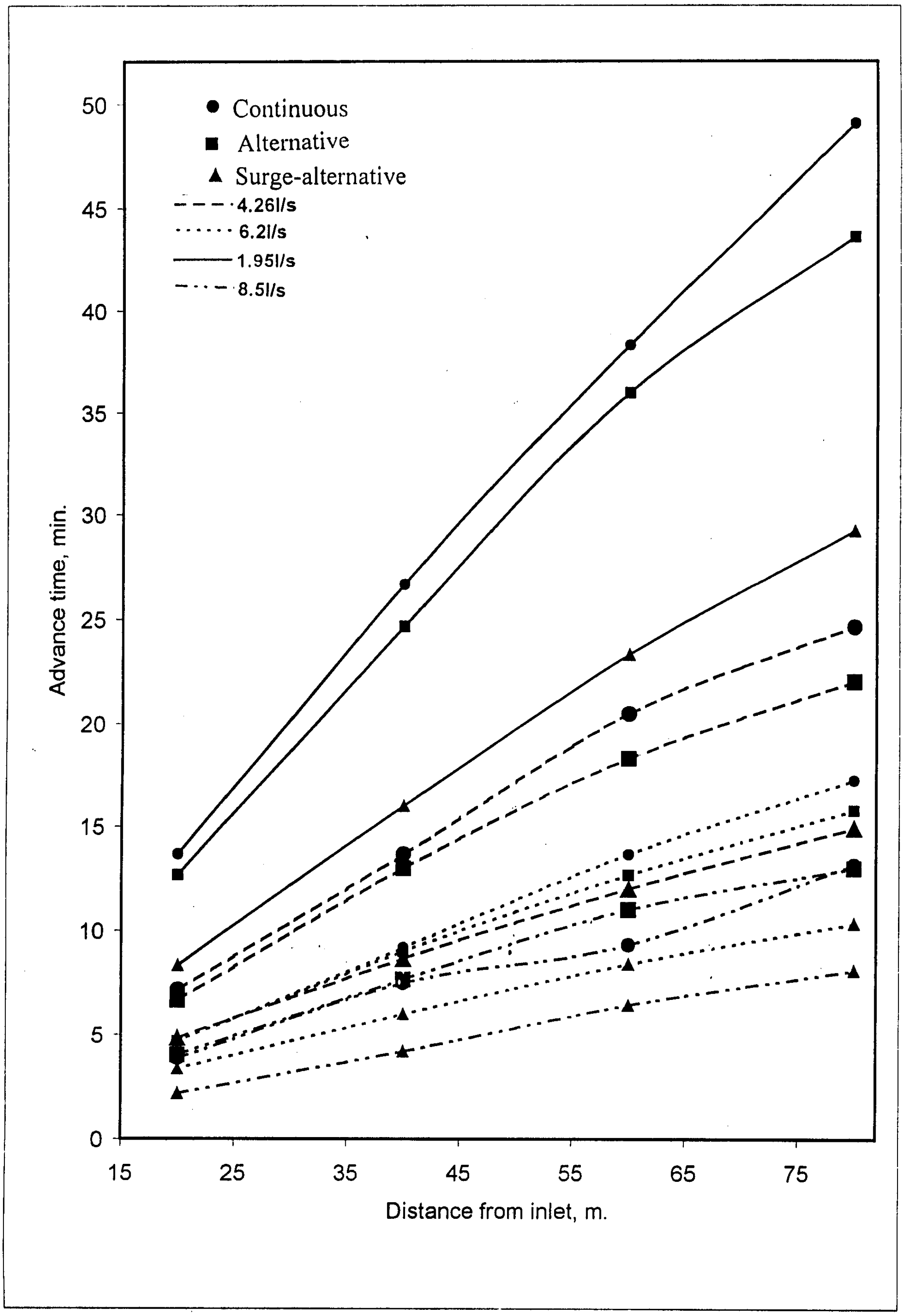

Fig. 7 :Effect of distance from water inlet, irrigation system and discharge on advan rate at 80 m furrow length

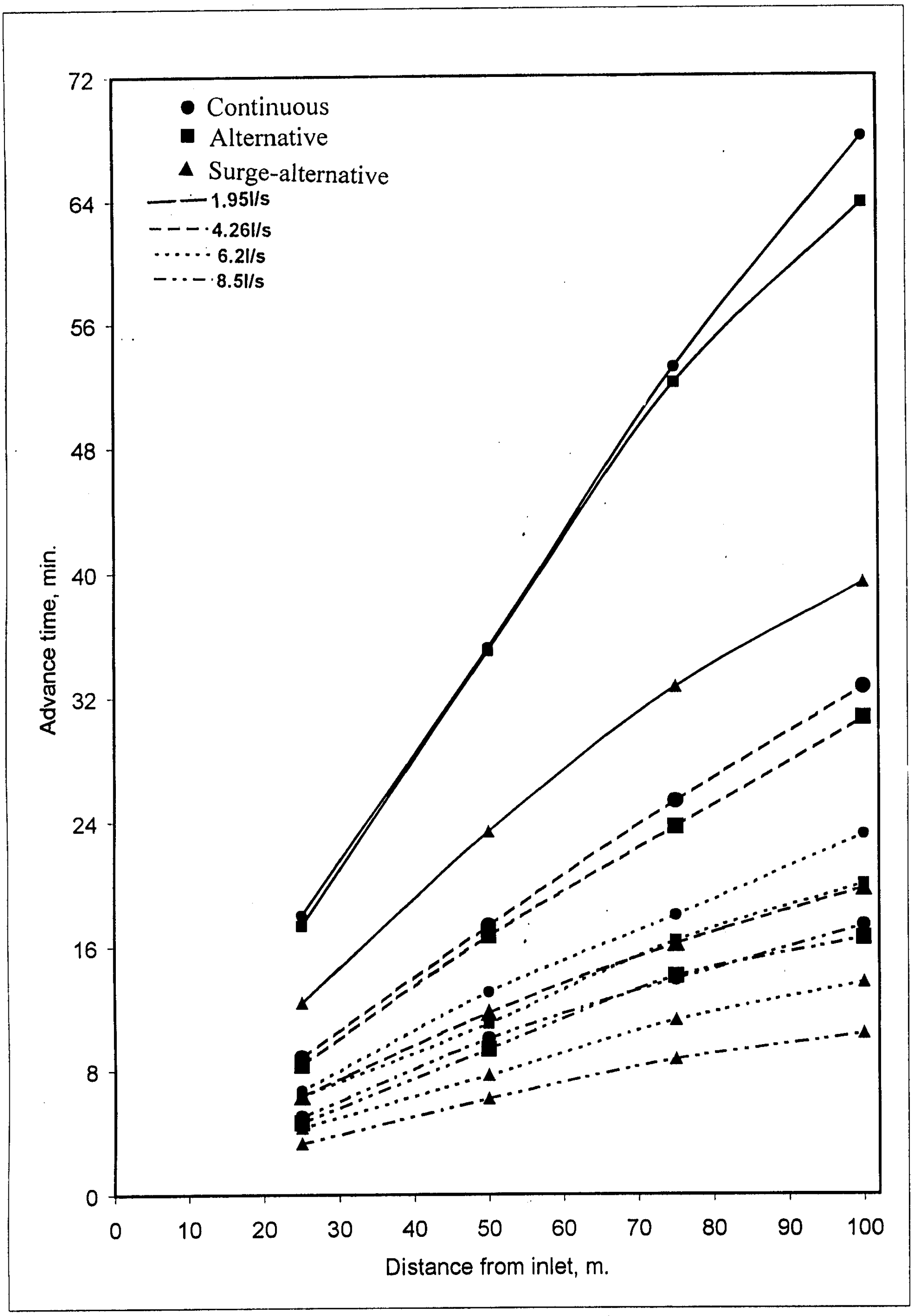

Fig. 8 :Effect of distance from water inlet, irrigation system and dischargeon advance rate at 100 m furrow length

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4.2. Applied irrigation water:

The number of irrigation during the whole season were five for continuous irrigation method and seven for alternative and surge-alternative irrigation method addition to sowing and El-Mohaya irrigation. The amount of irrigation water that added to each treatment during the season are given in Table 4 and illustrated in Fig 9. Amounts of irrigation water for every irrigation under different irrigation method are presented in Tables 4,5 and 6 in appendix.

The results indicated that surge-alternative irrigation method saved about 417 (15.45%) and 1281 (35.95%) m^3/fed. Per season compared with alternative and continuous irrigation method, respectively, where the amount of irrigation water that added under surge-alternative irrigation method was 2282 m^3/fed.per season. These results were agreement with **Khater (1992)**.

Least amount of water was used by surge-alternative irrigation method at 80m furrow length and 1.95l/s discharge where it was 2144 m^3/fed.per season, while the highest amount was used by continuous irrigation at 100m furrow length and 8.5l/s discharge where it was 3840m^3/fed.per season.

Increasing furrow length tended to increase the total water for continuous and alternative irrigation and increase water losses due to deep percolation. But, the amount of water decreased by increasing furrow length from 40 to 80m under surge-alternative irrigation, after that the amount of irrigation water increased by increasing furrow length over 80m because the number of pulses increased by increasing furrow length and improve irrigation method specifications. Also increasing furrow length more than 80m tended to increase the lateral movement.

Increasing discharge caused the total irrigation water increased for all treatments because of the run off and drainage losses which was increased by increasing the discharge.

The analysis of variance Table 18,19,20,21 and 22 in appendix indicated that, the irrigation system, furrow length and discharge had a highly significant effect on the amount of irrigation water per feddan.

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Table 4: Effect of irrigation method, furrow length and discharge on irrigation time, min., water applied/furrow, m^3 water applied/feddan, m^3 and water applied/feddan, m^3 per season.

L	The parameter	Continuous flow (C)				Alternative flow (A)				Surge-Alternative flow (S – A)			
		Discharge, l/s*				Discharge, l/s				Discharge, l/s			
		1.95	4.26	6.2	8.5	1.95	4.26	6.2	8.5	1.95	4.26	6.2	8.5
40	T_i	22.87	11.1	8.2	6.5	20.7	10	7.13	6	16.3	8.06	5.6	4.47
	W_f	2.67	2.79	2.98	3.19	2.42	2.5	2.65	3.03	1.87	2.07	2.07	2.27
	W_{fed}	400.7	419	446	478.7	180.3	188.6	195	222.6	141.67	152	156	170.3
	W_{season}	3227	3382	3500	3644	2487	2520	2651	2756	2216	2278	2620	2680
60	T_i	36	17.67	12.8	9.7	35.2	15.5	11.1	8.8	24	11.8	8.2	8.27
	W_f	4.21	4.51	4.66	4.92	3.72	4	4.08	4.57	2.81	3.03	3.06	3.188
	W_{fed}	421.3	451.7	466	492.3	186	198	203	226.6	139.7	145.3	151.67	155.3
	W_{season}	3334	3440	3528	3680	2518	2592	2606	2756	2212	2251	2271	2388
80	T_i	49.1	24.6	17.2	13.1	43.6	22	15.8	13	29.3	14.9	10.3	8.1
	W_f	5.75	6.25	6.38	6.67	5.11	5.66	5.88	6.6	3.42	3.85	3.85	4.13
	W_{fed}	431	469	478.3	500	192.3	210.3	218	242.6	128.3	141.6	144.67	150.6
	W_{season}	3402	3577	3601	3740	2552	2677	2743	2906	2144	2205	2224	2254
100	T_i	68.1	32.6	23.1	17.3	63.8	30.6	20	16.53	39.3	19.7	13.6	10.3
	W_f	4.96	8.38	8.53	8.67	7.47	7.86	7.46	8.4	4.6	5.07	5.05	5.27
	W_{fed}	477.3	507	511.7	520	223	233	224	249.3	138.3	149.3	152.7	156.3
	W_{season}	3620	3730	3763	3840	2780	2849	2812	2963	2201	2265	2291	2312

T_i = Irrigation time, min., W_f = Water applied/furrow, m^3 W_{fed} = Water applied/feddan, m3.
L = Furrow length, m. W_{season} = water applied/feddan, m^3 per season.
* = The average of discharge for five replicates.

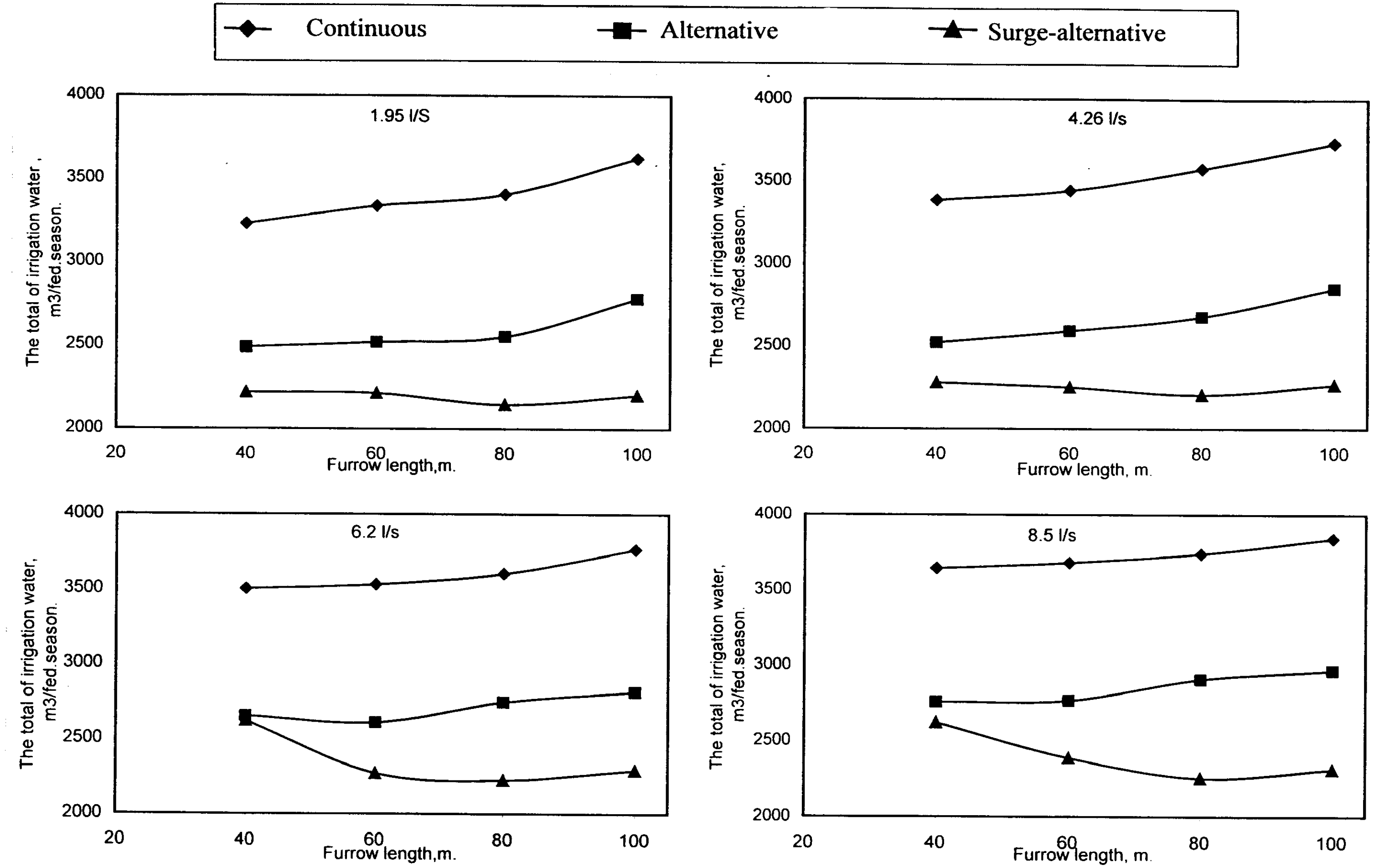

Fig. 9 : Effect of furrow length and irrigation method on total of irrigation water, m^3 under different discharges.

4.3.Infiltration rate (IR):

Basic infiltration rate was measured at three sites along the furrow (up, middle and down) four time during the irrigation. The first one was before planting, the second one was after El-Mohaya irrigation, the third one was at middle of the season while the last one was at the end of the season. Basic infiltration rate was 29mm/h and 25.5mm/h for first and second times respectively. Basic infiltration rate at middle and end of the season presented in Table 5 and figure 10 illustrated the basic infiltration rate at end of the season.

The results indicated that surge-alternative irrigation method had the lowest values of basic infiltration rate because, surge-alternative irrigation method tended to (a) consolidation of the furrow perimeter due to increased soil water tension during flow interruptions, (b) filling of cracks which develop during flow interruptions with bed load during the following surges, (c) forced settlement of suspended sediment on the furrow perimeter when the water supply is interrupted, and (d) greater sediment detachment of the surged stream front, ***Kemper et. al. (1988)***.

The average values of basic infiltration rate at the end of the season were 19.17, 21.24 and 21.7 mm/h for surge-alternative, alternative and continuous irrigation methods respectively. Also the results showed that, basic infiltration rate under three irrigation methods was decreased during the season, **Malano (1982)** and **Eid (1998)** obtained similar results.

Increasing furrow length lead to increase basic infiltration rate for continuous and alternative irrigation methods where lateral movement increased, while basic infiltration rate decreased by increasing furrow length under surge-alternative irrigation method. Increasing water discharge lead to increase basic infiltration rate under different irrigation methods, where cracks formation increased by increasing water discharge. These results are in agreement with **Moustafa (1992)**.

The statistical analysis showed that, the irrigation methods, furrow length and water discharge and their interaction had a highly significant effect on basic infiltration rate as shown in Tables 23,24,25,26 and 27 in appendix.

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Table 5: Effect of irrigation method, furrow length and discharge on infiltration rate at middle and end of the season (mm/h).

Furrow length, (m)	Date	Continuous flow (C)				Alternative flow (A)				Surge-Alternative flow (S – A)			
		Discharge, l/s*				Discharge, l/s				Discharge, l/s			
		1.95	4.26	6.2	8.5	1.95	4.26	6.2	8.5	1.95	4.26	6.2	8.5
40	22/8	21	22	22	24	21	21	23.5	24.5	21.5	22	22	23
	15/10	19.9	20.4	21.5	22	19.5	20	21	21.5	19.4	19.8	20.8	21.6
60	22/8	22	22.5	23.5	24	21	22	23	24.5	22	22	19.5	19
	15/10	20.2	21.1	22	22.5	19.8	20.8	21.3	22	18.9	19	19.4	19.8
80	22/8	22.5	23	24.5	25	22	22.5	23.5	25	20	20	18	17.5
	15/10	20.3	21.5	23	23.5	20	21	22.2	22.8	18.2	18.6	19	20.6
100	22/8	23.5	24	25	25	23	24	24.5	25.5	19	18.5	17	16
	15/10	20.5	22	23	23.9	20	21.8	22.5	23.6	17.1	17.5	18	19

* = The average of discharge for five replicates.

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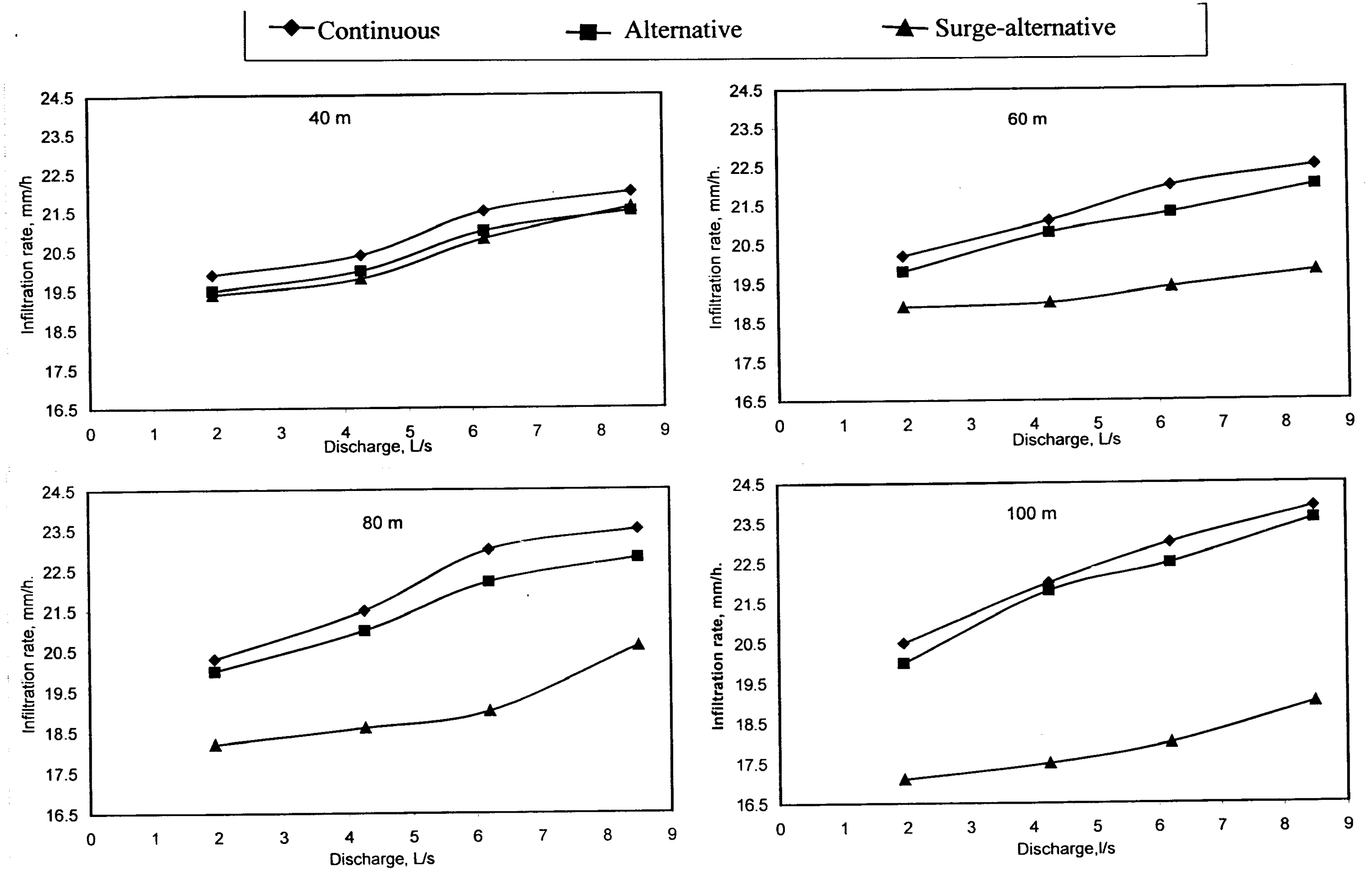

Fig. 10 : Effect of water discharges and irrigation system on basic infiltration rate mm/h under different furrow lengths.

4.4. Soil moisture distribution:

Tables 7,8,9,10,11 and 12 in appendix indicate that the soil moisture content before irrigation and two days after irrigation. That effected by irrigation methods, furrow length and water discharge. The soil moisture distribution was described as an infiltration depth at field capacity and presented in Figs 11,12 and 13 for different irrigation methods.

The results revealed that, the alternative and surge-alternative irrigation methods had developed soil moisture distribution along the furrow compared with continuous irrigation method. The excess depth of water for alternative and surge-alternative irrigation methods were decreased by about 39.3% and 44.17% compared with continuous irrigation method. The lowest value of irrigation water losses (excess water) was obtained with surge-alternative irrigation method at 40m furrow length and 1.95 l/s water discharge.

Continuous irrigation method at 100 m furrow and 8.5 l/s water discharge presented the highest value of irrigation water losses.

Increasing furrow length tended to increase both of excess water at the head of the furrow and deficit water at the tail of the furrow for the different of irrigation methods.

Generally, increasing water discharge tended to increase excess water and decrease the deficit water.

4.5. Water application efficiency (WAE):

Water application efficiency (WAE) is one of the most important criteria that used to describe field irrigation efficiency. The water application efficiency is the ratio between water storage in the root zone to total water applied. The high Water application efficiency means that less deep percolation below the crop root zone and less tail water of furrow ***Samani et al (1985)***.

Data presented in Table 6 and illustrated in Fig. 14 showed that, the alternative and surge-alternative irrigation method had developed the water application efficiency compared with continuous method because alternative and surge-alternative irrigation used amount of irrigation water that less than that needed continuous irrigation method and increase amount of water stored in root zone , that results from decreasing water losses by infiltration rate .

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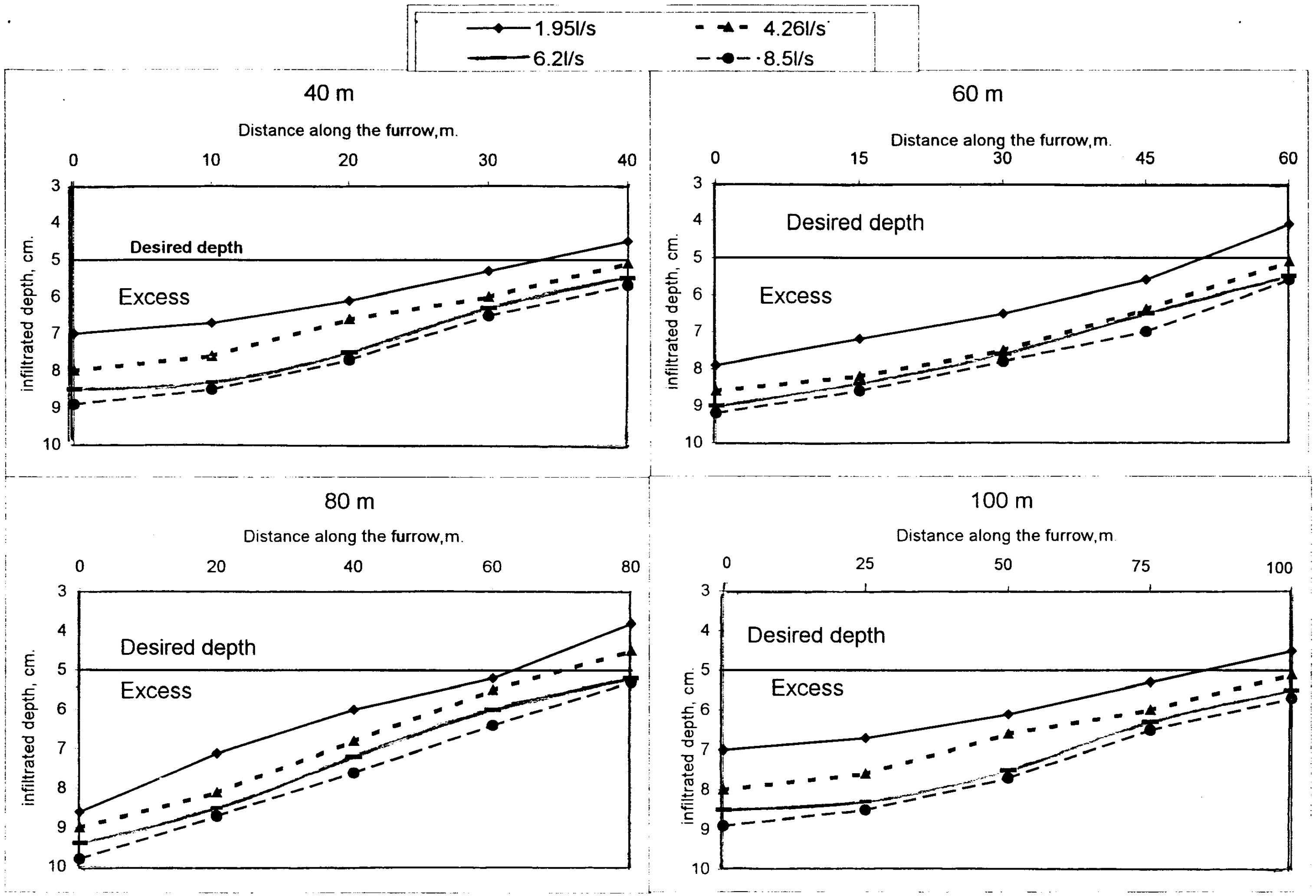

Fig. 11 : Effect of water discharge and furrow length on excess and deficit infiltrated depth under continuous irrigation method.

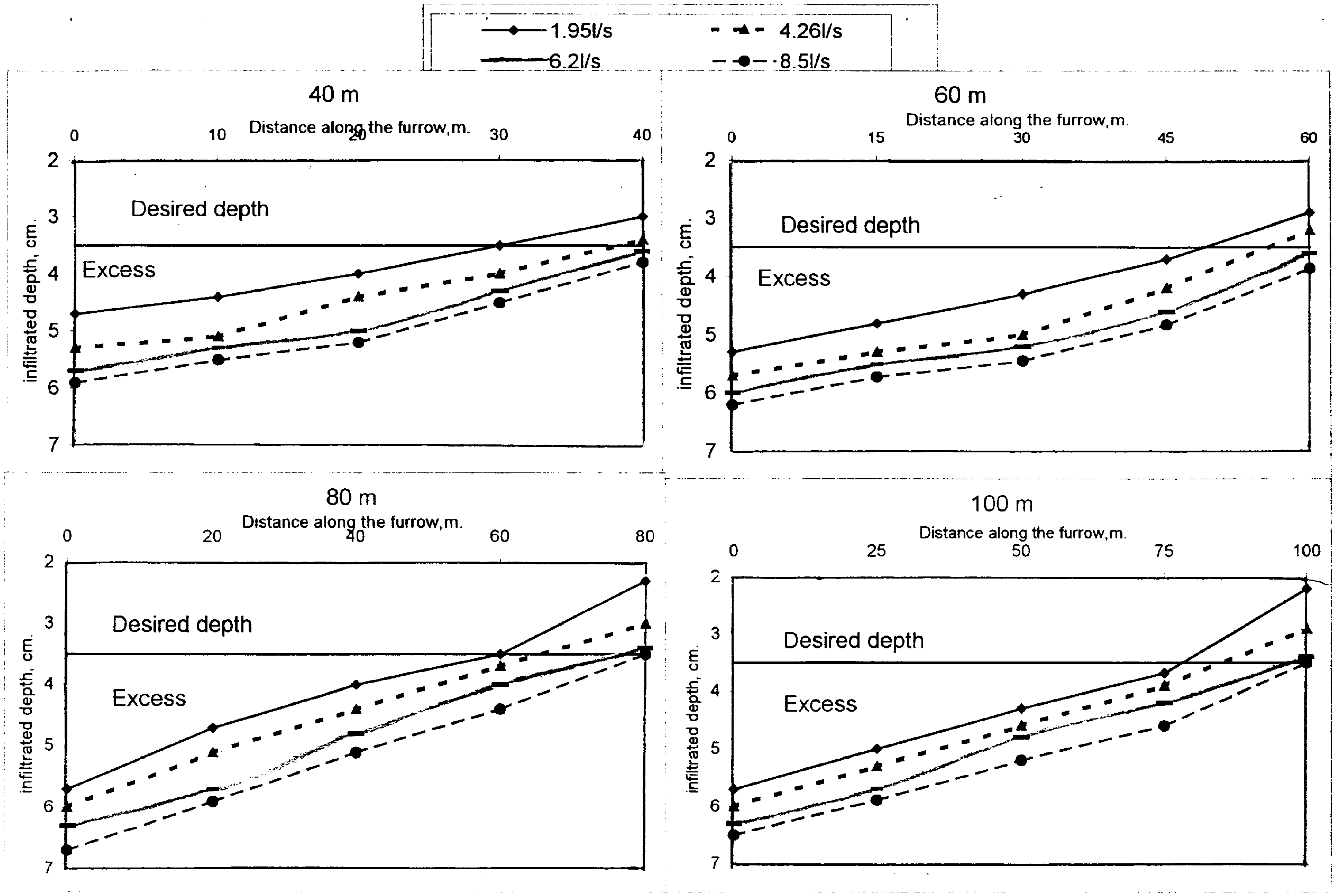

Fig. 12 : Effect of water discharge and furrow length on excess and deficit infiltrated depth under alternative irrigation method.

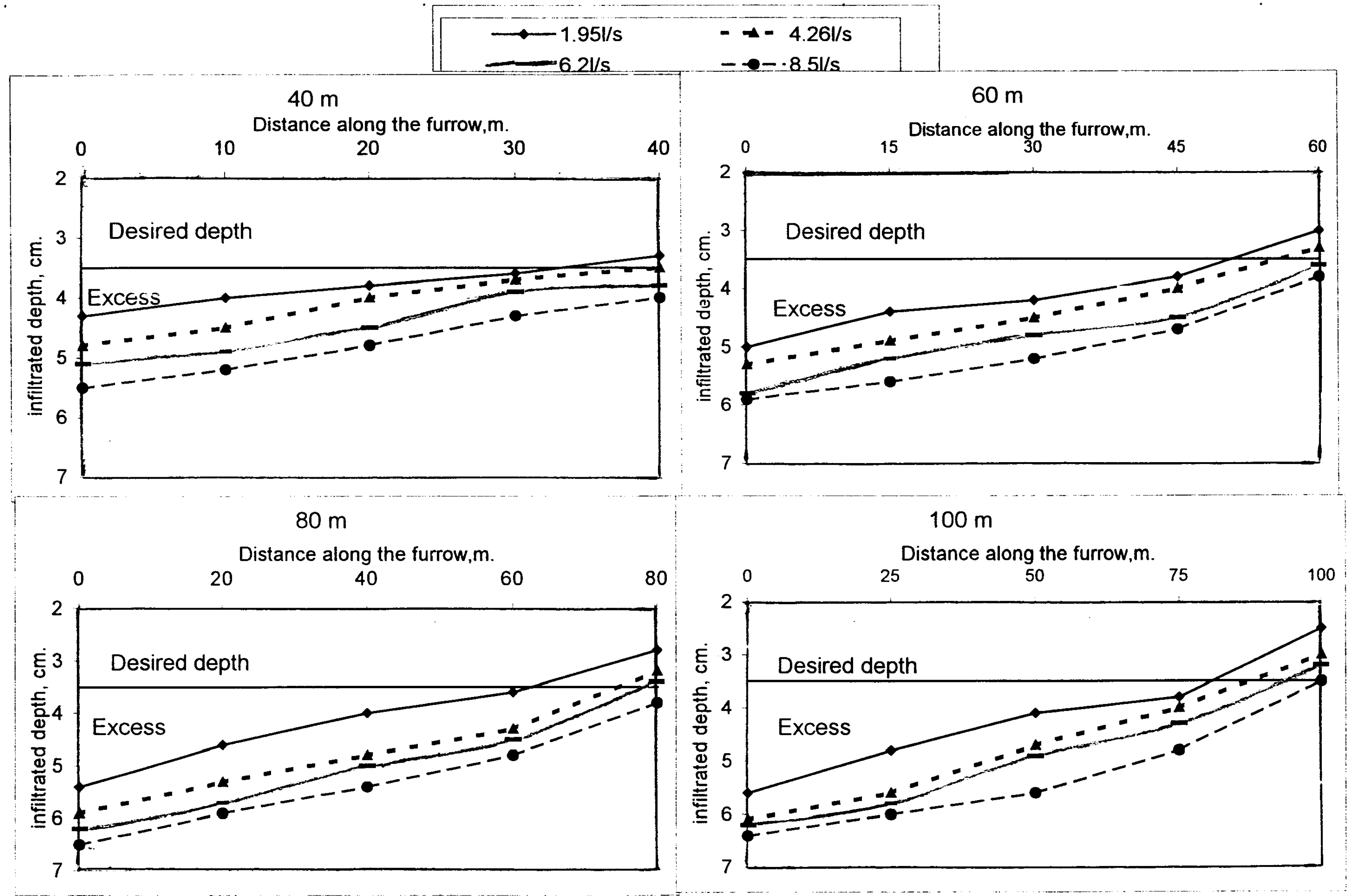

Fig. 13 : Effect of water discharge and furrow length on excess and deficit infiltrated depth under surge-alternative irrigation method.

The water application efficiency for alternative and surge-alternative irrigation were increased by 7.73% and 28.16% compared with continuous method, where the average value of water application efficiency for continuous irrigation was 49.69%.

The highest value of water application efficiency was 88.9% for surge-alternative irrigation, 80m furrow length and 6.2l/s discharge. Also the worst value was 39.9% for continuous, irrigation method, 100m furrow length and 8.5l/s discharge.

Increasing furrow length tended to decrease the water application efficiency for continuous and alternative irrigation method and increase water losses. But the water application efficiency increased by increasing furrow length from 40 to 80m under surge-alternative method, after that the water application efficiency decreased by increasing furrow length over 80m because the amount of irrigation water increased.

The results indicated that, the water application efficiency decreased by increasing the water discharge for all treatments because increasing discharge tend to increase the amount of water applied, therefore the water application efficiency will be decreased.

The statistical analysis showed that, the irrigation methods, furrow length and water discharge and their interaction had a highly significant effect on water application efficiency as shown in Tables 28,29,30,31 and 32 in appendix.

4.6. Water distribution efficiency (WDE):

The distribution efficiency describes water distribution along the irrigation furrow. High value of water distribution efficiency means that the different sections of the field received similar application depths, low value imply that some areas of a field receive more water than other areas ***James (1988)***.

Data presented in Table 7 and illustrated in Fig. 15 showed that, the surge-alternative irrigation method has developed the water application efficiency compared with alternative and continuous irrigation method, this is due to the faster water advance which tended to increase water distribution efficiency, **Izuno et al (1984)**.

The water distribution efficiency for surge-alternative irrigation method increased by 12.5% and 11.3% compared with alternative and

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Table 6: Effect of irrigation method, furrow length and discharge on water application efficiency, (%)

Furrow length, (m)	Continuous flow (C) Discharge, l/s*				Alternative flow (A) Discharge, l/s				Surge-Alternative flow (S – A) Discharge, l/s			
	1.95	4.26	6.2	8.5	1.95	4.26	6.2	8.5	1.95	4.26	6.2	8.5
40	55.3	58.5	59.4	53.7	64.8	72	70.7	61.1	66.8	75.7	73.8	68.8
60	55	57	50.2	47.4	56.6	71.9	67.4	55.3	75.5	84.6	82.1	82.1
80	48.52	52	50	46	53.2	66	60	51.7	79	85.4	88.9	86.8
100	45	44.9	44.5	39.9	51.6	53.6	48.5	42.8	77.3	85.1	83.7	80.8

* = The average of discharge for five replicates.

Table 7: Effect of irrigation method, furrow length and discharge on water distribution efficiency, (%)

Furrow length, (m)	Continuous flow (C) Discharge, l/s*				Alternative flow (A) Discharge, l/s				Surge-Alternative flow (S – A) Discharge, l/s			
	1.95	4.26	6.2	8.5	1.95	4.26	6.2	8.5	1.95	4.26	6.2	8.5
40	69.4	78.7	79	72	68.8	77.3	82.4	74.1	68.3	83.5	84.7	75.2
60	68.4	76.2	79.9	72.3	65	74.6	81.9	72	69.4	84.7	85.2	80
80	65.7	75	75.5	69.1	64	71.6	73.5	69	70.2	85.9	86.3	81.9
100	60.6	71.5	73	67.5	58.7	69.2	71.3	68.3	72.5	86.3	87.3	83

* = The average of discharge for five replicates.

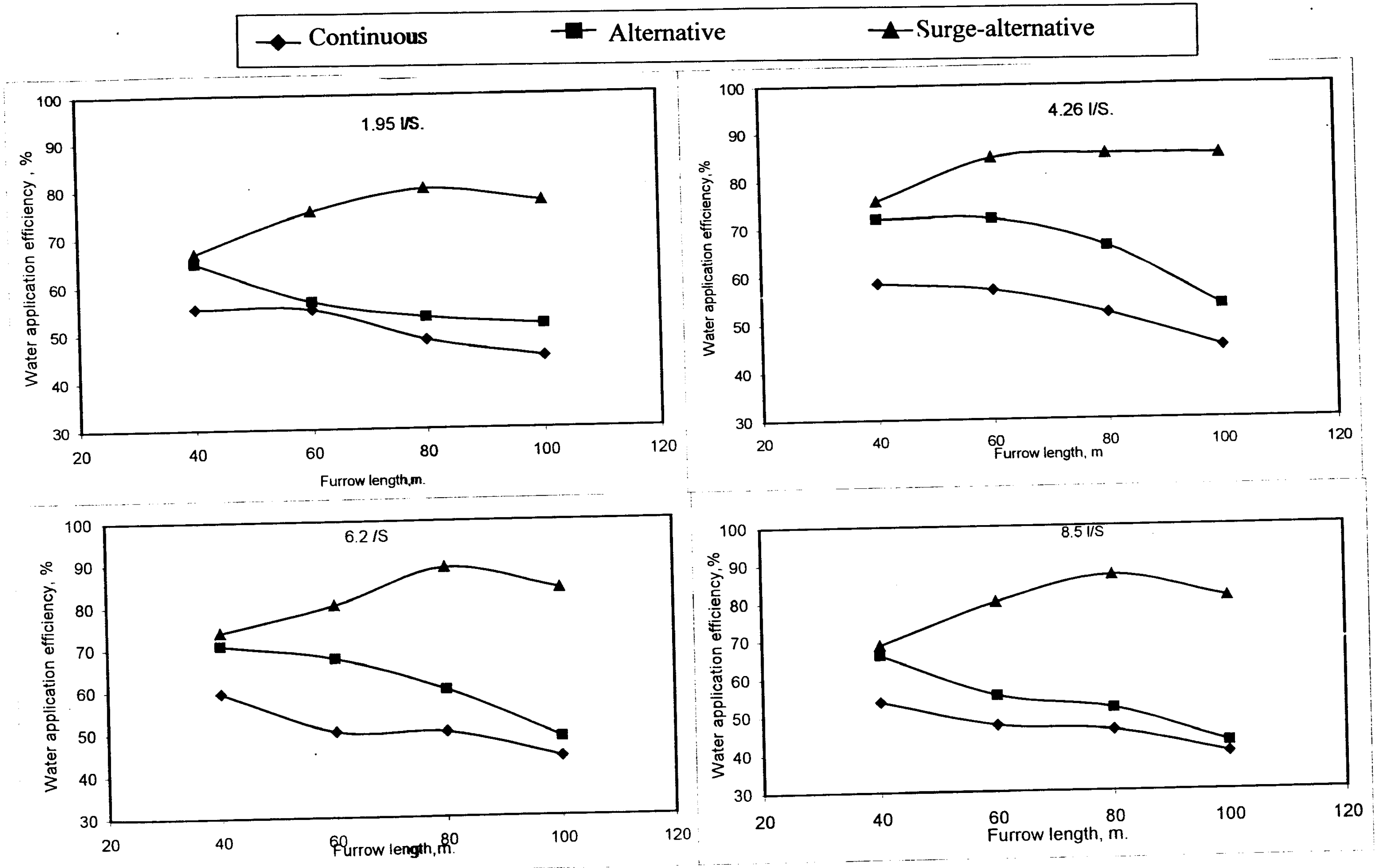

Fig. 14 : Effect of furrow length and irrigation method on water application efficiency, % under different discharges.

continuous method respectively, where the average value of water distribution efficiency for surge-alternative irrigation method was 80.2%.

The highest value of water distribution efficiency was 87.3% for surge-alternative irrigation method,100m furrow length and 6.2l/s water discharge. Also the worst value was 58.7% for alternative irrigation, 100m furrow length and 1.95l/s water discharge.

Increasing furrow length tended to decrease the water distribution efficiency for continuous and alternative methods. But the water distribution increased by increasing furrow length under surge-alternative method.

The results indicated that, the water distribution efficiency increased by increasing the water discharge from 1.95l/s to 6.2l/s under three methods, after that the water distribution efficiency decreased by increasing water discharge over than 6.2l/s because the deep percolation and difference in water stored along the furrow increased.

The statistical analysis showed that, the irrigation methods, furrow length and water discharge and their interaction had a highly significant effect on water distribution efficiency as shown in Tables 33,34,35,36 and 37 in appendix.

4.7. Crop yield and its components:

4.7.1. Leaf area index:

Leaf area at 90 days from sowing and leaf area index were presented in Table 8, the effect of irrigation method, furrow length and water discharge on leaf area were showed in Fig 16.

The results indicated that surge-alternative method had increased leaf area index as compared with alternative and continuous irrigation methods. Because surge-alternative method tended to improve soil aeration conditions and maintenance of nutrient.

Increasing lateral movement tended to decrease leaf area index under alternative method. Surge-alternative method increased leaf area index about of 29.3 % and 37.4 % as compared with continuous and alternative methods, where the leaf area index for surge-alternative irrigation method was 3.31.

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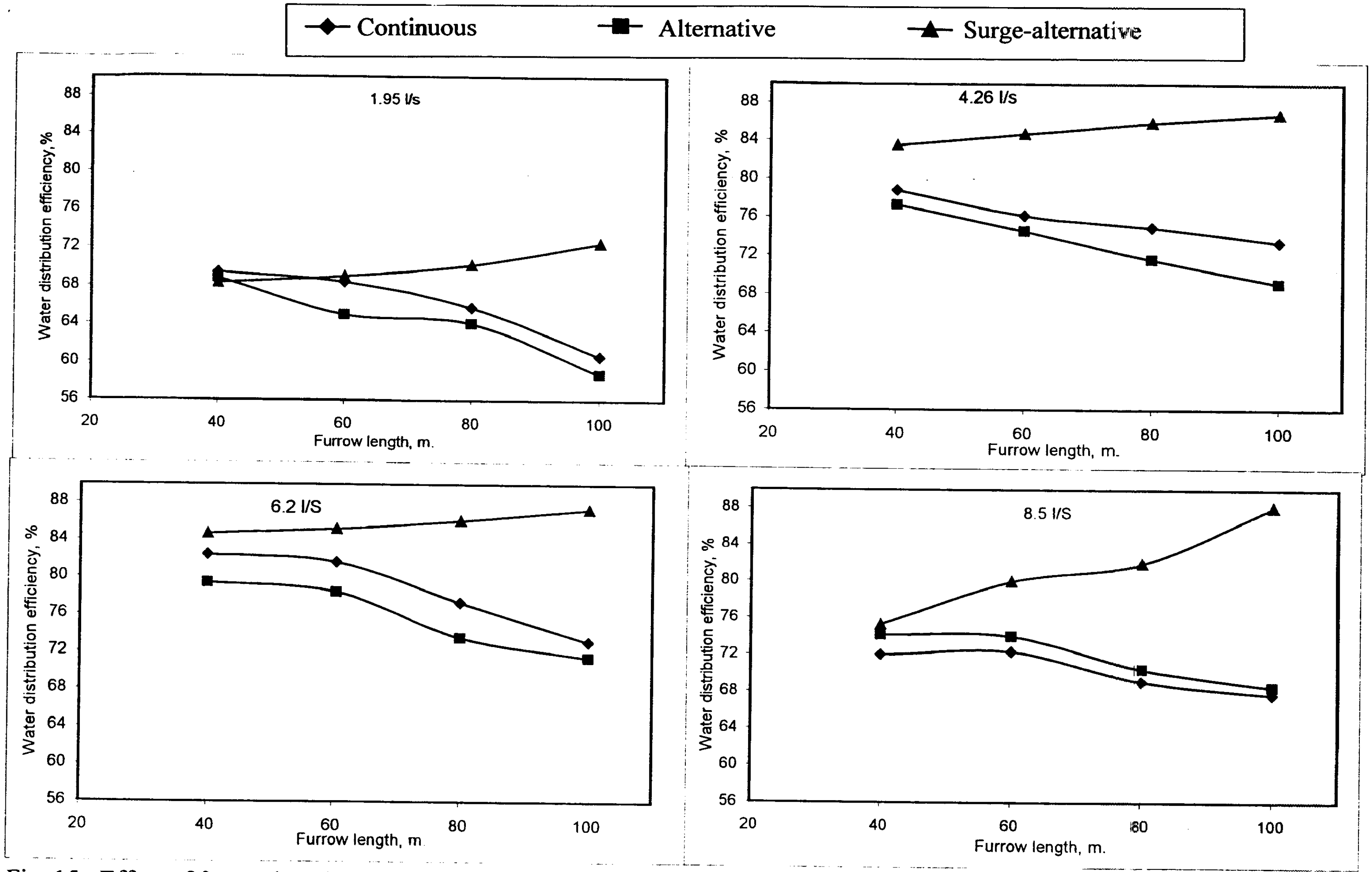

Fig. 15 : Effect of furrow length and irrigation method on water distribution efficiency, % under different discharges.

The highest leaf area index was 3.95 for surge-alternative irrigation, 100 m furrow length and 8.5 l/s water discharge. The worst leaf area index 1.21 for alternative irrigation, 100 m furrow length and 1.95l/s water discharge.

Increasing furrow length tended to decrease leaf area index for continuous and alternative irrigation method, where the deficit depth infiltrated increased But leaf area index increased by increasing furrow length under surge-alternative irrigation method. Increasing water discharge tended to increase leaf area index under different irrigation method, where deficit depth infiltrated at the end of the furrow decreased. The irrigation methods, furrow length and water discharge had the same effect on leaf area.

The statistical analysis showed that, the irrigation methods, furrow length and water discharge and their interaction had a highly significant effect on leaf area and leaf area index as shown in Tables 38,39,40,41 and 42 in appendix.

4.7.2. Plant height:

Plant height was presented in Table 9 and illustrated in Fig 17. The results indicated that surge-alternative irrigation method had increased plant height by 5.2% and 6.93% as compared with continuous and alternative irrigation methods. Because more uniformity of water distribution, improve soil aeration conditions and maintenance of nutrients were increased under surge-alternative method, the average value of plant height under surge-alternative method was 310 cm.

The highest value of the plant height was 331 cm for surge-alternative irrigation, 100 m furrow length and 8.5 l/s water discharge, While the worst value of the plant height was 272 for alternative irrigation, 100 m furrow length and 1.95l/s water discharge.

Increasing furrow length tended to decrease plant height for continuous and alternative irrigation method, where deficit depth infiltrated at end of the furrow increased. But plant height increased by increasing furrow length under surge-alternative irrigation.

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Table 8: Effect of irrigation method, furrow length and flow rate on discharge (m^2) and leaf area index.

Furrow length, (m)	The parameters	Continuous flow (C) Discharge, l/s*				Alternative flow (A) Discharge, l/s				Surge-Alternative flow (S – A) Discharge, l/s			
		1.95	4.26	6.2	8.5	1.95	4.26	6.2	8.5	1.95	4.26	6.2	8.5
40	L.A.	0.385	0.462	0.54	0.596	0.357	0.404	0.48	0.52	0.4	0.5	0.57	0.6
	L.A.I.	2.2	2.64	3.08	3.41	2.04	2.31	2.75	2.97	2.3	2.9	3.25	3.4
60	L.A.	0.338	0.40	0.44	0.48	0.31	0.346	0.40	0.443	0.455	0.54	0.6	0.65
	L.A.I.	1.93	2.26	2.53	2.75	1.76	1.98	2.26	2.53	2.6	3.1	3.4	3.7
80	L.A.	0.289	0.374	0.424	0.443	0.27	0.327	0.34	0.385	0.508	0.578	0.64	.683
	L.A.I.	1.65	2.14	2.42	2.53	1.54	1.87	1.98	2.2	2.9	3.3	3.65	3.9
100	L.A.	0.27	0.34	0.366	0.404	0.212	0.289	0.33	0.365	0.56	0.61	0.683	.69
	L.A.I.	1.54	1.94	2.09	2.31	1.21	1.65	1.87	2.09	3.2	3.5	3.9	3.95

L.A. = Leaf area m^2. L.A.I. = Leaf area index. * = The average of discharge for five replicates.

Table 9: Effect of irrigation method, furrow length and discharge on plant height (cm).

Furrow length, (m)	Continuous flow (C) Discharge, l/s*				Alternative flow (A) Discharge, l/s				Surge-Alternative flow (S – A) Discharge, l/s			
	1.95	4.26	6.2	8.5	1.95	4.26	6.2	8.5	1.92	4.26	6.2	8.5
40	292	303	306	308	284	297	300	300	283	301	311	313
60	290	296	297	300	280	290	294	298	294	304	316	320
80	283	290	294	296	278	286	290	294	301	309	320	326
100	279	285	290	292	272	280	286	290	304	315	322	331

* = The average of discharge for five replicates.

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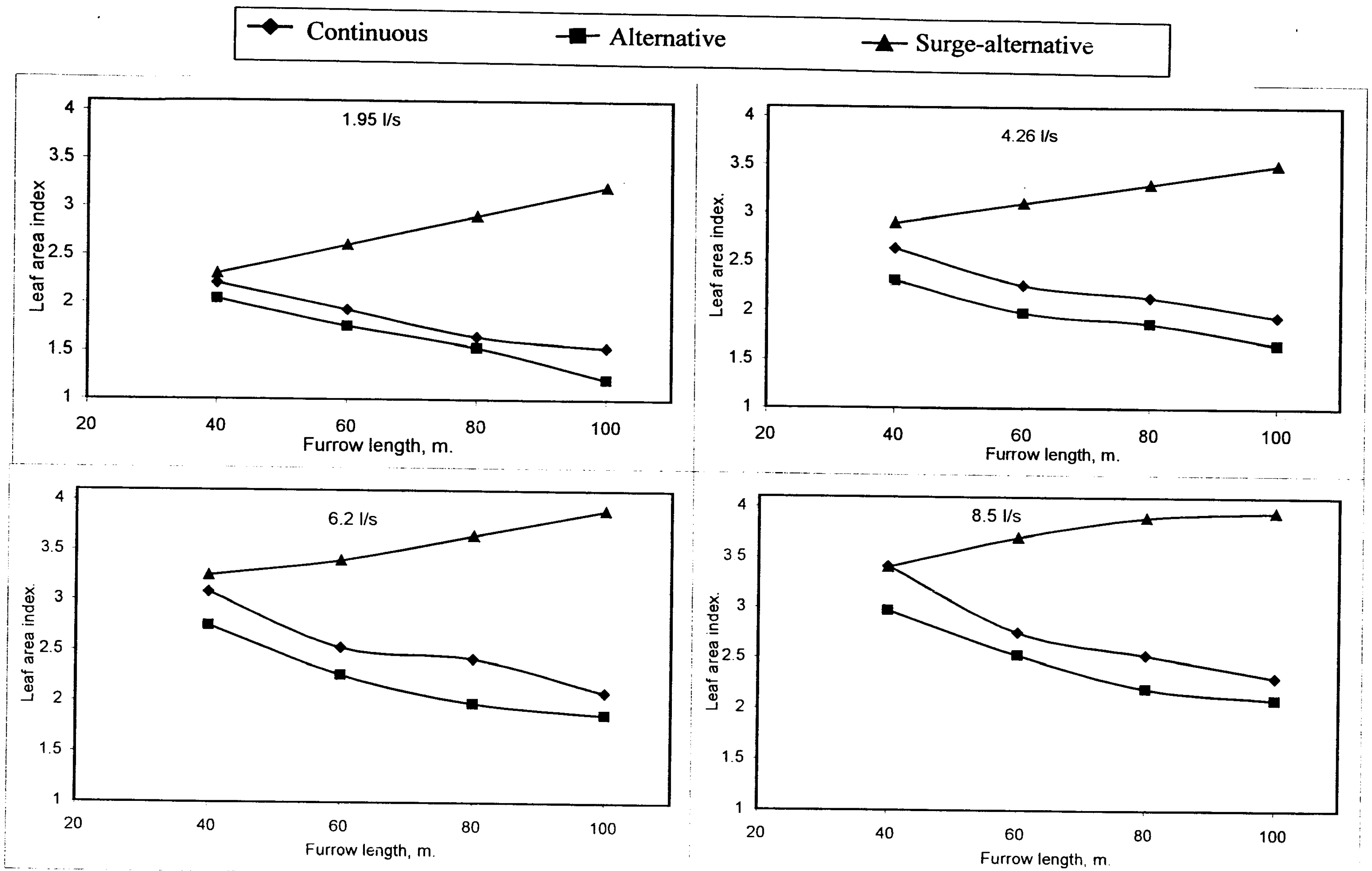

Fig. 16: Effect of furrow length and irrigation method on leaf area index under different discharges.

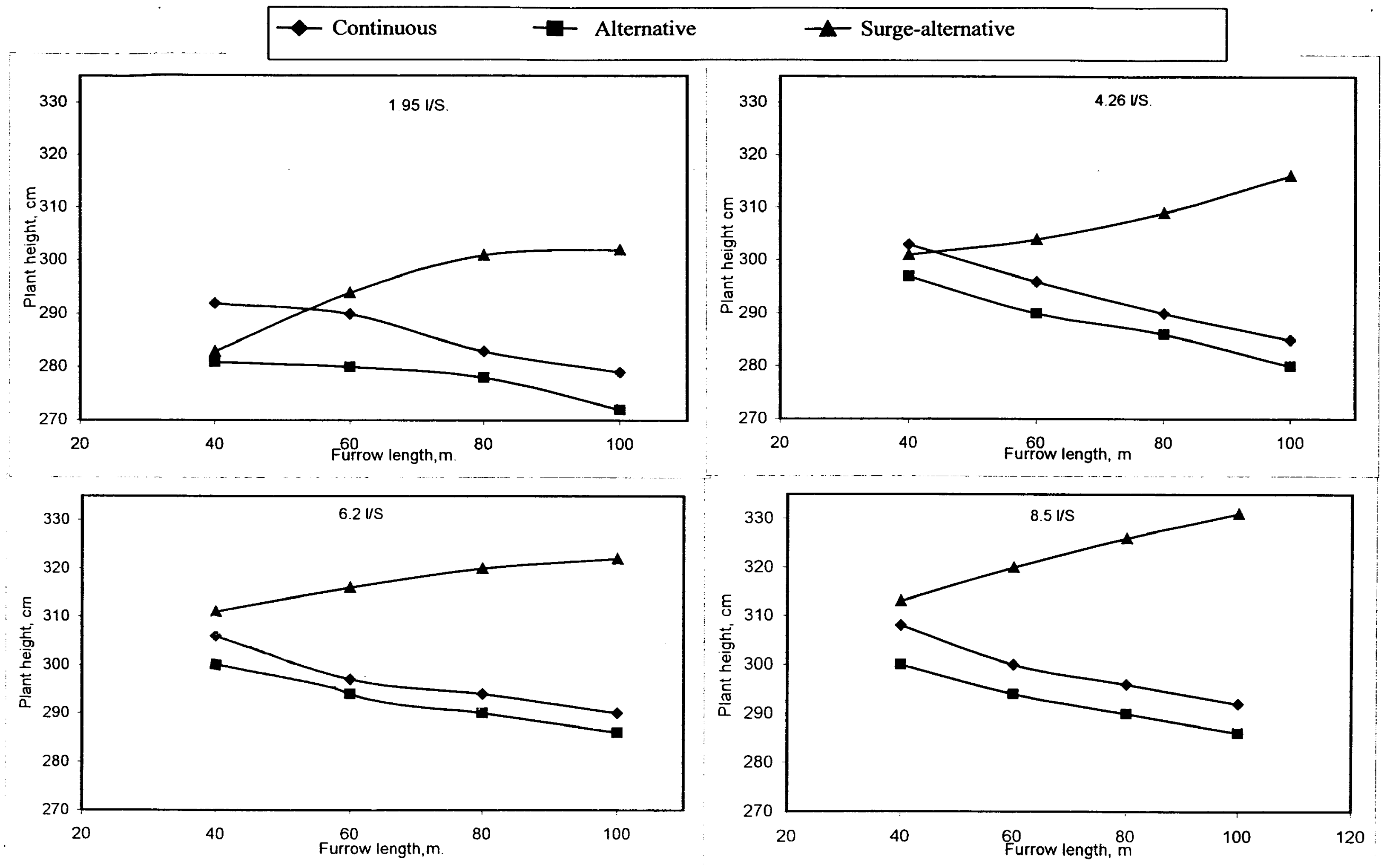

Fig. 17: Effect of furrow length and irrigation method on plant height, cm under different discharges.

Increasing water discharge tended to increase plant height under different irrigation method, where deficit depth infiltrated at the end of the furrow decreased.

The statistical analysis showed that, the irrigation methods, furrow length and water discharge and their interaction had a highly significant effect on plant height as shown in Tables 43,44,45,46 and 47 in appendix.

4.7.3. Root volume:

Corn root volume for different irrigation methods are presented in Table and showed in Fig 18. The results indicated that, alternative and surge-alternative irrigation methods increased root volume by 12.38% and 20.89% respectively as compared with continuous method, where best aeration under alternative and surge-alternative irrigation methods than continuous irrigation method.

The highest value of root volume was 498 cm^3 for surge-alternative method, 100 m furrow length and 8.5 l/s water discharge, While the worst value of root volume was 324 cm^3 for continuous irrigation method, 100 m furrow length and 8.5l/s water discharge.

Increasing furrow length tended to decrease root volume under continuous and alternative methods, where the amount of irrigation water increased. Root volume increased by increasing furrow length under surge-alternative method.

Increasing water discharge tended to increase root volume under alternative and surge-alternative methods, while root volume under continuous irrigation method decreased.

The statistical analysis showed that, the irrigation methods, furrow length and water discharge and their interaction had a highly significant effect on root volume as shown in Tables 48,49,50,51 and 52 in appendix.

4.7.4. Grain yield:

Data presented in Table 11 and illustrated in Fig 19 showed that, surge-alternative irrigation method increased grain yield 3.21% and 4.73 % as compared with continuous and alternative methods respectively, where the grain yield for surge-alternative method was 2.96 Mg/fed.

The high production of corn under surge-alternative irrigation attributed to the improvement of soil aeration conditions, more uniformity

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Table 10: Effect of irrigation method, furrow length and discharge on root volume (cm^3).

Furrow length, (m)	Continuous flow (C)				Alternative flow (A)				Surge-Alternative flow (S – A)			
	Discharge, l/s*				Discharge, l/s				Discharge, l/s			
	1.95	4.26	6.2	8.5	1.95	4.26	6.2	8.5	1.95	4.26	6.2	8.5
40	440	418	408	391	430	452	456	460	456	473	479	483
60	431	406	384	366	420	444	449	456	470	481	484	487
80	400	360	340	326	391	434	440	449	478	488	490	496
100	384	371	360	324	370	410	415	439	483	485	491	498

* = The average of discharge for five replicates.

Table 11: Effect of irrigation method, furrow length and discharge on grain yield (Mg)

Furrow length, (m)	Continuous flow (C)				Alternative flow (A)				Surge-Alternative flow (S – A)			
	Discharge, l/s*				Discharge, l/s				Discharge, l/s			
	1.95	4.26	6.2	8.5	1.95	4.26	6.2	8.5	1.95	4.26	6.2	8.5
40	2.86	2.91	2.94	2.98	2.82	2.88	2.91	2.94	2.87	2.90	2.94	2.96
60	2.83	2.89	2.91	2.94	2.78	2.84	2.88	2.9	2.89	2.94	2.97	2.99
80	2.79	2.84	2.87	2.9	2.73	2.8	2.83	2.86	2.94	2.98	2.99	3.00
100	2.73	2.77	2.82	2.88	2.68	2.73	2.77	2.81	2.95	2.99	3.00	3.06

* = The average of discharge for five replicates.

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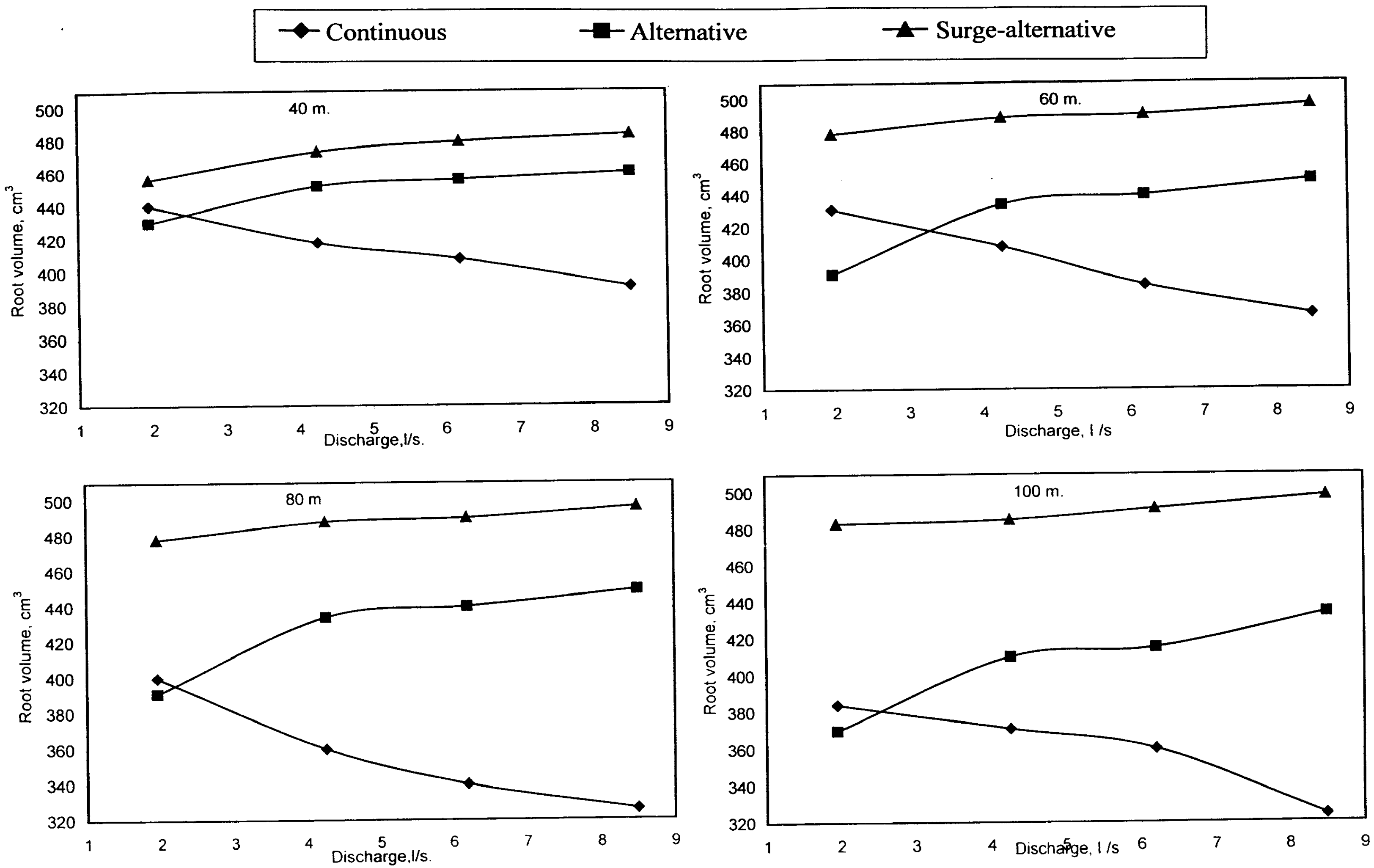

Fig. 18: Effect of furrow length and irrigation method on root volume, cm^3 under different discharges.

water distribution along the furrow and maintenance of nutrients. These results are in agreement with ***Ghalleb (1987)*** and ***Eid (1998)***. The highest grain yield was 3.01 Mg/fed for surge-alternative method,100m furrow length and 8.5 l/s water discharge, while the worst grain yield was 2.68 Mg/fed for alternative method, 100m furrow length and 1.95 l/s water discharge.

Increasing furrow length tended to decrease grain yield for continuous and alternative methods. But grain yield increased by increasing furrow length under surge alternative method.

The results indicated that, grain yield increased by increasing water discharge under different irrigation methods, where the deficit depth at the end of the furrow decreased.

The statistical analysis showed that, the irrigation methods, furrow length and water discharge and their interaction had a highly significant effect on grain yield as shown in Tables 53,54,55,56 and 57 in appendix.

4.8. Water use efficiency (WUE):

Water use efficiency is one of the most important criteria, where it is of greater practical importance. Water use efficiency is the ratio of crop yield to the total amount of water. The highest value of water use efficiency means that less amount of irrigation water and highly crop yield **(Michael,1978)**.

Data presented in Table 12 and illustrated in Fig 20 showed that the surge-alternative followed by alternative methods recorded highly crop yield as compared with continuous method, because surge-alternative and alternative methods used amount of water less than continuous method and increase crop yield under surge-alternative irrigation method. Water use efficiency increased by 38.2% and 18.06% for surge-alternative and alternative irrigation methods respectively as compared with continuous method, where water use efficiency was 0.806kg/m^3 for continuous irrigation method.

The highest value of water use efficiency was 1.37 kg/m^3 for surge-alternative irrigation method, 80 m furrow length and 1.95l/s water discharge. The worst value was 0.74 kg/m^3 for continuous irrigation method, 100 m furrow length and 4.26l/s water discharge.

Increasing furrow length tended to decrease water use efficiency for continuous and alternative irrigation method. Because amount of irrigation

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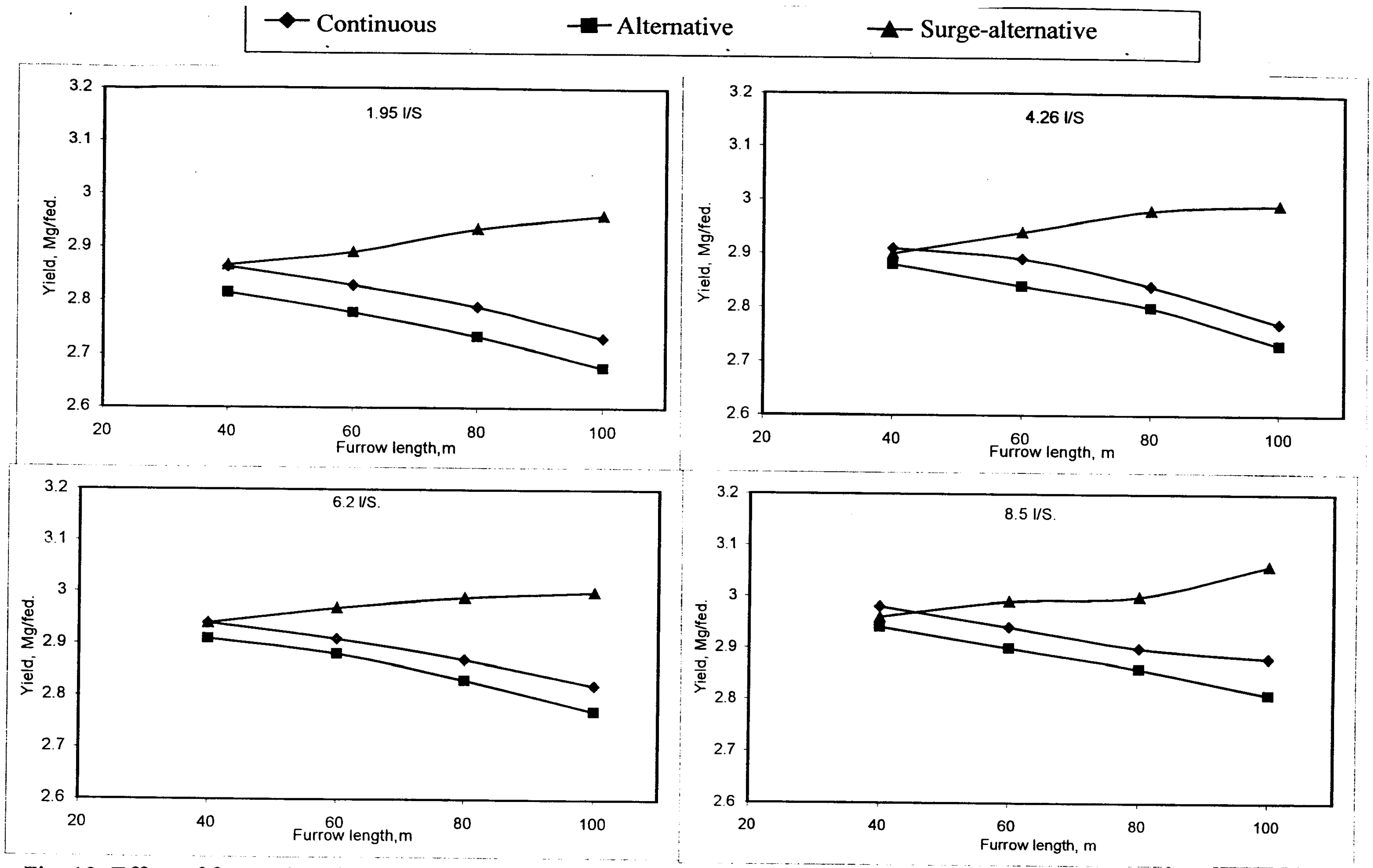

Fig. 19: Effect of furrow length and irrigation method on grain yield, Mg/fed under different discharges.

water increased. While water use efficiency increased by increasing furrow length from 40 m to 80 m under surge-alternative method, after that water use efficiency decreased by increasing furrow length over than 80 m, where amount of irrigation water increased.

Increasing water discharge tended to decrease water use efficiency under continuous and alternative methods at 40,60 and 80 m furrow length, but under 100 m furrow length, water discharge had no effect on water use efficiency at continuous irrigation method, while 6.2 l/s water discharge produced the highly water use efficiency at alternative irrigation method.

Increasing water discharge tended to decrease water use efficiency under surge-alternative irrigation method.

The statistical analysis showed that, the irrigation methods, furrow length and water discharge and their interaction had a highly significant effect on water use efficiency as shown in Tables 58,59,60,61 and 62 in appendix.

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Table 12: Effect of irrigation method, furrow length and discharge on water use efficiency (kg/m^3).

Furrow length, (m)	Continuous flow (C)				Alternative flow (A)				Surge-Alternative flow (S – A)			
	Discharge, l/s•				Discharge, l/s				Discharge, l/s			
	1.95	4.26	6.2	8.5	1.95	4.26	6.2	8.5	1.92	4.26	6.2	8.5
40	0.886	0.886	0.84	0.818	1.13	1.11	1.10	1.07	1.295	1.27	1.12	1.14
60	0.849	0.84	0.825	0.80	1.1	1.10	1.10	1.05	1.306	1.306	1.3	1.30
80	0.82	0.79	0.79	0.775	1.07	1.05	1.03	0.98	1.37	1.35	1.34	1.33
100	0.75	0.74	0.75	0.75	0.96	0.96	0.985	0.95	1.34	1.32	1.31	1.30

• = The average of discharge for five replicates.

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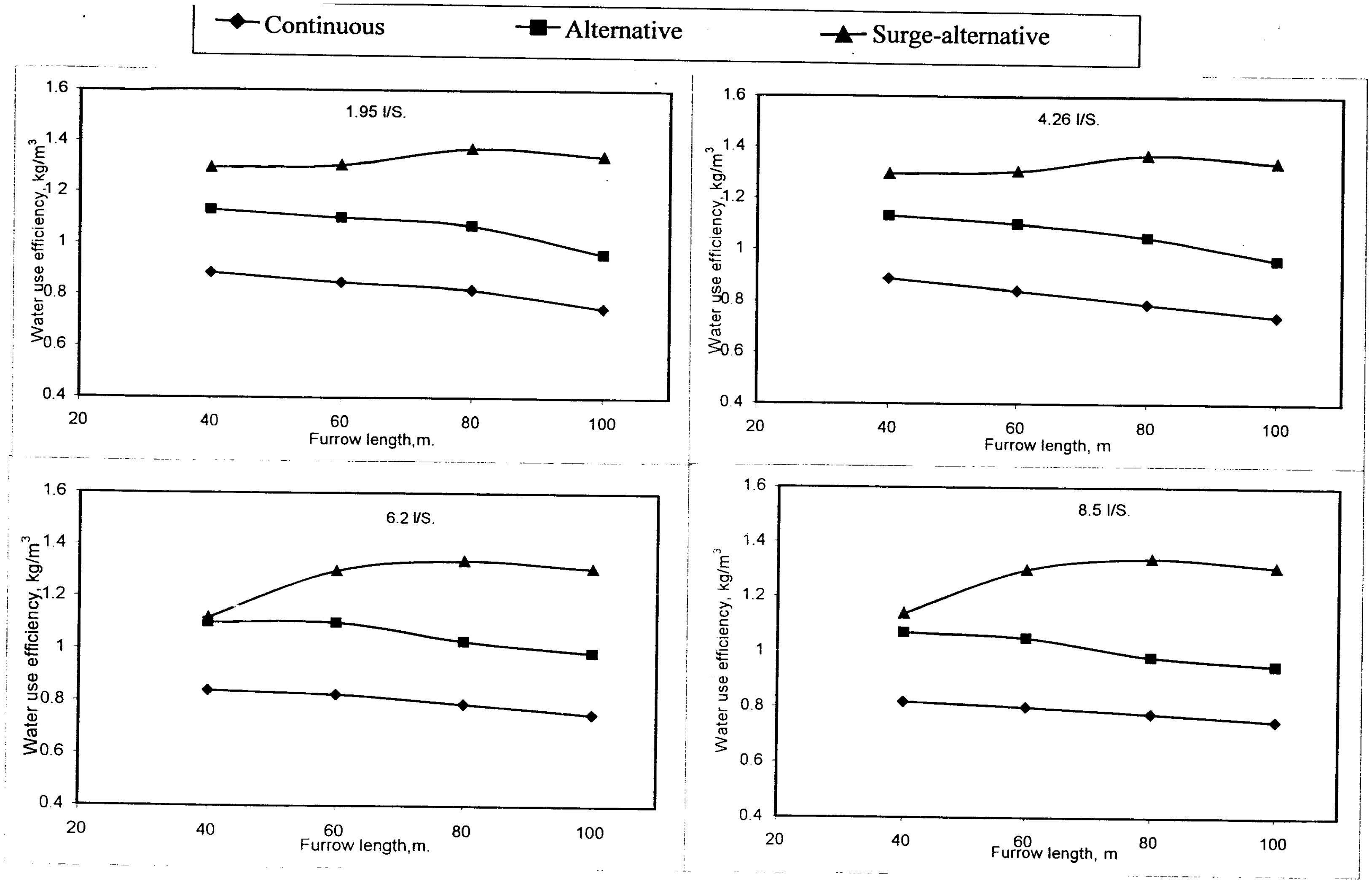

Fig. 20: Effect of furrow length and irrigation method on water use efficiency, Kg/m^3 under different discharges.

5. SUMMARY AND CONCLUSION

Field experiments were carried out during the successive growing season 2000 at Rice Mechanization Center (RMC), Meet El-Deepa, Kafr El-Sheikh Governorate, Egypt. The aim of the present work was to develop furrow surface irrigation by using alternative and Surge-alternative irrigation systems, in comparison with continuous furrow irrigation and studies the effect of developed irrigation methods on corn production and irrigation efficiency.

1- Irrigation methods.

Three irrigation methods were used:

a) Continuous furrow irrigation,

b) Alternative furrow irrigation,

c) Surge-alternative furrow irrigation

2- Furrow length,

Four different furrow lengths were used, (40, 60, 80 and 100 m.).

3- Discharge,

Four different discharge were used, (1.95, 4.26, 6.2 and 8.5 l/s)

The irrigation intervals were 15 days for continuous flow and 12 days for alternative and surge-alternative flow, after the first post irrigation (El-Mohaya). Amount of water delivered to each treatment was measured using spile tubes submerged in the irrigation channel. Head of water was measured during irrigation. The effective head of water above the cross section center of irrigation spile was measured several times during irrigation. The water in the channel was controlled to maintain a constant head by means of fixed sliding type gates.

The main results of this study can be summarized as follow:

1. Advance time:

The shortest advance time was 4.5 min and obtained by surge-alternative irrigation method with 40 m furrow length and 8.5l/s discharge. The results indicated that, the total irrigation time per feddan was decreased by about 9.75% under alternative method and by about 37.22% under surge-alternative method compared to continuous method. The average of total irrigation time for continuous irrigation method was 23.11 min/fed. The soil moisture content in case of alternative and surge-alternative irrigation method before the next irrigation was higher than the moisture content in case of continuous method. Decreasing advance time for surge-alternative method can be attributed to infiltration rate reduction which results from the surface sealing and soil consolidation. Increasing furrow length lead to increase advance time while increasing discharge lead to decrease it.

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2. Applied irrigation water:

The results indicated that surge-alternative method saved about 15.45% and 35.95%. per season compared with alternative and continuous methods, respectively. Where the amount of irrigation water added under surge-alternative method was 2282 m^3/fed. per season. The lowest amount of water was 2144 m^3/ fed. Per season by using surge-alternative method at 80 m furrow length and 1.95l/s discharge. The highest value was 3840 m^3 / fed. per season by using continuous irrigation method at 100 m furrow length and 8.5 l/s discharge. Increasing furrow length tended to increase the total water for continuous and alternative irrigation method and increase water losses due to deep percolation. But, the amount of irrigation water decreased by increasing furrow length from 40 to 80m under surge-alternative method, after that the amount of irrigation water increased by increasing furrow length over 80 m because this increase tended to increase the lateral movement. Increasing discharge caused the total water to increase for all treatments, because the run off and drainage losses increased.

3. Infiltration rate :

The results indicated that surge-alternative method had the lowest values of basic infiltration rate because surge-alternative irrigation method lead to:

(a) Consolidation of the furrow perimeter due to increased soil water tension during flow interruptions

(b) Filling of cracks which were developed during flow interruptions with bed load during the following surges, and

(c) Forced settlement of suspended sediment on the furrow perimeter when the water supply is interrupted.

The average values of basic infiltration rate at the end of the season were 19.17, 21.24 and 21.7 mm/h for surge-alternative, alternative and continuous methods at fixed another conditions respectively. Increasing furrow length lead to increase basic infiltration rate for continuous and alternative methods where lateral movement increased, while basic infiltration rate decreased by increasing furrow length under surge-alternative method. Increasing water discharge lead to increase basic infiltration rate under different methods, where cracks formation increased by increasing water discharge.

4. Soil moisture distribution:

The excess depth of water for alternative and surge-alternative irrigation methods were decreased by about 39.3% and 44.17% compared with continuous method. The lowest value of irrigation water losses (excess water) was obtained with surge-alternative method at 40 m furrow length and 1.95 l/s water discharge. Continuous irrigation method at 100 m furrow and 8.5 l/s water discharge presented the highest value of irrigation water losses. Increasing furrow length tended to increase both of excess water at the head of the furrow and deficit water at the tail of the furrow for different methods.

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Generally increasing water discharge tended to increase excess water and decrease the deficit water.

5. Water application efficiency:

The water application efficiency for alternative and surge-alternative irrigation method were increased by 7.73% and 28.16% compared with continuous irrigation method, where the average value of water application efficiency for continuous method was 49.69%. The highest value of water application efficiency was 88.9% for surge-alternative method, 80 m furrow length and 6.2 l/s discharge. Also the worst value was 39.9% for continuous, method, 100 m furrow length and 8.5 l/s water discharge. Increasing furrow length tended to decrease the water application efficiency for continuous and alternative methods where water losses increase. But the water application efficiency increased by increasing furrow length from 40 to 80 m under surge-alternative irrigation method, after that the water application efficiency decreased by increasing furrow length over than 80 m because the amount of water increased. The results indicated that, the water application efficiency decreased by increasing the water discharge for different irrigation methods where the amount of applied water increased.

6. Water distribution efficiency:

The water distribution efficiency for surge-alternative irrigation method was increased by 12.5% and 11.3% compared with alternative and continuous method respectively, where the average value of water distribution efficiency for surge-alternative method was 80.2%. The highest value of water distribution efficiency was 87.3% for surge-alternative method, 100 m furrow length and 6.2l/s water discharge. Also the worst value was 58.7% for alternative method, 100 m furrow length and 1.95 l/s water discharge. Increasing furrow length tended to decrease the water distribution efficiency for continuous and alternative methods. But the water distribution increased by increasing furrow length under surge-alternative method. The results indicated that, the water distribution efficiency increased by increasing the water discharge from 1.95 l/s to 6.2 l/s under the three irrigation methods, after that the water distribution efficiency decreased by increasing water discharge over than 6.2 l/s because of the deep percolation and difference in stored water along the furrow increased.

7. Crop yield and its components:

7.1. Leaf area index:

Surge-alternative irrigation method increased leaf area index about of 29.3% and 37.4% as compared with continuous and alternative irrigation methods because surge-alternative method tend to improve soil aeration conditions and maintenance of nutrient. Where the leaf area index for surge-alternative method was 3.3 . The highest leaf area index was 3.95 for surge-

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alternative method, 100 m furrow length and 8.5 l/s water discharge. The worst leaf area index 1.21 for alternative irrigation method, 100 m furrow length and 1.95 l/s water discharge. Increasing furrow length tended to decrease leaf area index for continuous and alternative methods. Where the deficit depth infiltrated increased But leaf area index increased by increasing furrow length under surge-alternative method. Increasing water discharge tended to increase leaf area index under different methods, where deficit depth infiltrated at the end of the furrow decreased.

7.2. Plant height:

Plant height was increased by about 5.2 % and 6.93 % under surge-alternative irrigation comparing with continuous and alternative irrigation methods, because of more uniformity of water distribution, improvement of soil aeration conditions under surge-alternativė irrigation. The height value was 310 cm under surge-alternative irrigation method. The highest value was 331 cm for surge-alternative irrigation method, 100 m furrow length and 8.5 l/s water discharge, While the worst value of the plant height was 272 for alternative method, 100 m furrow length and 1.95 l/s water discharge. Increasing furrow length tended to decrease plant height for continuous and alternative method. Where the deficit depth infiltrated increased. But plant height increased by increasing furrow length under surge-alternative method. Increasing water discharge tended to increase plant height under different methods, where deficit depth infiltrated at the end of the furrow decreased

7.3.Root volume:

The results indicated that, the root volume for alternative and surge-alternative methods increased by about of 12.38% and 20.89% respectively comparing with continuous method, where best aeration under alternative and surge-alternative methods than continuous irrigation method. The highest value of root volume was 498 cm^3 for surge-alternative method, 100 m furrow length and 8.5 l/s water discharge, while the worst value of root volume was 324 cm^3 for continuous method, 100 m furrow length and 8.5 l/s water discharge. Increasing furrow length tended to decrease root volume under continuous and alternative irrigation method, where the amount of irrigation water increased. Root volume increased by increasing furrow length under surge-alternative method. Increasing water discharge tended to increase root volume under alternative and surge-alternative method, while root volume under continuous method decreased.

7.4. Grain yield:

The grain yield for urge-alternative method increased by about 3.21% and 4.73 % comparing with continuous and alternative methods respectively, where the grain yield for surge-alternative irrigation method was 2.96 Mg/fed. The high production of corn under surge-alternative irrigation was attributed to the improvement of soil aeration conditions, more uniformity of water distribution along the furrow and maintenance of nutrients. The highest grain

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yield was 3.01 Mg/fed for surge-alternative method, 100 m furrow length and 8.5 l/s water discharge. While the worst grain yield was 2.68 Mg/fed for alternative method, 100 m furrow length and 1.95 l/s water discharge. Increasing furrow length tended to decrease grain yield for continuous and alternative methods. But grain yield increased by increasing furrow length under surge alternative method. Increasing water discharge tended to increase crop yield under different irrigation methods, where deficit depth decreased.

8. Water use efficiency (WUE):

Water use efficiency increased by about of 38.2% and 18.06% for surge-alternative and alternative methods respectively comparing with continuous method, where water use efficiency was 0.806 kg/m^3 for continuous method. The highest value of water use efficiency was 1.37 kg/m^3 for surge-alternative method, 80 m furrow length and 1.951/s water discharge. The worst value was 0.74 kg/m^3 for continuous method, 100 m furrow length and 4.26 l/s water discharge. Increasing furrow length tended to decrease water use efficiency for continuous and alternative methods, because the amount of irrigation water increased. While water use efficiency increased by increasing furrow length from 40 m to 80 m under surge-alternative method, after that water use efficiency decreased by increasing furrow length over than 80 m because amount of irrigation water increased. Increasing water discharge tended to decrease water use efficiency under continuous and alternative methods at 40, 60 and 80 m furrow length, increasing water discharge tended to decrease water use efficiency under surge-alternative method.

Applied recommendations.

1- Surge-alternative irrigation method at 100 m furrow length and 6.2 or 8.5 l/s discharge gave the best results where irrigation water was saved and corn grain yield increased at ten days irrigation intervals.

2- Surge-alternative has difficulties in application and need special requirements such as gated pipe, surge-valves and pipeline.

3- if surge-alternative requirements is not available and amount of irrigation water is little, then alternative irrigation method at 40 m furrow length and 4.26 l/s discharge gave satisfactory results at ten days irrigation intervals.

4- it can be obtaining best results under alternative irrigation at furrow length less than 40 m and 1.95 l/s discharge at ten days irrigation intervals.

5- Continuous irrigation at 40 m furrow and 6.2 or 8.5 l/s discharge is favorable if the water is available and there is no problem in irrigation water, where corn grain yield increased. Application of continuous irrigation at furrow length less than 40 m gave best results.

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Table 1: Effect of irrigation method, furrow length and discharge on advance time (min) during the irrigation in date 14 / 7 / 2000.

L	D	Continuous flow (C)				Alternative flow (A)				Surge-Alternative flow (S – A)			
		Discharge, l /s*				Discharge, l/s				Discharge, l/ s			
		1.95	4.26	6.2	8.5	1.95	4.26	6.2	8.5	1.95	4.26	6.2	8.5
40	10	7	4	2	2	7	4	3	2	6	3	2	1.5
	20	14	7	4	4	13	7	5	4	11	6	4	3
	30	22	10	5.5	5.5	18	9	7	5.5	15	8	5	4
	40	26	13	7	7	22	11	8	6.5	18	9	7.6	5
60	15	12	6	4	3	10	6	4	3	8	4	3	2
	30	22	11	8	6	19	11	7	6	14	8	5	4
	45	32	15	11	8	28	14	10	8	20	11	8	6
	60	40	19	14	10	34	17	12	10	25	13	9	7
80	20	16	8	5	4	14	8	6	5	10	4	4	3
	40	30	15	10	8	26	14	10	9	18	8	7	6
	60	43	21	14	11	37	19	14	12	26	11	9	8
	80	55	26	18	14	46	23	17	14	32	15.4	11	9
100	25	19	10	8	6	19	10	8	5	13	7	5	4
	50	37	19	15	11	36	17	13	10	24	13	9	7
	75	55	28	19	15	54	25	17	14	34	18	12	10
	100	70	35	25	19	68	32	21	17	42	21	14	11

L = Furrow length,m.
D = Distance from water inlet,m
* = The average value of discharge for five replicates.

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Table 2: Effect of irrigation method, furrow length and discharge on advance time (min) during the irrigation in date 14 / 8 / 2000.

L	D	Continuous flow (C)				Alternative flow (A)				Surge-Alternative flow (S – A)			
		Discharge,l /s*				Discharge, l/s				Discharge, l/ s			
		1.95	4.26	6.2	8.5	1.95	4.26	6.2	8.5	1.95	4.26	6.2	8.5
40	10	6	3	2.5	2	6	3	2	2	5	2.5	2	2
	20	11	5.5	4.5	4	11	7	4	3	9	4.5	3.5	3
	30	18	8.5	6.5	5.3	16	9	5	5	13	6	4.5	3.8
	40	21.6	10.3	8	6.4	21	10	7	6	16	7.8	7.2	4.2
60	15	9	4	3	2.5	9	4	3	3	6	3	2.5	2
	30	17.5	8	7	4.5	2	9	6.2	5	14	6	5	3.5
	45	29	13.5	10	7	27	10	9.2	6.5	20	9.6	7	5
	60	36.5	17	12.4	9.6	32	15	11.3	9	25	11.6	8	12
80	20	13	7	4.5	3.5	12	6	4	3	8	4.5	3	1.5
	40	25	13.5	8.5	7	25	12	9	7	16	8	6	3
	60	38	19	13	11	37	18	12	11	25	12	8.5	5.5
	80	49.7	24.5	16.8	13	45	22.6	15.6	12.8	30.8	14.6	10.4	7.9
100	25	17	8.5	6	4.5	17	7	6	5	14	6	4	3
	50	33	16.5	11	9	36	16	11	9	27	11	7	5.5
	75	52.5	24	17.5	13	52.5	22	17	15	36	15.4	10.6	8
	100	67.4	32	22.5	17	64.5	30	20	17	40.8	19.4	13.6	10.2

L = Furrow length,m.
D = Distance from water inlet,m
* = The average value of discharge for five replicates.

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Table 3: Effect of irrigation method, furrow length and discharge on advance time (min) during the irrigation in date 14 / 9 / 2000.

L	D	Continuous flow (C) Discharge,l /s*				Alternative flow (A) Discharge, l/s				Surge-Alternative flow (S – A) Discharge, l/ s			
		1.95	4.26	6.2	8.5	1.95	4.26	6.2	8.5	1.95	4.26	6.2	8.5
40	10	5.5	3	2	1.5	5	3	2	1	4	2	1.5	1
	20	10.5	5.5	3.5	3	10	6	3.5	3	7.5	4	3	2.3
	30	16.5	8	6	4	15.3	8	5	4	12	5.4	4	3.5
	40	21	10	7.5	6	19.3	9	6.4	5.4	14.8	7.4	6.8	4.2
60	15	8	4.5	3.5	2.5	8	4	3	2	6	3	3	1.6
	30	16.5	8	6.5	5	15	8	6	4	12	6	4.5	3
	45	25	13	9	7.5	22	11	8	5.6	17	8.8	6.3	4.5
	60	31.5	17	12	9.5	39.6	14.6	10	7.6	22	10.8	7.6	6.2
80	20	12	6.5	4.5	4	12	6	4	4	8	5	3	2.3
	40	25	12.5	9	7.5	23	13	8	7	14	8	5	4.2
	60	34	18	14	10	34	18	12	10	19	11	7.6	5.8
	80	42.5	23.5	17	12.5	10	20.6	14.8	12.2	25	14.3	9.3	7.4
100	25	18	8	6	4.5	16	8	5	4	10	6	4	3.3
	50	35.5	16.5	13	10	33	17	9	9	19	11	7	6
	75	52	24	17.5	13.5	50	24	15	13	28	15	11	8
	100	67	31	22	16	59	30	19.5	15.6	35.2	18.8	13.2	9.8

L = Furrow length,m.
D = Distance from water inlet,m
* = The average value of discharge for five replicates.

Table 4: Amount of irrigation water , m^3, for continuous irrigation method during the season

D	d	Furrow length,m				D	d	Furrow length,m			
		40	60	80	100			40	60	80	100
1.95	7/6	740	740	740	740	6.2	7/6	740	740	740	740
	30/6	490	490	490	490		30/6	490	490	490	490
	14/7	455	467	483	487		14/7	482	493	495	546
	29/7	410	452	467	482		29/7	480	451	473	502
	14/8	380	427	436	473		14/8	445	462	469	498
	29/8	385	388	412	476		29/8	450	449	463	496
	14/9	467	350	474	472		14/9	413	443	471	491
	W_s	3227	3334	3402	3620		W_s	3500	3528	3601	3763
4.26	7/6	740	740	740	740	8.5	7/6	740	740	740	740
	30/6	490	490	490	490		30/6	490	490	490	490
	14/7	478	480	489	538		14/7	496	502	518	561
	29/7	470	435	461	503		29/7	495	482	507	633
	14/8	395	438	466	492		14/8	490	493	498	516
	29/8	425	420	479	491		29/8	483	491	501	517
	14/9	384	437	452	476		14/9	450	482	486	483
	W_s	3382	3440	3577	3730		W_s	3644	3680	3740	3840

D = discharge, l/s.
d = Date of irrigation.
W_s = Total water applied per season, m^3.

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Table 5: Amount of irrigation water , m^3, for alternative irrigation system during the season

D	d	Furrow length, m				D	d	Furrow length,m			
		40	60	80	100			40	60	80	100
1.95	7/6	740	740	740	740	6.2	7/6	740	740	740	740
	30/6	490	490	490	490		30/6	490	490	490	490
	14/7	189	199	204	236		14/7	221	220	229	235
	24/7	178	187	195	232		24/7	212	199	223	242
	4/8	179	185	186	225		4/8	204	196	217	234
	14/8	183	186	198	226		14/8	205	207	219	223
	24/8	185	180	176	218		24/8	194	187	211	218
	4/9	174	178	188	206		4/9	196	185	208	216
	14/9	169	173	175	107		14/9	189	182	206	214
	W_S	2487	2518	2552	2780		W_S	2651	2606	2743	2812
4.26	7/6	740	740	740	740	8.5	7/6	740	740	740	740
	30/6	490	490	490	490		30/6	490	490	490	490
	14/7	199	217	218	241		14/7	237	249	251	253
	24/7	189	202	209	240		24/7	215	219	238	250
	4/8	186	189	208	223		4/8	211	213	239	248
	14/8	188	191	216	230		14/8	226	238	245	256
	24/8	179	190	200	231		24/8	220	198	236	245
	4/9	176	187	199	226		4/9	217	225	235	243
	14/9	173	186	197	228		14/9	208	193	232	238
	W_S	2520	2592	2677	2849		W_S	2765	2756	2906	2963

D = discharge, l/s.
d = Date of irrigation.
W_s = Total water applied per season, m^3 .

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Table 6: Amount of irrigation water , m^3, for surge-alternative irrigation system during the season

D	d	Furrow length,m 40	60	80	100	D	d	Furrow length,m 40	60	80	100
1.95	7/6	740	740	740	740	6.2	7/6	740	740	740	740
	30/6	490	490	490	490		30/6	490	490	490	490
	14/7	155	143	140	148		14/7	214	164	155	158
	24/7	145	148	140	147		24/7	208	151	143	155
	4/8	140	146	135	143		4/8	201	148	145	152
	14/8	140	136	129	139		14/8	192	145	142	120
	24/8	140	142	130	136		24/8	192	146	139	149
	4/9	135	137	130	134		4/9	190	144	136	149
	14/9	130	130	110	124		14/9	189	143	134	148
	W_s	2216	2212	2144	2201		W_s	2620	2271	2224	2291
4.26	7/6	740	740	740	740	8.5	7/6	740	740	740	740
	30/6	490	490	490	490		30/6	490	490	490	490
	14/7	166	159	148	156		14/7	223	179	162	163
	24/7	151	147	140	154		24/7	218	167	149	158
	4/8	148	147	140	148		4/8	204	165	145	157
	14/8	149	142	136	145		14/8	205	164	144	154
	24/8	148	149	137	145		24/8	201	162	142	150
	4/9	144	139	137	143		4/9	199	182	141	151
	14/9	142	138	137	144		14/9	200	159	141	149
	W_s	2278	2251	2205	2265		W_s	2680	2388	2254	2312

D = discharge, l/s.

d = Date of irrigation.

W_s = Total water applied per season, m^3 .

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Table 7: Effect of furrow length and discharge on moisture content, %, before irrigation under continuous Irrigation method.

D	d	Furrow length, m											
		40			60			80			100		
		Distance from water inlet			Distance from water inlet			Distance from water inlet			Distance from water inlet		
		10	20	30	10	30	50	10	40	70	10	50	90
1.95	15	31.6	30.8	27.2	32.5	31.6	29.8	32.6	31.7	31.1	32.3	30.2	30.1
	30	33.6	30.5	28.1	35.6	33.2	30.6	33.8	34.1	32.2	35.7	31	30.5
	45	34.1	31.2	29.8	36.9	34	31.5	34.6	34.2	33.6	36.6	32.2	31.8
	60	34.5	31.7	30.3	38	36.1	32.2	35.6	35.1	34	37.8	36.5	32.5
4.26	15	30.1	29.8	28.2	31.6	29.8	27.2	32.5	31.6	29.8	32.9	30.7	30.5
	30	32.5	31.1	28.7	33.6	30.5	28.1	35.6	33.2	30.7	36.2	31.8	31.1
	45	33.6	31.9	29.3	35.1	31.2	29.8	36.6	34.2	31.6	37.1	33.8	32.2
	60	34.2	32.6	29.9	34.5	31.7	30.3	38.1	36.2	32.2	38.2	36.9	32.9
6.2	15	30.3	29.6	29.2	30.3	29.6	29.1	31.7	30.8	29.2	33.2	32.1	32
	30	31.7	30.1	29.9	31.7	30.1	29.9	34.5	32.1	30.6	37.2	32.6	31.8
	45	32	30.8	30.1	32	30.8	30.1	35.9	34.1	32	38.1	34.2	33.6
	60	32.6	31.2	30.8	32.6	31.2	30.8	36.6	35.5	34.2	38.1	37.2	36.1
8.5	15	32.3	30.2	30	31.5	30.7	30.3	31.7	30.9	30.5	31.8	30.2	29.4
	30	35.7	31	30.5	32.8	31.2	31.1	32.9	31.4	31.3	33.9	30.8	28.5
	45	36.6	32.2	32	33.1	31.9	31.5	33.3	32.1	31.9	34.2	32.6	30.2
	60	38	32.9	32.9	33.6	32.4	32	36.8	35.7	34.5	35.8	34.2	33.2

D = Discharge, l/s.
d = depth of the soil, cm.

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Table 8: Effect of furrow length and discharge on moisture content, %, before irrigation under alternative Irrigation method.

D	d	Furrow length, m											
		40			60			80			100		
		Distance from water inlet			Distance from water inlet			Distance from water inlet			Distance from water inlet		
		10	20	30	10	30	50	10	40	70	10	50	90
1.95	15	31.4	30.6	28	32.6	32.6	31.7	32.9	32.1	31.8	32.5	30.4	30.3
	30	33.4	30.3	28.3	33.9	33.9	33.3	34	33.6	32.9	36	31.3	30.8
	45	33.9	31	29.6	34.1	34.1	33.9	34.6	34.1	33.9	37	32.5	32.1
	60	34.3	31.5	30.1	34.3	34.9	34	35.9	35.3	34.9	37.4	32.9	32.5
4.26	15	30.3	30.1	29.6	31.8	30.2	29.1	32.9	32.1	30.2	32.5	30.2	30.2
	30	32.7	31.4	29.9	33.8	30.7	29.6	35.9	33.6	31.1	32.9	33.2	33.2
	45	33.9	32.3	29.6	34.2	31.2	30.5	36.8	34.6	33.9	33.6	33.6	33.6
	60	34.5	32.9	30.2	34.6	31.9	31.1	37.3	36.9	34.7	34.9	34.1	34.3
6.2	15	30.6	29.9	29.4	30.1	29.4	29	31.7	30.8	29.6	35.6	35.2	34.8
	30	32	30.4	30.2	31.5	30.7	30.2	33.5	32.1	30.6	36.2	35.8	35.2
	45	32.3	31.1	30.5	32	31.2	30.5	34.7	32.9	31.2	36.9	36.2	35.8
	60	32.9	31.5	31.1	32.8	31.9	31.2	35.1	33.6	31.4	37.6	36.8	36.3
8.5	15	32.6	30.5	30.3	31.8	31	30.6	31.2	30.6	30.1	34.8	34.2	33.9
	30	34.1	31.9	30.9	33.1	31.5	31.4	33.2	31.5	31.6	35.2	34.8	34.5
	45	35.1	32.6	32.5	33.3	32.6	31.9	34.1	32.1	31.9	35.8	35.2	34.9
	60	36.2	33.5	33.4	33.9	33.1	32.2	34.6	33.8	32.3	35.9	35.7	35.2

D = Discharge, l/s.
d = depth of the soil, cm.

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Table 9: Effect of furrow length and discharge on moisture content, %, before irrigation under surge-alternative Irrigation method.

D	d	Furrow length , m											
		40			60			80			100		
		Distance from water inlet			Distance from water inlet			Distance from water inlet			Distance from water inlet		
		10	20	30	10	30	50	10	40	70	10	50	90
1.95	15	31.8	31	27.5	32.8	31.9	30.2	32.9	32	31.4	32.7	30.6	30.5
	30	33.8	31.3	28.5	35.9	33.6	30.9	34.2	34.5	32.6	36	31.4	30.9
	45	34.5	31.6	30.1	37.2	34.4	31.9	34.9	34.6	34	37	32.6	32.2
	60	34.7	31.9	30.8	38.4	36.5	32.6	35.9	35.3	32.6	38.1	36.9	32.9
4.26	15	30.4	29.9	28.7	31.9	30.2	27.5	32.9	32	30.2	35.3	31.1	30.9
	30	32.8	31.4	28.9	34	30.9	28.4	35.9	33.5	31	36.6	32.2	31.4
	45	33.9	32.2	29.6	35.5	31.5	30.2	36.9	34.5	31.9	37.4	34.1	32.5
	60	34.5	33.1	30.5	34.9	32	30.8	38.4	36.5	32.6	38.5	37.2	33.2
6.2	15	30.8	30.2	29.8	30.9	30.1	29.8	32	31.1	29.5	33.6	32.4	32.3
	30	32.1	30.5	30.2	32.1	30.4	30.2	34.8	32.4	31	37.5	32.9	32.2
	45	32.5	31.3	30.5	32.5	31.2	30.4	36.3	34.4	32.4	38.4	34.6	33.9
	60	32.9	31.8	31.2	32.9	31.5	31.1	36.9	35.6	34.5	38.9	37.5	36.4
8.5	15	32.6	30.8	30.4	31.9	31.1	30.7	32.1	31.3	30.9	32.2	30.5	29.3
	30	36.1	31.5	30.9	33.1	31.6	31.2	33.2	31.7	31.6	34.2	31.3	29.8
	45	37.3	32.6	32.4	33.7	32.3	31.8	33.6	32.4	32.2	34.7	33.1	30.7
	60	38.5	33.2	33.3	34.1	32.7	32.4	37.2	35.9	34.8	36.2	34.6	33.8

D = Discharge, l/s.
d = depth of the soil, cm.

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Table 10: Effect of furrow length and discharge on moisture content, %, after irrigation under continuous Irrigation method.

D	d	Furrow length , m											
		40			60			80			100		
		Distance from water inlet			Distance from water inlet			Distance from water inlet			Distance from water inlet		
		10	20	30	10	30	50	10	40	70	10	50	90
1.95	15	43.6	39.1	34.9	48.8	40.2	38.2	44.3	39	38.2	43	38.9	38.2
	30	43.3	35.9	33.1	46.1	38.8	35.4	43.7	38.8	36.9	43.6	36.7	35.8
	45	42.2	34.8	33.9	43.6	38.6	36.1	42	38.1	37.4	41.8	36.9	36.2
	60	41	35.3	33.6	40.1	39.8	35.8	41.5	38.6	37	40	38.5	36
4.26	15	44.3	39.8	37.7	35.6	40.4	37.5	44.7	41.5	39.5	44.7	39.5	39.2
	30	43.3	37.6	34.8	43.9	37.4	34.8	42.2	39.6	37	44.8	37.5	36.7
	45	40.7	37.3	34.4	43.7	36.9	35.4	40.4	39.5	36.8	42.1	38.6	36.9
	60	40.8	37	34	41.5	36.3	34.8	40.2	40.5	36.5	41.6	40.7	36.7
6.2	15	44.8	41	39.7	44	39.8	38.9	46.1	40.6	38.7	49.5	41.5	40.2
	30	42.4	37.5	36.8	43.3	36.7	36.3	43.1	38.4	36.8	47.8	39.7	39.1
	45	40.9	36.9	35.8	42	36.3	35.4	41.7	39.4	37.2	41.9	38.8	37.6
	60	39.8	36.1	35.5	39	35.6	35.1	40.7	39.7	38.4	41.2	38.2	37.1
8.5	15	47.5	40.8	40.2	45.5	39.9	39.3	45.5	40.3	39.2	48.8	38.2	37.6
	30	44.5	37.8	37.1	44.2	37.2	36.9	42.8	37.5	36.9	44.6	37.3	36.3
	45	42.5	37.9	37.5	42.8	36.9	36.3	41.4	37.2	36.6	42.3	36.2	35.3
	60	40.9	37.5	37.3	40.5	36.4	36	40.2	39.5	38.3	40.2	35.6	34.6

D = Discharge, l/s.
d = depth of the soil, cm.

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Table 11: Effect of furrow length and discharge on moisture content, %, after irrigation under alternative Irrigation method.

D	d	Furrow length, m											
		40			60			80			100		
		Distance from water inlet			Distance from water inlet			Distance from water inlet			Distance from water inlet		
		10	20	30	10	30	50	10	40	70	10	50	90
1.95	15	38.5	37.4	36.5	38.9	38.6	36.5	39.7	39	38.4	39	38.4	37.2
	30	38.4	37.1	36.2	38.1	33.6	35.7	39.5	38.7	38	38.6	38.1	37
	45	37.6	36.2	35.4	37.3	37	35.1	39.1	38.2	37.6	38.1	37.4	36.6
	60	37.2	35.9	35	36.9	36.4	34.5	38.6	37.6	38.2	37.6	37	36.1
4.26	15	37.7	37	36.2	39.3	38.4	37.6	41.5	40.6	39.6	39.8	39.4	38.9
	30	37.2	36.5	36	38.5	38.2	36.8	41.1	40.1	39.2	39.5	38.6	38.4
	45	36.4	362	35.4	38	37.5	36.3	40.6	39.5	38.4	39.1	38.1	37.5
	60	35.9	35.6	35	37.6	37	35.4	40.2	39	38.1	38.4	37.7	37.2
6.2	15	37.8	37	36.2	42.5	40.8	39.6	42.9	40.2	39.4	40.4	39.8	39.4
	30	37.5	34.5	35.8	40.3	39.6	39.2	42.2	39.5	39	39.6	39.4	38.5
	45	36.3	34	35.1	39.9	39.2	38.6	41.5	39.2	38.5	39.2	39	38.2
	60	36	33.2	34.6	39.4	38.8	38.3	41.3	38.8	382	38.4	38.5	37.5
8.5	15	40.2	39.6	37.2	44.6	43.5	42	43	40.2	39	41	40	39.2
	30	35.6	36.7	36.4	43.3	43	41.6	42.1	39.6	38.4	39.5	38.8	38.6
	45	34.8	35.6	35.8	41.6	42.5	41.3	41.3	39.1	381	39	38.1	38.1
	60	34.2	35	35.2	40	42.1	39	40.6	38.4	37.6	38.4	37.6	37.2

D = Discharge, l/s.
d = depth of the soil, cm.

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Table 12: Effect of furrow length and discharge on moisture content, %, after irrigation under surge-alternative Irrigation method.

D	d	Furrow length , m											
		40			60			80			100		
		Distance from water inlet			Distance from water inlet			Distance from water inlet			Distance from water inlet		
		10	20	30	10	30	50	10	40	70	10	50	90
1.95	15	38.6	38.4	38	38.9	38.4	37.8	39.1	38.7	38.1	40	39.6	38.7
	30	38.3	37.8	37.6	38.5	38	37.3	38.6	38.3	37.5	39.6	39.2	38.2
	45	37.6	37.2	36.8	38.1	37.6	36.9	38.1	37.6	37.2	39.2	38.6	37.5
	60	37.2	36.8	36.4	37.6	37.2	36.6	38	37.4	36.8	38.5	38.2	37.2
4.26	15	39.4	39	38.7	39.6	39.4	38.7	39.6	39.1	38.4	40	39.5	39
	30	39	38.5	38.2	39.2	38.6	38.4	39.4	38.5	38	39.5	39.1	38.4
	45	38.5	38	37.5	38.7	38.2	38.1	38.6	38.1	37.2	39.2	38.3	38.1
	60	37.9	38.2	37	38.2	38	37.5	38.4	37.7	38.1	38.8	38	37.6
6.2	15	39.8	39.2	38.7	39.6	39.5	39	39.8	39.6	38.8	40.4	39.9	39.4
	30	39.2	38.5	38.5	39.3	39.1	38.7	39.4	39.1	38.4	39.9	39.4	39
	45	38.6	38.3	38	38.7	38.4	38.2	39.2	39	38	39.7	39.1	38.8
	60	38.3	37.8	37.2	38.4	37.7	38.5	38.7	38.8	37.5	39	38.8	38.4
8.5	15	40	39.5	384	40.3	39.5	39	40.2	39.7	39.6	40.2	39.8	39.1
	30	39.2	39.1	37.6	40	39.2	38.7	39.7	39.2	39.1	39.5	39.8	38.5
	45	38.6	38.4	37.1	39.6	38.7	38.3	39.1	38.8	38.6	39.4	39.2	38.1
	60	37.6	37.7	36.4	39.1	38	37.8	38.8	38.4	38.4	39.5	38.8	37.3

D = Discharge, l/s.
d = depth of the soil, cm.

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Table 13 : Analysis variance for advance rate.

SV	DF	SS	MS	F
REPS (R)	2	166.71904	83.35952	---
IRRIGATION SYSTEM (I)	2	2035.45053	1017.72526	---
ERROR (a)	4	9.14366	2.28591	
LENGTH (L)	3	7078.75330	2359.58443	1651.12 **
LXL	6	485.82469	80.97078	56.66 **
ERROR (b)	18	25.72345	1.42908	
DISCHARGE (Q)	3	16416.00402	5472.00134	2298.43 **
IXQ	6	640.06797	106.67799	44.81 **
LXQ	9	2261.87850	251.31893	105.56 **
IXLXQ	18	193.23524	10.73529	4.51 **
ERROR (c)	72	171.41445	2.38076	
TOTAL	143	29484.21484		

** =significant at 1% level , --- =insufficient error df

Table 14 :Interaction between irrigation method I , furrow length (L) and discharge (Q) for advance rate.

Discharge (Q)	Length (L)				
	L_1	L_2	L_3	L_4	L – MEAN
I = REP1					
Q_1	22.86a	36a	49.04a	68.13a	44.017
Q_2	11.1b	17.6b	24.7b	32.6b	21.525
Q_3	8.2c	12.8c	17.3c	23.3c	15.35
Q_4	6.5c	9.7d	13.16d	17.3d	11.7
I = REP 2					
Q_1	20.77a	35.2a	43.67a	63.83a	40.9
Q_2	10b	15.5b	22.07b	30.7b	19.5
Q_3	7.13c	11.11c	15.8c	20.1c	13.6
Q_4	5.96c	8.9c	13.0d	16.53d	11.1
I = REP 3					
Q_1	16.2a	24a	29.3a	39.33a	27.21
Q_2	8.02b	11.8b	14.93b	19.73b	13.6
Q_3	5.6bc	8.2c	10.33c	13.6c	9.4
Q_4	4.5c	6.6c	8.1c	10.33d	7.3
Q –MEAN	10.56	16.43	21.8	29.62	19.6

	LSD (5%)	LSD (1%)
L means at each I*Q	2.404	3.21
Q means at each I*L	2.511	3.33

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Table 15 : Interaction between furrow length (L) and discharge (Q) for advance rate.

Discharge (Q)	Length (L)				
	L_1	L_2	L_3	L_4	L - MEAN
Q_1	19.99	31.73	40.67	57.1	37.4
Q_2	9.73	15	20.6	27.6	18.24
Q_3	6.99	10.703	14.5	18.94	12.8
Q_4	5.63	8.27	11.4	14.7	10.02
Q – MEAN	10.57	16.3	21.8	29.61	19.6

Table 16 : Interaction between irrigation method I and discharge (Q) for advance rate.

Discharge (Q)	Irrigation system (I)			
	I_1	I_2	I_3	I - MEAN
Q_1	44.02	40.9	27.2	37.4
Q_2	21.53	19.6	13.63	18.2
Q_3	15.3	13.53	9.43	12.7
Q_4	11.7	11.1	7.32	10.01
Q – MEAN	23.14	21.3	14.4	19.6

Table 17: Interaction between Irrigation system I and furrow length (L) for advance rate.

Furrow length (L)	Irrigation system (I)			
	I_1	I_2	I_3	I - MEAN
L_1	12.15	10.99	8.6	10.6
L_2	19.04	17.67	12.6	16.43
L_3	26.4	23.64	15.7	21.8
L_4	35.34	32.8	20.75	29.62
L – MEAN	23.14	21.3	14.4	19.6

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Table 18 : Analysis variance for water applied.

SV	DF	SS	MS	F
REPS (R)	2	21.88	10.9	---
IRRIGATION SYSTEM (I)	2	41692188	20846094	---
ERROR (a)	4	130	32.56	
LENGTH (L)	3	495943.7	165314	4554.3 **
IXL	6	589886	98314	2708.5 **
ERROR (b)	18	653.4	36.3	
DISCHARGE (Q)	3	549737	183245	5069.6 **
IXQ	6	561710	93618	2590 **
LXQ	9	510733	56748	1569 **
IXLXQ	18	1321854	73436	2031.6 **
ERROE (c)	72	2602	35.16	
TOTAL	143	45725462		

** = Significant at level 1% ; --- insufficient error df

Table 19:Interaction between irrigation method I , furrow length (L) and discharge (Q) for water applied.

Discharge (Q)	Length (L)				
	L_1	L_2	L_3	L_4	L – MEAN
I = REP1					
Q_1	3227d	3334d	3402d	3620d	3395.7
Q_2	3382c	3440c	2577c	3730c	3532
Q_3	3500b	3528b	2601b	3763b	3598
Q_4	3644a	3680a	2740a	3840a	3726
I = REP 2					
Q_1	3487a	2518d	2552d	2780d	2834
Q_2	2544d	2592c	2677c	2849c	2668
Q_3	2561c	2606b	2743b	2812b	2680
Q_4	2756b	2765a	2906a	2963a	2847
I = REP 3					
Q_1	2216d	2212d	2144d	2201d	2193
Q_2	2278c	2251c	2205c	2265c	2249
Q_3	2297b	2271b	2224b	2291b	2270
Q_4	2386a	2303a	2254a	2312a	2313
Q –MEAN	2856.5	2791.6	2835.4	2952.2	2858.9

	LSD (5%)	LSD (1%)
L means at each I*Q	9.92	13.28
Q means at each I*L	9.79	12.99

Table 20 : Interaction between furrow length (L) and discharge (Q) for water applied

Discharge (Q)	Length (L)				
	L_1	L_2	L_3	L_4	L - MEAN
Q_1	2976.7	2688	2699	2867	2807
Q_2	2734	2761	2819	2948	2815
Q_3	2786	2801	2865	2955	2849
Q_4	2928	2916	2966	3038	2962
Q – MEAN	2856	2790	2835	2952	2858

Table 21 : Interaction between irrigation method I and discharge (Q) for water applied

Discharge (Q)	Irrigation system (I)			
	I_1	I_2	I_3	I - MEAN
Q_1	3395	2834	2193	2807
Q_2	3532	2665	2249	2815
Q_3	3598	2680	2270	2849
Q_4	3726	2847	2313	2965
Q – MEAN	3562	2756	2256.9	2858

Table 22 : Interaction between Irrigation system I and furrow length (L) for water applied

Furrow length (L)	Irrigation system (I)			
	I_1	I_2	I_3	I - MEAN
L_1	3438	2837	2294	2856
L_2	3495	2620	2259	2791
L_3	3580	2719	2206	2835
L_4	3738	2851	2267	2952
L – MEAN	3563	2756	2256.9	2858

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Table 23 : Analysis variance infiltration rate.

SV	DF	SS	MS	F
REPS (R)	2	0.96	0.48	---
IRRIGATION SYSTEM (I)	2	369.3	184.6	---
ERROR (a)	4	0.002	0.00007	
LENGTH (L)	3	4.22	1.41	20296 **
IXL	6	91.7	15.3	220095 **
ERROR (b)	18	0.0013	0.0006	
DISCHARGE (Q)	3	43	14.32	206256 **
IXQ	6	130.4	21.3	312876 **
LXQ	9	2.64	0.3	4216 **
IXLXQ	18	2.64	0.7	9456 **
ERROE (c)	72	11.82	0.00007	
		0.005		
TOTAL	143	654		

** = Significant at level 1% ;   --- insufficient error df

Table 24 :Interaction between irrigation method I , furrow length (L) and discharge (Q) for infiltration rate..

Discharge (Q)	Length (L)				
	L_1	L_2	L_3	L_4	L – MEAN
I = REP1					
Q_1	19.5	20.0	20.2	20.5	20.0
Q_2	21.0	20.5	21.5	21.5	20.9
Q_3	21.5	22	22.5	22.5	22.0
Q_4	21.5	22	23.0	23.0	22.4
I = REP 2					
Q_1	19.5	20	20.0	20.0	19.9
Q_2	20.0	21.5	21.5	22.0	21.24
Q_3	21.0	23.0	23.5	24.0	22.9
Q_4	22.5	23.5	24.0	24.50	23.63
I = REP 3					
Q_1	21.00	18.5	19.0	18.5	19.3
Q_2	20.00	18.00	18.5	18.0	18.63
Q_3	20.20	17.5	17.0	17.0	18.0
Q_4	19.500	16.00	17.0	16.0	17.13
Q –MEAN	20.63	20.21	20.5	20.63	20.5

	LSD (5%)	LSD (1%)
L means at each I*Q	0.014	0.018
Q means at each I*L	0.014	0.018

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Table 25: Interaction between furrow length (L) and discharge (Q) for water distribution efficiency

Discharge (Q)	Length (L)				
	L_1	L_2	L_3	L_4	L - MEAN
Q_1	20.0	19.5	19.7	19.7	19.71
Q_2	20.3	20	20.2	20.5	20.25
Q_3	21.0	20.83	20.83	21.2	21
Q_4	21.2	21.33	21.3	21.2	21.04
Q - MEAN	20.63	20.21	20.5	20.63	20.5

Table 26 : Interaction between irrigation method I and discharge (Q) for water distribution efficiency

Discharge (Q)	Irrigation system (I)			
	I_1	I_2	I_3	I - MEAN
Q_1	20.00	19.88	19.25	19.71
Q_2	20.86	21.2	18.63	20.25
Q_3	22.0	22.9	18.0	21
Q_4	22.4	23.63	17.125	21
Q - MEAN	21.3	21.9	18.25	20.5

Table 27: Interaction between Irrigation system I and furrow length (L) for water distribution efficiency

Furrow length (L)	Irrigation system (I)			
	I_1	I_2	I_3	I - MEAN
L_1	20.88	20.8	20.25	20.63
L_2	21.13	22	17.5	20.21
L_3	21.4	22.25	17.9	20.5
L_4	21.9	22.63	17.4	20.63
L - MEAN	21.3	21.9	18.3	20.5

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Table 28 : Analysis variance for application efficiency.

SV	DF	SS	MS	F
REPS (R)	2	160.4	80.2	---
IRRIGATION SYSTEM (I)	2	21094.7	10547.4	---
ERROR (a)	4	37.5	9.4	
		783.6	261.2	66.32 **
LENGTH (L)	3	3523.7	587.3	149.2 **
IXL	6	70.9	3.93	
ERROR (b)	18	1492.6	497.5	110.08 **
		845.8	141	31.19 **
DISCHARGE (Q)	3	488.6	54.3	12.01 **
IXQ	6	713.5	23	5.08 **
LXQ	9	325.4	4.5	
IXLXQ	18			
ERROE (c)	72			
TOTAL	143	29236.7		

** = significant at level 1% ; --- insufficient error df

Table 29 :Interaction between irrigation method I , furrow length (L) and discharge (Q) for application efficiency.

Discharge (Q)	Length (L)				
	L_1	L_2	L_3	L_4	L – MEAN
I = REP1					
Q_1	55.4 bc	55.1a	43.51 c	48.02 a	80.5
Q_2	58.6 ab	57.1 a	52.03 a	44.9 a	53.15
Q_3	59.5 a	50.3 b	51.63 a	48.5 a	52.47
Q_4	53.8c	46.5 c	47.03 b	39.9 b	46.8
I = REP 2					
Q_1	65.3 c	56.7 c	53.28 c	57.8 a	58.3
Q_2	75.05 a	71.9 a	66.03 a	53.6 b	66.7
Q_3	70.7 b	67.4 b	59.99 b	48.6 c	61.7
Q_4	61.1 d	48.6 d	51.8 c	42.8 d	51.06
I = REP 3					
Q_1	64.95 c	75.53 c	79.03 b	77.3 c	74.21
Q_2	69.74 b	84.7 a	88.433 a	85.0 a	82
Q_3	73.84 a	82.2 ab	88.9 a	83.73 ab	82.16
Q_4	72.8 ab	79.9 b	86.87 a	80.9 b	80.12
Q - MEAN	65.06	64.66	64.04	59.26	63.24

	LSD (5%)	LSD (1%)
L means at each I*Q	3.445	4.607
Q means at each I*L	3.46	4.6

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Table 30: Interaction between furrow length (L) and discharge (Q) for application efficiency

Discharge (Q)	Length (L)				
	L_1	L_2	L_3	L_4	L – MEAN
Q_1	61.8	62.42	58.61	61.04	60.99
Q_2	67.8	41.23	68.83	61.22	67.27
Q_3	68.01	66.64	66.84	60.3	65.44
Q_4	62.6	58.33	61.9	54.52	59.32
Q - MEAN	65.06	64.66	64.04	59.26	63.25

Table 31: Interaction between irrigation method I and discharge (Q) for application efficiency

Discharge (Q)	Irrigation system (I)			
	I_1	I_2	I_3	I – MEAN
Q_1	50.5	58.3	74.21	60.99
Q_2	53.15	66.7	81.99	67.3
Q_3	52.5	61.7	82.2	65.44
Q_4	46.8	51.06	80.12	59.32
Q - MEAN	50.73	59.06	79.62	63.3

Table 32 : Interaction between Irrigation system I and furrow length (L) for application efficiency

Furrow length (L)	Irrigation system (I)			
	I_1	I_2	I_3	I – MEAN
L_1	56.8	68.04	70.33	65.06
L_2	52.2	61.2	80.6	64.66
L_3	48.5	57.8	85.81	64.04
L_4	45.34	50.7	81.7	59.3
L - MEAN	50.73	59.82	79.62	63.25

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Table 33 : Analysis variance for water distribution efficiency.

SV	DF	SS	MS	F
REPS (R)	2	602.2	301.1	---
IRRIGATION SYSTEM (I)	2	867.6	433.8	---
ERROR (a)	4	9.4	2.36	
LENGTH (L)	3	294.6	98.2	28.4 **
IXL	6	747.6	124.6	36.04 **
ERROR (b)	18	62.24	3.5	
				1880.5 **
DISCHARGE (Q)	3	5123	1707.7	131.4 **
IXQ	6	716	119.3	5.12 **
LXQ	9	71	4.7	3.7 **
IXLXQ	18	60.5	3.4	
ERROE (c)	72	65.4	0.9	
TOTAL	143	8590.8		

** = significant at level 1% ; --- insufficient error df

Table 34 :Interaction between irrigation method I , furrow length (L) and discharge (Q) for water distribution efficiency.

Discharge (Q)	Length (L)				
	L_1	L_2	L_3	L_4	L – MEAN
I = REP1					
Q_1	69.7c	68.4c	67.7b	65.7d	67.9
Q_2	78.7a	79.2a	75a	74.3a	76.8
Q_3	79a	79.3a	73.5a	71.7b	75.9
Q_4	72b	72.3b	69.1b	67.5c	70.2
I = REP 2					
Q_1	68.8c	65d	60.1d	58.7d	63.2
Q_2	84.3a	82.9b	77.6b	73.7b	79.6
Q_3	84.4a	85.7a	80.5a	75.4a	81.5
Q_4	74.1b	72c	69.03c	67.8c	70.8
I = REP 3					
Q_1	61.8d	65.4d	68.33d	68.7d	66.05
Q_2	82.4a	84.7a	86.9a	86.13a	85.05
Q_3	79.5b	82.3b	84.2b	82.9b	82.2
Q_4	77.3c	80.03c	81.9c	81.1c	80.08
Q –MEAN	76.11	76.4	74.5	72.803	74.9

	LSD (5%)	LSD (1%)
L means at each I*Q	2.085	2.818
Q means at each I*L	1.55	2.06

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Table 35 : Interaction between furrow length (L) and discharge (Q) for water distribution efficiency

Discharge (Q)	Length (L)				
	L_1	L_2	L_3	L_4	L – MEAN
Q_1	66.8	66.3	65.4	64.4	65.7
Q_2	81.8	82.3	79.9	78.02	80.5
Q_3	81	82.44	79.4	76.7	79.9
Q_4	74.5	74.8	73.4	72.2	73.7
Q - MEAN	76.1	76.5	74.5	72.13	74.94

Table 36 : Interaction between irrigation method I and discharge (Q) for water distribution efficiency

Discharge (Q)	Irrigation system (I)			
	I_1	I_2	I_3	I – MEAN
Q_1	67.9	63.2	66.05	65.7
Q_2	76.8	79.6	85.05	80.5
Q_3	75.9	81.5	82.24	79.9
Q_4	70.23	70.7	80.05	73.7
Q - MEAN	72.7	73.7	78.4	74.9

Table 37 : Interaction between Irrigation system I and furrow length (L) for water distribution efficiency

Furrow length (L)	Irrigation system (I)			
	I_1	I_2	I_3	I – MEAN
L_1	74.88	77.2	75.2	76.01
L_2	74.8	76.4	78.2	76.45
L_3	71.33	71.81	80.4	74.5
L_4	69.8	68.91	79.81	72.8
L - MEAN	72.7	73.7	78.4	74.9

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Table 38 : Analysis variance for yield.

SV	DF	SS	MS	F
REPS (R)	2	302.4	151.2	---
IRRIGATION SYSTEM (I)	2	207237	103618.8	---
ERROR (a)	4	138.9	53.4	
LENGTH (L)	3	32882	10960.9	205.33 **
IXL	6	157925	26320.8	493.07 **
ERROR (b)	18	960.8	53.4	
DISCHARGE (Q)	3	106949.8	35649.9	852.05 **
IXQ	6	24018	4003	95.7 **
LXQ	9	10641	1182.4	28.3 **
IXLXQ	18	25076	1393.2	33.3 **
ERROE (c)	72	3012.5	41.84	
TOTAL	143	569145.6		

** = Significant at level 1% ; --- insufficient error df

Table 39 :Interaction between irrigation method I , furrow length (L) and discharge (Q) for yield.

Discharge (Q)	Length (L)				
	L_1	L_2	L_3	L_4	L – MEAN
I = REP1					
Q_1	2864d	2861d	2861c	2860c	2861
Q_2	2951a	2940a	2940a	2936a	2947
Q_3	2890b	2884b	2884b	2878b	2885
Q_4	2876c	2875c	2875b	2877b	2875
I = REP 2					
Q_1	2878c	2871b	2808b	2784b	2835
Q_2	2958a	2907c	2793a	2855a	2878
Q_3	2948a	2901a	2826c	2740c	2853
Q_4	2894b	2880b	2804d	2704d	2820
I = REP 3					
Q_1	2867c	2875d	2894c	2908c	2886
Q_2	2946a	2967a	2982a	2997a	2973
Q_3	2944a	2959b	2969a	2990a	2965
Q_4	2901b	2926c	2947b	2965b	2934
Q –MEAN	2909.7	2906	2881.9	2874	2893

	LSD (5%)	LSD (1%)
L means at each I*Q	11.06	14.83
Q means at each I*L	10.53	13.97

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Table 40 : Interaction between furrow length (L) and discharge (Q) for Yield.

Discharge (Q)	Length (L)				
	L_1	L_2	L_3	L_4	L - MEAN
Q_1	2869.6	2868.3	2854.3	2850.6	2860.7
Q_2	2951.6	2945.6	2905	2929.3	2932.9
Q_3	2927.3	2917	2893	2869.3	2901.7
Q_4	2890.3	2893	2875	2848.7	2876.5
Q - MEAN	2909.7	2906	2881.99	2874.5	2893.1

Table 41 : Interaction between irrigation method I and discharge (Q) for Yield.

Discharge (Q)	Irrigation system (I)			
	I_1	I_2	I_3	I - MEAN
Q_1	2861	2835.2	2886	2860.7
Q_2	2947.5	2878.3	2973	2932.9
Q_3	2885.6	2853.7	2965.7	2901.7
Q_4	2875.2	2820.5	2934.7	2876.3
Q - MEAN	2892.4	2846.9	2939.8	2893.1

Table 42 : Interaction between Irrigation system I and furrow length (L) for Yield.

Furrow length (L)	Irrigation system (I)			
	I_1	I_2	I_3	I - MEAN
L_1	2895.2	2919.5	2914.5	2909.8
L_2	2896.5	2889.7	2931.7	2906
L_3	2890	2807.7	2948.17	2881.9
L_4	2887.8	2770.6	2965	2874.5
L - MEAN	2892.4	2846.9	2939	2893

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Table 43 : Analysis variance for leaf area.

SV	DF	SS	MS	F
REPS (R)	2	0.818	0.409	---
IRRIGATION SYSTEM (I)	2	9056.04	4528.04	--
ERROR (a)	4	0.0046	0.0012	
LENGTH (L)	3	1057.8	352.6	120889 **
IXL	6	10703.04	1783.84	6116 03 **
ERROR (b)	18	0.053	0.003	
DISCHARGE (Q)	3	496.83	10586.07	525654 **
IXQ	6	264.97	82.8	41117 **
LXQ	9	693.94	29.44	4117 1462 **
IXLXQ	18	0.145	38.55	19134 **
ERROE (c)	72		0.002	
TOTAL	143	54031.95		

** = Significant at level 1% ; --- insufficient error df

Table 44:Interaction between irrigation method I , furrow length (L) and discharge (Q) for leaf area.

Discharge (Q)	Length (L)				
	L_1	L_2	L_3	L_4	L – MEAN
I = REP1					
Q_1	809.2d	810.6d	806.8d	801.6d	807.05
Q_2	835.4c	834.1c	830.6c	832.4c	833.2
Q_3	854.7a	849.6b	847.1a	841.6a	848.1
Q_4	846.6b	850.2a	841.1b	842.5b	845.1
I = REP 2					
Q_1	810.7d	804.2d	790.5d	784.6d	797.5
Q_2	841.6c	835.7c	812.4c	804.6c	823.6
Q_3	843.8b	842.3a	826.2a	812.9a	831.3
Q_4	851.6a	847.5b	823.7b	824.1b	836.7
I = REP 3					
Q_1	804.7d	812.8d	820.6d	836.7d	818.7
Q_2	838.6c	839.2c	842.4c	858.9c	844.8
Q_3	844.2b	843.6b	852.1a	864.6a	851.2
Q_4	849.1a	841.2a	856.8b	860.8b	851.99
Q –MEAN	835.9	834.2	829.2	830.5	832.44

	LSD (5%)	LSD (1%)
L means at each I*Q	0.078	0.105
Q means at each I*L	0.073	0.97

Table 45: Interaction between furrow length (L) and discharge (Q) for leaf area.

Discharge (Q)	Length (L)				
	L_1	L_2	L_3	L_4	L - MEAN
Q_1	808.2	809.2	805.99	807.7	807.7
Q_2	838.5	836.33	828.5	831.99	833.8
Q_3	847.6	845.2	841.8	839.7	843.5
Q_4	849.1	846.3	840.5	842.5	844.6
Q - MEAN	835.9	834.3	829.2	830.5	832.5

Table 46: Interaction between irrigation method I and discharge (Q) for leaf area.

Discharge (Q)	Irrigation system (I)			
	I_1	I_2	I_3	I - MEAN
Q_1	807.05	797.6	818.7	807.77
Q_2	833.12	823.6	844.7	833.82
Q_3	848.25	831.3	851.2	843.56
Q_4	845.1	836.7	851.99	844.6
Q - MEAN	833.4	822.3	841.66	832.4

Table 47 : Interaction between Irrigation system I and furrow length (L) for leaf area.

Furrow length (L)	Irrigation system (I)			
	I_1	I_2	I_3	I - MEAN
L_1	836.5	836.9	834.12	835.85
L_2	836.2	832.4	834.2	834.25
L_3	831.4	831.2	842.99	829.2
L_4	829.5	806.6	855.25	830.46
L - MEAN	833.4	822.3	841.64	832.43

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Table 48 : Analysis variance for plant height.

SV	DF	SS	MS	F
REPS (R)	2	0.19	0.093	---
IRRIGATION SYSTEM (I)	2	6489.2	3224.6	---
ERROR (a)	4	1.9	0.466	
LENGTH (L)	3	133.95	44.6	105.23 **
IXL	6	2297.4	382.9	902.41 **
ERROR (b)	18	7.64	0.424	
DISCHARGE (Q)	3	5507.9	183.93	4291.8 **
IXQ	6	1344.41	224.06	523.8 **
LXQ	9	187.1	20.8	48.6 **
IXLXQ	18	178.4	9.91	23.17 **
ERROE (c)	72	30.8	0.43	
TOTAL	143	16178.62		

** = Significant at level 1% ; --- insufficient error df

Table 49:Interaction between irrigation method I , furrow length (L) and discharge (Q) for plant height.

Discharge (Q)	Length (L)				
	L_1	L_2	L_3	L_4	L – MEAN
I = REP1					
Q_1	292.5d	290d	292.4c	287.6d	290.6
Q_2	303.1b	300.4b	301.6a	298.4a	300.97
Q_3	308.1a	302.2a	301.1a	295.6b	301.8
Q_4	296.4c	294.2c	296.3b	291.2c	294.5
I = REP 2					
Q_1	284.3d	280.6d	276.3d	274.6d	278.9
Q_2	297.6c	290.4c	286.3c	284.8c	289.88
Q_3	305.8a	296.2a	290.1b	292.1b	296.15
Q_4	307.6b	300.7b	296.1a	294.2a	299.6
I = REP 3					
Q_1	283.1d	294.3d	301.6d	302.1d	295.5
Q_2	301.6c	304.1c	309.7c	309c	306.1
Q_3	307.9b	311b	316.8a	320.7a	314.1
Q_4	310.4a	313.6a	315.6b	316.4b	314
Q –MEAN	299.9	298.2	298.7	297.3	298.5

	LSD (5%)	LSD (1%)
L means at each I*Q	1.078	1.442
Q means at each I*L	1.065	1.413

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Table 50: Interaction between furrow length (L) and discharge (Q) for plant height.

Discharge (Q)	Length (L)				
	L_1	L_2	L_3	L_4	L - MEAN
Q_1	286.6	288.3	290.1	288.11	288.4
Q_2	300.9	298.3	299.2	297.4	298.9
Q_3	307.3	303.3	302.8	302.4	304.03
Q_4	304.8	302.8	302.7	300.6	302.7
Q - MEAN	299.9	298.2	298.7	297.23	298.5

Table 51: Interaction between irrigation method I and discharge (Q) for plant height.

Discharge (Q)	Irrigation system (I)			
	I_1	I_2	I_3	I - MEAN
Q_1	290.6	278.9	295.3	288.3
Q_2	300.99	289.77	306.1	298.96
Q_3	301.8	296.15	314.1	304.03
Q_4	294.5	299.6	314	302.73
Q - MEAN	296.99	291.13	307.4	298.5

Table 52 : Interaction between Irrigation system I and furrow length (L) for plant height

Furrow length (L)	Irrigation system (I)			
	I_1	I_2	I_3	I - MEAN
L_1	300.13	298.8	300.7	299.9
L_2	296.8	291.9	305.7	298.17
L_3	297.8	287.3	310.9	298.7
L_4	293.2	286.4	312.02	297.23
L - MEAN	296.99	298.8	307.4	

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Table 53: Analysis variance for root volume.

SV	DF	SS	MS	F
REPS (R)	2	66.5	33.25	---
IRRIGATION SYSTEM (I)	2	108195.8	54097.9	---
ERROR (a)	4	1.25	0.3125	
LENGTH (L)	3	4042.5	1347.5	3880.8 **
IXL	6	17959.13	2993.2	8620.4 **
ERROR (b)	18	6.25	0.347	
DISCHARGE (Q)	3	23961	7987	26139.2 **
IXQ	6	9841.12	1640.2	5367.8 **
LXQ	9	7582.5	842.5	2757.3 **
IXLXQ	18	25513.9	1417.4	4638.9 **
ERROE (c)	72	22	0.3056	
TOTAL	143	197192		

** = Significant at level 1% ; --- insufficient error df

Table 54 :Interaction between irrigation method 1 , furrow length (L) and discharge (Q) for root volume.

Discharge (Q)	Length (L)				
	L_1	L_2	L_3	L_4	L – MEAN
I = REP1					
Q_1	452a	446a	417a	401a	429
Q_2	440b	423b	400b	388b	412
Q_3	427c	416c	387c	471c	425
Q_4	408d	486d	368d	340d	375
I = REP 2					
Q_1	484a	480a	451a	446a	465.2
Q_2	465b	450b	438b	440b	448.25
Q_3	448c	442c	430c	421c	435.25
Q_4	435d	419d	410d	494d	439.5
I = REP 3					
Q_1	481a	489a	491a	497a	489.5
Q_2	469b	487b	487b	504b	487
Q_3	451c	470c	487c	487c	473.7
Q_4	438d	457d	168d	481d	461
Q –MEAN	449.5	447.05	436.2	447	445.2

	LSD (5%)	LSD (1%)
L means at each I*Q	0.298	1.244
Q means at each I*L	0.9	1.194

Table 55 : Interaction between furrow length (L) and discharge (Q) for root volume

Discharge (Q)	Length (L)				
	L_1	L_2	L_3	L_4	L - MEAN
Q_1	472.3	471.7	453	448	461.2
Q_2	458	453.3	441.7	444	449.25
Q_3	442	442.67	434.6	459.7	444.28
Q_4	427	420.67	415.3	438.7	425.42
Q - MEAN	449.8	447.7	436.3	447.6	445.42

Table 56 : Interaction between irrigation method I and discharge (Q) for Root volume.

Discharge (Q)	Irrigation system (I)			
	I_1	I_2	I_3	I - MEAN
Q_1	429	465.2	489.5	461.25
Q_2	412.7	448.25	486.7	449.25
Q_3	425.2	435.25	473.75	444.75
Q_4	375.7	439.5	461	425.42
Q - MEAN	410.7	447.06	477.7	445.2

Table 57 : Interaction between Irrigation system I and furrow length (L) for leaf area.

Furrow length (L)	Irrigation system (I)			
	I_1	I_2	I_3	I - MEAN
L_1	431.7	458	459.7	449.83
L_2	417.7	447.7	475.75	447.08
L_3	393	432.2	483.25	436.2
L_4	400.25	450.25	492.25	447.6
L - MEAN	410.7	447.06	477.7	445.2

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Table 58: Analysis variance for water use efficiency.

SV	DF	SS	MS	F
REPS (R)	2	0.0113	0.006	
IRRIGATION SYSTEM (I)	2	4.91	2.46	---
ERROR (a)	4	0.0008	0.00021	---
LENGTH (L)	3	0.294	0.098	388.3 **
IXL	6	0.116	0.019	77.1 **
ERROR (b)	18	0.0045	0.00026	
DISCHARGE (Q)	3	0.103	0.034	124.38 **
IXQ	6	0.049	0.008	30.19 **
LXQ	9	0.091	0.0101	36.60 **
IXLXQ	18	0.131	0.0073	26.5
ERROE (c)	72	0.019	0.0003	
TOTAL	143	5.74		

** = Significant at level 1% ; --- insufficient error df

Table 59 :Interaction between irrigation method I , furrow length (L) and discharge (Q) for water use efficiency

Discharge (Q)	Length (L)				
	L_1	L_2	L_3	L_4	L – MEAN
I = REP1					
Q_1	0.98	0.86	0.84	0.79	0.845
Q_2	0.87	.085	0.82	0.78	0.83
Q_3	0.83	.082	0.800	0.76	0.802
Q_4	0.79	.078	0.77	0.75	0.773
I = REP 2					
Q_1	1.15	1.14	1.10	1.00	14.098
Q_2	1.16	1.12	1.040	0.990	1.078
Q_3	1.15	1.11	1.030	0.97	1.065
Q_4	1.050	1.040	0.96	0.94	0.998
I = REP 3					
Q_1	1.29	1.30	1.38	1.32	1.315
Q_2	1.29	1.31	1.35	1.010	1.24
Q_3	1.28	1.30	1.33	1.030	1.235
Q_4	1.21	1.27	1.31	1.28	1.27
Q –MEAN	1.080	1.075	1.058	0.968	1.045

	LSD (5%)	LSD (1%)
L means at each I*Q	0.027	0.036
Q means at each I*L	0.27	0.036

Table 60: Interaction between furrow length (L) and discharge (Q) for water use efficiency

Discharge (Q)	Length (L)				
	L_1	L_2	L_3	L_4	L - MEAN
Q_1	1.11	1.1	1.097	1.037	1.086
Q_2	1.107	1.093	1.070	0.927	1.049
Q_3	1.087	1.077	1.053	0.920	1.034
Q_4	1.017	1.030	1.013	0.990	1.013
Q - MEAN	1.080	1.075	1.058	0.98	1.045

Table 61 : Interaction between irrigation method I and discharge (Q) for water use efficiency.

Discharge (Q)	Irrigation system (I)			
	I_1	I_2	I_3	I - MEAN
Q_1	0.845	1.098	1.315	1.086
Q_2	0.83	1.078	1.24	1.049
Q_3	0.802	1.065	1.235	1.034
Q_4	0.773	0.997	1.268	1.013
Q - MEAN	0.813	1.059	1.264	1.045

Table 62 : Interaction between Irrigation system I and furrow length (L) for water use efficiency.

Furrow length (L)	Irrigation system (I)			
	I_1	I_2	I_3	I - MEAN
L_1	0.845	1.128	1.268	1.080
L_2	0.828	1.103	1.295	1.075
L_3	0.808	1.033	1.335	1.058
L_4	0.770	0.975	1.16	0.968
L - MEAN	0.813	1.059	1.264	1.045

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الملخص العربى

الرى السطحى هو اقدم الطرق المستخدمة فى عملية الرى حيث بدأ فى مصر منذ ٦٠٠٠ سنة قبل الميلاد *(Nakayama and Bucks 1986)*. يتميز الرى السطحى بسهولة التشغيل وعدم الحاجة الى عمالة فنية مدربة ويناسب المساحات الزراعية الصغيرة ، لكن يعيبة ان كفائتة لا تزيد عن ٥٥ ٪ *(James 1988)* حيث فواقد عملية الري كثيرة ، وحيث ان حصة مصر من ماء النيل هي ٥٥,٥ مليار متر مكعب وهى كمية ثابتة كما ان نصيب الفرد فى العالم العربى من الماء يعادل ٠,١ نصيب الفرد فى العالم. لذلك كان لابد من تطوير الرى السطحى لتقليل هذه الفواقد ومحاولة توفير الماء اللازم لاستزراع الأراضي الصحراوية (توشكي وشرق العوينات) وذلك لمواجهة الزيادة السكانية المتزايدة فى مصر .

نظرا لما يمثله محصول الذرة من أهمية فى غذاء الإنسان والحيوان وفى الصناعة فأنة أجريت هذه الدراسة على محصول الذرة في المزرعة البحثية بمركز ميكنة الأرز بميت الديبة محافظة كفر الشيخ خلال موسم عام ٢٠٠٠ وكان الغرض منها :

١- تطوير الري السطحى للخطوط وذلك باستخدام الري التبادلي و الري النبضي التبادلي (نظام يجمع بين الري النبضي والتبادلي)، ومقارنتهما بالري المستمر (التقليدي).

٢- دراسة تأثير هذه النظم على كلا من محصول الذرة كفاءة الري ،

واشتملت الدراسة على العوامل الآتية :

أ- طرق الرى :

١- الرى المستمر

٢- الري التبادلي

٣- الري النبضي التبادلي (زمن فتح = ٣ دقيقة ، زمن غلق = ٧ دقيقة).

ب - أطوال الخطوط :

تم استخدام أربعة أطوال هي ٤٠ ، ٦٠، ٨٠ ، ١٠٠ مترا

ج - التصرف :

تم استخدام أربعة تصرفات هي ١,٩٥، ٤,٢٦، ٦,٢، ٨,٥ لتر/ ث.

الفترة بين الريات كانت ١٥ يوم للرى المستمر و ١٠ أيام لكلا من الري التبادلي والنبضي التبادلي وتم تطبيق الريات التجريبية بعد ريه المحاياة ، وتم حساب كمية الماء المضافة لكل خط باستخدام مجموعة من الأنابيب ذات الأقطار المختلفة ، والتي تمثل التصرفات المختلفة المدفونة في قناة الري من أحد الأطراف ويمتد الطرف الثاني داخل الخط تم التحكم في الري النبضي باستخدام مجموعة من الصمامات المثبتة في طرف الأنبوبة الممتد في الخط. ضاغط الماء المؤثر على التصرف تم التحكم فيه بواسطة مجموعة من البوابات المثبتة في قناة الري وذلك للحصول على ضاغط ثابت ، وتم قياس الضاغط الفعال بين سطح المياه فى القناة ومحور الأنبوبة خلال الرى اكثر من مرة.

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يمكن تلخيص النتائج التي تم التوصل إليها فيما يلي:

١ - زمن التقدم:

زمن الرى أنخفض بنسبة ٩,٧٥ ٪ للرى التبادلى ، ٣٧,٢٢٪ للرى النبضى التبادلى مقارنة بالري المستمر ,حيث كان زمن الرى للنظام المستمر ٢٣,١١ دقيقة/ فدان . يرجع ذلك الى المحتوى الرطوبى لنظامى الرى التبادلي والنبضـى التبـادلى قبل الـرى مباشـرة حيث يكون أعلى منة فى حالة الرى المستمر . أقل زمن ري تم الحصول علية مـع الـرى النبضى التبادلى عند طول خط ٤٠ متر وتصرف ٨,٥ لـتر/ ث حيث كـان ٤,٥ دقيقـة . زيادة طول الخط تؤدى الى زيادة زمن التقدم بينما زيادة التصرف تقلل زمن الرى.

٢- كمية الماء المضافة:

نظام الرى النبضى التبـادلي وفـر ٤٧١ م٣ / فدان (١٥,٤٥ ٪) ، ١٢٨١ م٣/ فدان (٣٥,٩٥ ٪) فى الموسم مقارنة بالري التبادلي والمستمر علـى التوالـي ، حيـث كـانت الكمية المضافة خلال الموسم للرى النبضى التبادلى ٢٢٨٢ م٣ / فدان. أقل كمية ماء رى كانت مع الرى النبضى التبادلى عند طول خط ٨٠ م وتصرف ١,٩٥ لتر/ ث حيث كانت ٢١٤٤ م٣ / فدان ، بينما كانت اكبر كمية ماء مستخدمة مع الرى المستمر عند طول خط ١٠٠ متر وتصرف ٨,٥ لتر/ث حيث كانت الكميـة المضافـة ٣٨٤٠ م٣ / فدان . زيـادة طول الخط ادت الـى زيـادة كميـة الماء المضافة للـرى المستمر والتبـادلي حيـث يـزداد الرشح، بينما زيادة طول الخط من ٤٠ الـى ٨٠ مـترا ادت لخفض كميـة المـاء المضافـة للرى النبضى التبادلى ثم تزداد الكمية المضافة بزيادة طـول الخـط اكثـر مـن ٨٠ مـترا . زيادة التصرف أدت الى زيادة كمية الماء المضافة للنظم المختلفـة حيـث أدت الـى زيـادة الرشح والجريان السطحى .

٣- معدل الرشح :

تشير النتائج الى ان نظام الرى النبضى التبادلى خفض معدل الرشح الأساسي حيـث تؤدى النبضات الى:

(ا) ضم سطح التربة مما يؤدى الى زيادة الشد الرطوبى ،
(ب) امتلاء الشقوق بالماء خلال النبضات المتلاحقة ،
(ج) رسوب الحبيبات الدقيقة فى محيط الخط أثناء زمن التوقف .

معدل الرشح الاساسى فى نهاية الموسم كان ١٩,١٧ ، ٢١,٢٤ ، ٢١,٧ مم/ سـاعة للرى النبضى التبادلي والمستمر والتبادلى علـى التوالـى . زيـادة طـول الخـط أدت إلـي زيادة معدل الرشح الاساسى للرى المستمر والتبادلي حيث تزداد الحركة الجانبية للماء ، بينمـا يقل معدل الرشـح الاساسـى بزيـادة طـول الخـط للـرى النبضـى التبـادلى . زيـادة التصرف ادت الى زيادة معدل الرشح النـهائى لنظـم الـرى المختلفـة حيث يـزداد تكـون الشقوق .

٤- توزيع الرطوبة الأرضية :

انخفضت كمية الماء الزائدة (فقد) فى منطقة الجذور لنظامي الرى النبضى التبادلى والتبادلى بنسبة ٣٩,٣ ٪ ، ٤٤,١٧ ٪ على التوالي مقارنة بالري المستمر . أقل فقـد فـى

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منطقة الجذور كان مع الرى النبضى التبادلى عند طول خط ٤٠ مترا وتصرف ١,٩٥ لتر/ ث ، بينما كان أعلى فقد مع الرى المستمر عند طول خط ١٠٠ متر وتصرف ٨,٥ لتر/ ث . زيادة طول الخط ادت الى زيادة الفقد فى منطقة الجذور عند بداية الخط وزيادة حجم المنطقة غبر المشبعة فى نهاية الخط. زيادة التصرف ادت الى زيادة الفقد فى بداية الخط وتقليل الفقد فى نهايته .

٥- كفاءة اضافة الماء:

زادت كفاءة اضافة الماء بنسبة ٧,٧٣٪ ، ٢٨,١٦٪ على التوالي لنظامي الرى التبادلى والنبضى التبادلى مقارنة بالري المستمر ، حيث كانت كفاءة اضافة الماء للرى المستمر ٤٩,٦٩ ٪ . وكانت أعلى قيمة ٨٨,٩ ٪ للرى النبضى التبادلى مع طول خط ٨٠ متر وتصرف ٦,٢ لتر/ ث ، كانت اقل قيمة ٣٩,٩٪ للرى المستمر مع طول خط ١٠٠ مترا وتصرف ٨,٥ لتر/ ث . وقد ادت زيادة طول الخط الى خفض كفاءة اضافة الماء للرى المستمر والتبادلى حيث زادت كمية الماء المضافة . بينما تزداد كفاءة اضافة الماء للرى النبضى التبادلى عند زيادة طول الخط من ٤٠ الى ٨٠ مترا ثم تنخفض عند زيادة طول الخط عن ٨٠ مترا نتيجة لزيادة كمية الماء المضافة . زيادة التصرف ادت الى انخفاض كفاءة اضافة الماء للنظم الثلاث حيث تزداد كمية الماء المضافة.

٦- كفاءة توزيع الماء :

زادت كفاءة توزيع الماء بنسبة ١٢,٥٪ ، ١١,٣٪ للرى النبضى التبادلى مقارنة بالري التبادلى والمستمر على التوالي ، حيث كانت كفاءة توزيع الماء للرىالنبضى التبادلى ٨٠,٢٪. كانت أعلى قيمة لكفاءة توزيع الماء ٨٧,٣٪ للرى النبضى التبادلى مع طول خط ١٠٠ مترا وتصرف ٦,٢ لتر/ ث ، وكانت اقل قيمة ٥٨,٧ ٪ للرى التبادلى مع طول خط ١٠٠ متر وتصرف ١,٩٥ لتر/ ث .وقد ادت زيادة طول الخط الى خفض كفاءة توزيع الماء للرى المستمر والتبادلى . بينما تزداد كفاءة توزيع الماء للرى النبضى التبادلى عند زيادة طول الخط حيث مع زيادة طول الخط يزداد عدد النبضات وبالتالي تزداد قدرة الرى النبضى التبادلى على خفض الرشح وزيادة حركة الماء على طول الخط بصورة اكثر انتظاما . زيادة التصرف من ١,٩٥ الى ٦,٢ لتر/ ث ادت الى زيادة كفاءة توزيع الماء للأنظمة الثلاثة ثم بزيادة التصرف عن ٦,٢ لتر/ ث تنخفض كفاءة توزيع الماء حيث يزداد الفرق فى الماء المخزن بمنطقة الجذور على طول الخط.

٧- ناتج محصول الذرة ومكوناته:

٧-١ نسبة المساحة الورقية :

زادت نسبة المساحة الورقية للرى النبضى التبادلى بنسبة ٢٩,٣٪ ، ٣٧,٤٪ على التوالي مقارنة بالري المستمر والتبادلى ، حيث كانت نسبة المساحة الورقية للنظام النبضى التبادلى ٣,٣١ . كانت أعلى قيمة ٣,٩٥ للرى النبضى التبادلى عند طول خط ١٠٠ متر وتصرف ٨,٥ لتر/ ث ، بينما كانت اقل قيمة ١,٢١ للنظام التبادلى عند ١٠٠ متر طول خط وتصرف ١,٩٥ لتر/ ث . ادت زيادة طول الخط الى خفض نسبة

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المساحة الورقية للرى المستمر والتبادلى حيث تزداد منطقة الجذور غير المشبعة ، بينما تزداد نسبة المساحة الورقية للرى النبضى التبادلى بزيادة طول الخط . ادت زيادة التصرف الى زيادة نسبة المساحة الورقية للنظم الثلاث حيث تقل منطقة الجذور غير المشبعة فى نهاية الخط.

٢-٧ ارتفاع للنبات :

زاد ارتفاع النبات للرى النبضى التبادلى بنسبة ٥,٢٪ ، ٦,٩٣٪ على التوالي مقارنة بالري المستمر والتبادلى ، حيث كان توزيع الرطوبة اكثر انتظاما . حيث كان اقصى ارتفاع للنبات ٣١٠ سم للرى النبضى التبادلى. أعلى قيمة كانت ٣٣١ سم للرى النبضى التبادلى عند طول خط ١٠٠ مترا وتصرف ٨,٥ لتر/ ث ، بينما اقل قيمة كانت ٢٧٢ سم للنظام التبادلى عند ١٠٠ مترا طول الخط وتصرف ١,٩٥ لتر/ ث . زيادة طول الخط ادت الى خفض اقصى ارتفاع للنبات للرى المستمر والتبادلى حيث تزداد منطقة الجذور غير المشبعة ، بينما يزداد اقصى ارتفاع للنبات للرى النبضى التبادلى بزيادة طول الخط . زيادة التصرف ادت الى زيادة اقصى ارتفاع للنبات للنظم الثلاث حيث تقل منطقة الجذور غير المشبعة فى نهاية الخط.

٣-٧ حجم الجذور :

زاد حجم الجذور للرى التبادلى والنبضى التبادلى بنسبة ١٢,٨ ٪ ، ٢٠,٨٩ ٪ على التوالي مقارنة بالري المستمر ، حيث كان توزيع الرطوبة اكثر انتظاما . حيث كان اقصى حجم للجذور ٤٩٨ سم^{3} للرى النبضى التبادلى عند طول خط ١٠٠ مترا وتصرف ٨,٥ لتر/ ث ، كانت بينما اقل قيمة ٣٢٤ سم^{3} للنظام المستمر عند ١٠٠ متر طول الخط وتصرف ٨,٥ لتر/ ث . ادت زيادة طول الخط الى خفض حجم الجذور للرى المستمر والتبادلى حيث تزداد كمية الماء ، بينما يزداد حجم الجذور للرى النبضى التبادلى بزيادة طول الخط . ادت زيادة التصرف الى زيادة حجم الجذور للرى التبادلى والنبضى التبادلى بينما يقل للرى المستمر .

٧- ٤ ناتج محصول الحبوب:

ارتفع محصول الحبوب بنسبة ٣,٢١٪ ، ٤,٧٣٪ للرى النبضى التبادلى مقارنة بالري المستمر والتبادلى على التوالي وذلك نتيجة تحسين تهوية التربة والتوزيع الجيد للماء ومسك المواد المغذية بصورة جيدة ، حيث كان محصول الحبوب للرى النبضى التبادلى ٢,٦٩ ميجا جرام / فدان. أعلى محصول كان ٣,٠٦ ميجا جرام/ فدان للرى النبضى التبادلى عند طول خط ١٠٠ متر وتصرف ٨,٥ لتر/ ث ، بينما كان اقل محصول ٢,٦٨ ميجا جرام / فدان عند طول خط ١٠٠ مترا وتصرف ١,٩٥ لتر / ث . زيادة طول الخط ادت لخفض المحصول للرى التبادلى والمستمر حيث تزداد المساحة غير المشبعة بالماء فى نهاية الخط، بينما تؤدى لزيادة المحصول للرى النبضى التبادلى حيث بزيادة طول الخط

يصبح توزيع الماء أكثر انتظاما. زيادة التصرف ادت الى زيادة المحصول للأنظمة المختلفة حيث تقل منطقة الجذور غير المشبعة بالماء فى نهاية الخط .

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٨. كفاءة استخدام الماء:

ارتفعت قيمة كفاءة استخدام الماء بنسبة ٣٨,٢ ٪ ، ١٨,٦ ٪ للرى النبضى التبادلى والتبادلي على التوالى مقارنة بالرى المستمر ، حيث كان كفاءة استخدام الماء ٠,٨٠٦ كج/ م^{٣} للرى المستمر. أعلى قيمة لكفاءة استخدام الماء كانت ١,٣٧ كج/ م^{٣} للرى النبضى التبادلي عند طول خط ٨٠ متر وتصرف ١,٩٥ لتر/ ث، بينما اقل قيمة كانت ٠,٧٤ كجم/ م^{٣} للرى المستمر عند طول خط ١٠٠ متر وتصرف ٤,٢٦ لتر/ ث . زيادة طول الخط ادت الى خفض كفاءة استخدام الماء حيث زادت كمية الماء المضافة للرى المستمر والتبادلى ، بينما زادت كفاءة استخدام الماء للرى النبضى التبادلى عند زيادة طول الخط من ٤٠ الى ٨٠ مترا وبعد ذلك تقل حيث تزداد كمية الماء المضافة بزيادة طول الخط عن ٨٠ مترا . زيادة التصرف ادت الى خفض كفاءة استخدام الماء للرى المستمر والتبادلى عند طول خط اقل من ٨٠ مترا ، زيادة التصرف ادت لخفض كفاءة استخدام الماء للرى النبضى التبادلى.

أهــم التــوصيـــات:

١- أعطت طريقة الرى النبضى التبادلى عند طول خط ١٠٠م وتصرف ٨,٥ ل/ ث أفضل النتائج حيث أعلى توفير فى ماء الرى مع زيادة كبيرة فى المحصول عند فترة ري ١٠ أيام.

٢- الرى النبضى التبادلى هو أفضل النظم الثلاث فى حالة ندرة مياه الرى، ولكنة يحتاج الى متطلبات خاصة (بوابات- صمامات ...) مما يجعله عالي التكلفة.

٣- فى حالة عدم توافر متطلبات الرى النبضى التبادلى مع الحاجة المستمرة لماء الرى فأنة يفضل استخدام الرى التبادلى بأطوال خطوط ٤٠ م وتصرف ٤,٢٦ ل/ ث مع فترة رى ١٠ أيام .

٤- عند توافر ماء الرى بكميات كبيرة فأنة يمكن استخدام الرى المستمر بأطوال خطوط ٤٠ م وتصرف ٨,٥ ل/ ث حيث يعطى انتاجية عالية.

٥- يمكن للرى التبادلى أن يعطى إنتاجية أعلى من الرى المستمر مع توفير كبير فى ماء الرى وذلك عند استخدام خطوط بأطوال أقل من ٤٠ م وفترة رى ١٠ أيام ، أيضا يمكن للرى المستمر إعطاء إنتاجية أفضل مع أطوال خطوط أقل من ٤٠ م .

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لجنة الاشراف

د/ سمير محمود جمعة

أستاذ الهندسة الزراعية المساعد،
قسم الميكنة الزراعية،
كلية الزراعة بكفر الشيخ،
جامعة طنطا.

د/ السعيد محمد أحمد خليفة

أستاذ الهندسة الزراعية المساعد،
قسم الميكنة الزراعية،
كلية الزراعة بكفر الشيخ،
جامعة طنطا.

د/ زكريا محمد إسماعيل عمارة

باحث بمعهد بحوث الهندسة الزراعية،
مركز البحوث الزراعية، الدقى - القاهرة،
مصر.

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تطوير طريقة الرى بالخطوط لمحصول الذرة تحت الظروف المحلية

رسالة مقدمة من

طارق محمود عطافى مرسى

للحصول على درجة الماجستير
فى العلوم الزراعية (الميكنة الزراعية)

<u>لجنة المناقشة والحكم على الرسالة</u>

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د./ سمير محمود جمعة ....
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أستاذ الهندسة الزراعية المساعد
قسم الميكنة الزراعية
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دراســـة على نظــم الــرى
تطوير طريقة الري بالخطوط لمحصول الذرة تحت الظروف المحلية

رسالة مقدمة من

طـارق مـحمود عطافـى مـرسـى
بكالوريوس العلوم الزراعية (ميكنة زراعية)

كلية الزراعة بكفر الشيخ – جامعة طنطا (١٩٩٦).

استيفاء لمتطلبات الحصول على درجة الماجستير

فـــى

العـــلوم الـــزراعيـــة

(الميكنة الزراعية)

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