DRIP IRRIGATION SYSTEMS IN SANDY SOIL USING PHYSICAL AND HYDRAULIC BARRIERS.

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ABSTRACT

A new method to barricade water deep percolation was investigated. This method was called 'The hydraulic barrier technique'. The method involves burying a secondary dripper line under the primary one in order to increase the deep layers' water content whereas to minimize matric potential in these layers. So that to increase the side movement of water from the primary dripper line. The method was validated by a field experiment in Sinai sandy soil. The field experiment tested four burying depths of primary dripper line, with and without the hydraulic barrier, compared with the physical barrier. Two crops were used, Jerusalem artichokes (Tartoufa) as example to tuber roots, and tomato as fibrous root. The results showed that the physical barrier extremely increased both crops more than double its normal in the absence of physical barrier value (2.35 for Tartoufa and 2.19 for Tomato), and the hydraulic barrier existence increased the total crop yield of Tartoufa by about 12% and marketable yield by 47%. Reduction of Tomato yield was found due to existence of hydraulic barrier by about 25%. The Tartoufa yield increased directly proportional to the burying depth of the primary lateral while the situation is inverted in the tomato. The hydraulic barrier acted the same like the physical barrier when the gap between the two dripper-lines getting narrower.

INTRODUCTION

Deep percolation is a big problem in coarse textured soils. However, this problem exists in both dripping systems (surface and subsurface). Its' effect is worst in subsurface drip irrigation. When water is applied on top of a coarse textured soil, it took some time (depending on the infiltration rate) to run away from the root zone. Surely, this time will decrease if the dripping source is closer to the end of the root

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zone.

The main avenue for water losses under this system is deep percolation, which is highest during the seedling stage and declined with the increase of root system (El-Berry, 1989). On the other hand, Phene et al., (1992a) showed that deep percolation losses and runoff could be reduced with properly designed and managed subsurface drip irrigation (SDI) systems.

Barth (1995), suggested that laying an impermeable polyethylene foil below the lateral pipes, however, he used a 60 cm wide, 0.06 mm thick plastic sheet laid on depth 30 to 40 cm. He deduced that this physical barrier had significantly increased the amount of water held in the root zone, either from dripper line or from rain, and limited the deep percolation. He stated also that the V shape of it increases the amount of water stored. In addition, he developed a special installation equipment to release the dripper line and the V shaped plastic foil simultaneously into the soil without disturbing the natural soil profile.

Welsh et al., (1995) developed a technique to increase horizontal flow of water applied through SDI, this technique is called vector flow™. This technique involves placing an impermeable V shaped line just below the dripper line, i.e., the dripper line is laid over the small V shaped stripe, which is only 7.5 cm wide (3 inches). They deduced that this technique lets 70% of the water-applied spread up to 90 cm wide in the upper 15 cm of soil, from a 3.5 L/h dripper in a sandy loam soil, while only 25% of the applied water spread without the technique.

The method of barricading water percolation through physical means succeeded in its job. It raises the water content above its location and leads to minimized leakage of water. On the other hand, it had some drawbacks. The major drawback of this solution is the technical and economical problems to trench a wide and deep furrow to lay the physical barrier in. Moreover, the hazard of air lack may appear in the root zone due to the moist environment created by the physical barrier, in addition to root dwarfness hazard.

Therefore, a new method was investigated which was called the Hydraulic Barrier system or the bilateral drip system. This new method barricades water without performing such problems. The hydraulic barrier method could be briefed as burying a secondary pipeline similar to the primary one but beneath it, and dividing the required water volume between the two pipes. The purpose of this is to formulate the water pattern so as to increase its width and hence to increase the available water in the shallow root zone. This technique, as seen, requires no extra trenching width, and does not cause air lack or root dwarfness.

The study aimed to evaluate the hydraulic barrier technique and to compare it to the previous barricading technique by establishing a field experiment.

MATERIAL AND METHODS

A field experiment was conducted in the North Sinai research station of the Desert Research Center in "El-Shaikh Zowayed" city, 30 km east of "El-Arish", and 12 km west of "Rafah" on the Egyptian-Palestinians' borders. The experimental soil texture through particle size distribution, soil moisture characteristic curve, EC, and pH were also determined according to FAO (1970). Soil hydraulic conductivity was determined using van Beers (1976) method, while the infiltration rate was established using the method of Philip (1957). These values were listed in Table (1) and Table (2). The site was initially prepared by shallow disking to remove surface herbs and clean the land surface. Due to the texture of the soil, no tillage was performed.

Table (1). Soil moisture characteristic curve values of the experimental site soil.

Suction (bar)	0.10	0.50	1.00	5.00	10.00	15.00
Water content (cm^3/cm^3)	0.23	0.21	0.20	0.17	0.10	0.03

Table (2). Some soil properties of the experimental site soil.

Soil depth (cm)	Texture	EC (dS/m)	pH	Infiltration rate (cm/h)	Hydraulic conductivity (m/day)
0 to 30	medium to fine sand	5.86	7.72	66.62	24.6
30 to 60	medium to fine sand	4.51	7.72	-	-

Water was supplied through the control head. Which consisted of main pump station, sand media filter, and followed by screen filter to the drip network irrigation system. The lateral lines were installed in the field according to the treatments distribution. The dripper lines used was GR type with built in emitters of discharge 4 l/h, at 30 cm spacing between emitters. In order to bury the dripper lines, soil was trenched manually to the desired depth and the dripper line was laid then the gutter was covered. This operation was performed line by line as the soil tumbles back rapidly after trenching.

Soil moisture was measured using a neutron scattering meter. The access tube was 120 cm tall and 65 mm outer diameter. A part of 105 cm long of the access tube was put down under ground and 15 cm above soil surface to mount the neutron scattering device on it. Each access tube was isolated from the bottom by a plastic sheet similar to the one used in the physical barrier in order to prevent the ground water from entering the tube. Seventy-two access tubes were installed by digging a hole by the soil auger after moisten the sand to increase the ability of sand carrying by the auger. When installing the access tubes in the plastic sheet zone, some special operation was made. The access tube was attached to a special peace of plastic sheet on the desired depth, then a 50*50 cm^2 trench was dig till the depth of plastic sheet (40 cm). Then the installed plastic sheet is punched to allow the soil auger to go through then the auger completes the rest 65 cm. The examined treatments are summarized in Table(3), and the field layout is shown in Fig (1).

Table (1): Summary of field treatments.

1	No barrier	• On soil-surface • Buried at 10, 20, and 30 cm
2	Hydraulic barrier	• Not exists (Single lateral) • Exists (Double laterals , the upper was variable depth while the lower was fixed at 40 cm)
3	Physical barrier	• Exists (a plastic sheet installed at 40 cm depth) • Not exists

Two crops were planted in the field each in half of the area; the first crop was Jerusalem Artichokes, known in Arab world as “Tartoufa”. The second crop was the tomato to compare two root types (tubers, and normal roots) as affected by subsurface drip irrigation system and its wetting pattern shape.

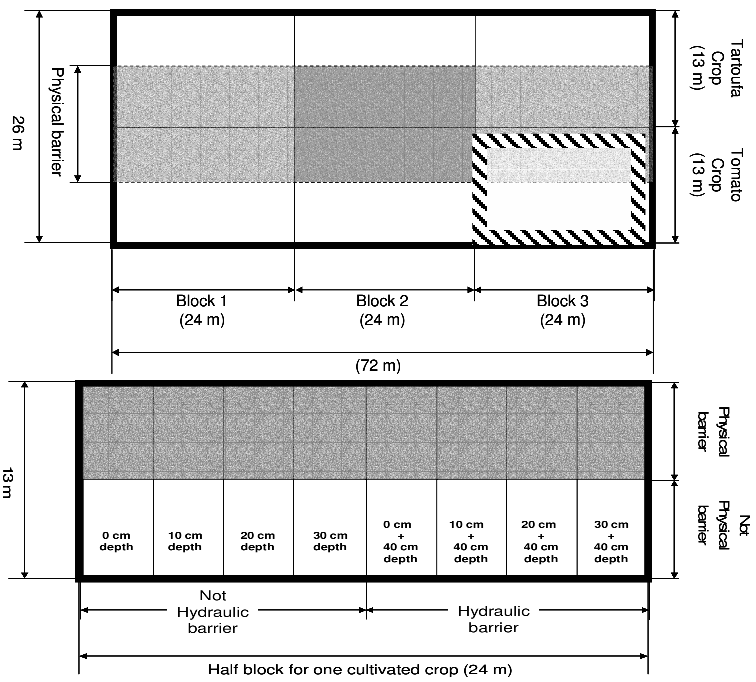


Fig.(1): Field layout of the experiment

RESULTS AND DISCUSSION

Field soil water patterns:

Field measurement of soil moisture distribution under the experiments treatments was made using a field-calibrated neutron scattering meter, however, in order to take truthful results, measurements was taken after 6 to 8 hours after irrigation to ensure that water redistribution occur. Moisture measurements were taken during the growing season. All results will be discussed in the following.

It can be noticed that the existence of the physical barrier pushes the water content isolines (contours) upward, above its location, in the upper 40 cm of soil profile, this comparison could be seen through comparing treatment (P) to (N), and treatment (B) to (H) in Fig(2). The hydraulic barrier effect on moisture pattern could be noticed too by comparing treatment (H) to (N), and treatment (B) to (P). It increases the slope of the isolines in the space between the dripper lines (it lets the space between them narrower).

However, the hydraulic barrier effect appears clearly (as a barrier) when the gap between the two lines is smaller. i.e., smaller gaps acts like a real barrier as shown in Figure (3).

Where the existence of the hydraulic barrier with 10cm gap raises the water content above it as could be noticed comparing treatment (H) to (N). Notice that the water isolines of pattern (P) are almost similar to pattern (H). This concludes that both physical and hydraulic barriers act approximately the same when the gap is small.

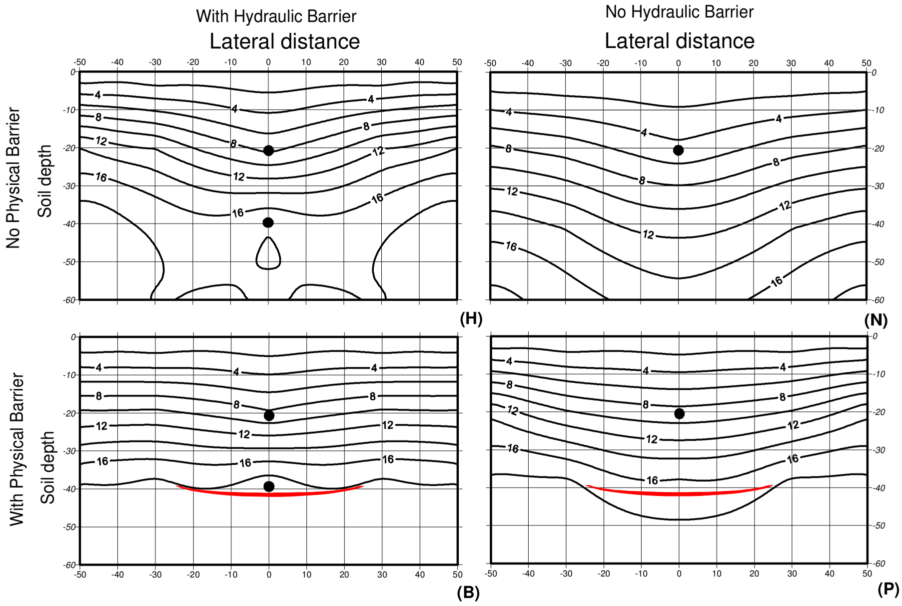


Figure (2): Moisture distribution under 20cm subsurface drip treatments in the tartoufa crop with physical and hydraulic barriers.
N: no barriers, H: with hydraulic barrier, P: with physical barrier, and B: both barriers

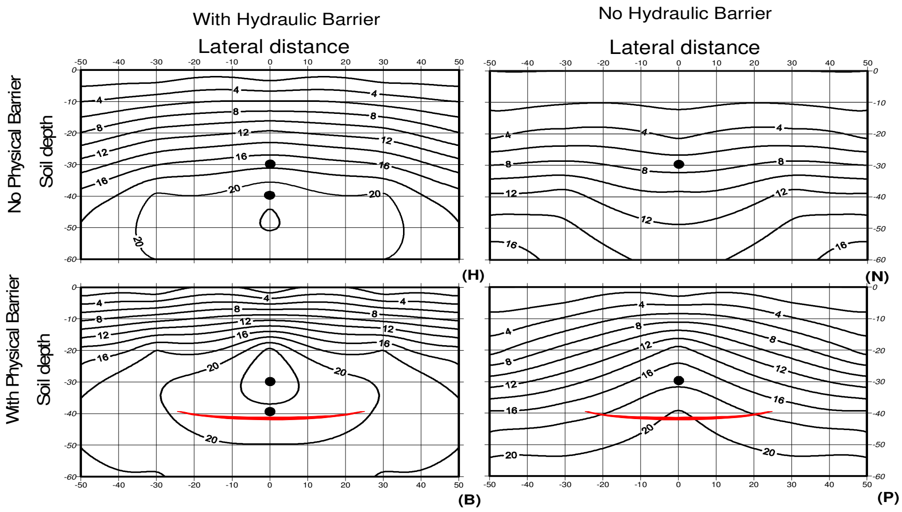


Figure (3): Moisture distribution under 30cm subsurface drip treatments in the tomato crop with physical and hydraulic barriers.

Yield of crops.

Statistical analysis of field data was done in split-split-plot design with Hydraulic barrier existence {Hb} as the whole plots factor, Physical barrier existence or plastic isolation {Pb} as sub-plot factor, the remainder factor is pipeline depth of burying {Dp}. The analysis of results show that only {Pb} parameter was significant by its own in most measured data, means-comparison was done as well. Detailed analyses of the results were discussed on as follows.

a) Tartoufa yield.

Tartoufa total and marketable yield were measured. Total yield indicates the weight of all tubers regardless of its size or state, while marketable yield indicates tubers, which can be sold on market (not so-small, not broken, and not suffering of any disease's syndromes).

The analysis of variance shows that when "Total yield" was considered as dependent variable, only factors {Pb}, {Dp}, and the interaction {Pb}×{Dp} had significant effect. This shows that hydraulic barrier {Hb} main effect and interactions are not significant on the total tartoufa yield.

However, when considering "marketable yield", ANOVA shows that the same significant variables in "total yield" are significant too. But one more variable appears as significant variable; that is the interaction between burying depth and hydraulic barrier {Dp}×{Hb}. This shows that although the hydraulic barrier existence variable {Hb} is not significant but its interaction with depth {Dp} shows significance.

a. Effect of physical, hydraulic barrier and burring depth

Regarding the main effect of {Pb}, Figure (4) shows that the physical barrier existence almost doubles the yield of Tartoufa tubers, actually it leads to 2.31-2.38 times the value of the yield than when it was absent for both total and marketable yield respectively. This result proves the importance of the physical barrier.

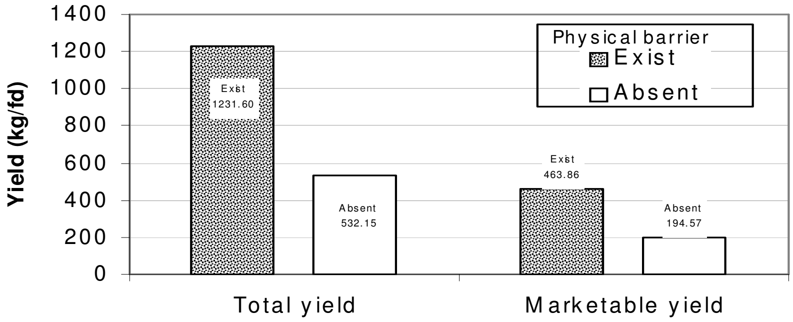
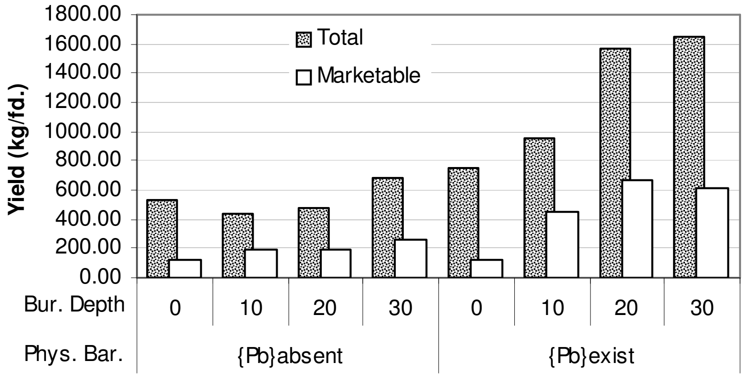


Figure (4): Tartoufa yield as affected by physical barrier existence.

As shown in Figure(5), the {Pb}×{Dp} interaction showed the superiority of the physical barrier's treatments, with the yield increment with deeper burying depth. On the other hand, the {Hb}×{Dp} interaction Figure (6) show that deeper depths with the existence of the hydraulic barrier gave better results than shallower depths.

Although not statistically significant, the hydraulic barrier existence leads to 47% more marketable yield and 12% more total yield than in the absence of the hydraulic barrier, as shown in Figure (7). The insignificance may be attributed to that the hydraulic barrier treatment has big error value as a main-plots factor.

Also, the interaction between hydraulic and physical barriers is not statistically significant as well, but the marketable yield increased in the existence of both barriers, while the total yield decreased in the existence of only physical barrier. On the other hand, total and marketable yield increase in the absence of the physical barrier and the existence of the hydraulic barrier, as shown in **Figure** (8).



Figure(5): Tartoufa yield as affected by the physical barrier existence and burying depth.

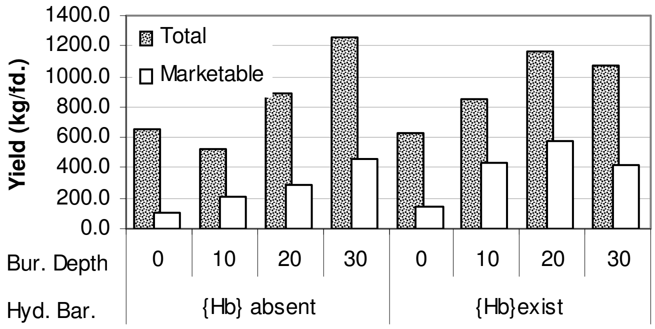


Figure (6): Tartoufa yield as affected by the hydraulic barrier existence and burying depth.

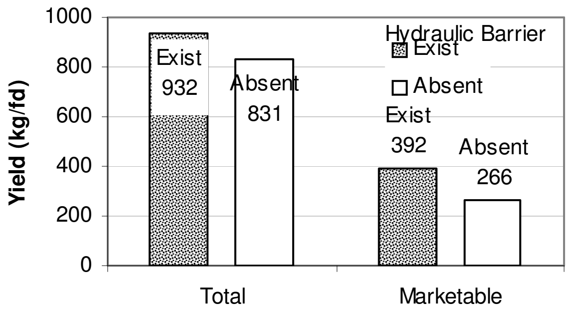


Figure (7): Tartoufa yield as affected by hydraulic barrier existence.

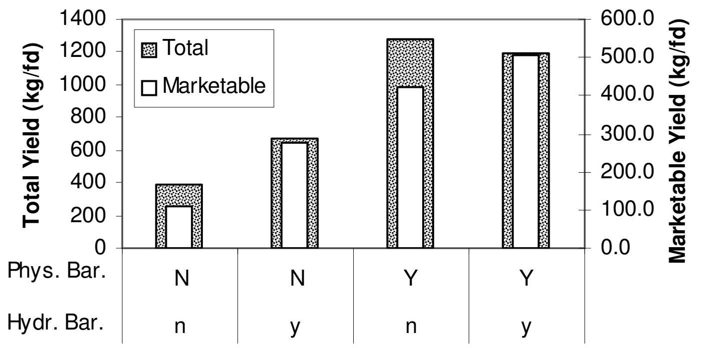


Figure (8): Tartoufa yield as affected by hydraulic and physical barriers.

b. Effect of burring depth

As shown in Figure (9), Tartoufa yield increased directly proportional to the burying depth. This was with no significant difference neither between the pair 30cm, and 20cm, nor between the pair 10cm and 0 cm. while there was significant difference between these depth groups. This may be attributed to those Tartoufa tubers, which grow in the top 10 to 15cm, prefer non-saturated conditions.

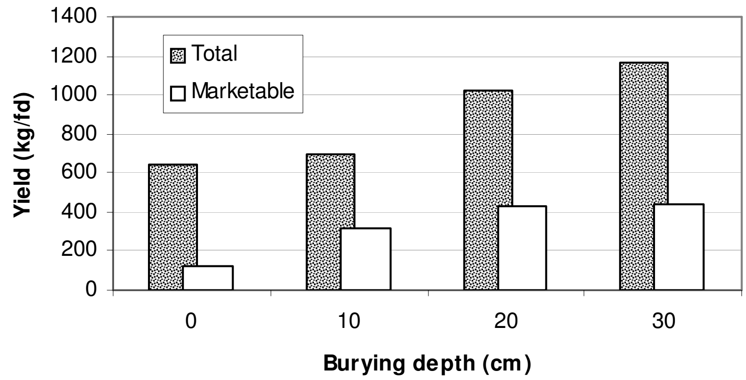


Figure (9): Tartoufa yield as affected by burying depth

2. Tomato yield.

a. Effect of physical, hydraulic barrier and burring depth

The tomato yield in the existence of physical barrier (about 20.78 ton /fed.) was significantly more than that of the absence of it, which was about 9.49 ton/fed. However, unlike Tartoufa, the ANOVA showed that only physical barrier treatment had significant effect on total yield. This means that neither the hydraulic barrier nor the burying depth had significant effect on the tomato yield. Even though, the tomato yield was 12.98 ton / fed. in the existence of the hydraulic barrier, while the yield was 17.29 ton /fed. in the absence of it (reduced by 25%). This could be attributed to the shallow root of tomato and the deep burying depth of the hydraulic barrier (at 40 cm), which took half the irrigation water away from the root system.

b. Effect of burring depth

Unlike Tartoufa; surface drip treatments gave better results than subsurface results i.e. total tomato yield increased inversely proportional to the burying depth, except the 30cm depth that got the maximum yield, as shown in Fig. (10), the superiority of the 30cm treatment (contrasting the trend) may be attributed to the closeness to the physical and hydraulic barriers which both are at 40 cm.

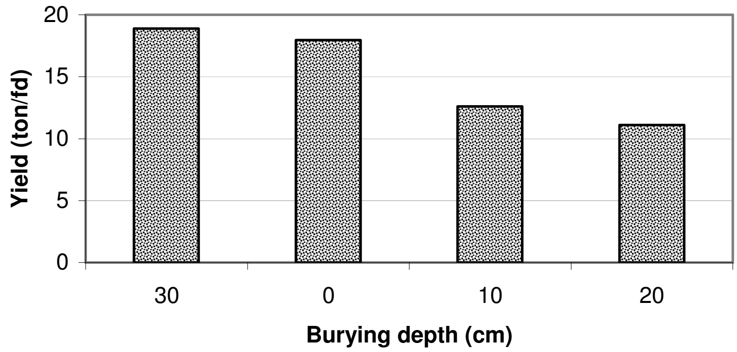


Figure (10): Tomato yield as affected by burying depth

In the interaction {Pb}x{Dp}, Fig(11) shows that yield increased inversely proportion to the depth except at the 30cm depth as mentioned before. Detailed results of all treatments and measures are found at El-Nesr (2006).

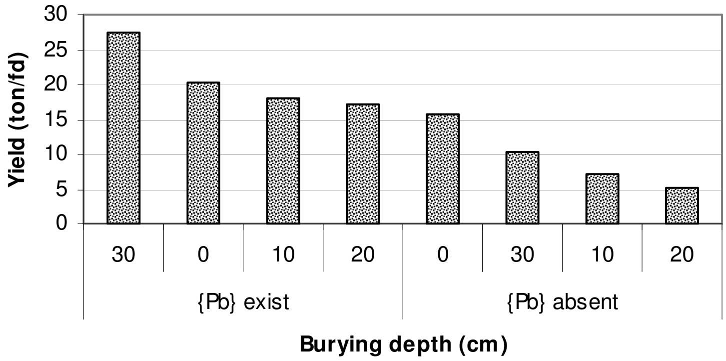


Figure (11): Tomato yield as affected by burying depth and physical barrier existence

CONCLUSION

Both physical and hydraulic barriers act approximately the same when the gap is small.

The physical barrier existence almost doubles the yield of Tartoufa tubers; actually, it leads to 2.31-2.38 times the value of the yield than when it was absent for both total and marketable yield respectively. The hydraulic barrier existence leads to 47% more marketable yield and 12% more total yield than in the absence of the hydraulic barrier,

The tomato yield in the existence of physical barrier was about 20.78 ton /fed. Moreover, was significantly more than that of the absence of it, which was about 9.49 ton/fed. The tomato yield was 12.98 ton / fed. in the existence of the hydraulic barrier, while the yield was 17.29 ton /fed. in the absence of it (reduced by 25%).

Tartoufa yield increased directly proportional to the burying depth. This was with no significant difference neither between the pair 30cm, and 20cm, nor between the pair 10cm and 0 cm. while there was significant difference between these depth groups.

Unlike Tartoufa; surface drip treatments gave better results than subsurface results i.e. total tomato yield increased inversely proportional to the burying depth, except the 30cm depth that got the maximum yield.

Tartoufa tubers appear to prefer partial wetness to grow properly, however, better results reached on deeper laterals as discussed above. Moreover, the yield of Tartoufa records better results mostly on double lateral treatments.

On the other hand, in most tomato results, the single tube treatments recorded better results than double tube treatments, because the latter distributes water into two points, one variable at 0, 10, 20, 30 cm, and the other is fixed at 40 cm. However, tomato root system absorbs about 75% of its needs in the top soil layers, hence, if water exists on such layers, the yield may increase. It can be said that the second dripper line in the double lateral treatment is not useful to tomato as it was laid at 40 cm depth and it took half the water away from the tomato root zone. It could be estimated that if the second lateral was buried on 20 cm depth the results could have been changed completely.

REFERENCES

Barth H.K., 1995. *Resource conservation and preservation through a new subsurface irrigation system.* 5th International microirrigation congress, Florida, ASAE, Proc.: 168-174

El-Berry, A. M., 1989. *Design and utilization of subsurface drip irrigation system for fodder production in arid lands*, Misr J. Agr. Eng. 6 (2): 153-165

El-Nesr, M. N., 2006. Subsurface Drip Irrigation System Development and Modeling of Wetting Pattern Distribution. Unpublished PhD. Thesis, Fac. of Agr. Alex. Univ.

FAO, 1970. *Methods of soil and water analyses*, Soil Bulletin # (10), FAO, Rome, Italy.

Phene, C. J., Hutmacher, R.B., Ayars, J.E., Davis, K.R., Mead, R.M., and Schoneman, R.A, 1992a. *Maximizing water use efficiency with subsurface drip irrigation.* ASAE. Paper No.92-2090

Philip, J. *R*`., 1957. *The theory of infiltration, 4: sorptivity and algebric infiltration equations*. Soil Science, 84: 257-264.

van Beers, W. F. J., (1976). *The auger hole method*, International Institute for Land Reclamation. ILRI, Neitherlands.

Welsh D.F., U.P., Kreuter, and J.D. Byles, 1995. *Enhancing subsurface drip irrigation through vector flow.* 5th International microirrigation congress, Florida, ASAE, Proc.: 688-693.

الملخص العربي

نظم الري بالتنقيط فى الأراضى الرملية باستخدام الحاجزين المادي والمائي

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قدم هذا البحث فكرة جديدة لحجز المياه بطريقة هيدروليكية سميت بالحاجز المائي وذلك عن طريق وضع أنبوب تنقيط تحت الأنبوب الأصلي ليعمل على ترطيب التربة تحته مما يدفع المياه للتحرك الجانبي.

تم أختبار هذه الطريقة فى أجراء تجربة حقلية فى مدينة الشيخ زويد فى شمال سيناء وقد جربت أربعة أعماق للأنبوب الرئيسي (سطحي وأعماق ١٠، ٢٠، ٣٠سم) مع وضع الحاجز المائي أو المادي على عمق ٤٠ سم. وقد زرع فى أرض التجربة محصولان أحدهما درني الجذور (الطرطوفة) والأخر ليفي الجذور (الطماطم). وقد روعي أن كل المعاملات تحصل على نفس القدر من المياه (فى حالة وجود الحاجز المائي تقسم المياه بين خط التنقيط الرئيسي وبين الخط الحاجز).

أثبتت التجارب أن كل من الحاجز المادى والحاجز المائى يعملا بطريقة متشابه تقريبا وخصوصا عندما تكون المسافة البينية للحاجز المائى صغيرة. أيضا الحاجز المادي يعطي كمية مضاعفة من الطرطوفة بنسبة حوالى ٢,٣١ إلى ٢,٣٨% وذلك لكل من المحصول الكلى والمحصول التسويقى. فى حين أن الحاجز المائى تسبب فى زيادة المحصول الكلى بنسبة ١٢% و حوالى ٤٧% للمحصول التسويقى. كما أن الحاجز المادى أدى إلى زيادة محصول الطماطم بنسبة ٢,٣٥% بينما تسبب الحاجز المائى فى نقص محصول الطماطم بمقدار ٢٥% نظرا لاحتياج الطماطم للمياه فى الطبقة السطحية التي تأخذ نصف المياه بينما الحاجز المائي يأخذ النصف الآخر بعيدا عن منطقة الجذور. كما أثبتت التجارب أن عمق دفن خطوط التنقيط غير معنوي التأثير إحصائيا ولكن مع هذا لوحظت زيادة فى محصول الطرطوفة كلما زاد عمق الدفن بينما حدث العكس مع الطماطم.

يمكن التأكيد على أن العامل الأكثر تأثيرا على عمل الحاجز المائي هو المسافة الرأسية بين الخطين(الفجوة). حيث بينت مخططات الرطوبة أن تأثير الحاجز المائي يكاد يطابق تأثير الحاجز المادي فقط فى حالة فجوة ١٠سمبينما يقل التأثير كلما زادت الفجوة.

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