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EVALUATION OF SURGE IRRIGATION IN CLAYEY SOIL

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ABSTRACT

Two field trials were carried out at Sakha Agricultural Research Station Farm, Kafr El-Sheikh Governorate Egypt, during 2001/2002 and 2002/2003 winter growing seasons in order to upgrade the furrow irrigation regarding water saving by trying the surface irrigation technique of surge flow irrigation and compare it with the continuous furrow irrigation in clayey soil at North Nile Delta of Egypt, under three, different discharges: 4, 6 and 8 L/S which labeled as D_1, D_2 and D_3, respectively. Four irrigation treatments were implemented as follows (I_1) continuous irrigation (control), (I_2) surge irrigation with cycle ratio of 0.5 (10 min. On-10 min. Off) (I_3) surge irrigation with cycle ratio of 0.4 (10 min. On-15 min. Off) (I_4) surge irrigation with cycle ratio of 0.33 (10 min. On-20 min. Off). The experiments were carried out with faba bean as a test crop.

Data revealed that, water advance times for 80 m. irrigation strip were 110, 96, 81.5 and 66 min.; 77.5, 66.5, 58 and 46 min.; 59, 51, 44 and 37 min. for treatments I_1, I_2, I_3 and I_4 under the stated three discharges, respectively. Data also showed that, surge irrigation treatment with cycle ratio of 0.33 (10 min. On-20 min. Off) resulted in a significant reduction in applied irrigation water, with an average of 39.3% which equaled 811 m^3/fed. The results indicated that surge irrigation had the lowest values of basic infiltration. The average values of basic infiltration rate (IR_b) at the end of the two seasons were 4.0, 4.0 and 5.0 mm/h; 5.0, 6.0 and 7.5 mm/hr and 6.0, 7.0 and 8.0 mm/hr for treatments I_4 (10 min. On-20 min. Of) under 4, 6 and 8 L/S at head medial and tail furrow, respectively. The corresponding values for I_1 continuous irrigation were 7.0, 10 and 12.0 mm/hr; 8.0, 10.0 and 12.0 mm/hr and 9.0, 12.0 and 14 mm/hr, respectively.

INTRODUCTION

Surface irrigation is the common used irrigation method worldwide However, water application efficiency of such irrigation is low (around 45%, Wolters, 1992). Surge irrigation is the intermittent application of surface irrigation water (Stringham, 1988). It has the potential to increase infiltration uniformity of surface irrigation application by:

1. Increasing the advance rate, which decreases cross field differences in infiltration opportunity time and
2. Decreasing the IR at the upstream of furrows to compensate the longer opportunity times at this locations (Kemper *et al.*, 1988).

The decrease in infiltration which caused by surge flow is highly variable, is not fully understood, and is difficult to predict (Izuno *et al.*, 1985; Kemper *et al.*, 1985; Samani *et al.*, 1985; Trout, 1991 and Ibrahim *et al.*, 2003). Many studies have been conducted to determine the mechanisms taking place during the intermittent off period of surge flow irrigation. Several basic phenomena have been recognized.

Surge irrigation is the intermittent application of water in furrows. by alternating flow an each side, an intermittent wetting and soaking cycle is created in the furrow. This wetting and soaking action settles soil particles in the bottom of the furrow and may reduce the intake rate of the soil. If the intake rate is reduced water will advance down the furrow faster. Faster advance can be resulted in a higher uniform application, reducing the amount of water needed to effectively irrigate the field. Proper use of surge irrigation system could be partially achieved the following:

1.- Reduce excess infiltration.
2.- Reduce the gross water application.
3.- Minimize or reduce surface runoff.
4.- Manage time and labor more effectively.

How surge irrigation works:

When water initially contacts the soil of an irrigation furrow, the initial infiltration rate is high. As the water continues to run, value at such point of the furrow is reduced to a near consant rate. If water is shut off and allowed to infiltrate the surface soil particles consolidate and form a partial seal in the furrow. When water is re-applied to the furrow, the intake rate can be reduced due to this partial sealing action. The result is more water movement down the furrow and less water will be infiltrated into the soil.

High infiltration rate can lead to poor irrigation system performance due to deep percolation and poor water distribution across the field. Surge flow can increase irrigation performance by providing a more uniform distribution of irrigation water. In previous paper, Eid *et al.* (2004) studied the performance of surge irrigation on crop yield, they concluded that the mean yield of faba bean for the two seasons of 4, 6 and 8 L/sec water discharge were: 1310, 1346 and 1375 kg/fed, respectively..

Therefore, the objective of this research is to study advance time, water applied and infiltration rate for surge flow irrigation in comparing with the conventional continuous furrow irrigation in clay soil using faba bean as a test crop.

MATERIALS AND METHODS

Two field experiments were conducted during 2001-2002 and 2002/2003 winter seasons at Sakha Agricultural Research Station Farm, Kafr El-Sheikh Governorate, using faba bean crop. Table (1) shows some physical properties of the experimental soils. Dates of sowing (s) and harvesting (H) were as follows:

1st Season: S = 10/11/2001 H = 15/5/2002
2nd Season: S = 15/11/2002 H = 20/5/2003

All cultural practices were done as recommended by the Egyptian Ministry of Agricultural and Land Reclamation (MALR) except for the two factors of study which they were; irrigation treatments and discharge. Area of field plot was 3.5 x 80 = 280 m^2 = (1/15 fed.). Eight stations (S_1-S_8) were arranged every 10 m along the furrow, to measure the water flow advance pattern. The experimental design was a split plot design with four replicates as follows:

A.- Main treatments = discharge D, L/S:

D_1 = 4 L/S D_2 = 6 L/S D_3 = 8 L/S

B.- Subtreatments, irrigation treatments I:

I_1 - Continuous flow.

I_2 - Surge 20 min. cycle with 10 min. On and 10 min. Off.

I_3 -Surge 25 min. cycle with 10 min. On and 15 min. Off.

I_4. Surge 30 min. cycle with 10 min. On and 20 min. Off.

Irrigation water was applied to furrows whatever number of surge needed until reaching the tail end of the furrow for each irrigation treatment through a plastic pipe of 5 cm inner diameter and 70 cm length submerged in the field embankment. Two, four and six pipes were used per plot depending upon the different discharges. The average effective water head above each pipe was determined during the on-watering time.

Advance time:

Advance time could be differed as the on-time required to advance irrigation water from the upstream to the down stream end of the furrow length. The advance time of the water flow for each treatment was recorded when the water front was reached of the various stations along the furrow. The numbers of surges were recorded when the irrigation water reached about 95% of the furrow length. The 95% of the furrow length is the criteria to stop irrigation for all treatments i.e. continuous and surge.

Applied irrigation water (I..W.):

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

$$Q = q \times T \times n \qquad (1)$$

Where:

Q = Water volume L/plot.

q = Irrigation flow rate L/S

T = Total irrigation time per plot calculated by using stopwatch and

n = Number of pipes.

The irrigation flow rate per plot was calculated as follows:

$$q = 0.0\,226\, D^2\, h^{1/2} \qquad (2)$$

Israelson and Hansen (1962)

Where:

h = Average effective head (cm) and

D = Inside diameter of the pipe (cm)

Infiltration rate:

Infiltration rate was determined at the end of the growing season using blocked furrow infiltrometer as described by Garcia (1978).

The measurements were taken at three sites along the furrow (up, middle and down), i.e. 20, 40 and 60 m from inlet.

Table (1): Some soil physical analysis of experimental site.

Soil depth, cm	Particle size distribution			Texture	Bulk density, g/cm^3	FC, w%	PWP, w%	Available water, w%
	Sand %	Silt %	Clay %					
0-15	15.18	18.85	65.97	Clay	1.12	47.2	25.28	21.92
15-30	19.90	13.80	66.30	Clay	1.15	40.5	21.85	18.65
30-45	16.59	16.47	66.94	Clay	1.24	39.0	21.19	17.81
45-60	17.65	15.24	67.11	Clay	1.26	38.5	20.81	17.69

RESULTS AND DISCUSSION

Advance time:

Data revealed that, in general term, the continuous flow treatment (I_1) required more time to complete the advance phase than all tested numbers of surge flow (I_1, I_2, I_3 and I_4), Table (2). The shortest advance time was obtained by using (I_4) i.e. 10 min. On and 20 min. Off and 8 L/s discharge, where it was 37 min. This finding mainly because of increasing water flow rate, reducing number of surges and the shorter contact period and consequently the water moves further down the furrow.

Regarding the type of surface irrigation, the average advance time of water applied to reach the end of the furrow (80 m) were 82.2, 71.2, 61.2 and 49.7 min. for the continuous and different surge cycles, respectively. While the effect of different discharges on advance time took the opposite trend i.e. an increase in discharge leads to a decrease in advance time. The corresponding mean values were 88.4, 62.0 and 47.6 min. for 4, 6 and 8 L/s, respectively. These values suggest that with cycle ratio of 0.33 i.e. 10 min. On and 20 min. Off and discharge of 8 L/sec, the irrigation event was completed faster. In this treatment water reached the end of the furrow in about 62.7% of the time needed under continuous flow. These results are in agreement with those obtained by Morsi (2001), Allen (1980), Coolidge (1981). They showed that the surge flow with the highest flow rates traveled further each surge then those of smaller flow rates and the continuos flow required more time to complete the advance time than the surge flow. Decreasing advance time for surge treatments can be attributed to infiltration rate reduction which resulted from surface sealing and soil consolidation.

Water applied (WA):

Water applied (WA) to faba bean as a winter crop consists of two items. These are (1) irrigation water applied (1W) and (2) rainfall (RF), as shown in Table (2) and illustrated in Fig. (1). Data revealed that all surge irrigation treatments used less amount of 1W than that in continuous one. The overall average of irrigation water (1W) to faba bean by surge treatments I_2, I_3 and I_4 were 86.4, 74.5 and 60.7% of the irrigation water by continuous treatment (I_1) respectively. Meaningfully, water savings were 13.6, 25.5 and 39.3% from the above mentioned results, it can be concluded that the cycle ratio 0.33 treatment I_4 (10 min. On and 20 min. Off) was the best implemented treatment in water saving due to less deep percolation compared with all other treatments. Moreover, water losses through deep percolation was the highest in case of continuous flow than that in all surge treatments. These results are in accordance with those obtained by Allen (1980) and Coolidge (1981). Increasing discharge increased irrigation water for all treatments because of the run off and drainage losses which was increased with increasing the discharge the best treatment in saving water was I_4 (10 min. On and 20 min. Off) with D_1 (445).

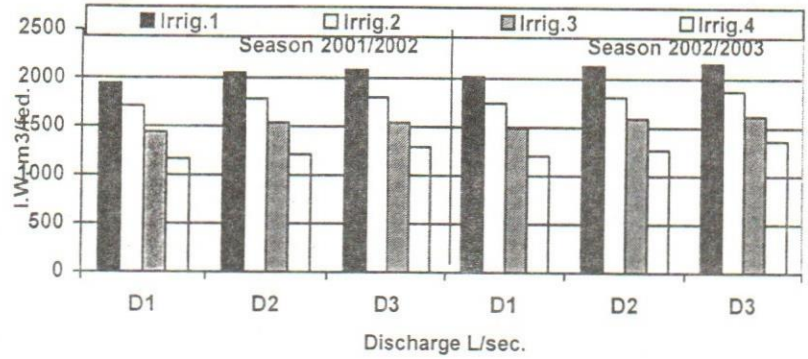

Fig. (1):Water applied (m^3/fed) to faba bean during the two growing seasons 2001/2002 and 2002/2003.

Table (2):Advance time (min.) and irrigation water 1W (m^3/fed. and cm) to faba bean during the two growing seasons 2001/2002 and 2002/2003.

Advance time, min.												
Treat.	Cycle		Seasons 2001/2002			Season 2002/2003			Average of two seasons			
	On	Off	Discharge			Discharge			Discharge			Mean
			4L/S D_1	6 L/S D_2	8 L/S D_3	4L/S D_1	6 L/S D_2	8 L/S D_3	4L/S D_1	6 L/S D_2	8 L/S D_3	
I_1	Cont.	Cont.	108.0	76.0	58.0	112.0	79.0	60.0	110.0	77.5	59.0	82.2
I_2	10	10	95.0	66.0	50.0	97.0	67.0	52.0	96.0	66.5	51.0	71.2
I_3	10	15	80.0	57.0	43.0	83.0	59.0	45.0	81.5	58.0	44.0	61.2
I_4	10	20	65.0	45.0	36.0	67.0	47.0	38.0	66.0	46.0	37.0	49.7
Mean									88.4	62.0	47.8	
I.W, m^3/fed.												
I_1	Cont.	Cont.	1944.0	2052.0	20.88	2016	2133.0	2160.0	1980.0	2092.5	21240	2065.5
I_2	10	10	1710.0	1782.0	1800	1746.0	1809.0	1872.0	1728.0	1795.5	1836.0	1786.5
I_3	10	15	1440.0	1539.0	1545	1494.0	1593.0	1620.0	1467	1566.0	1584.0	1539.0
I_4	10	20	1170.0	1215.0	1296	1206.0	1269.0	1368.0	1188.0	1242.0	1332.0	1254.0
Mean									1590.8	1674.0	1716.5	
I.W., cm/fed.												
I_1	Cont.	Cont.	46.3	48.9	49.7	48.0	50.8	51.4	47.1	49.8	50.6	49.2
I_2	10	10	40.1	42.3	42.9	41.6	43.1	44.6	42.8	42.8	43.7	43.1
I_3	10	15	34.3	36.6	36.9	35.6	37.9	38.6	37.3	37.3	37.7	37.4
I_4	10	20	27.9	28.9	30.9	28.7	30.2	32.6	29.6	29.6	31.7	30.3
Mean									39.2	39.8	40.9	

Notes: Rain water was not included (rainfall: 111 and 46 mm in 2001/2002 and 2002/2003 seasons, respectively).

Infiltration rate (IR):

Data in Table (3) and Fig. (2) illustrated that infiltration rate decreases with time until it nearly reaches a constant value which called the basic infiltration rate (IR) of the soil. The decrease in IR is due to some internal changes in the soil which affect water movement through it. Infiltration rate IR and cumulative infiltration (Cum. I) were measured and computed after harvesting of faba bean at different locations along the furrow. The overall averages of IR were 8.0, 10.6 and 12.65; 6.65, 7.8 and 11.15; 6.0, 7.0 and 9.3; 5.0, 5.7 and 6.8 mm/h for L_1, I_2, I_3 and I_4, respectively.

Regarding the main effect of surge flow irrigation IR was the highest with I_1 (continuous) as compared with all surge irrigation treatments. This occurred in both seasons. The mean IR for the 2nd seasons under I_1, I_2, I_3 and I_4 were 10.4, 8.5, 7.4 and 5.8 mm/h, respectively. Surge flow irrigation treatments reduce the basic IR compared with the continuous irrigation due to the intermittent wetting and dewatering process. The mechanisms by which surge flow irrigation reduces the infiltration rates include (a) filling of cracks that develop during flow interuption with bed load during the following surge (Kemper *et al.*, 1988), (b) air entrapment between successive rewetting (Izadi *et al.,* 1995) (c) a combination of surface sealing and consolidation of the soil matrix near the surface (Samani *et al.,* 1985 and Trout, 1991) and (d) reduction of the hydraulic gradient within the soil surface layer (Coolidge *et al.*, 1982). Similar results are obtained by Malano (1982) and Podmore and Duck (1982) and Ibrahim *et al.* (2003). They noted that basic IR under surge and continuous irrigation decreased during a season. These studies indicted that the basic IR under surge irrigation was lower than that under continuous irrigation.

Data also indicated that basic IR decreases with increasing the Off time, the lowest basic IR 5.0, 5.7 and 6.8 mm/h was recorded under treatment I_4 (10 min. On and 20 min. Off) after faba bean harvesting. the trends of these results are in agreement with those of Guirguis (1988), who attributed the intake rate decrease with increasing the Off time to the rate at which the negative pressure in the soil slows down as Off time continuos and to the reduction in the consolidation rate of the soil as the negative pressure increases.

Infiltration rate was increased at the tail end of furrow due to the less initial soil water content compared with that of the upstream portion of the furrow.

Regarding the effect of water discharge. IR was greater with discharge 8 L/S. Increasing water discharge lead to increased basic IR under different irrigation treatments where cracks formation increased with increasing discharge. Mean IR for the two seasons under D_1 D_2 and D_3 are 6.4, 7.8 and 8.9 mm/hour, respectively. Increasing water discharge lead to increasing IR under different irrigation treatments, where cracks formation increase with increasing water discharge. These results are in agreement with those obtained by Moustafa (1992), Eid (1998) and Morsi (2001).

On the other hand (Fig. 3) illustrates the effect of surge flow irrigation treatments on the cum. 1. under all the studied treatments at different sites along the irrigation pathway. The sites were at 20, 40 and 60 m from water inlet, representing head, middle and tail of the field.

Table (3):Basic infiltration rate (mm/h) during the two growing seasons.

Treat.	Cycle		Head			Medial			Tail			Average			Mean
	On	Off	D_1	D_2	D_3	D_1	D_2	D_3	D_1	D_2	D_3	D_1	D_2	D_3	
1st season 2001/2002															
I_1	Cont.	Cont.	7.0	10.0	12.0	8.0	10.0	13.0	2.0	12.0	14.0				
I_2	10	10	7.0	7.0	10.0	7.0	7.0	12.0	7.0	9.0	13.0				
I_3	10	15	5.0	6.0	7.0	7.0	7.0	10.0	7.0	8.0	1.0				
I_4	10	20	4.0	4.0	5.0	5.0	5.0	7.5	6.0	7.0	7.0				
2nd season 2002/2003															
I_1	Cont.	Cont.	8.0	10.0	12.0	8.0	11.0	12.0	9.0	12.0	15.0				
I_2	10	10	6.0	8.0	10.0	7.0	8.0	11.0	7.0	8.0	12.0				
I_3	10	15	5.0	6.0	8.0	6.0	7.0	10.0	7.0	8.0	10.0				
I_4	10	20	4.0	4.0	5.0	5.0	5.0	8.0	6.0	7.0	7.0				
Overall average of two seasons															
I_1	Cont.	Cont.	7.0	10.0	12.0	8.0	10.0	12.0	9.0	12.0	14.0	8.0	10.6	12.65	10.4
I_2	10	10	6.5	7.5	10.0	2.0	7.5	11.0	7.0	8.5	12.5	6.65	7.8	11.15	8.5
I_3	10	15	5.0	6.0	7.5	6.0	7.0	10.0	7.0	8.0	10.5	6.0	7.0	9.3	7.4
I_4	10	20	4.0	4.0	5.0	5.0	6.0	7.5	6.0	7.0	8.0	5.0	5.7	6.8	5.8
Mean												6.4	7.8	9.9	

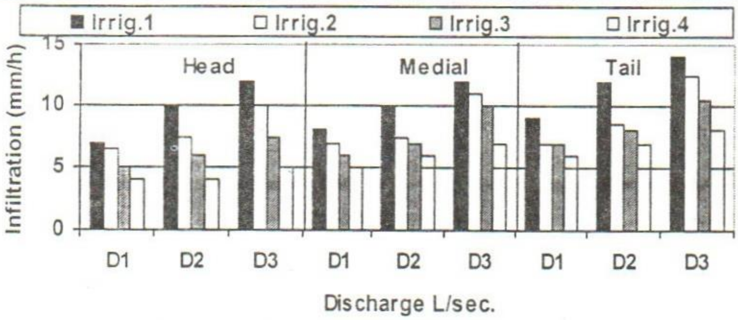

Fig. (2):Basic infiltration rate (mm/h) (average of two growing seasons).

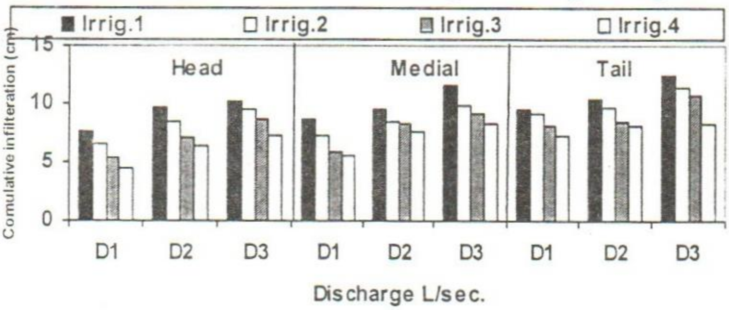

Fig. (3):Commulative infilteration (Cum. I., cm) after three hours at different cites along the furrow (average of two growing seasons).

The results showed that cum. 1. values, for both continuous and surge flow treatments were found to be increased with increasing the distance from water inlet. In the other words cum. 1. values were less for all treatments at the head than at the tail of the field. This could be attributed to that the number of surges is greater at the head than at the end of the furrow. Since surge causes the decrease of infiltration rate, then Cum. 1. at the head is more reduced than at the end of the furrow. The greater reduction of Cum. 1. at the head than at the end of the furrow was more pronounced for continuous flow compared with surge flow irrigation treatments. This is due to the more uniformity water distribution along the furrow under surge flow irrigation, whereas water content is greater at head than at the tail of the field under the continuous irrigation. Coolidge *et al.* (1982) and Ibrahim *et al.* (2003) reported the same trend of results. They concluded that surge can improve uniformity of application but the infiltration can be deeper at the tail and the middle of the field than at the head. They asserted that the reduction in infiltration occurs during the first Off time after the initial wetting. Also, they added that the surge has no effect on Cum. 1. with subsequent surges, but it remains constant at the reduced level for all pulses after the first one.

CONCLUSION

Surge flow irrigation in clayey soils might be recommended as a mean to improve the efficiency of surface irrigation and water saving as presented under the conditions of the present study, surge flow irrigation for faba bean with cycle ratio of 0.33 (10 min. On and 20 min. Off) along with discharge of 8 L/s is the best irrigation treatment.

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تقييم الرى النبضى فى الاراضى الطينية

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معهد بحوث الاراضى والمياه والبيئية ــ مركز البحوث الزراعية ــ كفرالشيخ ــ مصر

اقيمت تجربتان حقليتان فى مزرعة محطة البحوث الزراعية بسخا خلال موسمى الدراسة ٢٠٠١/٢٠٠٢ ، ٢٠٠٢/٢٠٠٣ وذلك لتوفير المياه من خلال تطوير الرى السطحىفى خطوط دلتا النيل وذلك تحت ثلاث تصرفات مختلفة ٤ ، ٦ ، ٨ لتر/ث والتى مثلت بـ D_1, D_2, D_3 ، واربع معاملات رى مختلفة I_1 (رى مستمر) ، I_2 (رى نبضى دورة ٢٠ دقيقة ١٠ دقائق فتح و ١٠ دقائق غلق) ، I_3 رى نبضى دورة ٢٥ دقيقة (١٠ دقائق فتح و ١٥ دقيقة غلق) ، I_4 رى نبضى دورة ٣٠ دقيقة (١٠ دقائق فتح و ٢٠ دقيقة غلق) واجريت هذه المعاملات على محصول الفول البلدى وكانت النتائج كالاتى:

١- زمن تقدم المياه لطول خط ٨٠ متر كان ١١٠ ، ٩٦ ، ٨١,٥ ، ٦٦ دقيقة و ٧٧,٥ ، ٦٦,٥ ، ٨٥ ، ٤٦ دقيقة و ٥٩ ، ٥١ ، ٤٤ ، ٣٧ دقيقة للمعاملات I_1, I_2, I_3, I_4 تحت تصرفات رى ٤ ، ٦ ، ٨ لتر/ث على الترتيب.

٢- حققت المعاملة I_4 أى ١٠ دقائق فتح ، ٢٠ دقيقة غلق توفير فى مياه الرى مقداره ٣٩,٣% أى ما يعادل ٨١١ متر مكعب للفدان.

٣- حققت معاملات الرى النبضى أقل القيم فى معدل التسرب حيث كانت ٤ ، ٤ ، ٥ مم/ساعة و ٥ ، ٦ ، ٧,٥ مم/ساعة و ٦ ، ٧ ، ٨ مم/ساعة للمعاملة I_4 تحت معدل تصرف ٤ ، ٦ ، ٨ لتر/ث فى اول ووسط واخر الخط على الترتيب فيما كانت القيم المقابلة للرى المستمر ٧ ، ١٠ ، ١٢ مم/ساعة و ٨ ، ١٠ ، ١٢ مم/ساعة و ٩ ، ١٢ ، ١٤ مم/ساعة على الترتيب.

٤- يوصى بإستعمال الرى النبضى للفول البلدى المزروع فى خطوط فى الأراضى الطينية بنسبة دورة قدرها ٠,٣٣ (١٠ دقائق فتح و ٢٠ دقيقة غلق) مع إستعمال تصرف لمياه الرى يعادل ٨ لتر/ث.