Effect of planting methods and drip irrigation intervals on onion (*Allium cepa* L.) yield under silt-loamy soil, Kassala State, Sudan

Ahmed B.A. Khalifa[1], Mohamed A. Algali[2], Adlan M. A. Adlan[1], Ibtihal H. M. Hamed[1], Ali M. Ali[1], Ebtehag H. Babiker[1], Shaker B. Ahmed[3], Lotfie A. Yousif[1], Imad-eldin A. Ali Babiker[1], Amir B. Saeed[4], Mohamed A. Ali[1] and Lee Heng[5]

[1]Agricultural Research Corporation, Wad Medani, Sudan.
[2]Ministry of Agriculture, Forestry and Irrigation, Kassala State, Kassala, Sudan.
[3]Faculty of Agriculture, Omdurman Islamic University, Omdurman, Sudan.
[4]Faculty of Agriculture, University of Khartoum, Shambat, Sudan.
[5]Soil and Water Management and Crop Nutrition Section, IAEA, Vienna, Austria.

ABSTRACT

The objective of this research work was to investigate the effects of planting methods and drip irrigation intervals on onion yield under silt-loamy soil. An experiment was conducted for two consecutive seasons (2014/15 and 2015/16). The experiment was composed of planting methods and drip irrigation intervals. The planting methods were flat, ridge and bed planting, whereas drip irrigation intervals were daily, every 3 days and every 5 days. The nine treatments were randomly laid out in a split-plot design with three replicates, the main plots were irrigation intervals and the subplots were allotted to planting methods. The calculated total water requirement for onion crop was 8113 and 7633 m^3/ha in the first and second seasons, respectively. The results showed that the combination of flat planting and daily irrigation produced significantly the highest bulb weight (218.4g), marketable yield (43.8ton/ha) and highest total yield (46.6 ton/ha). The results revealed that flat planting and daily irrigation was the most economical combination for producing onion crop in Kassala state.

INTRODUCTION

Drip irrigation is a promising system for economizing the available irrigation water. It is also necessary to manage the available water efficiently for maximum crop production. It can also apply water more precisely and uniformly at a high irrigation frequency compared to furrow and sprinkler irrigation (Khalifa, 2012).

In Sudan, drip irrigation has been used to produce crops of high value in open field as well as in greenhouses. However, the National Crop Husbandry Committee of the Sudan has recommended the use of drip irrigation system for producing banana, onion and citrus (Khalifa, *et al.* 2013; 2014a and 2014b). Khalifa, *et al.* (2014a) found that drip irrigation system saved irrigation water by 67% and increased the total yield of onion by 43% compared to surface irrigation. They also reported that drip irrigation system scored higher net return and benefit cost ratio compared to the surface irrigation system.

The conventional cultivation method for onion crop in Kassala is by planting on flat and the use of surface irrigation. Farmers usually use animal and labors power to prepare their fields and to construct canals for surface irrigation. Testing different planting methods can provide some information which help farmers for better field management. Crop production in Kassala depends mainly on underground water for irrigation. The limited water supply from the underground water is a real problem facing crop cultivation in Kassala city. The estimated annual recharge rate to the underground water is about 50 million m^3 whereas the annual requirements are about 100 million m^3. Eighty percent of this requirement is used for cultivation and the rest for home uses and drinking (R. A. U. W. V., 2009). Therefore, it is important to study the integrated effect of planting method and drip irrigation interval on onion productivity in Kassala city.

The research work in Sudan, concerning onion crop, was focused on variety improvement and management practices such as transplanting and seed production (Nourai *et al*., 2010). However, more research work is needed in proper water management as onion crop requires regular watering throughout its growth period for maximum production. Drost (2004) mentioned that for good onion production, soil moisture had to be kept near field capacity and any drought stress during growth decreased yield, reduced bulb size and affected flavor. The objective of this research work was to investigate the technical and economic effects of planting methods and drip irrigation intervals on onion yield under silt-loamy soil in Kassala State, eastern Sudan.

MATERIALS AND METHODS

The experiment was conducted for two consecutive seasons, 2014/15 and 2015/16, at the farm of the Horticulture Department, Ministry of Agriculture and Irrigation in Kassala State. This farm is located at latitude 15° 27´ N and longitude 36° 24´ E and altitude of 500 masl. The soil is silt-loam. The climate is semi desert with annual rainfall between 100 and 250 mm, which normally occurs between July and October. The temperature ranges between 20°C and 45°C in winter and summer, respectively.

The experiment consisted of planting methods and drip irrigation intervals. The planting methods were flat, ridge, and bed planting, whereas drip irrigation intervals were daily, every 3 days and 5 days. The nine treatments were randomly laid out in a split-plot design with three replicates. The

main plots were assigned for irrigation intervals and the subplots for planting methods. The subplot size was 8.4 m^2 (2.8 m × 3 m). The experimental plots were plowed, harrowed and leveled. The ridges and beds were constructed at 70 cm apart and 140 cm wide, respectively. The recommended onion cultivar (*Baftaim*) was transplanted on the first of November in both seasons. All other cultural practices were performed as recommended by the ARC. Onion crop was harvested manually on the first of March in both seasons.

Drip irrigation system was properly installed in the experimental plots. The irrigation water was applied according to crop water requirements (ET_c) in a way that each plot received the same amount of water throughout the growing season. Daily meteorological data were used to calculate the daily reference evapotranspiration (ET_0) from the first of November to the end of February. Moreover, the standard crop coefficient (K_c) for onion was taken from FAO-56 and adjusted to the local field conditions according to the equation described by Allen *et al*. (1998) as follows:

$$K_{ci} = K_{c\,prev} + \left[\frac{i-\sum(L_{prev}}{L_{stage}}\right](K_{c\,next} - K_{c\,prev}) \quad \text{..... (1)}$$

where

i = day number within the growing season, K_{ci} = crop coefficient for day i., L_{stage} = length of the stage under consideration (day) and $\sum(L_{prev})$ = sum of the lengths of all previous stages (day).

Thereafter, the field discharge uniformity was calculated using the formula described by Choudhary and Kadam (2006).

$$EU_f = [(Q\ min) \times 100]/\ Q\ avg. \quad \text{..... (2)}$$

where

EU_f = Field discharge uniformity (%), Q min = minimum emitter discharge (l/h) and Q avg. = average emitter discharge (l/h).

To apply 100% of the crop water requirement, modification is needed in the ET_c to compensate the loss in the discharge uniformity of the drip irrigation system. This modification was done by using the following equation.

$$dg = ET_c / EU_f \quad \text{.....(3)}$$

where

dg = Net depth required, mm/day.

The quantity of water to be applied by the drip irrigation system was calculated by the equation described by (Bagali, *et al*., 2012) as follows:

Quantity of water to be applied (liters) = ET_c (cm) x area (ha) x 10^5… (4)

The quantity of water required (CWR) for every drip irrigation interval was calculated using the following equation:

$CWR = ET_c \times$ interval (days)…… (5)

Running time (RT) was calculated using the following equation as described by Sankar *et al*., (2015)

RT = Volume of water applied divided by no. of drippers x dripper discharge rate…… (6)

At harvest, data on bulb yield and its quality were collected and statistically analyzed.

The economic indicators such as partial budget and marginal rate of returns (MRR) were used according to the procedure described by CIMMYT (1988) to evaluate and compare the profitability of the tested treatments.

Data were analysed using the standard analysis of variance procedure. Means were separated using Duncan's Multiple Range Test at 5% level of significance.

RESULTS AND DISCUSSION

The results of the hydraulic characteristic of drip irrigation system for the two seasons are shown in Table 1. The average and the lowest emitters discharge rate values in the first season were 7.5 l/hr and 6.8 l/hr, respectively. The average field emission uniformity for both seasons was 90.6% and 90.5% for the first and second seasons, respectively. The obtained field emission uniformity of the drip irrigation system was excellent. Choudhary and Kadam (2006) reported that 90% is excellent, 80-90% is good and 70-80% is acceptable but less than 70% is not acceptable.

Table 1. Hydraulic characteristics of drip irrigation system for the two seasons.

Hydraulic characteristic	Season	
	2014/15	2015/16
Average discharge rate (l/hr)	7.5	7.4
Lowest emitter discharge rate (l/hr)	6.8	6.7
Emission uniformity (%)	90.6	90.5

The average values of the calculated K_c crop stage and duration of onion was presented in Table 2. The K_c value started from 1.05 in the initial stage and increased up to 1.08 in the developed stage, increased even more in the mid- stage to 1.43 and decreased to 0.97 late in the season.

Table 2. Calculated crop coefficient (K_c) for onion at different stages.

Crop stage	Initial	Development	Mid-season	Late-season
Duration (days)	30	31	31	28
K_c	1.05	1.08	1.43	0.97

The calculated values of reference evapotranspiration (ET_0) in Kassala local conditions were 5.5 and 5.2 mm/day for the first and second seasons, respectively (Table 3).

The crop evapotranspiration (ET_c) is a term that describes the water consumed by a crop during the growing season. The average values of reference evapotranspiration during the growing period were 6.2 and 5.8 mm/day for the first and second seasons, respectively (Table 3). Total water requirements for onion crop were 8113 and 7633m^3/ha for the first and second seasons, respectively.

Table 3. Reference evapotranspiration (ET_0), crop evapotranspiration (ET_c) and crop water requirement (CWR) for onion crop at different stages during the two seasons.

Month	Season					
	2014/15			2015/16		
	ET_o (mm/day)	ET_c (mm/day)	CWR (m^3/ha)	ET_o (mm/day)	ET_c (mm/day)	CWR (m^3/ha)
November	5.4	5.67	1868	5.6	5.88	1937
December	4.9	5.29	1802	4.6	4.97	1690
January	4.9	7.01	2387	4.8	6.86	2335
February	6.9	6.69	2056	5.6	5.43	1671
Mean	5.5	6.2	-	5.2	5.8	-
Total	-	-	8113	-	-	7633

The effect of planting method, drip irrigation interval and their interaction on bulb weight for the two seasons is shown in Table 4. The effect of planting methods on bulb weight showed no significant difference in the first season and very highly significant difference in the second season and the combined analysis. Flat planting resulted in the highest bulb weight throughout the two seasons and combine analysis. The highest bulb weight was 177.7 g, 222.2 g and 200.0 g for the first, second seasons and combined analysis, respectively. The lowest bulb weight was obtained by ridge planting (164 g) in the first season, bed planting in the second season (176.3 g) and combined analysis (176.7 g).

The effects of drip irrigation interval on bulb weight showed no significant differences in the second season, very highly significant difference in the first season and combined analysis (Table 4). These results indicated that bulb weight was affected by irrigation intervals. Daily irrigation interval gave the highest bulb weight while the lowest bulb weight was obtained by the 5 days interval. These findings agreed with the results obtained by Bagali *et al*., (2012) who reported that shorter irrigation intervals i.e., one and two days interval significantly increased onion bulb weight compared to three days interval.

The combination of flat planting and daily irrigation resulted in the highest bulb weight in both seasons and their combined analysis. These results indicated that bulb weight was affected by irrigation intervals and planting methods.

Table 4. Effect of planting method and drip irrigation interval on onion bulb weight (g) for the two seasons and their combined analysis.

Planting method	Irrigation interval (days)			
	1	3	5	Mean
		Season 2014/15		
Ridge	175.8	175.9	140.2	164.0
Flat	202.7	199.6	130.8	177.7
Bed planting	170.0	179.3	182.0	177.1
Mean	182.8	184.9	151.0	172.9
Sig. level	NS		***	*
SE±	6(planting method)		6(irrigation interval)	12(interaction)
CV (%)		8.5		
		Season 2015/16		
Ridge	196.1	186.5	192.2	191.6
Flat	234.1	217.9	214.6	222.2
Bed planting	181.9	171.0	175.9	176.3

Mean	204.0	191.8	194.2	196.7
Sig. level	***		NS	NS
SE±	6.8(planting method)		7(irrigation interval)	6.8(interaction)
CV (%)		7.4		
		Combined analysis		
Ridge	186.0	181.2	166.2	177.8
Flat	218.4	208.8	172.7	200.0
Bed planting	176.0	175.1	178.9	176.7
Mean	193.5	188.4	172.6	184.8
Sig. level	***		***	***
SE±	4.8(planting method)		4.8(irrigation interval)	7(interaction)
CV (%)		7.8		

*and *** and NS indicate significance at ≤ 0.05, 0.001 levels and not significant, respectively.

The effect of planting methods on bulb diameter showed no significant differences in the first season but significant difference in the second season and combined analysis (Table 5). Flat planting method obtained the biggest bulb diameter. Similar results were found by Kanwar and Akbar (2013) who reported that flat planting of onion produced the highest bulb diameter than the other planting methods.

On the other side, the result indicated that bulb diameter was significantly affected by irrigation intervals in the first season and combined analysis (Table 5). Daily irrigation gave the biggest bulb diameter which agrees with the results of Bagali *et al*. (2012). This may be due to the availability of moisture near the root zone.

The results showed no significant differences due to the interaction of planting method and irrigation interval on bulb diameter in both seasons and their combined analysis (Table 5).

Table 5. Effect of planting method and drip irrigation interval on onion bulb diameter (cm) for two seasons and their combined analysis.

Planting method	Irrigation interval (days)			
	1	3	5	Mean
	Season 2014/15			
Ridge	7.4	6.9	7.0	7.1
Flat	7.3	7.4	7.1	7.3
Bed planting	7.2	6.5	6.9	6.9
Mean	7.3	6.9	7.0	7.1
Sig. level	NS		*	NS
SE±	0.1(planting method)		0.1(irrigation interval)	0.1(interaction)
CV (%)		4.7		
	Season 2015/16			
Ridge	7.7	7.2	7.5	7.5
Flat	8.1	8.0	8.1	8.1
Bed planting	7.2	7.1	7.0	7.1
Mean	7.7	7.4	7.5	7.6
Sig. level	NS		*	NS
SE±	0.1 (planting method)		0.1(irrigation interval)	0.1(interaction)
CV (%)		4.8		
	Combined analysis			
Ridge	7.6	7.1	7.1	7.3
Flat	7.7	7.7	7.3	7.6
Bed planting	7.1	7.3	7.0	7.1
Mean	7.5	7.5	7.1	7.3
Sig. level	*		*	NS
SE±	0.1(planting method)		0.1(irrigation interval)	0.1(interaction)
CV (%)		4.7		

* and NS indicate significance at ≤ 0.05 level and not significant, respectively.

The results showed that planting methods significantly affected onion total yield in the first season (Table 6). Combined analysis showed that ridges and flat planting gave higher total yield compared to bed planting. Kanwar and Akbar (2013) found that planting onion on flat produced significantly the highest yield than other planting methods.

The results showed that irrigation interval had significant effect on total yield in both seasons and their combined analyses. Daily irrigation interval resulted in the highest total yield in the first season and combined analyses. These results indicated that daily irrigation positively affected total onion yield compared to other irrigation intervals. The results of this study agreed with the findings of Bagali *et al*. (2012) as they reported that daily irrigation interval recorded significantly higher bulb

yield over other irrigation intervals. Onion is a shallow rooted bulb crop which is highly sensitive to irrigation, once the plant has started growing, it must not suffer from shortage of water. The shorter irrigation interval ensures optimum growth of the crop by securing balanced water supply throughout the crop growth period.

The interaction effect of planting methods and irrigation intervals on total onion yield showed no significant effects in the first season and very highly significant effects in the second season and combined analysis. These results indicated that the total yield was affected by irrigation intervals and planting methods. Some studies showed that onion yield was significantly affected by irrigation interval (Quadir *et al.*, 2005) with more emphasis on shorter irrigation interval (Bagali *et al*., 2012)

Table 6. Effect of planting method and drip irrigation interval on onion total yield (ton/ha) for two seasons and their combined analysis.

Planting method	Irrigation interval (days)			Mean
	1	3	5	
	Season 2014/15			
Ridge	49.6	39.7	40.4	43.2
Flat	50.8	33.2	42.0	42.0
Bed planting	38.4	35.8	40.4	38.1
Mean	46.27	36.1	40.9	41.1
Sig. level	*		***	NS
SE±	1.6 (planting method)		1.6 (irrig interval)	0.8 (interaction)
CV (%)	8.3			
	Season 2015/16			
Ridge	41.3	39.2	48.6	43.1
Flat	42.4	44.5	42.7	43.2
Bed planting	37.5	49.0	39.7	42.1
Mean	40.4	44.2	43.7	42.8
Sig. level	***		**	***
SE±	0.2 (planting method)		0.5 (irrig interval)	0.2 (interaction)
CV (%)	1.3			
	Combined analysis			
Ridge	46.4	39.5	43.8	43.2
Flat	46.6	38.8	42.2	42.6
Bed planting	37.8	42.2	41.8	40.6
Mean	43.6	40.2	42.6	42.1
Sig. level	*		*	***
SE±	0.9 (planting method)		0.9 (irrig interval)	0.6 (interaction)
CV (%)	6.8			

*and *** and NS indicate significance at ≤ 0.05, 0.001 levels and not significant, respectively.

The results showed no significant differences in marketable yield due to the effect of planting methods in the second season, and significant differences in the first season (Table 7). These results indicated that marketable yield was affected by planting methods which agreed with those of Arian *et al.* (2004) who reported significant differences on total marketable yield under different planting methods. Flat planting gave the highest marketable yield in both seasons and their combined analyses.

Irrigation interval had significant effects on marketable yield in both seasons and their combined analyses (Table 7). Daily irrigation resulted in the highest marketable yield in the first season and combined analysis. These results indicated that daily irrigation interval positively affected the marketable yield.

The results of the interaction of planting method and irrigation interval on marketable yield showed no significant differences in the first season, very highly significant differences in the second season and significant difference in the combined analysis. The highest marketable yield was obtained by the interaction between flat bed and daily irrigation in the first season. This could be due to the maintenance of soil moisture in the root zone closer to field capacity by daily irrigation.

Table 7. Effect of planting method and drip irrigation interval on onion marketable yield (ton/ha) for two seasons and their combined analysis.

Planting method	Irrigation interval (days)			
	1	3	5	Mean
	Season 2014/15			
Ridge	45.6	37.3	39.2	40.7
Flat	48.8	31.2	40.0	40.0
Bed planting	35.2	36.8	38.4	36.8
Mean	43.2	35.1	39.2	39.2
Sig. level	*		***	NS
SE±	1(planting method)		1(irrig interval)	0.2 (interaction)
CV (%)		5.7		
	Season 2015/16			
Ridge	37.2	35.3	41.0	37.8
Flat	38.8	40.2	39.7	39.6
Bed planting	36.2	43.4	40.4	30.0
Mean	37.4	39.6	40.4	39.1
Sig. level	NS		***	***
SE±	0.3 (planting method)		0.4 (irrig interval)	0.4 (interaction)
CV (%)		2.3		
	Combined analysis			
Ridge	41.4	36.8	40.9	39.7
Flat	43.8	35.7	39.9	39.8
Bed planting	34.7	40.1	38.6	37.8
Mean	39.9	37.5	39.8	39.1
Sig. level	*		*	*
SE±	0.6 (planting method)		0.6 (irrig interval)	0.7 (interaction)
CV (%)		5.4		

*and *** and NS indicate significance at ≤ 0.05, 0.001 levels and not significant, respectively.

The results of the partial budget analysis indicated that the treatment of flat bed planting and daily irrigation interval achieved the highest costs and the highest net return compared to the other treatments (Table 8). Table 9 shows the calculated marginal rate of return (MRR %) between treatments. All of the treatments achieved MRR% above the minimum marginal rate of return (100%). However, three treatments achieved higher MRR%; namely bed planting and daily irrigation interval, bed planting and 3 days irrigation interval, and flat planting and daily irrigation interval, which were 3018%, 2187% and 1459%, respectively.

As all MRR% was above the minimum marginal rate of return, it is difficult to choose the best treatment for farmers, thus further analysis, the residual analysis, is used. The results of the residual analysis (Table 10) showed that the treatment of the flat bed planting and daily irrigation interval gave the highest residual value. However, all of the other treatments, including farmers' practice, gave

negative residual values. Therefore, the treatment of the flat bed planting and daily irrigation interval is the most superior treatment from the economical point of view.

Table 8. Dominance analysis.

Treatment	Cost that vary (SDG/ha)	Net return (SDG/ha)
Farmers' Practice	32725	4760
Bed planting and daily irrigation	34431	26380
Bed planting and 5 day irrigation interval	35079	29481
Ridge planting and 3 day irrigation interval	35138	29419 D
Flat planting and 3 day irrigation interval	35481	30742
Bed planting and 3 day irrigation interval	35605	31871
Flat planting and 5 day irrigation interval	36102	33872
Ridge planting and 5 day irrigation interval	36326	34479
Ridge planting and daily irrigation	36576	35895
Flat planting and daily irrigation	37161	39477

Table 9. Marginal analysis.

Treatment	Cost that vary	MC	Net return	MR	MRR (%)
Farmers' practice	32725		4760		
Bed planting and daily irrigation	34431	1706	26380	21620	3018
Bed planting and 5 day irrigation interval	35079	647	29481	3101	1140
Flat planting and 3 day irrigation interval	35481	405	30742	1264	745
Bed planting and 3 day irrigation interval	35605	124	31871	1128	2187
Flat planting and 5 day irrigation interval	36102	497	33872	2002	957
Ridge planting and 5 day irrigation interval	36326	226	34479	609	643
Ridge planting and daily irrigation	36576	250	35895	1416	1349
Flat planting and daily irrigation	37161	585	39477	3582	1459

Table 10. Residual analysis.

Treatment	Cost that vary	Net return	Return required	Residual (SDG/ha)
Farmers' practice	32725	4760	32725	-27965
Bed planting and daily irrigation	34431	26380	34431	-8052
Bed planting and 5 day irrigation interval	35079	29481	35079	-5598
Flat planting and 3 day irrigation interval	35481	30742	35481	-4739
Bed planting and 3 day irrigation interval	35605	31871	35605	-3734
Flat planting and 5 day irrigation interval	36102	33872	36102	-2230
Ridge planting and 5 day irrigation interval	36326	34479	36326	-1847
Ridge planting and daily irrigation	36576	35895	36576	-681
Flat planting and daily irrigation	37161	39477	37161	**2316**

CONCLUSION

Flat planting with daily irrigation interval produced the highest bulb weight, the highest marketable yield and the highest net return.

ACKNOWLEDGEMENT

The authors would like to thank the IAEA Regional Project RAF/5/071 “Enhancing Crop Nutrition and Soil and Water Management and Technology Transfer in Irrigation Systems for Increased Food Production and Income Generation” for supporting this work. Special thanks, appreciation and gratitude to all staff of the Horticulture Department, Ministry of Agriculture and Irrigation in Kassala State for their contribution to the success of this work.

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تأثير طرق الزراعة وفترات الري بالتنقيط على انتاج البصل في التربة الطمييية في ولاية كسلا، السودان

أحمد بابكر احمد خليفة[1] ومحمد عبد الله الجعلي[2] وعدلان محمد احمد عدلان[1] و ابتهال حامد محمد[1] وعلي محمد علي[1] و ابتهاج حسن بابكر[1] وشاكر بابكر احمد[3] ولطفي عبد الرحمن يوسف[1] وعماد الدين احمد علي بابكر[1] واميربخيت سعيد[4] ومحمد احمد علي[1] ولي هينق[5]

[1] هيئة البحوث الزراعية، واد مدني, السودان.

[2] وزارة الزراعة والغابات والري, ولاية كسلا, كسلا، السودان.

[3] كلية الزراعة, جامعة ام درمان الاسلامية، ام درمان، السودان.

[4] كلية الزراعة, جامعة الخرطوم، شمبات، السودان.

[5] قسم التربة وادارة المياه وتغذية النبات, الوكاله الدولية للطاقة الذرية, فيينا, النمسا.

الخلاصة

الهدف الرئيسي من هذه الدراسة هو دراسة تأثير طرق الزراعة وفترات الري بالتنقيط على نمو وانتاجية البصل تحت التربة الطمييية في كسلا لموسمين متتاليين (2014/15 و16/2015). تتكون التجربة من عاملين هما طريقة الزراعة وفترات الري بالتنقيط. طرق الزراعة هي احواض مسطحة، سراب وزراعة في مساطب، في حين كانت فترات الري بالتنقيط يوميا و3 أيام و 5 أيام. التسع معاملات وزعت عشوائيا في تصميم القطع المنشقة بثلاث مكررات، حيث وضعت فترات الري في الأحواض الرئيسية وطرق الزراعة في الأحواض الفرعية. أظهرت النتائج أن طريقة الزراعة في احواض مسطحة مع الري اليومي اعطت أعلى وزن للبصلة مقارنة مع الزراعة في سراب ومساطب. تم الحصول على أعلى انتاجية تسويقية باستخدام الزراعة في احواض مسطحة والري اليومي. اثبتت النتائج ان الزراعة في احواض مسطحة والري بالتنقيط اليومي هي المعاملة الاقتصادية الاجدي لإنتاج محصول البصل في التربة الطمييية في كسلا. وفقا للنتائج فإن أفضل طريقة لإنتاج البصل في كسلا هي باستخدام الزراعة في احواض مسطحة والري اليومي.