Journal of Soil Sciences and Agricultural Engineering

Journal homepage & Available online at: www.jssae.journals.ekb.eg

Effect of Tillage Systems on a Soil Moisture Content and Crops Productivity

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ABSTRACT

The soil's physical properties and ability to retain moisture were investigated to keep it as long as possible by applying different tillage systems using various implements (mounted chisel plow ″Ch″, rotary tiller ″R″ and wooden leveler ″L″ and laser ″Z″), where the treatments were as follows; ChR, 2ChR, ChRZ, ChZ, 2ChZ, ChL and 2ChL. Sugar beet (as winter crop) and sunflower (as summer crop) were planted in the experiments as significant response to water in the root zone. The obtained results showed that the seed-bed preparation system using the tillage treatment of chisel plow one or twice followed by rotary tiller is considered as a suitable tillage system for preparing seed-bed, where they achieved the longest period of time to retain soil moisture either at 25% or 50% of the soil available water. Also, the highest yields were recorded for both sunflower and sugar beet under ChR and 2CHR treatments, while ChL and 2ChL treatments recorded the lowest yield. Generally, it can be concluded that the ChR and 2ChR treatments can be considered as a suitable tillage regime.

Keywords*:* Mounted chisel plow, rotary tiller, wooden leveler, sugar beet, water depletion.

INTRODUCTION

Sunflower (Helianthus annuus L.) is considered one of the most widely grown edible oil crops, where it attains great attention because of its high seed quality traits. Its production ranks the third just after both rapeseed and soybean for edible oil and occupies about 9% of the world's total arable region under oilseed crops(Kaya *et al*., 2012). In addition, it as a cut flower has been increasing in economic importance in the floral industry in Egypt (Elbohy, 2017). Sugar beet (Beta vulgaris L.) has an important position in Egyptian crop rotation as a winter crop. Recently, the Egyptian Government encouraged growers of sugar beet to increase the cultivated area for reducing the gap between consumption and production of sugar (Faiyad and Hozayn, 2020).

Under the surface irrigation regime, the soil water is a vital factor-affecting uptake of water from the soil through evaporation from the soil surface and water storage of plants as well as deep-water percolation losses. The structure of soil layers tilled is pronouncedly affected soil infiltration rate. Egypt is facing an issue in the irrigation water resources due to the water budget of it is fixed, so the main step of its Government strategy is raising agricultural productivity from the unit area via using the minimum quantity of irrigation water (Abd-Allah *et al*., 2010).

Because of the shortage of water resources in Egypt, the country has taken care of encouraging the use of modern irrigation methods to rationalize the use of irrigation water and save it to face the water requirements of different crops. This research has succeeded in the new soils, while it wasn't executed in the delta region (surface irrigation). Therefore, this study focused on searching for a method through which to rationalize water consumption without compromising the irrigation method used in the delta (Shams, 2011 and El-Banna *et al.*, 2011). Insertion of tillage in agricultural practice leads to reduce soil degradation phenomena and reduces production costs. Irrigation water penetration in soil and the increase of the water storage in soil profile depends on the amount of water as well as water and soil temperature, slope and soil form, hydro-physical properties, soil texture and compaction. All these soil properties are closely interdependent, where they are influenced by the tillage system (Gholami *et al.*, 2014 & Ismail 2002 and Acharya *et al.*, 2019).

There is not enough data on the impact of tillage regimes on alluvial soil's physical properties of the seedbed. Hence, further research is required to identify desired tillage regimes. For this purpose, its objective was to study the impact of various tillage regimes on the moisture content of alluvial soil to select the most suitable system that keeps up the available soil water for a long irrigation interval, thus raising water use efficiency.

MATERIALS AND METHODS

The current research work was carried out during three successive seasons (2018/2019 and 2019/2020) in the experimental farm at the experimental Station of Sakha Agric. Res., Kafr El-Sheikh Governorate (31° 30 0 7.59 00 and 31° 9 0 58.09 00 North) and between (30° 20 0 36.83 00 and 31° 17 0 15.16 00 East).

Soil sampling

The soil sample were taken at different depths i.e,0-15, 15-30, 30-45 and 45-60 cm by auger device. There were analyzed to identify soil mechanical analysis and hydro-physical properties relative to Wilke, (2005). The average of the maximum rising of the water table was among61 - 64 cm, whilst the average of the minimum rising varied between78 - 86 cm.

Depth, cm	Mechanical analysis			Soil texture	Field capacity, %	Wilting point, %	Bulk density, g/cm³
	Clay	Silt	Sand				
0 - 15	49.99	27.56	22.45	Clay	36.2	17.4	1.12
15 - 30	50.3	27.75	21.95	Clay	38.1	18.1	1.13
30 - 45	52.57	26.86	20.57	Clay	36.5	20.2	1.15
45 - 60	52.95	26.51	20.54	Clay	35.8	19	1.17
Mean	51.45	27.17	21.38	Clay	36.65	18.68	1.14

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DOI: 10.21608/jssae.2022.138432.1077

Table 1. Some soil characteristics of the experimental location

Soil depth (cm)	Hydro-physical properties (%)		Particle size distribution (%)			Texture class
	*F.C	**W.P	Sand	Silt	Clay	
0-15	47.5	25.8	21.29	25	53.71	
15-30	39.9	21.6	19.62	28.2	52.18	Clay
30-45	38.4	20.8	21.09	29.1	49.81	
45-60	38.5	20.6	21.10	29.2	50.0	

***F.C= field capacity and **W.P=wilting point.**

To determine the soil moisture content, soil samples were taken from each plot at the same aforementioned depths every two days until twenty days in the winter season and thirteen days in the summer season. There were calculated using the following equation as dry/ weight bass:

The experimental equipment

Mounted chisel plow: Locally manufactured, 7 shares, 175, 17 cm working width and depth, 350 kg mass.

Rotary tiller: Italy manufacture, 36 shares, 160, 7cm working width and depth, 330 kg mass.

Wooden leveler: Locally manufactured, 300 cm working width, 240 kg mass.

Laser leveler:

Experimental Setup

This investigation was executed to enhance the ability to keep the soil with free moisture as long as possible by applying different tillage systems (mounted chisel plow, rotary tiller, and wooden leveler) and consequently increasing water use efficiency.

The treatments were as follows; ChR (chisel plow once followed by rotary tiller), 2ChR (chisel plow twice followed by rotary tiller), ChRZ (chisel plow once followed by rotary tiller and Laser leveler), 2ChRZ (chisel plow twice followed by rotary tiller and Laser leveler), ChZ (chisel plow once followed by Laser leveler), 2ChZ (chisel plow twice followed by Laser leveler), ChL (chisel plow once followed by wooden leveler) and 2ChL (Chisel plow twice followed by wooden leveler).

Two different crops with different in water requirements were recognized. There were sugar beet (as winter crop) and sunflower (as summer crop) as an experimental plants based on their significant response to irrigation water alterations in the root zone. The experimental area was divided into 8.0 main plots, where each plot of 6.0 × 30m.The experimental farm is near to major irrigation canal, where a steel gate was fixed at the side of the feeder channel controlled the irrigation water.

The soil water depletion rate (SWD,%)

The SWD,% were calculated according a simple equation as the follows;

$$SWDR,\% = \frac{SMC_i - SMC_f}{SMC_i} * 100$$

Where:

SMC_i is the primary soil moisture content at irrigation time & SMC_f is the finally soil moisture content

RESULTS AND DISCUSSION

Soil moisture distribution

Figures 1 and 2 show the relation curves of the soil distribution moisture content for the layer's depth of 0-15, 15-30, 30-45, and 45-60cm as the relationship of different tillage treatments. It was noticed from these figs that soil moisture content in most cases reached near to the filled capacity (FC) of such soil layers per two days after irrigation. Then it is reduced as a result of each evaporation from the bare soil particularly, from the upper layer of the depth of 0 -15 cm, and the water exhausted by plants grown.

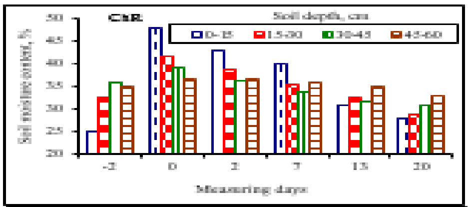


Fig. 1-1

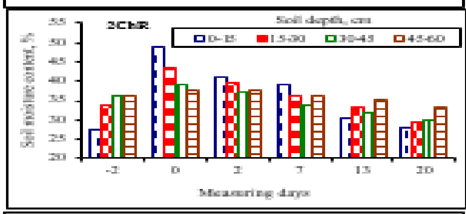
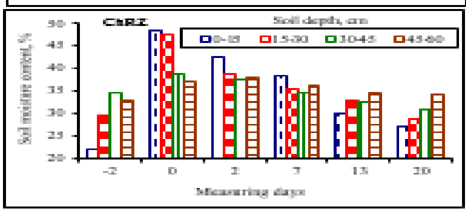


Fig. 1-2



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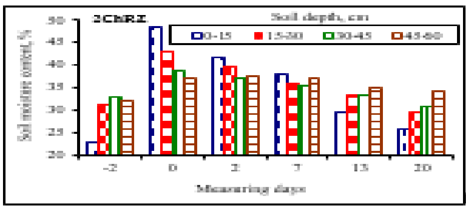

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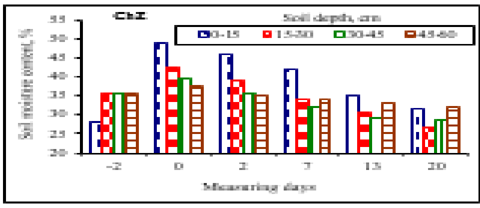

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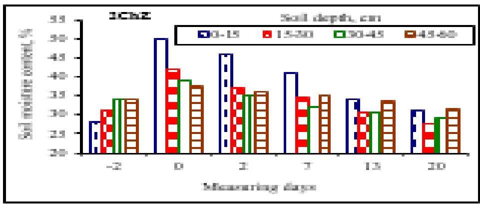


Fig.1-6

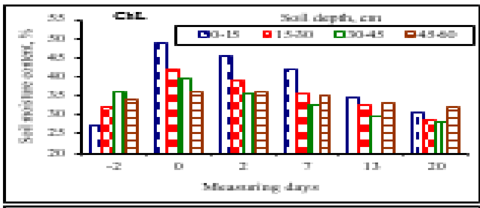


Fig. 1-7

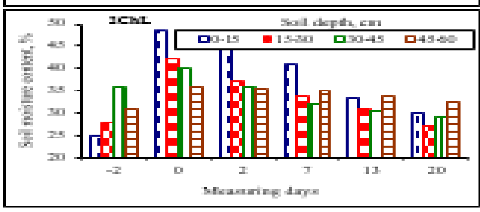


Fig. 1-8

Fig. 1. Soil moisture content in different soil layers at a period from 22th Jan to 17th Feb within an irrigation period

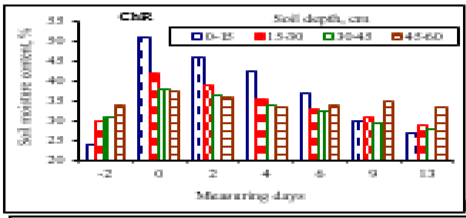


Fig. 2-1

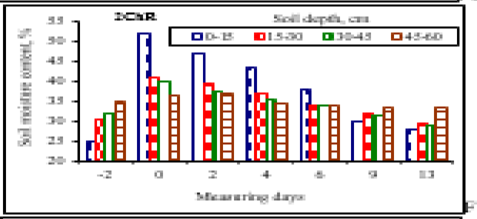


Fig.2-2

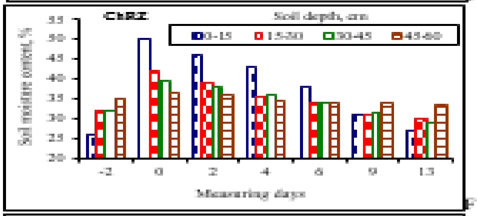
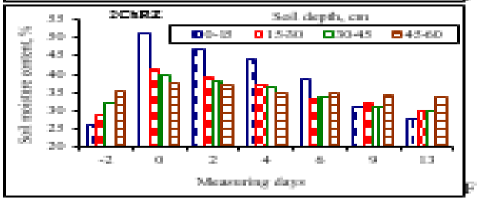


Fig. 2-3



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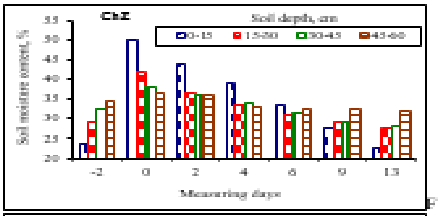

Fig. 2-5

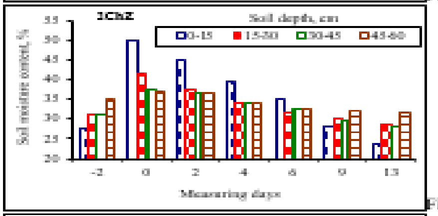

Fig. 2-6

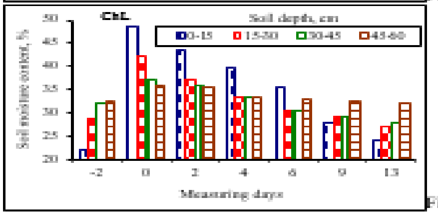

Fig. 2-7

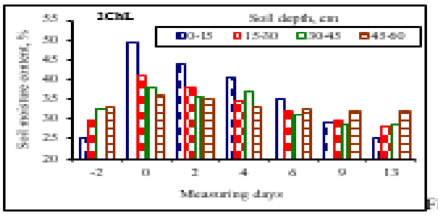

Fig. 2-8

Fig. 2. Soil moisture content in different soil layers at a period of from 25th Aug to 10th Sep within an irrigation period

Regarding Fig. (1) and at soil layer depth of 0-15cm, soil moisture content "SMC" of 43.5% represented 75% of the average water supply. But, at SMC of 37.2%, it represented 50.0 %. While 49.0 % of the water supply . At soil layer depth of 15-30cm, the "SMC" of 35.2% represented 75% of the average water supply. But, at SMC of 31.0 %, it represented 50.0 %, and 40.0 %.For layer depth of 30-45 cm, the "SMC" of 34.0 % represented 75% of average water supply; while 30.0 % represented 50.0 % and 39.0 %.Finally, a soil layer depth of 45-60 cm, soil moisture content 32.5% represented 75% of the average of water supply. While 28.0 % represented 36.3 % of the average water supply and 39.0 % represented F.C.

The same trend was found, as shown in figure 2. For example at soil layer depth of 0-15cm, soil moisture content "SMC" of 42.5% represented 75% of the average water supply. But, at SMC of 36.8%, it represented 50.0 %. While the 47.5 % of water supply . At soil layer depth of 15-30cm, the "SMC" of 35.3% represented 75% of the average water supply. But, at SMC of 31.0 %, it represented 50.0 %, and 40.0 % . For layer depth of 30-45 cm, the "SMC" of 34.9 % represented 75% of average water supply; while 30.0 % represented 50.0 % and 39.0 % . Finally, at soil layer depth of 45-60 cm, soil moisture content of 32.5 % represented 75% of the average of water supply; while 28.0 % represented 36.5 % the average water supply and 39.0 % .

Soil water depletion rate

Soil water depletion rate in different soil layers at a period from 22th Jan to 17th Feb within an irrigation period for sugar beet crop was a consequence of Fig. 1. From Fig. 1-1, the deficits of soil moisture content (DSMC,%) in percentage at soil depth layers of 0-15cm, 15-30, 30- 45 and 45-60cm were 41.66, 31.42, 21.27, and 10.27%, respectively during "chR" treatment. But, under treatment "2ChR" the "DSMC,%" increased to become 42.85, 32.18, 23.6, and 11.94% for the above soil depth layers, respectively (Fig. 1-2). From the above outcomes can be concluded that using twice of chisel plow recorded more loss of soil moisture content. It means increasing the depletion rate.

The "DSMC,%" in percentage at soil depth layers of 0-15cm, 15-30, 30- 45 and 45-60cm were 44.33, 39.37, 20.77 and 7.57% for ChRZ treatment (Fig. 1-3). Meanwhile, there were 46.59, 30.7, 20.51 and 8.31% for the mentioned layers respectively (Fig. 1-4). The above data indicated that using 2ChRZ treatment gives the lowest water depletion rate than that for ChRZ treatment for soil layers depths of 14-30 and 30-45 cm. The lowest depletion rate was found by comparing "ChZ" (Fig. 1-5) with "2ChZ" (Fig.1-6) at depths of 15-30 and 30-45 cm and per related "ChL" (Fig. 1-7) with "2ChL" only at depth 30-45cm. The same trends were found for soil water depletion rate in different soil layers during a period from 25th Aug to 10th Sep within an irrigation period for sunflower crop as shown in Fig. 2.

Therefore, by knowing the rate of soil water depletion, it is easy to define the time of watering. Generally, as it is cleared, the irrigation interval is a function of the tillage method and plants as well as the growing season. In this manner, the following analysis could be achieved from Figures 1 and 3.

Regarding the upper soil layer (depth of 0.0 -15 cm), 25% depletion equaled losses of 5.4 % from soil FC. So irrigation water is added until the soil moisture content equals

42.1%, while the 50% depletion of the available soil water equaled to irrigating when the moisture content of soil reached 36.7%. The soil moisture content almost reached the wilting point after 20 and 11 days of irrigation in both winter and summer seasons, respectively.

Concerning the 2nd soil layer (depth of 15.0 -30.0 cm), it was clear that the soil moisture content never reached the wilting point value under all studied tillage treatments. Depletion of 50% equaled losses of 9.20 % from F.C. So, irrigation water added until the moisture content of soil reaches 30.95%. Where this moisture value was reached after 11.0 and 6.0 days from the irrigation process in both winter and summer seasons, respectively under the investigated tillage treatments.

Concerning the 3rd soil layer (depth of 30.0 – 45.0 cm), 50% depletion which figured 29.6% was realized after 13.0 and 8.0 days from the irrigation process in both winter and summer seasons, respectively under the investigated tillage treatments.

The obtained findings in the same Figures 1 and 2 illustrated that tillage treatments executed using the rotary tiller realized the longest time to reach the 25% and 50% depletion from available soil water at the studied various soil layers in both winter and summer seasons compared to the other tillage treatments. Regarding the upper soil layer (depth of 0.0 -15 cm), in summer season, the depletion of 25% and 50% from available soil water were reached after four to six days from irrigation process regarding the treatments of ChR, 2ChR, ChRZ and 2ChRZ, respectively. Whilst, in winter season, the same depletion were reached after 6.0 and 10.0 days for treatments of ChR, 2ChR, ChRZ and 2ChRZ, respectively.

At 2nd soil layer (depth of 15.0 -30.0 cm), the depletion of 25 and 50% were reached after 4.0 and 8.0 days regarding the ChR and ChRZ treatments as well as after 4.0 and 9.0 days regarding the 2ChR and 2ChRZ treatments, respectively in summer season. Whereas, the same depletion were reached in winter season after 7.0 and 15.0 days regarding the ChR and ChRZ treatments as well as after 7.0 and 16.0 days regarding the 2ChR and 2ChRZ treatments, respectively.

The results illustrated that the suitable irrigation time at seed-bed prepared with tillage treatment using rotary tiller in the North zone of Nile Delta was every 5.0 or 6.0 days in the winter season, and 4.0 days in the summer season concerning shallow-rooted crops, grain crops and deep-rooted row crops as well as forage crops at the 1st growing stages. Whilst the suitable irrigation time for crops, its effective root distributed in soil layer (depth of 15-30 cm), was in every 15.0 or 16.0 days in the winter season and 7.0 days in the summer season. Our results are in harmony with those of Fanigliulo *et al*., (2012).

Yield of sugar beet and sunflower

Fig.3 shows the influence of different tillage treatments on yield of sugar beet plants (Mg h^{-1}) as well as on yield of sunflower plants (Mg h^{-1}). The average yield of both sugar beet and sunflower (Mg h^{-1}) differed due to investigated tillage treatments. The obtained findings demonstrated that the crop yields of both sugar beet and sunflower under tillage treatments using rotary tiller were higher compared to the other tillage treatments. The highest sunflower and sugar beet yields were realized under treatments of ChR and 2ChR, while treatments of ChL and 2ChL, achieved the lowest values of crop yields of both sugar beet and sunflower.

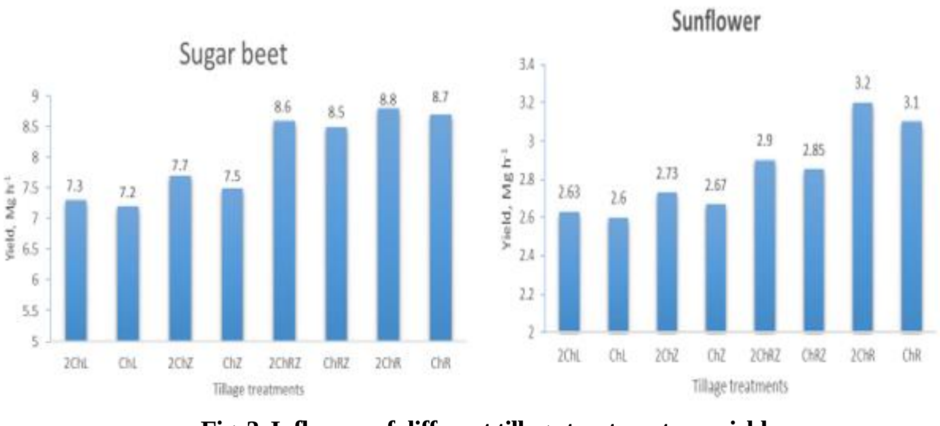

Fig. 3. Influence of different tillage treatments on yield

Many factors may be caused a high yield with ChR and 2ChR treatments. This may be attributed to the low bulk density, better imbibition rate, low soil shear and penetration resistance in treatments of ChR and 2ChR compared with other tillage treatments.

CONCLUSION

From the obtained results, it may be evident that ChR treatment (chisel plow one followed by rotary tiller) may be considered as a suitable tillage regime for alluvial soil in Nile-Delta region, where this system recorded long irrigation intervals and realized high crop yields of both sugar beet and sunflower with a decrease in the number of equipment passes compared to the 2ChR and ChRZ treatments.

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تأثير نظم حرث مختلفة على محتوى رطوبة التربة الرسوبية ومحصول بنجر السكر وعباد الشمس.

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الملخص

نظرًا لوجود علاقة قوية بين الخصائص الفيزيائية للتربة وقدرتها على الاحتفاظ بالرطوبة ، فقد تم تنفيذ هذا العمل البحثي بهدف تحسين قدرة التربة على الاحتفاظ بالرطوبة لأطول فترة ممكنة من خلال تطبيق أنظمة حرث مختلفة وبالتالي زيادة كفاءة استخدام المياه باستخدام آلات مختلفة (المحراث الحفار ، المحراث الدوراني ، آلة التسوية الخشبية) ، حيث كانت المعاملات على النحو التالي ؛ ChR (المحراث الحفار مرة واحدة متبوعًا المحراث الدوراني) ، ChR2 (المحراث الحفار مرتين متبوعًا بالمحراث الدوراني) ، ChRZ (المحراث الحفار مرة واحدة متبوعًا المحراث الدوراني وجهاز التسوية بالليزر) ، ChRZ2 (المحراث الحفار مرتين متبوعًا بالمحراث الدوراني وجهاز التسوية بالليزر) ، ChZ (محراث حفار متبوعًا بجهاز التسوية بالليزر) ، ChZ2 (محراث حفار مرتين متبوعًا بجهاز التسوية بالليزر) ، ChL (محراث الحفار مرة واحدة متبوعًا بالزحافة الخشبية) و ChL2 (محراث الحفار مرتين متبوعًا بالزحافة الخشبية). تم استخدام بنجر السكر (كمحصول شتوي) وعباد الشمس (كمحصول صيفي) كنباتات تجريبية بسبب استجابتهما الكبيرة لتغييرات مياه الري في منطقة الجذر. أوضحت النتائج المتحصل عليها أن نظام إعداد مرقد البذرة باستخدام المحراث الحفار لمرة واحدة أو مرتين متتاليتين يعقبه محراث دوراني يعتبر من أنسب نظم إعداد مرقد البذرة، حيث حققت أطول فترة زمنية للاحتفاظ برطوبة التربة سواء عند نسبة 25 % من الماء المتيسر بالتربةأو عند نسبة 50% من الماء المتيسر بالتربة. من ناحية أخرى، تم تسجيل أعلى إنتاجية لكل من عباد الشمس وبنجر السكر تحت معاملات ChRو CHR2، بينما حققت معاملات ChLو ChL2أقل محصول. بشكل عام، يمكن استنتاج أن المعاملاتChRو ChR2يمكن اعتبارها نظام حرث مناسب.