Research Article

The effect of tillage systems and irrigation water regimes on growth and yield of sunflower

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Abstract

The experiments were conducted for two successive summer seasons 2004 and 2005 at the Hudeib Agricultural Research Station in Eddamer Locality, Sudan. The study was carried out to investigate the effect of five tillage systems (Disc plow + land leveler + ditcher, Chisel plow + land leveler + ditcher, Disc harrow + land leveler + ditcher, Oxen plow + land leveler + ditcher, Zero tillage + ditcher) and two irrigation water regimes (100% and 75%) of crop water requirements on growth and yield of Sunflower (hybrid Hysun 33). The treatments were arranged in split plots in a randomized block design with three reps. The measured parameters were germination percentage, plant height, taproot length, crop disc diameter and crop yield. The results showed that tillage systems and the interactions had a significant effect on germination percentage. The highest germination percentage attained under disc plow and 100% water regime. Plant height at the first season, taproot length and disc diameter at the second season were significantly affected by the tillage systems at 5% level. The tillage systems and interactions had a significant effect on seed yield in both seasons. The disc plow and no tillage treatment significantly attained the highest seed yield in both seasons. The seeds yield of disc plow were 1012, 2016 kg/ha for 75% water regime and 1459, 1498 kg/ha for the 100% water regime the first and second seasons, respectively. Whereas no tillage treatment the crop seed yield were 1033, 1583 kg/ha for the 75% water regime and 1133, 1278 kg/ha for 100% water regime the first and second seasons, respectively. Water regimes had no significant effect on growth and seed yield.

Keywords: ***Sunflower; tillage systems; water regimes.***

Introduction

Sunflower (*Helianthus annuus* L.) is one of the most important oil crops produced under both rainfed and irrigated conditions in the semi-arid environment of Sudan. Cultivated area had shown an increasing manner in last years. In season 2018/19 the cultivated area is about 7000 hectares in rainfed sector and 10000 hectares in irrigated region [1]. According to Bashir and Mohamed [2] rapidly increased areas can be attributed to genetic improvement, short growth duration, farmers and private sector's interest, low labor needs, adaptability and suitability to mechanization, higher yield potential as well as its good quality.

Sunflower can perform well under wide spectrum of climatic and soil conditions. The crop is grown in both summer season under rainfed sector and as winter crop under irrigated system. In Northern Sudan the favorable seasons for sunflower growth would be the summer and the Damira seasons [3]. These are encouraging periods for the farmers to produce cash crops in less intensive land use.

Sunflower productivity was affected by irrigation regime at different growth stages. Maximum yield was obtained with irrigation at all critical growth stages. Application of irrigation at critical stages of plant growth regulates the metabolic

process, increase effectiveness of other inputs and increases the crop yields [4]. Many researchers recorded significant effect of the amount and distribution of water on sunflower yield [5-7]. Nevertheless, other scientists reported the importance of adequate water in the initial stages [8].

Generally, conservation tillage systems have been shown to contribute and improve soil properties. Tillage systems had different effects on soil physical properties such as bulk density, moisture content and penetration resistance [9]. It has been reported that direct effects are that soil is crushed and pulverized, disturbed and its volume increased decreasing the bulk density of the soil, whereas the indirect effect can be found by soil compaction as a result of heavy machinery passes over the soil and its bulk density increased [10].

In most semi-arid areas, conservation tillage systems (minimum and zero tillage systems) are constrained by soil densification, which decreases water infiltration, thereby limiting root access to water [11],[12]. Therefore, implementing low-tillage practices should be combined with other soil management options such as irrigation amounts to achieve the desired result.

Irrigation water amounts and tillage systems are important factors, which influence crop yield. Different tillage systems suit different amount of irrigation water. Some evaluates the effect of different irrigation water regimes and tillage systems on sunflower yield in Khartoum region and obtained that the combination of irrigation water amounts with tillage systems significantly affected the sunflower yield [13]. On the other hand, investigated the response of full and deficit irrigation of Sunflower hybrids yield under semi-arid environment of Gezira, Sudan [2]. They found that that sunflower should be fully irrigated or adequate water should be applied during seed filling, otherwise, under limited irrigation, water stopping of irrigation after flowering can also be acceptable under optimum sowing date.

Although Sudan is one of the most important countries in concern of agricultural production, there were no standard practices regarding irrigation amounts and tillage systems which resulted on low crop productivity. The objective of this study is to investigate the effect of conventional and conservation tillage systems and irrigation water regimes on growth and yield of Sunflower.

Materials and Methods

The experiment was conducted during two seasons 2004 and 2005 in Horticultural field of Hudeiba Research Station, (ltitudes17º 34′ N: longitudes 33º 56′ E and altitude is 350 m asl). The soil is medium clay. The experimental area lies on the semi desert region, which is characterized by hot dry desert climate.

This study was carried out to investigate the effect of five tillage systems and two irrigation water regimes on Sunflower (hybrid Hysun 33). The treatments were arranged in split plots in a randomized block design with three reps. Two irrigation water regimes: 75% of crop water requirements (W1) and 100% of crop water requirements (W2) assigned as main plots. Five tillage systems: Disc plow + land leveler + ditcher (T_1), Chisel plow + land leveler + ditcher (T2), Disc harrow + land leveler + ditcher (T3), Oxen plow + land leveler + ditcher (T4), Zero tillage + ditcher (T5) were assigned as sub plots.

Soil physical and chemical properties of the experimental site presented in Table 1. Two Parshal flumes, were used for measuring irrigation water. The flumes were constructed in a workshop at Atbara according to standardization tables [14]. A graduated 1000 ml volume plastic can and a stopwatch were used to calibrate the flume capacity. Sensitive scientific scale balance, used for weighing.

Sowing of the crop was carried out manually with the seeds of Hysun 33 variety at a rate of 8 kg/ha about 57000 seedlings per hectare. 3 seeds per hole were applied at 3 cm depth with 40 cm distances between holes.

Parshal flume was used for measuring the flow rate of the irrigation water. Depending

on the crop water requirements the time of irrigation was measured as 17-23 min and 25-30 min for W1 and W2, respectively. The irrigation interval was 14 days.

Table 1. Soil analysis of experimental site

Depth Cm	Mechanical Analysis			Texture	Total $CacO_3$ %	PH	Electrical conductivity	Chem. Analysis		Bulk density
	Sand %	Silt %	Clay %					P Mg/kg	N Mg/kg	
0-15	16	24.6	59.4		1.5	8.1	0.95	1.6	0.05	1.34
15-30	14	20.8	65.2	Heavy	1.2	8.0	0.95	1.6	0.05	1.38
30-45	13.5	20.9	65.6	Clay	1.0	8.3	1.2	1.8	0.05	1.39
45-60	12	20.9	67.1		1.08	8.3	1.41	1.8	0.05	1.41

Data collection

The plant measurements were carried at different stages of plant growth. The percentage of germination was determined. Two rows were randomly selected within each plot. Hence the average number of plants per plot was calculated. Plant height (cm) measurements were carried at two weeks interval. One plant was randomly selected from two rows in each plot. The plant height was measured using a meter rod adjusted along the plant height to the surface of the soil. The depth of tap root (cm) in the soil was determined by digging and pulling out the rooting system. Tapes and meters were used to measure the taproot length in each plot. The readings for the discs were taken at two weeks interval, started 45 days after sowing. Two rows were randomly selected from each plot, two plants for each row. Hence the average disc diameter was determined per plot.

The harvesting was carried at 95-102 days after sowing. Two rows were randomly selected within each plot. Hence the average seed weight per row was determined and also the seed weight per plot. Sensitive spring balance was used to weigh the seeds.

Analysis of variance was used to test the significance of treatment effect. Least Significant Difference Test was used to separate means.

Table 2. The effect of tillage systems and water regimes on germination and emergence% two weeks after sowing during 2004/05 and 2005/06 seasons

Tillage Systems	2004/05 season			2005/06 season		
	W_1	W_2	Mean	W_1	W_2	Mean
T_1	28.7	30.2	29.5	59.7	75.8	67.6
T_2	29.3	33.0	31.2	42.2	62.9	52.6
T_3	28.2	46.6	37.4	55.4	46.2	50.8
T_4	29.1	29.0	29.1	59.2	51.7	55.5
T_5	43.5	49.7	46.6	53.3	64.1	58.7
Mean	32.0	38.0	35.0	54.0	60.0	57.0
LSD(0.05)						
W	13.5^{ns}			1.11*		
T	13.6*			15.32*		
W x T	20			20.38*		

T1- Disc plow + leveling + ditching; T2- Chisel plow +leveling +ditching; T3- Disc harrow +leveling + ditching; T4- Oxen plow +leveling + ditching; T5- No tillage + ditching; $W_1$75% and $W_2$100%.

* Significant at P ≥ 0.05 ns: Not significant

Results and discussion

Germination and emergence percentage

The effect of tillage systems and water regimes on germination percentages of the seedling are given in Table 2. The before planting germination test was carried out on seeds and it was found to be 74% for the season 2004/05 and 82% for the season 2005/06. Tillage systems and interactions significantly influenced germination and emergence (%). The maximum emergence was recorded after 14 days from sowing, which agreed with previous study [15]. Water regimes did not significantly affect the germination and emergence percentage. The highest germination percentage was noticed with the treatment using the disc plow and this was due to the disc plow had the ability of crushing and pulverizing soil better than other plowing implements. This led to a good seed bed and a good germination. These results were in the same line of a report that tillage practice such as deep primary tillage had more positive effect on seedling emergence than zero tillage [16].

Plant height

The results of the effect of tillage systems and water regimes on plant height had a significantly different as shows in Table 3. The average plant height by the end of the season for the disc plow were 57.00 and 59.00 cm for the 75% and 100% water regimes, respectively. The average plant height for chisel plow was 53.55 and 54.85 cm for the 75% and 100% water regimes, respectively. For the disc harrow the average plant height was 55.4 and 56.55 cm for the 75% and 100% water regimes, respectively, whereas for the oxen driven plow the average plant height was 51.50 and 55.00 cm for the75% and 100% regimes. For the no tillage the average plant height was 52.15 cm for the 75% regime and 59.9 cm for 100% water regime (Figure 1).

Plant height for the different treatments were higher with 100% water regime in the first season. The statistical analysis of the plant height (Table 3) shows no significant differences between plant heights for tillage systems and water regimes and their interactions. In season 2005, tillage treatments showed significance ($p \geq 0.05$) while the water regimes and the interaction of treatments were not significant. The increment of increase of plant height is noticeable in the second season. Similar results were previously reported that different irrigation levels at establishment and vegetative stages increase vegetative growth of sunflower [17], [18].

Table 3. Mean square for plant height during 2004/05 and 2005/06 seasons

Source of variation	Degrees of freedom	Mean square 2004/05	Mean square 2005/06
Block	2	81.759	377.325
Irrigation	1	183.5213 ns	0.4083 ns
Error (a)	2	137.0223	116.858
Tillage	4	331.7867 ns	995.6583*
Irrigation and tillage	4	41.85717 ns	206.6583 ns
Error (b)	16	157.0569	297.5083

* Significant at $P \geq 0.05$ ns: Not significant

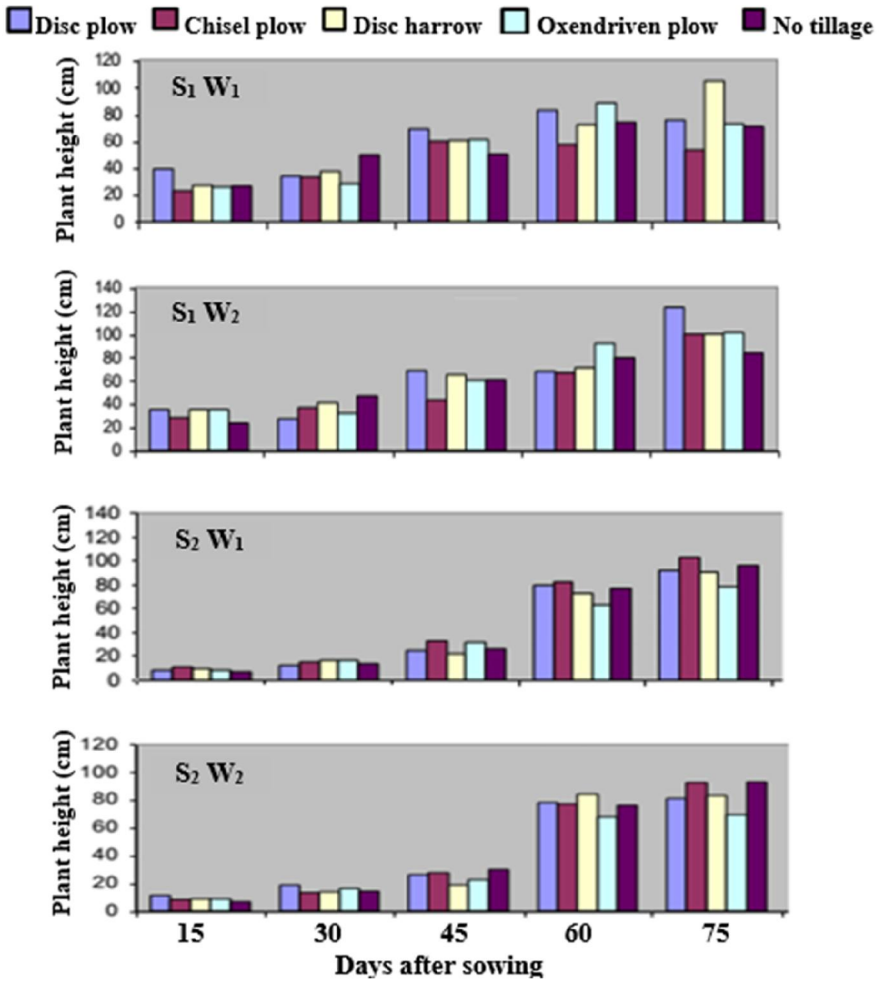


Figure 1. The effect of tillage treatments and water regimes on plant height. S1-Season 2004, S2-Season 2005, W1-75%of CWR, W2- 100 % of CWR

Taproot length

The results and statistical analysis of taproot length are shown in Figure 2. The average tap root length for the two seasons under the disc plow treatment were 20.47 and 21.73 cm for the 75% and 100% water regimes, respectively. For the chisel plow the tap root length was 18.4 and 19.8 cm for the 75% and 100% water regimes, respectively. For the disc harrow the tap root length was 17.18 and 18.65 cm for the 75% and 100% water regimes, respectively. For the oxen driven plow the tap root length was 18.0 and 18.87 cm for the 75% and 100% water regimes, respectively. For the chisel plow the tap root length was 18.4 and19.8 cm for the 75% and 100% water regimes, respectively. For the no tillage the tap root length was 16.85 and17.36 cm for the 75% and 100% water regimes, respectively.

There was a significant difference for the tap root length with the tillage treatments in season 2004 ($p \geq 0.05$) level of significance. The most effective tillage treatment was the disc plow. The effect of tillage systems, water regimes and their interaction on taproot for the season 2005, were not significantly different. Sunflowers develop strong lateral roots in the surface soil area around the top 10–30 cm of the soil which may extend up to 60–150 cm beyond the taproot. Under the present study, the moisture was available and the water depletion for the plant is easier.

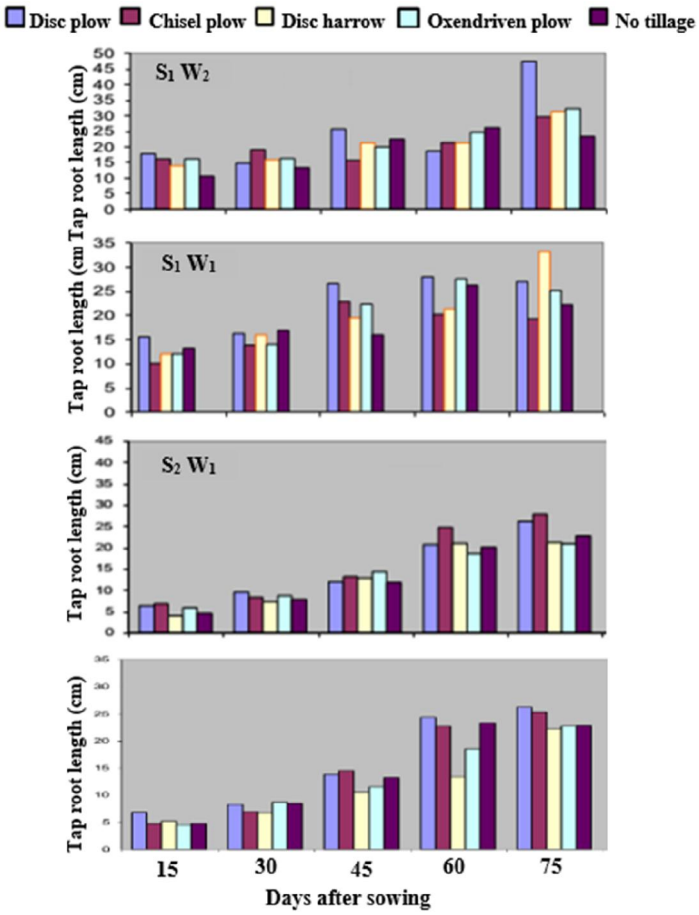


Figure 2. The effect of tillage and water regimes on length of tap root length (cm). S_1-Season 2004, S_2-Season 2005, W_1-75 % of CWR, W_2-100% of CWR

Disc diameter

The effect of tillage treatments and water regimes on disc diameter are presented in Figure 3. The tillage treatments showed a significance different in the second season. The disc and chisel plow treatments had the most effect on crop disc diameter. The irrigation regimes and the interaction of treatments showed no significant effect on disc diameter in both seasons. The average crop disc diameter for disc plow treatment for both seasons was 10.5 cm for 75% water regime and 12.0 cm for 100% water regime. For the chisel plow the disc diameter was 8.85 and 10.15 cm for the 75% and100% water regimes, respectively. for the disc harrow the disc diameter was 9.8 and 11.58 cm for the 75% and 100% water regimes, respectively. For the oxen driven plow the crop disc diameter was 7.35 and 10.9 cm for the 75% and 100% water regimes, respectively. For the no tillage, the crop disc diameter was 8.1 cm for the 75% water regime and 10.35 cm for the 100% water regime.

Seed yield

The tillage systems and interactions had a significant effect on seed yield in both seasons (Table 4). The disc plow and no tillage treatments significantly attained the highest seed yield in both seasons. The disc plow in first season was 1012 and 2016 kg/ha for 75% water regime and 1459 and 1498 kg/ha for the 100% water regime, for the first and second season, respectively. Whereas for the no tillage treatment the crop seed yield was 1033 kg/ha and 1583 kg/ha for the 75% water regime and 1133, 1278 kg/ha for 100% water regime for the first and second season, respectively. This result agreed with a previous finding [19]. It has been mentioned that tillage systems

have a positive effect on both; plant parameters and crop yield [20].

The growth parameters are affected by the overworked changes carried on the soil physical and mechanical properties. In general, the conventional tillage gives more chance for soil spacing and arrangement. Within the conventional tillage systems, the disc plow represents the best increase in all growth parameters.

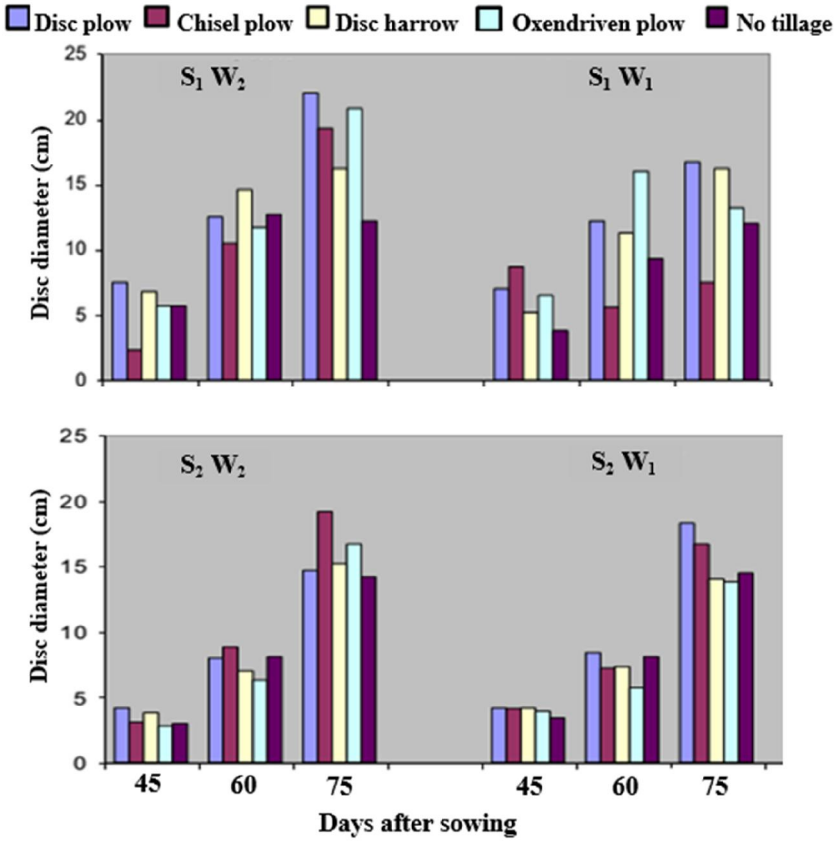


Figure 3. The effect of tillage and water regimes on Disc diameter. S1-Season 2004, S2-Season 2005, W1-75% of CWR, W2-100% of CWR.

Table 4. The effect of tillage systems and water regimes on seed yield (Kg/ha) during 2004/05 and 2005/06 seasons

Tillage Systems	Seasons					
	2004/05			2005/06		
	W_1	W_2	Mean	W_1	W_2	Mean
T1	1012	1459	1235	2016	1498	1757
T_2	627	1126	877	1839	1259	1549
T_3	867	998	933	828	1342	1085
T_4	612	373	492	1206	1315	1260
T_5	1033	1133	1083	1583	1278	1430
Mean	830	1018	**924**	1494	1338	1416
LSD (0.05)						
W	192^{ns}			811^{ns}		
T	330*			471*		
W x T	467*			665*		

Symbols as in table 2

Conclusions

The highest values of crop growth parameters were recorded by disc plow; for plant height 59 cm, root length 21.7 cm and 12.0 cm for disc diameter.

The highest seed yield was recorded by disc plow (2.7 and 1.5 ton/hectare), chisel plow (1.8 and 1.2 ton/hectare) and no tillage (2.4 and 1.3 ton/hectare) respectively. The difference between treatments was not significant.

The study advised to use the economical tillage whenever soil is sustained, because the farmers are interested in suitable seedbed and more yield with the lowest cost.

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References

1. FAO 2019. FAO Crop and Food Supply Assessment Mission to the Sudan – Special Report. Rome. 38 pp. License: CC BY-NC-SA 3.0 IGO.
2. Bashir MA, Mohamed YM. 2014. Evaluation of full and deficit irrigation on two sunflower hybrids under semi-arid environment of Gezira, Sudan. Journal of Agri-Food and Applied Sciences. Vol. 2(3), pp. 53-59.
3. Nayel M. H. 2007. Conservation and Conventional Tillage for Sunflower production in the River Nile State (Eddammer area). PhD. Thesis. College of Graduate Studies, Nile Valley University.
4. Ali A. and Noorka IR. 2013. Differential Growth and Development Response of Sunflower Hybrid in Contrasting Irrigation Regimes. American Journal of Plant Sciences, 4, 1060-1065.
5. Krizmanic, M., Liovic I., Mijic A., Bilandzic M. and Krizmanic G. (2003). Genetic Potential of Sunflower Hybrids in Different Agro-Ecological Conditions, Sjemenarstvo, Vol. 20, No. 5-6, pp. 237-245.
6. Reddy GKM, Dangi KS, Kumar S. and Reddy AV. 2003. Effect of Moisture Stress on Seed Yield and Quality in Sunflower. Journal of Oilseeds Research, Vol. 20, No. 2, pp. 282-283.
7. Iqbal N., Ashraf M. and Azam F. 2005. Effect of Oxygenous Application of Glycine betaineon Capitulumn Size and Achene Number of Sunflower under Water Stress. In- ternational Journal of Biology and Biotechnology, Vol. 2, No. 3, pp. 765-771.
8. Tolga E. and Lokman D. 2003. Yield Response of Sunflower to Water Stress under Tekirdag Conditions.Helia, Vol. 26, No. 38, pp. 149-158.
9. Sessiz, A., Sogut T., Alp A. and Esgici R. 2008. Tillage effects on sunflower (Helianthus annuus, L.) emergence, yield, quality and fuel consumption in double cropping system. J. Central European Agriculture.9:(4) 697-710.
10. Bashour II and Sayegh AH. 2007. Measurement of bulk density. Method of analysis for soils of arid and semi-arid regions. Food and Agric. Organization of the United Nations, Rome.
11. López-Fando C., Dorado J. and Pardo MT. 2007. Effects of zone-tillage in rotation with no-tillage on soil properties and crop yields in a semi-arid soil from central Spain. Soil Tillage Res. 2007, 95, 266–276.
12. Mirleau-ThebaudV, Dayde J. and Scheiner JD. 2016. The influence of soil compaction and conservation tillage on sunflower's (*Helianthus annuus* L.) below ground system.

Phyton Int. J. Exp. Bot. 2016, 86, 53–67.

13. Mohamed A.E., Adam B.A. and Mohamed Z.Y. 2017. Effect of irrigation quantities and tillage systems on sunflower yield under Khartoum State conditions, Sudan. International Research Journal of Agricultural Science and Soil Science. Vol. 7(1) pp. 001-007.
14. Michael AM. 1978. Irrigation, Theory and practice. VIKAS Publishing house, ltd., New Delhi, India.
15. Om-Singh Gupta- PC, Singh-O. 2002. Effect of sowing time and irrigation on phonology and growing degree days of spring sunflower. Indian journal of agricultural sciences. 72(7), 424-427.
16. Gurumurthy P., Singa Rao M., Bhaskar Reddy B. and Reddy BN. 2008. Optimizing Tillage and Irrigation for Sunflower Cultivation in Rice Fallow Alfisols of Semiarid Tropics.
17. Iqbal J. 1990. Growth, Yield and Oil Contents of Sunflower as Influence by Irrigation and Nitrogen Supply. M.Sc. Thesis, Department of Agronomy, University of Agriculture, Faisalabad.
18. Mirshekari M., Nasser MH., Reza A. and Omid RZ. 2012. Study the Effects of Planting Date and Low Irrigation Stress on Quantitative Traits of Spring Sunflower. Romanian Agricultural Research, Vol. 29, pp. 189- 199.
19. Lopez BRJ, Lopez B.L. and Castillo J.E. 2002. Sunflower response to tillage and soil residual nitrogen in a wheat sunflower rotation. University of extramadurabadajoz, Spain.
20. Elsamawal K.M. and Abdelmoneim E.M. 2005. Effect of Tillage and Irrigation Scheduling on Wheat. UK. J. Agric. Sci.13 (3):422-440.