European Scholar Journal (ESJ)
Available Online at: https://www.scholarzest.com
Vol. 5 No. 11 November 2024
ISSN: 2660-5562

EVALUATION OF SOME PROPERTIES OF SALINE SOIL AFTER APPLYING PLOWING, INTENSE IRRIGATION, FERTILIZATION, AND CULTIVATION WITH BARLEY (*HORDEUM VULGARE* L.)

[1] Talib Eghap Hussien, [2] Talal Jaber Abd Al Khanfous, [3] Qasim Badr Idress Al-Yasiri
[1,2,3]Filed Crops Department, College of Agriculture and Marshes, University of Thi-Qar, Iraq
Email: [1] dr.talib2@utq.edu.iq. [2] talal@utq.edu.iq. [3] qassim-badr@utq.edu.iq.

Article history:

Received: 7th September 2024
Accepted: 6th October 2024

Abstract:

The field experiment was conducted in a farmer's field in Thi-Qar governorate during the winter season of 2020 and the fall season 2021. The study was conducted in silty clay soil with high salinity, aiming to reclaim the soil and for the purpose of reclaiming it and to study the effect of five treat investigate the effect of five treatments T1: heavy irrigation 6 times + zero tillage ; T2: heavy irrigation 6 times + deep plowing without fertilization; T3: heavy irrigation 6 times + deep plowing once with fertilization ; T4: heavy irrigation 6 times + deep cultivating twice without fertilizing ; and T5: heavy irrigation 6 times + deep plowing twice with fertilization to restore the salt affected soil. The experiment utilized a randomized complete block design (RCBD) and with three replicates to analyzed the experiment data. Significant differences were observed among the treatments for all studied traits. The result indicated that treatment (T5) effectively improved soil properties by reducing salinity values, sodium, and chlorine levels, thereby enhancing reclamation efficiency. This improvement was further evidenced by the growth of the barley crop compared to the other treatments.

Keywords: Soil Reclamation, Deep Tillage, Heavy Irrigation

INTRODUCTION

The high levels of soil salinity are responsible for significant degeneration of agricultural production worldwide, particularly in dry and semi-dry regions. Very high salt concentrations, primarily consisting of sodium ions, increase the stress on microorganisms and disrupt their activity. These conditions also alter the soil physical and chemical characteristics, leading to a decrease in productivity. Furthermore, heightened salinity negatively influences the productivity of various crops due to increased subsurface compaction and the formation of surface crusts (Matosic et al., 2018). Soil reclamation is an essential solution for treating and mitigating salinity. Calculating the ideal amount of leaching water, referred a metered leaching, effectively removes excess salts from the soil (Ismail, 2000). The process relies on the salts movement to soil depth under saturated water flow conditions. The effective of salt leaching and the improving of soil properties are influenced by various factors, including filtration method, the amount of salts accumulated in the soil, the duration required for dissolving salts, the volume of water added for leaching, and soil characteristics. Therefore, the aims of study is to investigate the impact of tillage , intensive irrigation, and fertilizer addition on soil in order to improve the soil physical and chemical properties regarding salinity.

LITERATURE REVIEW

Many studies have scientifically demonstrated that intermittent leaching is more effective at dissolving salts in the surface layer than continuous leaching. (Ramos et al., 2011 & Skaggs et al., 2006) indicated that increasing leaching periods through the use of intermittent leaching technology significantly reduced the amount of leaching water required and increased the leaching rate. Additionally, Zeng el al., (2013) & Chu el al., (2016) found that increasing amount of water and extending leaching periods reduced the soil salinity, particularly in unsaturated soil. (Hoshan., 2021) noted that the use of intermittent irrigation in appropriate quantities significantly improved the soil physical and chemical properties, including a decrease in the buck density, as well as reductions in levels of sodium, and chlorine .

Soil plowing results in changes the soil physical, chemical, and biological properties. The various characteristics are used evaluate the soil physical and hydraulic properties, including the soil bulk density, total porosity, water- holding capacity, air capacity, and soil resistance, (Strudley el al., 2008)

Tillage operations impact soil characteristics based on several factors, such as geographical location, crop type, and weather conditions. Nevertheless, the tillage has advantages and disadvantages for soil physical properties of the treated topsoil (Bogunovic et al., 2018). The effectiveness of adaptive tillage techniques in saline soils depends on the amount of clay, salt, and exchangeable sodium present in the soil profile. It is crucial to avoid plowing deeper than the previously leached A-horizon in solunetz-type saline soils. Otherwise, plowing may alter the composition of the solonetzic B-horizon, which possesses undesirable chemical and physical characteristics due to its high clay concentration, exchangeable sodium, and water-soluble salt content. Therefore, the use of non-plowing and soil-loosening techniques is essential (Blaskó, 2017).

The depth of tillage can increase soil hydraulic conductivity (HC), thereby enhancing drainage and aeration. The improvement results in an expansion of the efficient root in saline and sodic soil (Bogunovic and Kisic, 2017). Henry et al. (2018) demonstrated that deep plowing may enhance water use efficiency and production of soybean (Glycine max L.).However, the implementation of low tillage systems in traditional cereal farming can challenges to sustainable crop production (Morris et al., 2010). Furthermore, merely altering the plowing technique is insufficient to achieve optimal crop production and soil quality, particularly in soils affected by elevated salt concentrations. The application of appropriate agronomic practices and soil amendments is essential for achieving these objectives (Norris and Congreves, 2018).

Several sources, including agricultural, forestry, and urban settings, have contributed to the incorporation of biological amendments in landscaping. The most prevalent organic amendments from agriculture, particularly from livestock species such as cattle and poultry, are animal wastes. These include fresh, composted, and solid components derived from anaerobic digesters (Francis and Denis, 2012). Animal waste can be formulated as an amendment to enhance and maintain overall soil fertility. This supplement is especially beneficial for the restoration in areas affected by salinity due to its substantial biological composition (Diacono and Montemurro, 2015). Qadir et al. (2007) demonstrated that the use of farmyard manure (FYM) positively impacts soil physical characteristics by mitigating the adverse effects of exchangeable salt (Yu et al., 2010). (Meng et al. 2016) indicated that the synergy of manure application and deep tillage maintenance is more efficient than conventional tilling in enhancing soil health. (Yu et al. 2010) conducted research confirming these findings. Additionally, observations by (Leroy et al. 2008) show that the addition of organic amendments improvements saturated hydraulic conductivity.

MATERIALS AND METHODS

The design of experimental consisted of a strip plot with four treatments. The size of each subplot was 50 m^2 (5 m × 10 m). The organic fertilizer applied to soil depth of 0-35 cm before the tillage process. the barley crop sowed during the winter and collected measurements in the middle and end of the season.

Table (1) Some soil physical and chemical properties of experiment field.

Soil Properties	Units	Soil Depths (cm)	
		15 - 0	30 – 15
EC	dsm^{-1}	34.52	30.21
pH		7.87	7.98
Organic matter	$g\ kg^{-1}$	1.03	0.85
$CaCO_3$	$g\ kg^{-1}$	30.48	31.23
BD	$g\ cm^{-3}$	1.35	1.38
Porosity	%	48.47	47.32
Na^+	$meq\ l^{-1}$	132.7	124.3
Cl^-	$meq\ l^{-1}$	113.8	103.5
Clay (< 0.002 mm)	$g\ kg^{-1}$	45.83	46.73
Silt (0.002–0.02 mm)	$g\ kg^{-1}$	50.55	48.34
Sand (0.02–2 mm)	g kg−1	3.62	4.93
Texture class		Silty clay	Silty clay

Table (2) The Treatments.

Treatment	
T1	Heavy Irrigation 6 Times + Zero Tillage
T2	Heavy Irrigation 6 Times + Deep Plowing Without Fertilization
T3	Heavy Irrigation 6 Times + Deep Plowing Once With Fertilization
T4	Heavy Irrigation 6Times +Deep Cultivating Twice Without Fertilizing
T5	Heavy Irrigation 6 Times + Deep Plowing Twice With Fertilization

Physical Analysis of Soil

Bulk density and porosity of the soil determined using the method defined by (Black et al.,1965). Additionally, penetration resistance was measured with a penetrometer device to the formula described by (Herrick and Jones., 2002).

Chemical Analysis of Soil

Before sowing and at harvest, the chemical analysis of the soil, including exchangeable sodium percentage (ESP) , the soil organic carbon (SOC), and electrical conductivity (EC), was conducted following the methods established by Cottenie et al. (1982); Klute (1986) and Burt (2004). Soil samples were collected to measure electrical conductivity (EC), pH, and organic carbon (SOC) content according to the methodologies employed by (Miyazawa et al., 2000; Nelson and Sommers, 1986).

The leaching efficiency (L.E.) was estimated using the equation described by (Dielman, 1963):

L.E. = (ECd / ECs) × 100 …… (3)

L.E. = leaching efficiency (%)

ECd = electrical conductivity of the tap water on the second piezometer of each plate (ds m^{-1}).

ECs = electrical conductivity rate of soil filtrate (ds m^{-1}).

Yield Components of Barley

The growth parameters measured in this study included plant height, number of branches (m^{-2}), fresh weight(g), dry weight (g), and biomass (ton ha^{-1}), were measured. The dry weight of ten barley plants from each experimental plot was determined by oven-drying them at 70 °C for 48 hours.

Statistical Analysis

The experimental data were statistically analyzed by using analysis of variance (ANOVA). The means were compared using the least significant difference (LSD) at a significance level of $P < 0.05$.

RESULTS AND DISCUSSION

The application of deep tillage, intense irrigation, and fertilization significantly improved the physical and chemical properties of soil (see Tables 3 and 4). The combination of deep tillage performed twice, intense irrigation, and fertilization resulted in optimal improvement. Specifically, the (T5) treatment significantly reduced the values of electrical conductivity (E.C.), exchangeable sodium percentage (ESP), bulk density (B.D.), and soil penetration resistance (P.R.), while increasing porosity, soil organic carbon (SOC), and leaching efficiency (L.E.) in saline soil compared to zero tillage and six rounds of heavy irrigation (see Table 3 and 4) across two growing seasons. When comparing the (T5) treatment to the (T1) treatment (no tillage and no fertilization), the application of (T5) resulted in a decrease in soil E.C., ESP, B.D., and PR by 11.64 and 7.31 ds m^{-1}, 17.91 and 14.55, 1.27 and 1.24 g cm^{-3}, and 2101 and 1716 kN, respectively, over the two growing seasons. Additionally, fertilization reduced E.C., B.D., and P.R. values compared to untreated soil throughout the growing seasons. Furthermore, it significantly increased porosity, SOC, and L.E. by 5.53% and 5.96%, 323% and 120%, and 141.77% and 115.36%, respectively, over the two growing seasons when compared to the (T1) treatment.

Table (3) Some Physical Properties of the Soil before and after Harvesting the Crop under Different Treatments.

Treatment	The Middle of the Experiment			The End of Experiment		
	BD g cm^{-3}	Porosity (%)	PR (KN)	BD g cm^{-3}	Porosity (%)	PR (KN)
T1	1.34	48.59	3075	1.31	49.49	2570
T2	1.33	48.98	2831	1.30	50.13	2324
T3	1.29	50.38	2254	1.26	51.54	1866
T4	1.30	50.00	2505	1.28	50.90	2007
T5	1.27	51.28	2101	1.24	52.44	1716
LSD	**0.015**	**0.557**	**203.3**	**0.018**	**0.675**	**76.0**

Table (4) Some soil chemical Properties before and after harvesting the crop under different treatments.

Treatment	The Middle of the Experiment				The End of the Experiment			
	EC (ds m^{-1})	SOC (%)	ESP (%)	L.E. (%)	EC (ds m^{-1})	SOC (%)	ESP (%)	L.E. (%)
T1	21.38	0.13	22.10	17.93	14.04	0.15	19.39	9.89
T2	17.38	0.26	21.21	23.70	10.58	0.28	17.18	12.47

T3	13.57	0.42	19.13	39.39	8.01	0.63	15.17	17.63
T4	15.07	0.28	20.00	31.61	9.24	0.33	16.18	13.67
T5	11.64	0.55	17.91	43.35	7.31	0.71	14.55	21.30
LSD	**1.334**	**0.098**	**1.788**	**3.002**	**1.415**	**0.071**	**0.918**	**1.561**

Table 5 illustrates the superiority of treatment T5, which resulted in the highest plant height, branch number, dry weight, and both fresh and Biomass weight at the end growing season of the barley. Additionally, the organic mulch treatments in the experiment demonstrated favorable values compared to treatment (T1). The noticeable improvement in the soil physical and chemical properties had a positive effect on plant growth. Furthermore, organic matter contributed to enhancing the biological properties of the soil, including microbial activity, which provided the essential nutrients for plant development.

Table (5) Yield Components of Barley Crop under Different Treatments.

Treatment	Plant Height (cm)	Number of Branches (m^{-2})	Fresh Weight (g)	Dry Weight (g)	Biomass (ton h^{-1})
T1	53.00	254.33	13.47	5.59	10.54
T2	64.33	286.00	14.63	6.38	11.29
T3	76.00	351.67	19.28	7.75	13.54
T4	70.00	312.00	15.94	7.19	12.61
T5	80.00	412.67	21.38	8.72	14.58
LSD	**4.321**	**20.386**	**1.134**	**0.257**	**0.356**

DISCUSSION

Overcoming the challenges of managing saline soils is a significant task, primarily due to their adverse the physical and chemical properties and the negative impact on soil microbial activity. These factors contribute to a decline in quality of soil and hinder crop productivity (Matosic et al., 2018). The decrease in bulk density values and the increase in porosity, especially at the end of barley growing season, is attributed to the superficial growth of barley roots, which affects the structure of soil and bulk density, increases soil granularity, and promotes soil aggregates. Additionally, the penetration of the roots to greater depth has contributed to reducing the bulk density at the end of growing season compared to mid-season (AL-Shammar, and Hamza, 2013).

The added quantities of water and organic matter to soil contribute to improve water movement within it. Chu et al. (2016) indicated that increasing amount of water leaching and periods of leaching contributed to decrease soil salinity, especially under unsaturated soil conditions, as a gradual increase in electrical conductivity was observed. The study demonstrated that increasing the amounts of leaching water enhances the solubility of salts and promotes diffusion from high to low concentrations. The increase in leaching water allows a greater percentage of water to flow through the fine pores, facilitating the more efficient displacement of salt filtrate through the large pores (Tanton et al., 1988) , thereby enhancing leaching efficiency.

The improvement of the soil physical and chemical characteristics leads to a decrease the rate of electrical conductivity, which contributes to the growth of the root system. Consequently, the enhanced vegetative growth, along with the improvement of soil physical and chemical properties from the addition of organic matter, creates suitable conditions for aeration and moisture retention. This, in turn, increases microbial activity, which plays a vital role in enhancing soil structure and increasing the stability of soil aggregates. These factors collectivity contribute to the availability of water and nutrients to the soil, ultimately facilitating the growth of the root system in proportion to increase in plant height and overall vegetative growth (Al-Mousawi, 2007; Diaz & Grattan, 2009).

The role of organic matter as a viable means to rehabilitate salt-affected soils by enhancing the chemical, physical, and biological properties is well-documented. Organic matter serves as a significant factor in forming soil particle structure, as research demonstrates it ability to improve soil structure (Bronick & Lal, 2005; Cha-um and Chalermpol, 2011). According to the findings reported by Tejada et al. (2006), the addition of organic matter (OM) significantly decreased the percentage of exchangeable sodium (ESP) and electrical conductivity (EC). This, in turn, enhanced water permeability, retention, and aggregate stability (Mahdy, 2011).

The farming techniques applied to the soil significantly affect soil's physical, chemical, and biological properties. The impact of tillage on soil's physical and hydrological characteristics is influenced by various factors, such as the soil bulk density, porosity, water holding capacity, and compressibility (Strudley et al., 2008). Conservation tillage can be implemented as an effective farming method, particularly in saline soil, as it enhances soil fertility by improving soil structure (Moussa-Machraoui et al., 2010; Choudhury et al., 2014).

CONCLUSION

In conclusion, the results demonstrated that all treatments significantly contributed to improving soil properties compared to the control treatment. The improvement helped reduce sodium and chlorine levels, thereby decreasing soil salinity. It is recommended to conduct further experiment using different techniques to enhance soil properties and mitigate salinity issues affecting the soils of central and southern Iraq.

REFERENCES:

1. **Al-Mousawi, K. A. H. (2007).** The Effect of Irrigation Water Rotation And Soil Moisture Level On The Physical Properties of Marshland Soil And Their Relationship To Water Consumption During The Growth Stages Of White Maize. Doctoral thesis, college of Agriculture, University of Basra.
2. **AL-Shammar, W. F. and Y. K. Hamza (2013).** Effect of Leaching requirements and plot dimensions on salt distribution and growth, Yield of maize (*Zea mays* L.) irrigated with saline water. Anbar J. Agri. Sci., 1(2) 260-273.
3. **Black, C. A. (1965).** Methods of soil analysis. Physical and Mineralogical. Part 1. Am. Soc. of Agron**.,** Madison , Wisconsin. U S A.1572 p.
4. **Blaskó, L. (2017).** Improvement of saline soils – chemical, biological, land management methods. In: Birkás M. (ed.) Soil management and land use, Mezőgazda Kiadó, Budapest, pp. 308-316. (in Hungarian)
5. **Bogunovic, I., and Kisic, I., (2017).** Compaction of a clay loam soil in Pannonia region of Croatia under different tillage systems. J. Agric. Sci. Technol. 19, 475–486
6. **Bogunovic, I., Pereira P., Kisic I., Sajko K., Sraka M. (2018).** Tillage management impacts on soil compaction, erosion and crop yield in Stagnosols (Croatia). CATENA, 160, 376-384.
7. **Bronick C. J., Lal R. (2005).** Soil structure and management: a review. Geoderma, 124(1), 3-22.
8. **Burt, R., (2004).** Soil Survey Laboratory Methods Manual. USDA–NRCS, Linoln, Nebraska.
9. **Cha-um, S. and Chalermpol K. (2011).** Remediation of salt-affected soil by the addition of organic matter: an investigation into improving glutinous rice productivity. Scientia Agricola 68.4, 406-410.
10. **Choudhury, S. G., Srivastava S., Singh R., Chaudhari S. K., Sharma D. K., Singh S. K., Sarkar D. (2014).** Tillage and residue management effects on soil aggregation, organic carbon dynamics and yield attribute in rice–wheat cropping system under reclaimed sodic soil. Soil and Tillage Research, 136, 76-83.
11. **Chu, L.; Y. Kang and W. Shu-qi (2016).** Effect of different water application intensity and irrigation amount treatments of micro irrigation on soil-leaching coastal saline soils of North China. Journal of Integrative Agriculture, 15(9): 2123–2131.
12. **Chu, L.; Y. Kang and W. Shu-qi (2016).** Effect of different water application intensity and irrigation amount treatments of micro irrigation on soil-leaching coastal saline soils of North China. J. Integ. Agri**.,** 15(9): 2123–2131.
13. **Cottenie, A., Verloo, M., Velghe, G., Kiekens, L., (1982).** Biological and Analytical Aspects of Soil Pollution. Laboratory of analytical and agrochemistry State Univ, GhentBelgium, p. 424p.
14. **Diacono, M., Montemurro F. (2015).** Effectiveness of organic wastes as fertilizers and amendments in salt-affected soils. Agriculture 5 (2): 221-230.
15. **Diaz, F. J. and S. R. Grattan (2009).** Performance of tall wheatgrass irrigated with saline high boron drainage water: Implications on ruminant mineral nutrition. Agric. Ecosyst. Environ., 131:128–136.
16. **Dieleman, P. J. (1963).** Reclamation of salt effect soil in Iraq. International Institute for land reclamation, Publication, No. 11. The Netherland.
17. **Francis, J. L. and Denis A. A. (2012).** The role of organic amendments in soil reclamation: A review. Can. J. Soil Sci. 92: 19-38.
18. **Henry, C. G., G. M. S. Sartori, J. P. Gaspar, E. Marchesan, S. M. Hirsh, A. P. Horton, L. Espinoza, and H. James, (2018).** Deep tillage and gypsum amendments on fully, deficit irrigated, and dryland soybean. Agron. J. 110, 1–12
19. **Herrick, J. E., and Jones, T. L., (2002).** A dynamic cone penetrometer for measuring soil penetration resistance. Soil Sci. Soc. Am. J. 66, 1320–1324.
20. **Hoshan, M. N. (2021).** The effect of the period between leaching, quantity and water salinity on some properties of saline soil and efficiency of salts leaching and plant growth. The requirements for a PhD. the College of Agriculture. University of Basra.
21. **Ismail, L. K. (2000).** Irrigation and drainage, fourth edition, Mosul University, Mosul.

22. **Klute, A., (1986).** Methods of soil analysis, Part 1. In: Physical and Mineralogical Methods, 2th Ed. ASA, Inc. SSSA, Inc., Publisher, Madison, Wisconsin, USA.
23. **Leroy, B. L. M., Herath, H. M. S. K., Sleutel, S., De Neve, S., Gabriels, D., Reheul, D. and Moens, M. (2008).** The quality of exogenous organic matter: Short-term effects on soil physical properties and soil organic matter fractions. Soil Use Manage. 24: 139147.
24. **Mahdy, A. M. (2011).** Comparative effects of different soil amendments on amelioration of saline-sodic soils. Soil & Water Research, 6(4), 205-216.
25. **Matosic, S., M. Birkas, V. Vukadinovic, I. Kisic, I. Bognovic (2018).** Tillage, Manure and Gypsum Use in Reclamation of Saline-Sodic Soils. Agriculture Conspectus Scientifics, Vol. 83 (2): 131-138.
26. **Meng, Q. F., Li D. W., Zhang J., Zhou L. R., Wang H. Y., Wang G. C. (2016).** Soil properties and corn (Zea mays L.) production under manure application combined with deep tillage management in solonetzic soils of Songnen Plain, Northeast China. Journal of Integrative Agriculture, 15(4), 879-890.
27. **Miyazawa, M., Pavan1, M. A., de Oliveira, E. L., Ionashiro, M., Silva, A. K., (2000).** Gravimetric determination of soil organic matter. Braz. Arch. Biol. Technol. 43 (5).
28. **Morris, N. L., Miller, P. C. H., Orson, J. H., Froud-Williams, R. J., (2010).** The adoption of non-inversion tillage systems in the United Kingdom and the agronomic impact on soil, crops and the environment – a review. Soil Tillage Res. 108, 1–15.
29. **Moussa-Machraoui, S. B., Errouissi F., Ben-Hammouda M., Nouira S. (2010).** Comparative effects of conventional and no-tillage management on some soil properties under Mediterranean semiarid conditions in northwestern Tunisia. Soil and Tillage Research, 106(2), 247-253.
30. **Nelson, D. W., Sommers, L. P., (1986).** Total carbon, organic carbon and organic matter. In: Page, A.L. (Ed.), Methods of Soil Analysis: Part 2: Agronomy Handbook No 9. American Society of Agronomy and Soil Science Society of America, Madison, WI, pp. 539–579.
31. **Norris, C. E., Congreves, K. A., (2018).** Alternative management practices improve soil health indices in intensive vegetable cropping systems: a review. Front. Environ. Sci. 6, 50. https://doi.org/10.3389/fenvs. 2018.00050.
32. **Qadir, M., Oster J. D., Schubert S., Noble A. D., Sahrawat K. L. (2007).** Phytoremediation of sodic and saline-sodic soils. Advances in Agronomy, 96, 197-247.
33. **Ramos, T. B.; N. L. Castanheira; M. C. Goncalves; M. L. Fernandes; M. I. Januario and M. E. Lourenco (2011)**. Effect of combined use of brackish water and nitrogen fertilizer on biomass and sugar yield of sweet sorghum. Pedosphere, 22(6):785-794.
34. **Skaggs, T. H.; T. L. Trout; J. Simunek and P. J. Shouse (2006).** Comparison of HYDRUS-2D simulations of drip irrigation with experimental observations. J. Irrig. Drainage Eng., 130(4):304–310.
35. **Strudley, M. W., Green T. R., Ascough J. C. (2008).** Tillage effects on soil hydraulic properties in space and time: state of the science. Soil & Tillage Research 99: 4–48.
36. **Strudley, M. W., Green T. R., Ascough J. C. (2008).** Tillage effects on soil hydraulic properties in space and time: state of the science. Soil & Tillage Research 99: 4–48.
37. **Tanton, T. W.; D. W. Rycroft and F. M. Wilkinson (1988).** The leaching of salts from saline heavy clay soils: Factors affecting the leaching process. Soil Use and Management, 4: 133-139.
38. **Tejada, M., Garcia C., Gonzalez J. L., Hernandez M. T. (2006).** Use of organic amendment as a strategy for saline soil remediation: influence on the physical, chemical and biological properties of soil. Soil Biology and Biochemistry, 38(6), 1413-1421.
39. **Yu, J., Wang Z., Meixner F. X., Yang F., Wu H., Chen X. (2010).** Biogeochemical characterizations and reclamation strategies of saline sodic soil in northeastern China. Clean–Soil, Air, Water, 38(11), 1010-1016.
40. **Zeng, W.; C. Xu; J. Wu and J. Huang (2014).**Soil salt leaching under different irrigation regimes: HYDRUS-1D modeling and analysis. J. Arid Land, 6(1): 44-58.