Journal of Biodiversity and Environmental Sciences (JBES)
ISSN: 2220-6663 (Print) 2222-3045 (Online)
Vol. 6, No. 6, p. 194-202, 2015
http://www.innspub.net

INNSPUB
RESEARCH PAPER
OPEN ACCESS

Response of soil physical properties and onion seed germination to irrigation methods

Davoud Zare Haghi, Mahmoud Shahabi, Hossein Rezaei*

Department of Soil Science, Faculty of Agriculture, University of Tabriz, Tabriz, Iran

Article published on June 08, 2015

Key words: Irrigation method, Mean of emergence date, Onion, Physical properties of soil.

Abstract

Mainly, final yield product depends on growth factors such as soil, irrigation and kind of seed. Aggregate collapse and crust formation due to drying prevent germination and reduce the population of vegetation. Greenhouse experiments were conducted to evaluate the effect of irrigation method on physical properties of seedbed and its outcome on the germination and establishment of onion. For this purpose, in 2 soil with different structure (weak and strong), onion cultivated and irrigated with 3 methods (surface flooding, sprinkler and subsurface). Soil physical parameters such as bulk density, saturated hydraulic conductivity and soil penetration resistance, and plant parameters such as mean of emergence date, seedling diameter, fresh and dry yield were measured. Statistical analysis showed that, the irrigation method, soil type, and interaction between them had significant effect on the physical properties and the only factor that affected plant parameters was irrigation method. Because of providing optimal physical conditions in the topsoil, reducing mean of emergence date, increasing diameter, fresh and dry yield, the subsurface irrigation method was selected as the preferred irrigation method.

***Corresponding Author:** Hossein Rezaei ✉ hosseinrezaei1984@gmail.com

Introduction

Soil and water are recognized as key factors in agriculture. Different soils have different properties, some of which inherited from the parent material and others have been created over time due to environmental conditions. Among the environmental factors, soil moisture or water can influence on the chemical and physical soil properties through cases such as degradation of soil structure, soil erosion, leaching of salts and minerals, transmission of soil components and change in soil quality (Bronick and Lal, 2005). Soil quality has two aspects; the former is an inherent quality of the soil's natural ability created by soil forming factors that is not influenced by soil management. The second, dynamic soil quality depends strongly on soil management. Tillage and irrigation management are important factors influencing the dynamic soil quality in many areas of the world (Karlen *et al.,* 1997). Khan *et al.* (2006) researched the consequences of irrigation water quality on soil salinity and analyzed the methods to solve this problem caused by different irrigation systems in order to have sustainable agriculture.

Basically, final yield product is affected by many Factors such as soil, irrigation methods and quality of seed during plant growth and germination. Soil productivity strongly depends on chemical properties, amount of soil nutrients and especially physical properties of soil; because the roots develop as one of the main supply routes of photosynthesis prerequisites into soil (Bronick and Lal, 2005). These factors are more important in arid and semiarid regions due to low crop yields as a result of drought and soil degradation. Successful cultivation in arid and semiarid regions like Iran has close relation to solve the problem of water consumption and prevent soil properties degradation. Soil structure is a variable soil property affected by various processes. These processes include expansion and contraction, freezing and thawing, tillage operations and soil compaction (Eghbal *et al.,* 1996). Ze-Qiang *et al.,* (2010) observed a significant difference in the total soil porosity, the air-filled porosity, capillary pores and even the pores of the soil irrigated under both surface and sprinkler irrigation. In bare soils, the direct collision of rainfall or water drips causes to be formed a thin and dense layer at the soil surface after the destruction of soil aggregates, thus it creates major obstacle to the penetration of water into soil due to colloidal particles transport to the lower layers and obstruction of channels. Recent studies indicate that crust formation after surface flooding irrigation is usual (Eghbal *et al.,* 1996). Crust is a general term that is used to describe the condition of the soil surface and form a dense layer on the soil surface. The main cause of crust formation is collapse of aggregates by water along with physical and chemical mechanisms. Aggregates destructions are intensified by swelling, shrinkage and Slaking of soil components and direct collision of rain drops (Anonymous, 1954). Aggregates collapse and crust formation prevent the emergence of seedlings and reduce vegetation population. In crust formation condition, the seedling growth force and crust thickness have the most effect on establishment and growth of plant. When the crust mechanical resistance is greater than seedling growth force, seedling emergence will be impossible. Seed weight and seedling emergence have close relation under condition of crust formation. Seedlings grown from large seeds have greater performance, growth rate and establishment than small seeds (Heather and Sieczka, 1991). Eghbal *et al.,* (1996) find that the crust formed after the first flooding irrigation decreased approximately 50% of the seedlings emergence. It is usually assumed that seedling growth force of monocotyledonous plants such as wheat is applied to a point of crust where it is causing a rapid breakdown. whereas in dicotyledonous plants such as cotton or sugar beet, growth force is less than a monocotyledonous plants because it is spread on small part of the crust (Sale and Harrison, 1964). Rasmussen *et al.,* (2007) reported that large amount of moisture even in soils that have been recently plowed cause soil compaction and crust formation with low permeability. Fapohunda, (1986) reported that slow wetting of soil by drip irrigation leads to better seedling emergence in comparison with flooding irrigation. Crust also decreases the exchange of gases due to low porosity and specific orientation of colloidal particles and therefore less oxygen reaches the seedlings (Morin, 1993).

Nowadays, all over the world, climate change and shortage of water resources led to more consider of water use in agriculture section. Then, the use of water for agriculture section requires innovative research especially in water scarcity region. According to Iran's climate and shortage of water resources in most regions, optimal use of water resources will require many researches on relationship among water, soil and plants in different conditions to have sustainable agriculture. There are many researches on relationship of water, soil and plant, but most of them focus on water relation of plant with soil and the irrigation methods are the missing link of this studies. Also each plant, based on its water requirement has different response to water availability. Then irrigation method should be mentioned in studies too. This paper discusses all three part of soil, plant and irrigation method one by one. In this research we focused on irrigation methods and onion plant as one of the strategic and economic crops in East-Azerbaijan province and then we researched to determine the best irrigation management and the consequences of its effects on soil physical properties changes and sustainable production of onion. Generally, we want to choose the best irrigation method to safe soil quality and produce maximum yield of onion. Then this paper is the base for sustainable development of agriculture with economical views.

Materials and methods

Physico-Chemical analysis

For this research, two soils with weak structure (Haplocambids) and strong structure (Haploxerolls) were selected. Some physical and chemical properties of the soils were measured, soil texture by hydrometer (Gee and Bauder, 1986), bulk density by Cylinder of 5 cm diameter and height (Blake and Hartage, 1986), soil organic carbon by wet burning method (Nelson and Sommers, 1996), pH by pH meter (Thomas, 1996), electrical conductivity by EC meter (Rhoades, 1996) and Calcium carbonate equivalent was measured by back titration procedure (Loeppert and Suarez, 1996). Saturated hydraulic conductivity in intact samples was measured by the constant hydraulic head method. Intact saturated soil cores of 5 cm diameter and height were placed within a permeameter and supplied with water at the top, keeping a stable hydraulic head of 3 cm (Reynolds and Elrick, 2002). Penetration resistance was measured on intact samples were taken from the pots by digital penetrometer.

Preparing planting boxes

The surface part of both soils after passing through the sieve was scattered uniformly into boxes of length 50cm, height and width 30 cm. The numbers of holes formerly were created at the bottom of the box with regular distances and determined numbers for drainage. Then some gravel was scattered to height of 2cm. Bulk density of weak structure soil 1.3 $g.cm^{-3}$ and strong structure soil 1.15 $g.cm^{-3}$ was selected and tried to minimize the bulk density changes with boxes depth as an indicator of favorable seedbed after primary and secondary tillage. In each of the boxes, 15 onion seeds were planted at regular distances and 2cm depth.

Irrigation method

The soil of boxes was irrigated by 3 methods including surface flooding, sprinkler and subsurface. In sprinkler method, rainfall simulator was used to spray water monotonously with 1.8 $cm.hr^{-1}$ intensity (Nelson and Terry, 1996). In flood irrigation method, required water was added to the soil surface and in Groundwater irrigation, soil suction was kept in the range of 20 to 50 KPa and every time the suction was greater than 50 KPa, irrigation was done by putting the bottom of boxes in water basin to decrease soil suction to 20 KPa.

Measurement of soil and plant parameters

Before each time of irrigation until the emergence of seedlings which lasted 25 days, soil physical properties such as bulk density, saturated hydraulic conductivity and soil penetration resistance and also the plant parameters such as mean day to emergence, seedling diameter and fresh and dry yield were measured. Counting the green seedlings was done several times during the time of emergence and plants establishment. Also mean day to emergence was calculated using the following equation (Braunack, 1995):

$$MDE = \frac{\sum N_i D_i}{\sum N_i}$$

Where D_i is the number of days after planting, N_i is the number of green seedlings. After the complete establishment of plants (25 days after seeds planting), diameter of the seedlings in each treatment was measured after removing the plant from the soil to increase the accuracy of experiment. Caliper with an accuracy of 0.01 mm was used and the mean of measurements was determined for each treatment. After removing the plant from the soil, fresh weight of seedlings was measured for each treatment and their dry weight was determined after putting them in the oven for 48 hours at 65 °C.

Statistical analysis

For interpretation of this research results, factorial design with 3 irrigation methods, 2 soil types and 1 plant in 4 repetitions was applied in a completely randomized design.

Results and discussion

Results of measured soil parameters

After soil sampling and preparation in the laboratory and before starting experiment, physical and chemical properties of both soils were determined (Table 1). According to Table 1, studied soils were susceptible to crust formation because both soil (A and B) textural classes were silty clay loam. But due to the high percentage of silt and low percentage of organic matter in soil B, this soil was more sensitive to soil crust formation because of the weaker structure. This result also has been confirmed by many previous studies (Eghbal *et al.,* 1996; Medinski *et al.,* 2009).

Table 1. Physical and chemical properties of studied soils.

Soil structure	Soil particle distribution (%)			Texture[a]	ρ_b[b] (g.cm^{-3})	EC[c] (dS.m^{-1})	pH[d]	OC[e] (%)	CCE[f] (%)
	Sand	Silt	Clay						
A (strong structure)	12	53	35	SCL	1.1	1.29	7.3	2.2	4.9
B (weak structure)	8	63	29	SCL	1.3	1.02	8	0.57	8.4

[a] Texture: SCL- sandy clay loam. [b] Bulk density. [c] Electrical conductivity in saturation extract of soil. [d] pH in saturation soil (H_2O). [e] Organic carbon. [f] Calcium carbonate equivalent.

After applying 3 irrigation methods on studied soil as treatments and variance analysis of measured properties (Table 2), it was observed that the soil physical properties of surface layer were affected by irrigation method and soil types, as well as their interactions. According to table 2, there are significant differences in both main effects and the interaction effects. The mean comparison of soil physical properties was determined with the LSD test at 1% probability level. The mean comparison of soil physical properties is shown in Fig.1. Based on principles of statistical comparisons and aim of this research, only the interaction effects between irrigation method and soil type were compared because there was significant difference between them and the main effects of each treatment were ignored.

Table 2. Variance analysis of soil physical properties.

Variables	Degrees of freedom	Mean-square		
		bulk density	saturated hydraulic conductivity	penetration resistance
Irrigation method	2	0.032**	4.65 **	6.36 **
Soil type	1	0.245**	14.24 **	1.15 **
Irrigation method×soil type	2	0.001**	0.35 **	0.04**
Error	18	0.0001	0.025	0.009
Total	23	-	-	-

**: Significant at 1% level.

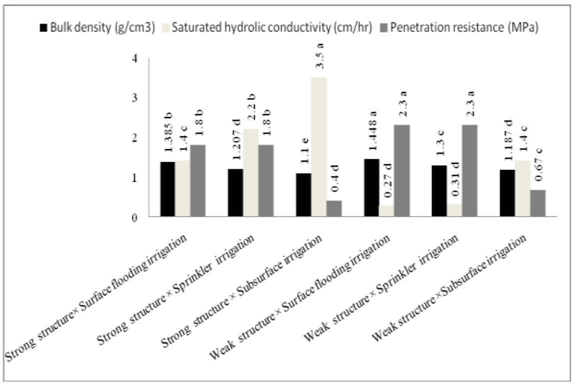

Fig. 1. Compare mean of physical properties for interactions of soil structure and irrigation method (LSD, 1%).

Soil bulk density

The results of mean comparison of bulk density showed that the highest increase in soil bulk density at 0-5 cm layer in soil with weak structure soil and flood irrigation and the lowest increase in soil with strong structure and subsurface irrigation has occurred. This increase in bulk density caused by flood irrigation and sprinkler may be due to aggregates destruction during wetting, sinking and resting fine particles in coarse pores. Slowinska, (1994) showed that after a rainfall, the soil bulk density of soil under plowing reached from 1.05 to 1.24 $g.cm^{-3}$. Also Nelson and Terry, (1996) concluded that flood irrigation increased significantly soil bulk density and surface crust formation more than soil irrigated by sprinkler irrigation. Dorner *et al.,* (2010) stated that bulk density and soil pores of weak structure soils under tillage and irrigation had more changes in compared with strong structure soils.

Saturated hydraulic conductivity

The mean comparison of the saturated hydraulic conductivity (Fig. 1) showed that the maximum saturated hydraulic conductivity has been in strong structure soil irrigated by subsurface irrigation. Comparison the results of saturated hydraulic conductivity with the results of bulk density indicated that changes in saturated hydraulic conductivity among treatments can be interpreted from bulk density changes. The greatest increase of bulk density and the lowest saturated hydraulic conductivity were for Flood irrigation because increasing the bulk density caused soil porosity decrease and subsequently low saturated hydraulic conductivity of soil. Dec *et al.,* (2008) studied correlation between bulk density and hydraulic conductivity of soil samples with different bulk density and found that apart from the expansion and contraction of the soil, bulk density was one of the main factors influencing hydraulic conductivity.

Penetration resistance

According to fig. 1, indicated maximum resistance in weak structure soil irrigated by both sprinkler and flooding irrigation and minimum resistance in subsurface irrigation and strong structure soil. This can be justified that in the flood and sprinkler irrigation, alternate wetting and drying have occurred in the soil surface and because of disintegrated particles deposit in soil pores, penetration resistance has increased while soil surface in subsurface irrigation was completely dry. These findings are consistent with the Rajaram and Erbach, (1999) findings. The high potential of aggregate degradation in weak structure soil also was a factor that intensified penetration resistance. Özgoze *et al.,* (2012) indicated a strong correlation between bulk density and penetration resistance and their changes under different management.

Measured plant parameters results

Variance analyses of onion germination and growth characteristics are shown in Table 3. The results show that different irrigation treatments on mean emergence date are significant at 1% level. Soil type also shows no significant effect on plant parameters. The interaction effects between soil type and irrigation method are also non-significant.

Table 3. Variance analysis of onion plant parameters.

Variables	**Degrees of freedom**	**Mean-square**			
		Mean mergence date	**Seedling diameter**	**Fresh yield**	**dry yield**
Irrigation method	2	8.68^{**}	0.0006^{**}	0.33^{**}	0.0016^{**}
Soil type	1	0.2^{ns}	0.0001^{ns}	0.1^{ns}	0.0007^{ns}
Irrigation method×soil type	2	0.85^{ns}	0.00001^{ns}	0.16^{ns}	0.0007^{ns}
Error	18	0.62	0.00004	0.019	0.0001
Total	23	-	-	-	-

**: Significant at 1% level., ns: Non-significant.

In order to interpret the results of irrigation method on four parameters of onion, mean comparison was done with LSD test at 1% probability level.

Mean emergence date

According to Fig. 2, the lowest mean date of emergence is related to subsurface irrigation and then respectively surface flooding and sprinkler irrigation. In other words, seedlings emergence rate has been maximum in subsurface irrigation and minimum in sprinkler irrigation. In subsurface irrigation, because of dry soil surface and nonexistence of crust, soil didn't show resistance against seedlings emergence while in both surface flooding and sprinkler irrigation due to high penetration resistance of crust, seedlings couldn't easily emerge. Sale and Harrison, (1964) stated that the seedlings emergence in presence of crust needed long time due to penetration resistance and made seedlings weak .

Diameter of onion seedlings

The mean comparison of seedlings diameter at different irrigation treatments (Fig. 2) show that the largest diameter of seedlings belongs to and there is no significant difference between flood irrigation and sprinkler. High seedlings diameter in subsurface irrigation can be related to nonexistence of crust and low resistance of soil surface layer to seedlings emergence. The results of this study are consistent with Fakouri-Ghaziani *et al.,* (2012) findings.

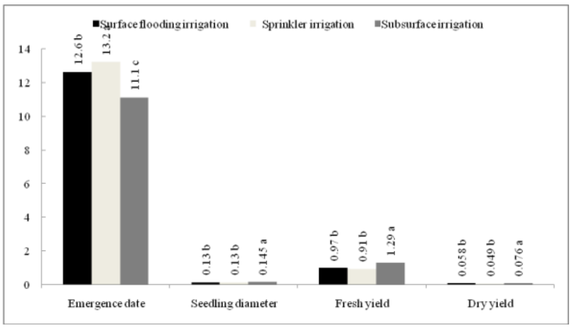

Fig. 2. Compare mean of plant parameters for irrigation treatments (LSD, 5%).

Fresh and dry yield

From fig. 2, subsurface irrigation has the highest performance and there is no significant difference between flood irrigation and sprinkler. The high efficiency of subsurface irrigation can be because of providing better growing conditions such as adequate ventilation, nonexistence of crust on the soil surface and thus rapid germination and establishment of seedlings. In a similar study, Mohammadi *et al.,* (2010) concluded that irrigation methods were effective on onion weight and final yield.

Conclusion

Sprinkler and flooding irrigation caused aggregates disintegration, higher bulk density, low hydraulic conductivity, crust formation with high mechanical strength and low permeability by forcing and pressuring on the aggregates. This condition was intensified in weak structure soil. Consequently in these irrigation treatments, Onion seedlings emerged and established later. While due to better soil physical conditions, low bulk density, and no crust formation in subsurface irrigation, seedlings emerged earlier and the conditions of topsoil indicated that the soil conditions under subsurface irrigation were better for crop growth in compared with both sprinkler and flooding irrigation. Therefore, the maximum diameter of the seedlings and dry yield were achieved by subsurface irrigation during experiments.

References

Anonymous. 1954. Diagnosis and improvement of saline and alkali soils. USDA Handbook. 60, Washington, DC, USA. Salinity Staff.

Blake GR, Hartage KH. 1986. Bulk density determination. In: Page AL, (ed). Methods of Soil Analysis, Part 1: Physical and Mineralogical Methods. Agronomy Monograph. American Society of Agronomy and Soil Science Society of American, Madison, WI. 363-373.

Braunack MV. 1995. Effect of aggregate size and soil water content on emergence of soybean (Glycine max, L. Merr.) and maize (Zea mays, L.). Soil and Tillage Research **33(3-4),** 149–161. http://dx.doi.org/10.1016/0167-1987(94)00444-J

Bronick CJ, Lal R. 2005. Soil structure and management: A review. Geoderma **124(1-2),** 3–22. http://dx.doi.org/10.1016/j.geoderma.2004.03.005

Dec D, Dorner J, Fazekas OB, Horn R. 2008. Effect of bulk density on hydraulic properties of homogenized and structured soils. Journal of Soil Science, Plant Nutrition **8(1),** 1-13. http://dx.doi.org/10.4067/S0718-27912008000100001

Dorner J, Sandoval P, Dec D. 2010. The role of soil structure on the pore functionality of an Ultisols. Journal of Soil Science, Plant Nutrition **10(4),** 495-508. http://dx.doi.org/10.4067/S0718-95162010000200009

Eghbal MK, Hajabbasi MA, Golsefldi HT. 1996. Mechanism of crust formation on soil in central Iran, Plant and Soil **180(1),** 6-73. http://dx.doi.org/10.1007/BF00015412

Fakouri Ghaziani MV, Berimavandi AR, Mohammadi Torkashvand A, Hashemabadi D, Kaviani B. 2012. Influence of plant density and irrigation method on the growth, flowering and quantity of essential oil of Calendula officinalis L. Indian Journal of Fundamental and Applied Life Sciences **2(2),** 184-190.

Fapohunda HO. 1986. Crop emergence as affected by soil and irrigation. Plant and Soil **92(2),** 201-208. http://dx.doi.org/10.1007/BF02372634

Gee GW, Or D. 2002. Particle size analysis. In: Dane JH, Topp GC (eds.). Methods of Soil Analysis. Physical Methods, Part 4. American Society of Agronomy and Soil Science Society of American, Madison, WI. 255-293.

Heather DW, Sieczka JB. 1991. Effect of seed size and cultivar on emergence and stand establishment of broccoli in crusted soil. Journal of American Society of Horticultural Science **116(6),** 946-949.

Karlen DL, Maushback MJ, Doran JW. 1997. Concepts of soil quality and their significance. In: Doran JW, Jones AJ, (eds.). Methods for assessing soil quality. Soil Science Society of America, Special Publication **61,** 4-10.

Khan S, Tariq R, Yuanlai C, Blackwell J. 2006. Can irrigation be sustainable?. Agricultural Water Management **80(1-3),** 87-99. http://dx.doi.org/10.1016/j.agwat.2005.07.006

Loeppert RH, Suarez DL. 1996. Carbonate and gypsum. In: Sparks DL, Page AL, Helmke PA, Loeppert RH, Soltanpour PN, Tabatabai MA, Johnson CT, Sumner ME, (eds). Methods of Soil Analysis Part 3: Chemical Methods. Agronomy Monograph, American Society of Agronomy and Soil Science Society of American, Madison, WI. 437-474.

Medinski TV, Mills AJ, Fey MV. 2009. Relationships between soil particle size fractions and infiltrability. South African Journal of Plant and Soil **26(3),** 147-156. http://dx.doi.org/10.1080/02571862.2009.10639948

Mohammadi J, Lamei J, Khasmakhi-Sabet A, Olfati JA, Peyvast Gh. 2010. Effect of irrigation methods and transplant size on onion cultivars yield and quality. Journal of Food, Agriculture and Environment **8,** 158-160.

Morin J. 1993. Soil crusting and sealing. In: Soil Tillage in Africa: Needs and Challenges. FAO, Soil Bulletin **69,** 41-67.

Nelson DW, Sommers LE, 1982. Total carbon, organic carbon and organic matter. In: Page AL, editor. Methods of Soil Analysis Part 2: Chemical and Microbiological Properties. Agronomy Monograph, American Society of Agronomy and Soil Science Society of American, Madison, WI. 539-579.

Nelson SD, Terry RE. 1996. The effects of soil physical properties and irrigation method on denitrification. Soil Science **161(4),** 242- 249. http://dx.doi.org/10.1097/00010694-199604000-00005

Özgoze E, Gunal H, Önen H, Bayram M, Acir N. 2012. Effect of management on spatial and temporal distribution of soil physical properties. Journal of Agricultural Sciences **18,** 77-91.

Rajaram G, Erbach DC. 1999. Effect of wetting and drying on soil physical properties. Journal of Terramechanics **36(1),** 39-49. http://dx.doi.org/10.1016/S0022-4898(98)00030-5

Rasmussen IA, Benoit DL, Davis A, Forcella F, Gonzalez-Andujar JL, Graziani F, Grundy AC, Karlsson LM, Mead A, Milberg P, Murdoch AJ, Neve P, Salonen J, Sera B, Sousa E, Tei F, Torresen K, Urbano JM. 2007. Effects of interactions between germination environment, seed provenance and soil disturbance on emergence of Chenopodium album. 14th EWRS Symposium. Hamar, Norway. 182 (Abst).

Reynolds WD, Elrick DE. 2002. Constant head soil core (tank) method. In: Warren AD. (ed.) Methods of Soil Analysis. Part 4. Physical Methods. Soil Science Society of America. 804- 808.

Rhoades JD. 1996. Salinity: Electrical conductivity and total dissolved solids. In: Sparks DL, Page AL, Helmke PA, Loeppert RH, Soltanpour PN, Tabatabai MA, Johnson CT, Sumner ME, (eds). Methods of Soil Analysis Part 3: Chemical Methods. Agronomy Monograph, American Society of Agronomy and Soil Science Society of American, Madison, WI. 417-435.

Sale PJM, Harrison DJ. 1964. Seedling emergence as affected by soil capping. Journal of Horticultural Science and biotechnology **39(3),** 147-161.

Slowinska JA. 1994. Change in structure and physical properties of soil during tillage operation. Soil and Tillage Research **29(4),** 397-407. http://dx.doi.org/10.1016/0167-1987(94)90111-2

Thomas GW. 1996. Soil pH and soil acidity. In: Sparks DL, Page AL, Helmke PA, Loeppert RH, Soltanpour PN, Tabatabai MA, Johnson CT, Sumner ME, (eds). Methods of Soil Analysis Part 3: Chemical Methods. Agronomy Monograph, American Society of Agronomy and Soil Science Society of American, Madison, Madison, WI. 475-490.

Ze-Qiang S, Yao-Hu K, Shu-Fang J. 2010. Effect of Sprinkler and Border Irrigation on Topsoil Structure in Winter Wheat Field. Pedospher Journal **20(4),** 419-426. http://dx.doi.org/10.1016/S1002-0160(10)60031-8