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### EFFECT ON SOIL WATER AND SALT TRANSFER BY AUTUMN IRRIGATION FOR FREEZING AND THAWING PERIOD

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**ABSTRACT** Autumn irrigation is a particular irrigation system designed to wash soil salts and encourage penetration into deeper layers, this application helps retain higher soil moisture in spring in the Inner Mongolia Hetao Irrigation District. Several problems have been identified when using this approach, such as full utilization of water resources, groundwater level control to prevent secondary soil Saline alkalization. Through experimental research on the relations between soil moisture and autumn irrigation standards, a feasible autumn irrigation standard for the Inner Mongolia Hetao Irrigation District was determined to be in the range of 150 to 200mm.

**Keywords:** Freezing and Thawing Period, Autumn irrigation norm,; Soil Water and Salt Transfer

**INTRODUCTION** Soil salinization control is a world problem. There are a large area of salinization land in China. According to statistics the area of varieties of salinization is about 99.13 thousand hm<sup>2</sup><sup>[1]</sup>. Inner Mongolia Hetao irrigation district is a main grain and oil crop production base of China and locates in arid desert area. The district have severe cold and less snow in winter, high temperature and dry-hot in summer, high evaporation, salty soil parent material and shallow groundwater level<sup>[2]</sup>. Irrigation escape is the main influenced and limited factor. It is also the typical region of salinization development of China. In the region the terrain is gentle and the groundwater runoff is extremely retarded, so the soil salt accumulates very easily. For irrational irrigation and increasing groundwater level the land develop into secondary salinization.

Autumn irrigation is a particular and traditional irrigation regime. It is salt leaching in autumn and soil moisture conversation in spring. In the region autumn irrigation is generally from late September to late October and is the largest amount of all the year. The irrigation amount for rational salt leaching not only depends on soil primary salt content and soil physical characteristics but also depends on the limit of crops salt

resistance and the crops reaction to salt. At present, autumn irrigation norm is too large<sup>[3]</sup>. It leads to water waste and groundwater level rising and then soil secondary salinization<sup>[4]</sup>. Rational autumn irrigation norm for this region is the research aim of the passage.

## MATERIAL AND METHOD

**2.1 basic condition of the experiment area** The experiment area located in Shahao experiment station which is lay in the northwest of Hetao irrigation area in Inner Mongolia. The experiment area is subordinate to the Jiefangzha irrigation field and is the base of irrigation management and scientific experiment in Hetao irrigation field. It is representative in hydrogeology, soil texture, water-salt and groundwater. Moderate and mild salinization is about 75 percents of the whole area. Severe salinization soil is about 25 percents. It is serious in middle and lower reaches. The whole management area of the experiment field is about  $4.93 \times 10^3 \text{hm}^2$ , including irrigation field which is about  $3.47 \times 10^3 \text{hm}^2$ . The highest temperature is on the average of  $14.8^\circ\text{C}$  for many years. The lowest one is  $1.6^\circ\text{C}$ . The annual average precipitation is 136.3mm and evaporation is 1937.9mm. The sunshine hours is 226h. The whole annual radiation is about  $6000 \text{MJ/m}^2$ . Soil freezing begins in the second half of November. The depth of the freezing is 1.0-1.3m. The ablation is in the middle of May. Freeze-thaw diachronic is about 180d<sup>[5]</sup>.

**2.2 experiment methods** The experiment arrange at Guangming village in Guangrong Township in Jiefangzha irrigation area. The experiment has three terrains that are high middle and low. (The step is from 20cm to 30cm which can make three different groundwater levels in natural condition.) The experiment also have three autumn irrigation level and one treatment of the control. (It can be seen in Table 1.) The autumn irrigation experiment is conduct in natural field blocks, combining with actual production condition in September 2005 to May 2006. The experiment treatment and the implementation situation can be seen in table 1. Sampling time is before autumn irrigation (September 27), after autumn irrigation (October 24), before freeze-up (November 23), the time of maximum frozen soil depth (February 17) and the time of thawing (April 28). It is use the method of taking out soil with drill (It is use manually operated mechanical drill in freezing time.), drying in oven, weighing to measure the soil water content in freezing time. The soil sale uses the method of Soil-water extract of mixed-speed to test the EC. The soil layer of sampling consists of 10, 20, 30, 40, 50, 60, 70, 80, 90, 100, 110, 120, 130, 140, 150, 175, 200, 225, 250cm

## 3 ANALYSIS

**3.1 Influence of wintering period soil water content by autumn irrigation requirment** Figure 1 is profile distribution map of soil water content of irrigated land and saline wasteland under the different autumn irrigation quotas before autumn irrigation to melting from 2005~2006.

Table 1. The autumn irrigation experiment treatments in September 2005 to May 2006

order	Block number	hypsography	Requirement in autumn irrigation mm	Block area m <sup>2</sup>	Cultivation State	Planting types in original
1	LG1A		148.7	1333	Cultivated	Wheat
2	LG2	high	247.8	1333	Cultivated	Maize
3	LG3B		203.5	933	Cultivated	Wheat
4	LZ0		0.0	1333	Untilled	Saline wasteland
5	LZ1	middle	242.3	2400	Cultivated	Sunflower
6	LZ2		145.2	600	Untilled	Mdlar
7	LZ3		234.9	800	Untilled	Mdlar
8	LD0		0.0	1333	Untilled	Saline wasteland
9	LD1	low	95.0	333	Untilled	Saline wasteland
10	LD2		150.7	1200	Cultivated	Maize
11	LD3		204.5	1333	Cultivated	Maize

**3.1.1 Arable land.** For arable land, soil water content of the surface is low before autumn irrigation, point LG1 that soil of 10cm of soil water content is minimum, only 7.8%; soil below 40cm of soil water content more than 20% . After autumn irrigation soil of 10cm soil water content increased to 27.%, an increase of nearly 3 times. 20cm of soil water content after the melting rate of 21.0%, according to the relevant information, for sandy loam soil, soil water content of spring wheat planting and seedling stage appropriate for 18.0% ~ 20.0%, shows that the basic suitability of water, which is slightly higher. Under the autumn irrigation quota by soil of 150mm, the soil profile of soil water content changes in the average of 6.7%.

Soil water content of the point LG2 that soil of 10cm is also low before autumn irrigation, it's only 10.8%□soil below 40cm of soil water content more than 20%. After autumn irrigation soil of 10cm soil water content increased to 28%, an increase of nearly 2 times. 20cm of soil water content after the melting rate of 24%; it shows that water is slightly higher. Under the autumn irrigation quota by soil of 250mm, the soil profile of soil water content changes in the average of 9.3%.

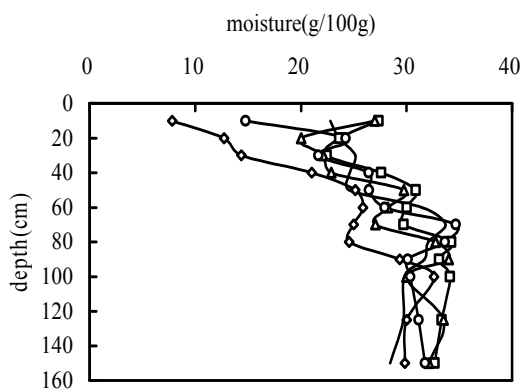
Soil water content of the point LG3 that soil of 10cm is also low before autumn irrigation, it's only 11.9%□soil below 40cm of soil water content more than 20%. After autumn irrigation soil of 10cm soil water content increased to 22.4%, an increase of nearly 1 times. 20cm of soil water content after the melting rate of 19%; it shows that water is appropriate. Water content of soil profile changes averagely 9.3%.

**3.1.2 Untilled land** 40cm soil water content of untilled land more than water content of arable land before autumn irrigation, the lowest water content is not at the surface, but in the 20mm soil. When autumn irrigation is 145.2mm on the point LZ2, soil of 20cm soil water content from 16.2% before autumn irrigation to 24% after autumn irrigation, an increase of 54%, soil water content after the melting rate of 21.8% and water is appropriate. Water content of soil profile changes averagely 8.7%.

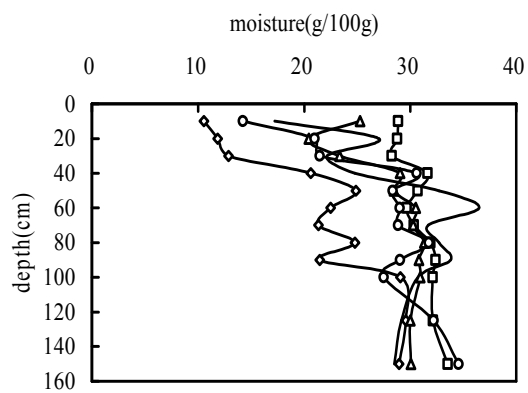
When autumn irrigation is 234.9mm on the point LZ3, soil of 20cm soil water content from 16.1% before autumn irrigation to 27.1% after autumn irrigation, an increase of 68%, soil water content after the melting rate of 24.5% , it exceeds water demand of

spring wheat planting and seed emergence, the soil profile of Water content of soil profile changes averagely 12.5%.

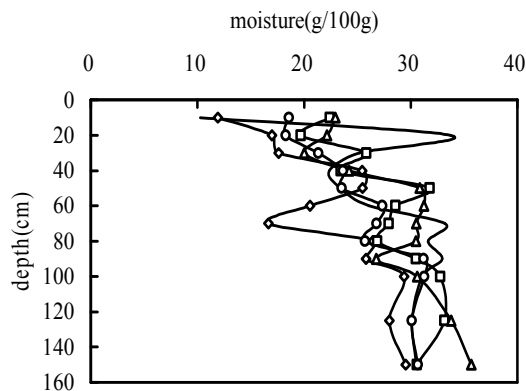
Conclusively, autumn irrigation requirement has some influence to soil water content, the soil profile of soil water content changes greatly when requirement changes greatly. Soil water content of spring planting and seedling stage obviously exceeds water requirements when the autumn irrigation norm more and effects spring planting. Experiment results show that soil moisture content is optimum when the norm is around 150~200mm and it is not very suitable when the norm is around 250mm. The reason is that norm is too large that can lead to the land damping and collapsing and delay sowing. Higher moisture content can decrease the ground temperature and influences directly sprouting and growth. Soil moisture content in arable land is much higher than the untilled land. Therefore, the range saving water of autumn irrigation is larger and it is better for water storage and moisture conservation if nothing tillage measures before autumn irrigation.



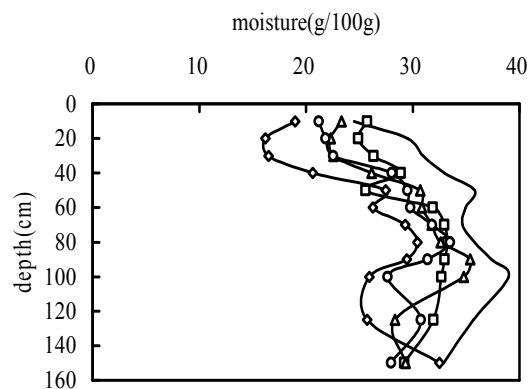
□a□LG1□Arable land IR=148.7mm□



□b□LG2□Arable land IR=247.8mm□



□c□LG3□Arable land IR=203.5mm□



□d□LZ2□Arable land IR=145.2mm□

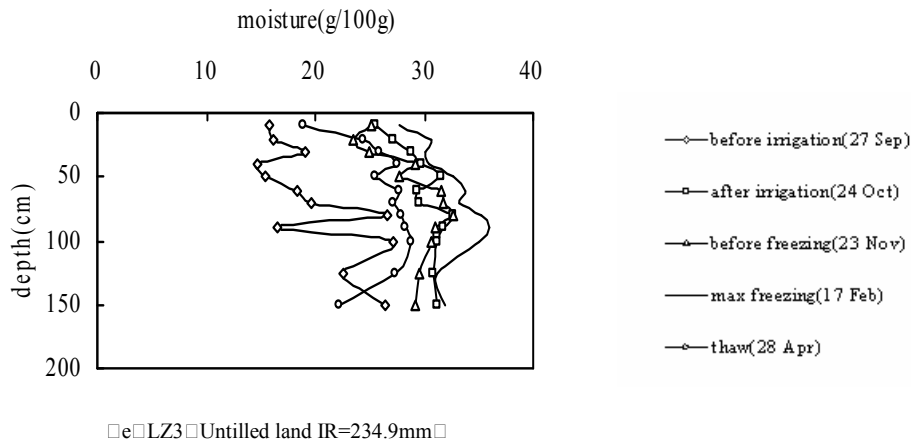


Fig1. Water content of soil profile distribution for different autumn irrigation norm

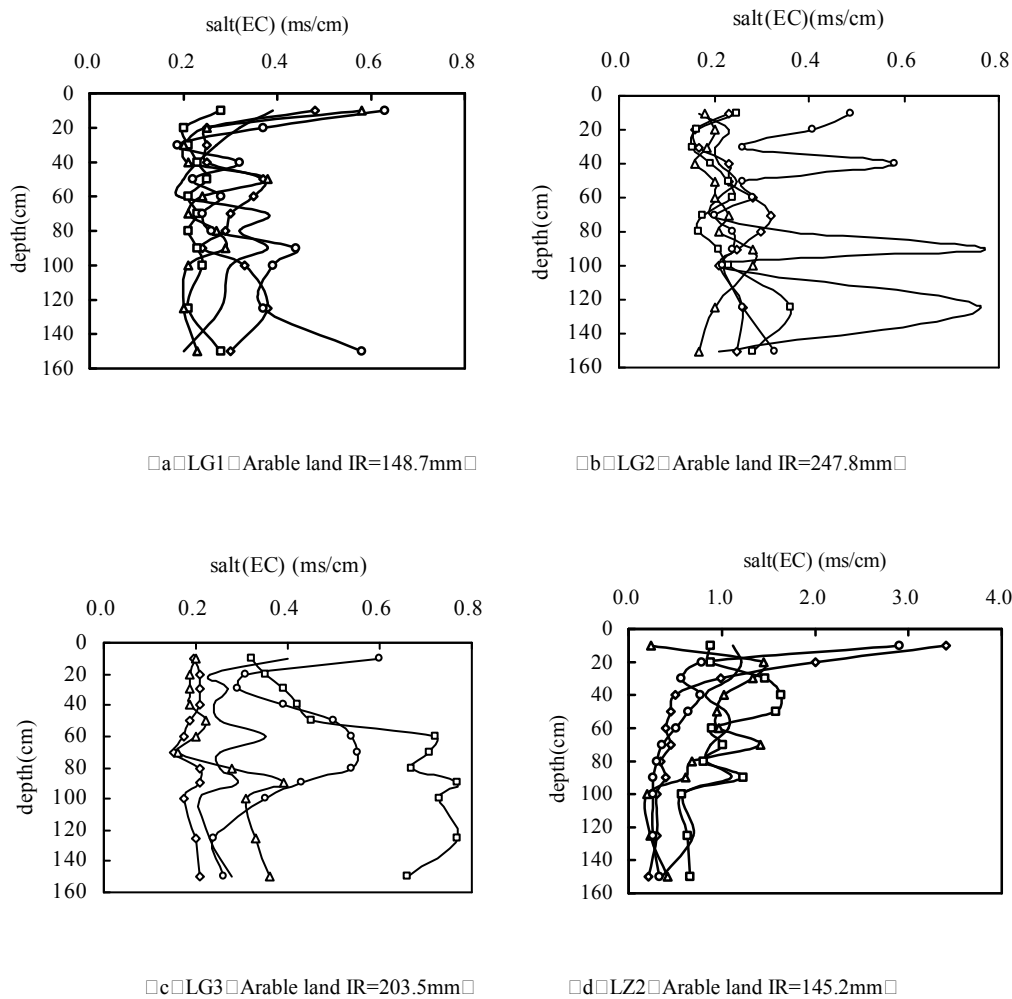
**3.2 autumn irrigation norm effects on soil salt content over wintering period** Figure 2 is respectively the year from 2005 to 2006 the soil salinity distribution on check treatment in profile, the different autumn irrigation norm between the autumn irrigation to after ice melting with the have cultivated land and the non cultivated land

**3.2.1 Arable land** We can see that the surface salt in have cultivated land and the non cultivated land compare to the check treatment was great decline, Shows that autumn water-storing irrigation have effect on washing salt. for the have cultivated land LG1 and LG2, except the surface(0~10cm),the soil salinity on other layer mainly distribution of 0.2~0.3ms/cm.after autumn irrigation, on the point of LG1,under 10cm on surface, soil salinity reduced from 0.48ms/cm before autumn irrigation to 0.28ms/cm, the salt on other layer has little decrease. On the point of LG2 because of the salt in different layers was less so after autumn irrigation the salt in different layers also have less change. On the process of soil freezing, part of salt moving up with the water, accumulation in frozen soil layer, make the salt in soil freezing increased, the deep of the highest moisture content in frozen soil layer and the highest salt content were almost same. By freezing-dissolving, the surface soil water evaporation made the surface salt rapid increase on the point of LG1,up to 0.65ms/cm, but the salt in other layer depending on with or without 0.3ms/cm; the same on the LG2 ,the surface salt rapid increased on 0.49ms/cm, the layer deep in 40cm the salt was 0.58ms/cm, the salt in other layer depending on with or without 0.3ms/cm.

**3.2.2 Untilled land** The soil salinity between in 0.3~1.0ms/cm expects the surface for untilled land. Salt content in soil surface shows salification and is more than deep ones. Salinity in surface decreases while increases in deeper soils after autumn irrigation and presents desalination. Such as fig.2, point LZ2 salt content is 0.88ms/cm at 10cm and 1.58ms/cm at 50cm. At point LZ3 salt content is 0.53ms/cm at 10cm and 0.70ms/cm at 50cm. During the process of soil freezing, some salt upward displacement with water and accumulates in the frozen layer. The maximum moisture content and salinity almost locates in a same depth. During thaw, freeze thawing water in surface evaporates largely, salt shift upwards with capillary water and accumulates in the soil surface. Therefore, the salt content in surface greatly exceeds deeper ones. Such as point LZ2 salt content is 2.9ms/cm at 10cm and 0.56ms/cm at 30cm. Point LZ3 salinity surface also is larger and decreases with the depth increases. The salt content is 2.5ms/cm in surface and

0.60ms/cm in 30cm only. However, point LZ2 surface salinity is less than point LZ3 after thaw compared with before autumn irrigation.

Based on the analysis and comparison above, autumn irrigation norm have more dynamically influence on soil salinity and autumn irrigation can able to militantly restrain salt content the results show that the salinity of the upper soil layer (0~40mm) next year autumn irrigation norm is around 150mm less than 250mm for land (slight salinization soil) and untilled land (moderate saline land). Autumn irrigation norm is about 250mm will lead to soil next year damping, collapsing and frost boiling. The accumulating salt in surface soil after water evaporation seriously affects crop sowing, sprouting and seeding stage growth in spring. Therefore, based on the dynamic change of autumn irrigation norm effecting thawing soil that the autumn irrigation norm should not be too large and about 150mm is the best.



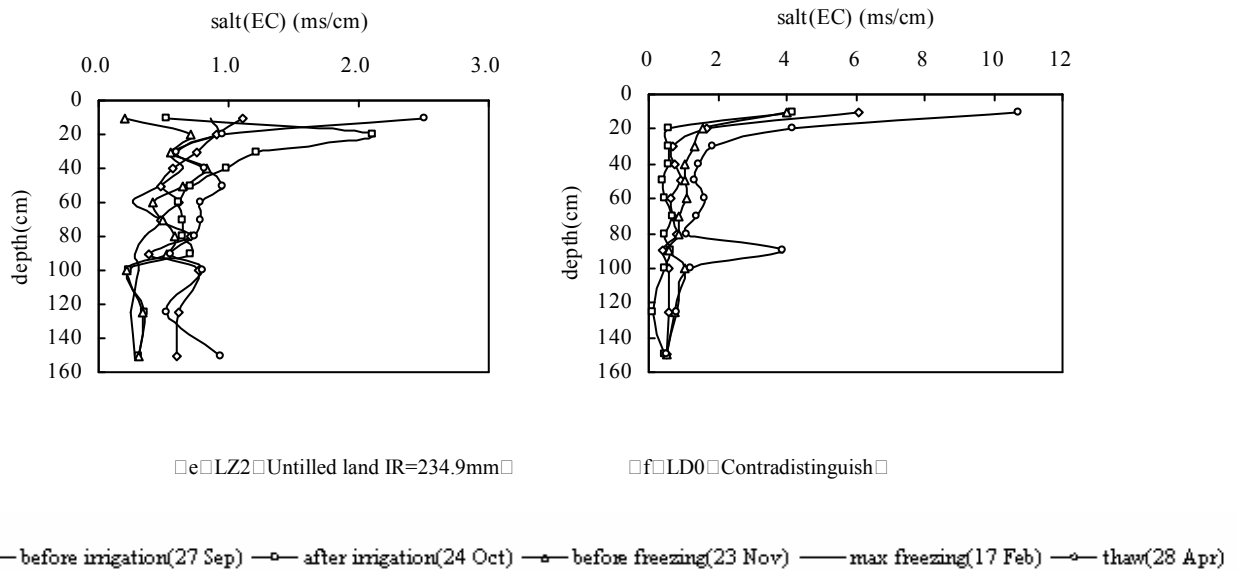


Fig2. Salt content of soil profile distribution for different norm between autumn irrigation and thaw

**CONCLUSION** (1)At the different condition of autumn irrigation norm ,average water content of 0~40cm horizon of soil has the same changing process of time, which is reserved some water for the next year spring sowing .Though the aim of reserving water between 150.0 mm and 250.0 mm is same, after 0~40 cm horizon of soil dissolved salt is different. When autumn irrigation norm is too large, it can cause damping, collapsing and frost boiling, be helpful to packing salt for surface soil after moisture evaporation, affect sowing date of spring crops and crop seeding will suffer negative function from salt.

(2)Water content of spring sowing soil is suitable, when autumn irrigation norm is about 150mm~200mm; autumn irrigation norm is about 250mm, water content of spring sowing soil is not suitable. Because of too large for norm, too high for water content and soil surface tidal and collapsed, not only are seeds delayed, but also decrease soil temperature and is directly affect seed germination and seedling growth. At the same time salt content of soil surface, when autumn irrigation norm is about 150mm(0~40), is lower than salt content of soil surface, when autumn irrigation norm is about 250mm(0~40cm); in addition layer water of untilled soil is higher than the tilled soil. In a word the range saving water of autumn irrigation is larger and it is helpful to water storage and moisture conservation if nothing tillage measures before autumn irrigation

## REFERENCES

- [1]SUN Sanmin, CAI Huanjie, CHEN Xinming. 2008. Experimental Research on the Rational Autumn Irrigation Norm in Alar Irrigation District. *Water saving Irrigation* 6:36-39
- [2] LI Ruiping, SHI Haibin,Takeo Akae, ZHANG Yiqiang. 2007. BP network model research on water and salt transfer forecast in seasonal freezing and thawing soils [J].*Transactions of the Chinese Society of Agricultural Engineering* 23(11):125-128
- [3] LUO Tingbin, REN Wei, XIE Chunhong. 2001. Necessity and Feasibility of Biotic Improving the Saline and Alkaline Land in Xin Jiang . *Arid Zone Research* 18 (1): 46 -

- [4] MENG Chunhong YANG, Jinzhong. Experimental Research on the Rational Selection of Autumn Irrigation Norm in Hetao Irrigation District.2002. China Rural Water and Hydropower (5): 23 – 25
- [5] LI Ruiping, SHI Haibin, Takeo Akae, ZHANG yiqiang. 2007. Characteristics of air temperature and water-salt transfer during freezing and thawing period. Transactions of the Chinese Society of Agricultural Engineering, 23(4): 70-74
- [6] LI Ruiping, SHI Haibin, Takeo Akae, ZHANG Yiqiang. 2009. Study on water-heat-salt transfer in soil freezing-thawing based on simultaneous heat and water model. Journal of Hydraulic Engineering 40(4): 403-412