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Research of Relationships between Initial Moisture Content of Sand Soil and its Nutrient Loss in Hulun Lake Basin

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Abstract: In the study, in order to make the study of influences of different early stage water content of the soil on the runoff and the concentration of the solute and migration, in the Hulun Lake, we adopt the traditional artificial rainfall method in the Grazing pasture; in the experiment the rain capacity is set as 87.34 mm h^{-1}. The results show when initial moisture content grassland sand soil is larger; the runoff moments is earlier and runoff coefficient is larger, that is the more rainfall is put into net flows, erosion intensity runoff is more serious. The soil erosion and early water content present approximate parabola relationships. Runoff changes of phosphorus and potassium in the grassland soil is similar to the change of water runoff and there exists a "turning point", before the turning point, the solute loss is decreasing, after turning point, phosphorus and potassium loss will be increased gradually. This because there exists rill erosion in the turning point, rill erosion on the surface of the slope increases loss of phosphorus and potassium, so the soil erosion is the important reason for the huge loss of nutrients. The research can provide the reference for rational utilization of Lake Basin in pasture and water environmental protection and the management of non-point source pollution.

Key words: Sand soil, initial moisture content, nutrient loss, relationships, research

INTRODUCTION

As known that the water runoff of the ground carries sediment and NPK nutrients and it is the main cause of eutrophication of water. Soil moisture plays an important role on the formation and transformation of water resources and also in its consumption process. It has close relationship with scientific fields such as agriculture, hydrology and environment (Lei and Yang, 1999). The erosion of grassland is mainly of hydraulic and the vegetation coverage rate is not high. So, the research of rainfall infiltration and rational utilization of soil water resources are the key problems of the regional ecological environment construction and sustainable development of farming and animal husbandry (Yang, 2000; Chen, 2003).

Initial moisture content of the soil will influence rainfall infiltration and runoff. When the initial moisture content is high, the soil infiltration rate will be reduced, wetting peak movement speed will also increase accordingly, with the passage of time, gradually influence of initial moisture content on the infiltration rate will be reduced, eventually it can be neglected. But its humid peak rate of mobile will be continued to increase (Philip, 1957). However, there are some studies suggest that the initial moisture content of moist peak has little influence on the movement speed of humid peak (Li *et al*., 1991).

Foreign scholars (Le Bissonnais *et al*., 1995) analyzed characteristics of runoff and sediment yield of 10 kinds of different soil with different water content through artificial rainfall, it can be concluded that the stability of the aggregate is significantly correlation with crust, runoff and erosion. The high clay content of saturated soil has the lowest soil erosion; on the other hand, erosion of the high content of organic carbon dry soil is minimum, the function of antecedent soil moisture is also depends on the soil properties.

The early stage of the soil water content on rainfall infiltration, runoff erosion and the effects of solute migration process, due to the different researchers focus on the different research object, so the conclusions are not comprehensive and some even think that the early stage of the moisture content of soil solute movement can not be ignored. The experiment is through simulating artificial rainfall, at the early stages with the different water content, the prairie migration process of phosphorus, potassium, bromine on the surface of the slope. Table 1 shows the physical and chemical properties of soil.

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Table 1: Main physical and chemical properties of soil

Soil	Saturated moisture content (cm^3 min^{-1})	Saturated water content (cm^3 min^{-1})	Nutrients (g kg^{-1})			
			Phosphorus	Potassium	Nitrogen	Organic matter
Grassland sand soil	0.048	0.06	0.58	21.42	1.12	18.65

PROFILE OF THE RESEARCH AREA

Call Aaron lake is located in the Northeastern Hulunbeier grasslands which is located on the border between China, Russia and Mongolia, it belongs to the typical alpine grassland lakes. In recent 10 years, the lake level is decreased, the water is also reduced year by year and the water exists eutrophication trend. The lake salt, value of pH, COD, BOD are rising year by year. The factors can accumulated to climate change and the related management. The rainfall in the year of 2013 is the largest among ten years, so it id best time for experiments, the experimental area is selected in new Barr tiger You Qi of Inner Mongolia.

Design and test materials: In the experiment, the self-made artificial rainfall device can produce the rainfall on the grassland 1×2 m^2. The measurement of moisture content is through the drying method, determination of cutting volume quality is through the ring method. Before the rainfall, soil water content is tested in the test area, according to the test needs, rainfall water content is set at 4, 8, 12 and 8%, respectively, slope is selected with 12°, duration of rainfall is 57 min. When production of flow is started, in the first 12 min, water samples are collected with the intervals of 3 min, in the later 37 min, the intervals of collecting runoff water samples is 5 min and then interval is turned to 10 min to collect runoff water samples, the rest is collected in the big plastic and are used for analysis of surface runoff.

ANALYSIS OF RESULT

Influence of initial water content on soil water and runoff: Initial soil water content has influence on soil water infiltration capacity and soil solute migration. Rain falls on the surface or infiltration into soil water movement along the slope surface form the surface runoff, the formation of surface runoff is one of the premise of soil water infiltration capacity is less than the rainfall intensity. As for low moisture content soil, the reunion of the soil is small, it is easy to be scattered by the rain. But the dispersion effect, in turn, will form compacted layer on the soil, thereby reducing the infiltration of the soil. This effect and initial water content influence is much smaller.

In the Fig. 1, it is the measured runoff process with initial water content of 4, 8, 12, 8%, rainfall intensity is 87.34 mm h^{-1}. there exists a mutation point of the soil early stage water content between 8 and 12%, the

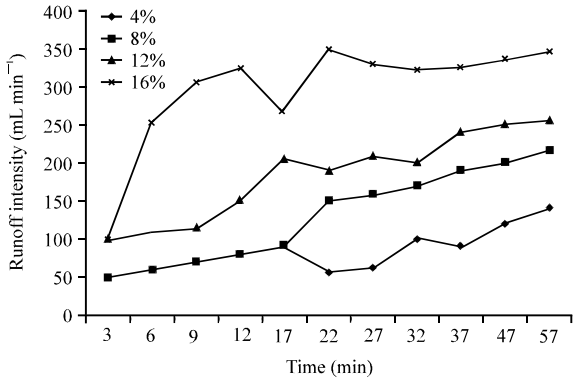

Fig. 1: Runoff flow under the conditions of different water content change process

mutation divides the runoff and infiltration process of different water content into two types of laws: From to the mutation point, the runoff change curve presents approximately "S" shape, from the mutation point to the point of 16% water content, the runoff change curve presents logarithmic distribution, these may be due to the growth cohesive force is not linear but presents approximate parabola distribution, between saturated soil and 45% water content of soil. The maximum point is in the 8-16% of soil moisture content.

Therefore, when the moisture content is 4%, soil is hit by raindrops and is scattered, it runs with water flow, filtrates and fills the gap of the soil. In the soil surface a relatively dense layer is formed and thus soil water infiltration capacity is greatly abated, runoff intensity will be increased. But when the high initial moisture content is larger than 12%, soil water infiltration capacity will depends on the soil and its gravity potential. When the early stage of the moisture content is higher, the larger the runoff will be. According to the measured runoff during the process of rainfall, through using the Eq. 1 and 2 (Luk, 1985), average slope runoff depth dynamic variation process of infiltration rate can be obtained, as shown in Fig. 2:

$$H = 10R/tS \quad (1)$$

$$I = [pt\ cosa-(10R/S]/t] \quad (2)$$

where, R represents the runoff in time of t and the arithmetical unit is mL, S represents actual bearing the rain area of the slope and arithmetical unit is cm^2, a represents the slope of surface, t represents rainfall time.

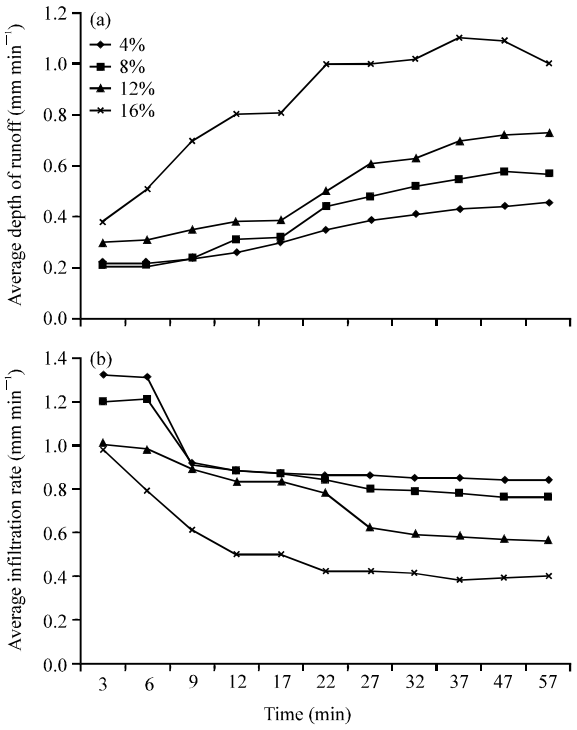

Fig. 2(a-b): Runoff depth of grassland sand soil slope surface and average infiltration rate change process

As shown in Fig. 2, the average runoff depth of grassland soil slope will increase with the increasing of initial moisture content and average infiltration rate presents inverse slope changes; That is to say, the bigger the initial soil water content, runoff moments will be earlier, runoff coefficient is also larger, the greater the runoff of soil erosion on the surface of the earth is, the greater the soil erosion will be.

Influence of water content on the slope surface runoff: Within the certain depth of the soil, the solute can be mixed with the surface runoff and below the depth, there exists no mixing. The conclusion is confirmed by many scholars (Walton *et al*., 2000). In the depth, the soil solute has two shipping ways in the entire rainfall process: One form is migration with the water seepage to the deep soil; the other form is the migration with the runoff on mixing layer and the solute runoff migrates with the surface runoff and is increased with the increasing of water content. The reason is that when the water content increases, migration of solutes with water seepage is also reduced. And runoff will increase when water content is increased which is the result of increasing soil (Ahuja *et al*., 1983; Zhang *et al*., 1992; Lin, 1995).

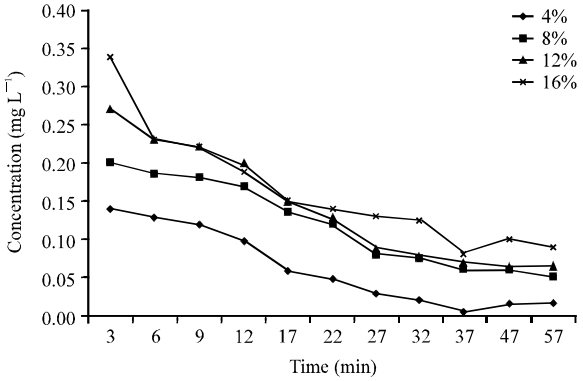

Fig. 3: Flow curves of dissolved phosphorus concentration in the runoff

In the Fig. 3, it presents the changing process that under the condition of different moisture content, runoff solute content changes along with the rainfall. When moisture content is higher than the 12 and 16%, due to the high soil moisture content, soil water infiltration capacity is reduced, runoff time is improved, the Macao ion of soil layer will outflow the raining area with rainfall runoff; When the early stage of the moisture content is lower than 12 and 16%, as a the delay of the runoff time, soil water infiltration capacity is relatively strong. Most bromide ions seep into the soil along with the deep water, therefore, bromide ion has rarely runoff erosion (Lin, 1995; Wang *et al*., 2006).

As for phosphorus and potassium, under the condition of different water content and different phosphorus proportion of dissolved and particulate state in the soil, runoff and sediment yield are also different. Raindrop strike and runoff scour resistance ability of the soil particle are also different, under the action of these factors, the variation of the runoff solute showed different characteristics. Each runoff solute content change curve is a decay process and has some volatility. This may due to steppe soil prone to rill erosion, under the surface of the soil solute sometimes may expose under the raindrop strike and runoff scour and constantly provide runoff for solute.

In the Fig. 3-5, they show changing process of phosphorus, potassium, bromine ion concentration in the runoff. The figures show that concentration change of phosphorus, potassium, bromine ion presents attenuation distribution in process of the runoff, water content and the average water content have similar parabola relationship. With the improvement of early water, runoff of phosphorus and potassium content will be increased.

The Fig. 3 shows that change of water soluble phosphorus shows the wavy changes along with the

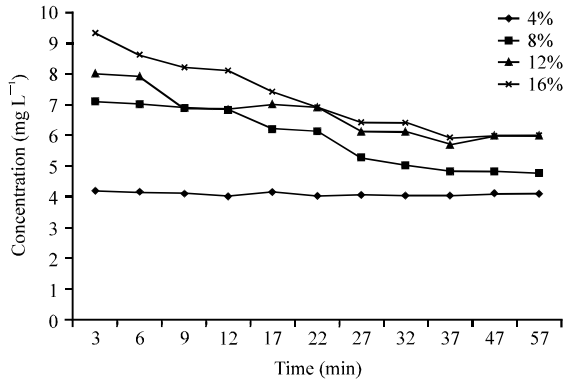

Fig. 4: Changes curve of potassium ion concentration in the runoff

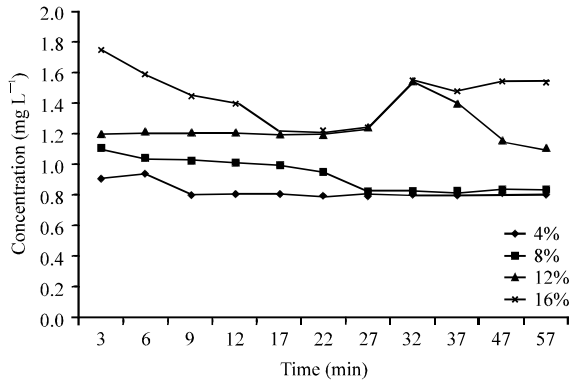

Fig. 5: Concentration curve of bromide ion in the runoff

increasing of initial moisture content, it may be related to the velocity of slope runoff, etc. Under the condition of the same grade, the increasing of initial water content will significantly increase the runoff which will lead to the increasing of nutrient runoff. Figure 4 shows that at the beginning of the runoff, runoff of the potassium ion concentration is higher, after 15 min it will be stable.

This is because at the beginning of the production of flow, liquid content in surface and soil is relatively high. In the slope dilute solution effect of surface runoff is strong; the runoff concentration is also higher. As the rain is continued, the surface potassium ions suffers continual rain leaching into deep soil layer or migrate to other section, the runoff nutrient content is gradually reduced and tends to be stable.

As shown In Fig. 5, the runoff bromide ion concentration change process is in the trend from low to high and with the increase of initial moisture content, the Ao ion migration with surface runoff is also increased.

The initial water content has significant impact on Ao ion. The above tests show that when the initial water content is not at the same time, nutrients in the process of rainfall runoff and the initial moisture content have strong correlations.

Effects of water content on migration of nutrients: The soil solute transport and soil moisture have closely relationships, if there is no moisture migration, it can only be changed in the form of diffusion.

Under the condition of production flow, the surface runoff solute concentration is low; it can rely on molecular diffusion and make the soil solute migration towards the surface runoff. Runoff of soil has disturbance and scouring effect and effects will increases with the increasing of runoff depth and runoff. As cases of certain water content, the size of the runoff depends on the soil water infiltration capacity in surface and soil water infiltration capacity depends on the size of the soil moisture content. Therefore, we can say that, the erosion of the soil by the runoff and the initial disturbance are determined by soil water content. With the increase of water content, soil water infiltration capacity is decreased and the amount of runoff, the soil disturbance ability will be enhanced accordingly. However, with the stability of infiltration, runoff will be stable; the soil disturbance is also tending to be stable. It can be said that the three migration methods in the soil have mutual connections and restrictions. If the initial soil water content is large, soil moisture migration space is reduced, the soil water infiltration capacity is reduced too which changes the hydrologic conditions. For the soil nutrient, soil with different initial water content, soil unit of charge density is also changed and thus the diffusion coefficient is not the same.

Changes of surface runoff nutrient loss: The size of the runoff of nutrient loss is determined by runoff concentration and the corresponding runoff. It also is influenced by the following factors: Soil; the early initial concentration of nutrients, soil bulk density, soil water content, soil texture and the characteristics of rainfall, the underlying surface conditions.

In this experiment, we only change the initial soil water content, other conditions are consistent and through control Eq. 3, runoff solute dynamic change process of three kinds of chemicals under the condition of different soil initial moisture content are as shown in Fig. 6-8:

$$m(t) = c(t) \times r(t) \quad (3)$$

where, m(t) represents slope runoff solute loss at the exit at t moment and the unit is (mg min^{-1}).

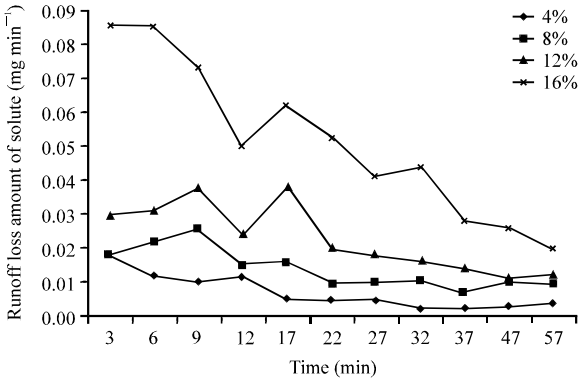

Fig. 6: Runoff changes of dissolved phosphorus loss

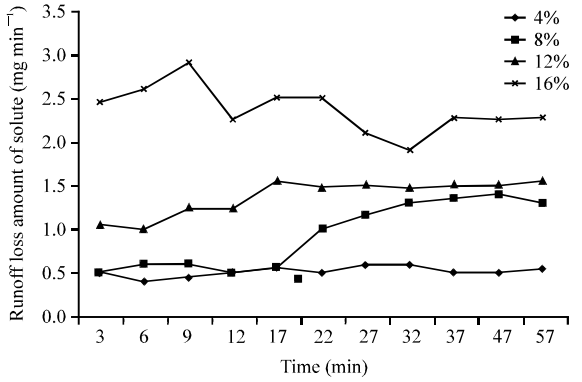

Fig. 7: Runoff changes of potassium loss

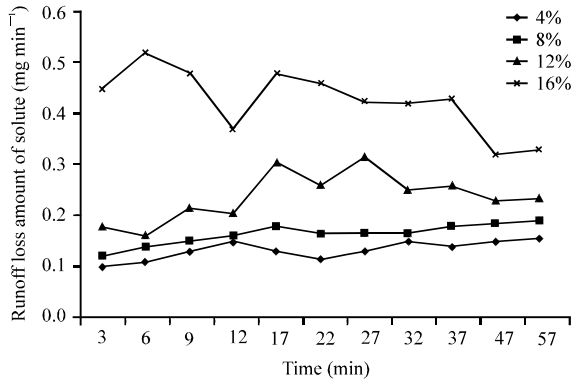

Fig. 8: Flow of bromine ion concentration and total loss of change

C(t) represents slope at the exit of the runoff concentration at t moment and the unit is (mg L^{-1}).

r(t) represents slope at the exit of runoff at t moment and the unit is (L min^{-1}).

As shown in Fig. 6 and 7, from change process of phosphorus and potassium in the quality in runoff, we can know that soil solute migration from soil to the runoff is the process from very small amount rapidly increases to a maximum value and then turns to be stable. Peak time and big or value will be different due to the bulk density and compound properties, initial soil water content is greater the required time will be shorter and the peak value will be greater; when compound soil adsorption is weak, the time to reach peak value will be faster. Soil soluble has a great influence on phosphorus runoff erosion, soil initial water content can control whole process of the runoff. Initial soil water content has little effects on process of potassium runoff; it's just a control to the peak of this period. It has no significantly effects on the attenuation process. As shown in Fig. 6 and 7, the process of grassland soil phosphorus and potassium changes of runoff and runoff concentration are similar, there exists "turning point". Because around the "turning point" there exists rill erosion, rill erosion on the surface of the slope increase the phosphorus and potassium loss, soil erosion become one of the important reasons for the nutrient loss.

Figure 6-8, respectively show that the soluble phosphorus, potassium, bromine ion with the migration of surface runoff and runoff in a different time. As shown, with the increase of initial moisture content and nutrient move up to the surface runoff in the cross section is increased, when the initial water content is 20%, the runoff solute loss appeared larger fluctuation, the reason is that under the condition of initial moisture content is higher, the erosion of the soil is relatively serious which affects the runoff solute loss.

Solute loss is determined by runoff, runoff solute concentration, sediment erosion and sediment solute concentration, etc. When the initial water contents is between 4 and 16%, the soil nutrient loss will increases with the increasing of initial moisture content.

CONCLUSION

This experiment make the research under the condition of different initial water content, nutrient affect runoff migration through simulating artificial rainfall; research results are as below:

- The initial moisture content grassland soil, the runoff moments is earlier, runoff coefficient will be larger. That is the rainfall turns into net flows will be larger, the soil erosion intensity of runoff on surface will be stronger and the soil erosion will be greater at the same time, soil erosion and early moisture content presents approximately parabola changes

- The average runoff phosphorus and potassium content and the early stage of the moisture content are not linear relationships but they presents the parabola relationships. Water content increases will increase the trend of solute loss
- The soil has strong ability of phosphorus, the change of the concentration range is mainly within 5 and 10 cm. With the increase of water content, the total amount of soil available also will be increased. But when the moisture content is too large while total soil erosion will be reduced; with the increase of water content, soil potassium ions to the total amount of migration in soil is decreased, this is because the difference of potassium ion adsorption. Along with the increase of water content, the water penetration is decreased, so that the potassium ions can reduce the amount of migration in the soil; with the increase of water content, depth migration of the bromine ions in soil is reduced, this is because the increase of initial moisture content, it can reduce the infiltration of water, thus cause the decreasing of solute migration to deep soil
- The change process of grassland soil phosphorus and potassium of runoff is similar to the runoff concentration change process, there also exists a "turning point", before the "turning point" the solute loss is decreased, after the 'turning point", phosphorus and potassium loss are increased gradually. This is because around the turning point, there exists the rill erosion, rill erosion on the surface of the slope can increase loss of phosphorus and potassium, soil erosion is the important reason for the huge loss of nutrients

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