Benefits of Soil and Water Conservation and Soil Moisture of Seabuckthorn Stands in Semi-Arid Hilly Region of Loess Plateau

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Abstract: There is a remarkable function on decreasing runoff and sediment in seabuckthorn and its mixed stands. Meanwhile, the effect of seabuckthorn and its mixed stands on soil and water conservation is different with change of their structure and patterns. The utilization of seabckthorn forest to soil water is more less in spring than that in rainy season as well as there is a definite recovery of soil water in the whole soil layer in the end of growing season. The age of seabuckthorn plantation has an influence on the using intensity of soil water and the 8 years old seabuckthorn plantation should be cut because of a soil dry-layer in the stand. Location of slope has remarkable effect on soil water of seabuckthorn woodlands. Average soil moisture of 500cm depth on the down slope is higher of 1.16% than that on the upper slope. Soil water status on northern slope is better than that on eastern slope. The utilization of Seabuckthorn plantation on soil water is more than the mixed stands of seabuckthorn with other tree species. Soil moisture of seabuckthorn woodland changes largely with the zones, soil moisture of seabuckthorn woodland in the depth of 350cm is low and the growth of seabuckthorn depends on the same year's rainfall in semi-arid region. Soil water of seabuckthorn woodland maintains perennial basic balance in semi-humid region.
Keywords: loess hilly region, semi-arid region, soil and water conservation, seabuckthorn stand soil moisture

1 Forword

The semi-arid loess hilly and gully region locating in the middle-upper reaches of Yellow River where climate is dry, soil and water loess is seriously, the ecological environment is frailty, is the key eco-environmental control region of our country. Along with implement of exploiting the western China, to expedite vegetation construction is regarded as core content of controlling eco-environment in loess plateau. However, water condition is a limited element for vegetation construction according to the geographic location and natural characteristics.

Seabuckthorn (*Hippophae rhamnoides Linn.*) has the capability of bearing dryness, developed root system, fast canopy covering the ground and better results of soil and water conservation, is a scarce pioneer tree species of soil and water conservation in the bad eco-environmental region. Meanwhile, seabuckthorn has rare economic values and its branch, leaf and fruit have quite wide purpose. To develop seabuckthorn vigorously, is helpful to expedite the development of regional economy and course of local farmer getting ride of poverty and becoming rich. Now, there are a lot of report about seabuckthorn study inside and outside, but which is focused on the introduction process and utilization of seabuckthorn. Seabuckthorn studies mainly focus on its soil and water conservation and selection of fine breed in loess plateau [1—4]. However, the studies on its soil and ecological character are very lack[5,6], especially the systemic studies on soil and water conservation function of seabuckthorn and its mixed stands and its effect on soil water environment.

In the Zhifanggou small watershed located in semi-arid area of loess hilly region, different types stands have a definite scale after many years of comprehensive control and scientific research, In which seabuckthorn is a main species for afforestation. It is worth to pay attention that how about the soil moisture and soil and water conservation of these mature seabuckthorn stands are, whether the status of soil moisture variation can restrict the sustainable development of the seabuckthorn stands. Therefore, we had studied runoff, sediment and soil moisture of seabuckthorn and its mixed stands in Ansai Zhifanggou

small watershed for providing theoretic reference to developing seabuckthorn forest in loess plateau.

2 General situation and research measures

2.1 General situation

The experiment area lies in seabuckthorn forest of Zhifanggou small watershed and seabuckthorn and its mixed stands experimental plot 8 km far the watershed in Ansai county. The physiognomy belongs to girder-shape hilly and gully area of middle loess plateau, soil type is loam loess, ravine density is 4.2 km • km^{-2}—8.0 km • km^{-2}, altitude is 1,010 m—1,431 m. It is semi-arid climate of warm temperate zone. Mean annual runfall is 535 mm, degree of dryness is1.48. Mean annual temperature is 8.8 ℃, period of non-frost is about 160days. Annual gross radiation is 132 therm. cm^{-2}. Vegetation is forest-steppe zone. The seabuckthorn and its mixed stands are planted in 1992 and lies on eastern and northern slopes of same catchment. The basic information is showed in Tab.1. seabuckthorn stands in Zhifanggou watershed are planted in 1989.

Table 1 Experimental plots and the basic situation of vegetation

types of vegetation	location	direction of slope	slope degree	tree age (a)	coverage	mean ground diameter (cm)	mean height (m)	density (plant.hm^{-2})	biomass of dry (kg •hm^{-2})
wasteland slope	Gully	Eastern	23°		0.35		0.31		601.5
seabuckthorn(cutting)	Gully	Eastern	23°	7	0.80		1.10	6,667	6,040.0
seabuckthorn+little leaf poplar	Gully	Eastern	23°	7	0.75	6.69 [2]	0.86[1] 3.91[2]	6,667	
pine+seabuckhtorn	Gully	Northern	27°	7	0.45	2.83[1]	0.98[1]	4,444	
seabuckthorn	Gully	Northern	27°	7	0.90	5.41	3.5	6,667	23,767.0

Note: [1] dominant tree species;[2]hypo-dominant tree species

2.2 Research measures

2.2.1 Runoff and sediment

Perpendicular projection area of experimental plots is 5 m×20 m, the border is made of reinforced concrete and embedded 35 cm depth underground and 10 cm height above ground. Runoff barrel volume is 0.42 m^3, and is used as two-grade distributary. The gross volume of runoff is measured after rainfall and the sediment samples are fetched for calculating the gross sediment after mixing round.

2.2.2 Soil moisture

Soil moisture in plots is measured by means of neutron apparatus. We had demarcated the neutron apparatus after installing an aluminum pipe 450 cm depth underground in every plot according to ways of the literature [7]. On the basis, we had measured 400 cm depth soil moisture according to the reading of every 20 cm depth. Using soil drill, we had measured soil moisture of seabuckthorn forest in Zhifanggou small watershed and taken a sample in the depth every 20 cm layers. The measured depth and date are 500 cm and 25^{th}—28^{th} of every month in the growing season respectively.

3 Results and analysis

3.1 Runoff and sediment

Field rainfall in the growing season (from April to October) is 261.0 mm in 1999. Runoff and

sediment of seabuckthorn and its mixed stands in the same period are showed in Tab.2. Results of Tab.2 have showed that in the same conditions of soil, slope degree and rainfall, the sequence of runoff depth in different stands is waste slope >seabuckthorn (cut in the end of 1998) >seabuckthorn＋little leaf poplar >pine＋seabuckthorn > seabuckthorn and the sediment discharge is waste slop > pine+seabuckthorn > seabuckthorn (cut in the end of 1998) > seabuckthorn+ little leaf poplar > seabuckthorn. Seabuckthorn and its mixed stands have remarkable effects on reducing surface runoff and sediment discharge and reveal remarkable function on soil and water conservation. However, along with the changes of seabuckthorn stands structure and its mixed patterns, the effective magnitude on reducing surface runoff and sediment discharge is different. Being 2 cm~4 cm depth litter on the ground, growing fast and its canopy closing ground in the 6th year, pure seabuckthorn stand has larger function on soil and water conservation than the other stands. Because of the cut seabuckthorn stand losing the canopy interception to rainfall and the mixed stand of pine and seabuckthorn having lower canopy coverage, their functions on soil and water conservation are lower than the mixed forest of seabuckthorn and little leaf poplar having fine stand structure.

Table 2 Runoff and sediment of different types vegetation plots

item	waste slope	seabuckthorn (cutting)	Seabuckthorn + little leaf poplar	pine+seabuckhtorn	seabuckthorn
Runoff (mm)	2.69	2.60	1.99	1.41	0.64
Sediment (t/km^2)	91.69	26.11	8.52	62.71	0.84

3.2 Seasonal trend of soil moisture in seabuckthorn stand

In the year of 2000, there is relatively plentiful rainfall that is 353.7 mm in the growing season and serious drought in spring. Fig.1 has showed: In April seabuckthorn forest has low soil moisture and deplete less because of drought climate and no growth of branch and leaf. In May, branch and leaf of seabuckthorn start to grow and the climate is still drought, the stand depletes soil moisture more seriously. Entering June, it gradually rains more and has more rain and heat in July, seabuckthorn grows vigorously and soil moisture is depleted seriously by transpiration, although soil moisture in the stand above 380 cm layer has a definite recovery and the above 70 cm soil layer has more recovery. Soil moisture in 70 cm—500 cm layer is still low and the range is 4.0%—6.70%. After the compensation to soil moisture in rainy season (July ~ September), soil moisture in the stand has an obvious recovery in the depth of 0—500 cm in October and higher in the depth of 100 cm—500 cm than that in April and July. Mean soil moisture of 0—500 cm depth in April, July and October are 6.07%、6.84% and 8.756% respectively.

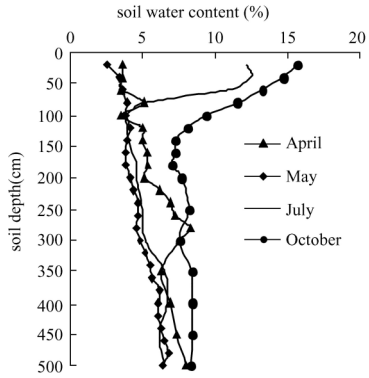

Fig. 1 Seasonal dynamic of soil water in seabuckthorn stand

3.3 Soil moisture utilization of seabuckthorn in different ages

Fig.2 has showed: Utilization intension to soil moisture of seabuckthorn stand is obvious different with the change of tree ages. Seabuckthorn stand usually starts to cover ground in 5 ages. In the stage, seabuckthorn consumes little soil moisture and the consumed intension gradually reduces with the increase of soil depth, soil moisture range of 100 cm—500 cm layer is 8.65%—12.15%. seabuckthorn has utilized soil moisture in shallow and deep layer in 6 ages. After rainy season, 50 cm—280 cm layer soil moisture can be recovered well and its mean soil moisture is 11.63%, soil moisture range of 300 cm—

500 cm soil layer is 8.6%—10.9%. Seabuckthorn forest has depleted more soil moisture with the increase of tree ages. Soil moisture in 8 ages seabuckthorn woodland has descended rapidly and there is a low-humid soil layer which soil moisture is about 5.0% in the depth of 150cm—500cm. It causes that the regulative function of soil reservoir has decreased. The maintenance of seabuckthorn growing depends on rainfall of the same year, the stand will has lower capability to resist drought and die in dry year.

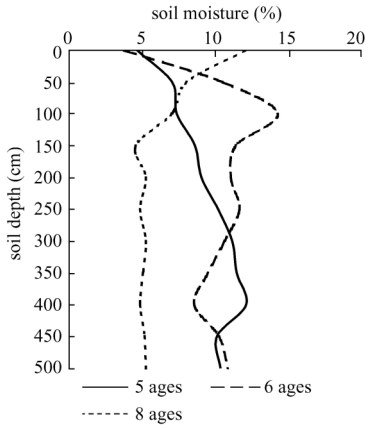

Fig. 2 Utilization of seabuckthorn in different ages to soil moisutre (measured in Nov.20 of each year)

3.4 Effect of slope location on soil moisture in seabuckthorn woodland

Usually, the down location has more rainfall than the upper in the same slope. The results have showed from Tab.3 as follows, effect of slope location on soil moisture in seabuckthorn stands is remarkable. Soil moisture of seabuckthorn stands in the down is better than that in the upper in the depth of 0—500 cm. Average soil moisture of 0—500 cm depth in the upper 6.25% and 7.41% in the down. Soil moisture discrepancy between the upper and the down is 1.16%. Therefore, it is in favor of stable growth to plant seabuckthorn tree in the down.

Table 3 The effect of slope location on soil water of seabuckthorn stands in the growing season（%）

Slope location	20~60	60~120	120~200	200~300	300~400	400~500
Soil moisture on the upper	7.77	6.01	5.02	5.67	6.41	6.90
Soil moisture on the down of slope	7.94	5.87	6.06	7.84	8.11	7.98
The down- the upper	0.17	–0.14	1.04	2.17	1.70	1.08

3.5 Utilization of seabuckthorn and its mixed forest to soil moisture

3.5.1 Soil moisture utilization in growing season (April~ Ocotober)

Utilization of seabuckthorn and its mixed stands to soil moisture are showed in Fig.3. In the growing season in 1999, mean value of soil moisture in seabuckthorn and its mixed stands is less, range of the mean values in depth of 0—400 cm layer is 0.063 $cm^3 \cdot cm^{-3}$—0.084$cm^3 \cdot cm^{-3}$, which has reflected the dry character of soil in the region. During the experiments, pine grows slowly in the mixed stand of seabuckthorn and pine. Being less density, the stand depletes soil moisture in deep layer less than the others stand. Mean soil moisture of the cut seabuck-thorn and seabuckthorn and little leaf poplar mixed stands are 0.063 $cm^3 \cdot cm^{-3}$ and 0.057 $cm^3 \cdot cm^{-3}$ respectively in the soil layer of 0—100 cm, which is similar with the mean value（0.056 $cm^3 \cdot cm^{-3}$）in waste slope. Compared with the vegetation in waste slope, soil moisture of seabuckthorn and its mixed stands is less in the whole depth of 0—400 cm, and the varied ranges of soil moisture in cut seabuckthorn and its mixed with

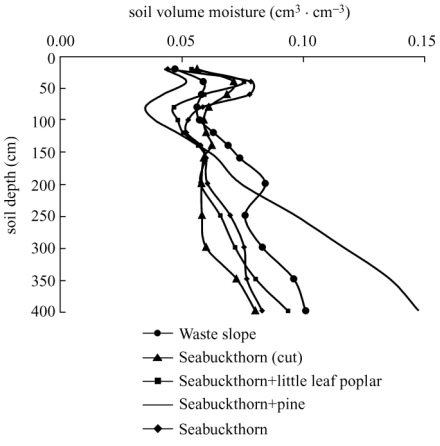

Fig. 3 Mean soil volume moisture distribution of seabuckthorn and its mixed stands in growing season

little leaf poplar stands are 0.056 $cm^3 \cdot cm^{-3}$—0.081 $cm^3 \cdot cm^{-3}$ and 0.047 $cm^3 \cdot cm^{-3}$— 0.094 $cm^3 \cdot cm^{-3}$ separately.

On northern slope, soil moisture in pure seabuckthorn stand is more lower compared with the seabuckthorn and pine mixed stand and is drought in the depth of 0—400 cm being the growth of seabuckthorn. We have also got such a result that soil moisture in different stands on northern slope is higher than that on eastern slope from Fig. 3. Mean soil moisture value in pure seabuckthorn stand is lower than that in its mixed stands and the difference range between pure seabuckthorn and its mixed stands is 0.005 $cm^3 \cdot cm^{-3}$—0.020 $cm^3 \cdot cm^{-3}$.

3.5.2 Incoming and expensing status of soil moisture in growing season

In light of the principle of water balance, the cycle is in a balance state if income and expense of soil moisture in system is equal in a definite period [8]. According to the data in Tab.4, the stored soil water of 0—300 cm layer in seabuckhtorn and its mixed stands varies slightly in the early (April) and the last (October)of growing season and the range is 5.1 mm—15.6 mm and the most stands have a little surplus of stored soil water in the whole growing season except seabuckthorn and little leaf poplar mixed stand. Therefore, soil moisture of the stands basically maintains a balance state. According to the measure[9], field capacity in the region is 18.4%, which is equal to 474.0 mm water in the soil layer of 0—200 cm depth. However, in whole growing season, ranges of mean soil moisture values and mean stored soil water values in seabuckthorn and its mixed stands are 0.063$cm^3 \cdot cm^{-3}$—0.084 $cm^3 \cdot cm^{-3}$ and 189.9 mm—250.8 mm respectively, which are more lower than the field moisture capacity and stored water capacity in the region. The results have showed that the level of seabuckthorn and its mixed stands maintaining soil water balance is very low and soil in the stands is in a quite drought state.

Table 4 Stored soil water variation (0~300 cm) in seabuckthorn and its mixed stands in the growing season (mm)

month	waste slope	seasbuckthorn（cut）	seabuckthorn + little leaf poplar	pine + eabuckthorn	seabuckthorn
April	184.6	178.6	179.7	197.7	180.2
July	250.5	231.0	233.7	242.7	232.2
October	213.3	189.3	172.8	202.8	195.9
October - April	28.7	10.7	–6.9	5.1	15.6
Average values from April to October	228.3	189.9	195.6	250.8	201.0

3.6 Zone discrepancy of seabuckthorn stands effecting soil moisture environment

Many researches [9,10] have showed that the soil dry layer can be formed with the growth of vegetation on loess plateau. Namely, that soil moisture is depleted excessively during the growing stage of vegetation causes a little soil moisture layer in a definite soil depth range and soil moisture in the layer couldn't be compensated by rainfall in raining season in a relative long term.

Fig.4 has showed the discrepancy of seabuckthorn forest using soil moisture in Ansai semi-arid forest-steppe zone and Chunhua semi-humid deciduous broad-leaf forest zone in loess hilly and gully region in 1994.

In the semi-arid region, soil moisture of seabuckthorn forest in depth of 20 cm—40 cm is higher and the range is 12.97%—14.31%. But in depth of 40 cm—350 cm is very low and the range is 5.87%—6.81% closing to the wilting moisture of 5.0% in the region. It showed that expense of soil water in seabuckthorn forest is slightly larger than the income perennially, soil layer in seabuckthorn forest is drought because of vegetation transpiration and the growth of tree only relies on annual rainfall to maintain.

Chunhua county is in the semi-humid region, which mean annual temperature is 9.8℃, mean annual

precipitation is 600.6mm and degree of dryness is 1.1—1.38. Soil water content of different soil layer in seabuckthorn forest is more higher than that in semi-arid region, the range of soil moisture in the depth of 0—350 cm is 12.36%—18.50%. The mean soil moisture of 350 cm depth is 15.79% which is 67.88% of the field moisture capacity (23.26%). Soil moisture in the seabuckthorn forest maintains a basic balance state perennially.

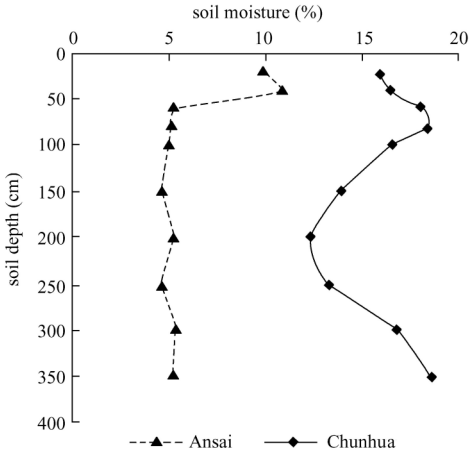

Fig. 4 Utilization of seabuckthorn stands to soil moisture in different regions

4 Conclusion

(1) effect of the seabuckthorn and its mixed stands on reducing runoff and sediment is different with the variations of structure and mixed patterns. Growing well and having 2 cm~4 cm depth litter in the woodland, pure seabuckthorn forest has better soil and water conservation function than the other stands. On the other hand, pure seabuckthorn forest has depleted more soil moisture than the other mixed forests. Therefore, we should consider the two factors together in vegetation construction.

(2) In April, seabuckthorn forest has low soil moisture and depletes less because of drought climate and no growth of branch and leaf. In May, branch and leaf of seabuckthorn start to grow and the climate is still drought, the stand depletes soil moisture more seriously. In the rainy season from July to September, seabuckthorn grows vigorously and soil moisture is depleted seriously by transpiration, soil moisture in the stands has a slightly recovery. Soil moisture has an obvious recovery in October after the compensation to soil moisture in rainy season.

(3) Pure seabuckthorn forest in 5 ages consumes little soil moisture and mainly focuses on the shallow soil layer, seabuckthorn forest has utilized soil moisture in shallow and deep layer in 6 ages and 50 cm—280 cm layer soil moisture can be recovered well after rainy season. Soil moisture in 8 ages has descended rapidly and there is a low-humid soil layer which soil moisture is about 5.0% in the depth of 150 cm—500 cm.

(4) Effect of slope location and direction on soil moisture in seabuckthorn stands is remarkable. Soil moisture of seabuckthorn stands in the down is better than that in the upper in the depth of 0—500 cm and the discrepancy between the upper and the down is 1.16%. Soil moisture in different stands on northern slope is higher than that on eastern slope. Therefore, it is in favor of stable growth to plant seabuckthorn tree in the down and on northern slope according to the soil moisture status.

(5) Mean value of soil moisture in seabuckthorn and its mixed stands is less, range of the mean values in the layer of 0—400 cm layer is 0.063 $cm^3 \cdot cm^{-3}$—0.084$cm^3 \cdot cm^{-3}$. In the perpendicular variation of soil moisture utilization intensity of seabuckthorn and its mixed forests to soil moisture is higher in the layer of 0—200 cm and soil moisture has a slowly increase in the layer of 200 cm—400 cm with the increase of depth. Mean soil moisture value in pure seabuckthorn stand is lower than that in its mixed stands no matter which on the northern or eastern slopes. Difference range between pure seabuckthorn and its mixed stands is 0.005 $cm^3 \cdot cm^{-3}$—0.020 $cm^3 \cdot cm^{-3}$.

(6) The discrepancy of seabuckthorn forest using soil moisture in Ansai semi-arid forest-steppe zone and Chunhua semi-humid deciduous broad-leaf forest zone is remarkable. In the semi-arid region, soil moisture of seabuckthorn forest in the depth of 350 cm is very low, the expense of soil water forest is slightly larger than the income perennially and the growth of tree only relies on annual rainfall to maintain. In the semi-humid region, soil water content of different soil layer in seabuckthorn forest is much higher than that in semi-arid region and it could maintain a basic balance state perennially.

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