Soil Improvement of Seabuckthorn Plantations and Its Characteristics of the Roots in Loess Plateau

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Abstract: Through determined the root amounts and nutrient status in the woodland of *Hippophae rhamnoides* plantations in the typical regions of the Loess plateau, the results show that the roots amounts of sea-buckthorn plantations distribute the form as anti-pyramid in the soil and the form changes into a parabola with the stand-age increasing. The root length and its surface area gradually decrease from the topsoil to the subsoil and cut down with the root's diameter increasing. The nutrient percentage and accumulating contents in the woodland of sea-buckthorn plantations are much higher than those in the farmland or grassland, especially organic matter and N contents in the stands, and improving K availability in the stands. However, sea-buckthorn plantations put obviously up the function of improving and fertilizing soil.
Keywords: *hippophae rhamnoides'* plantations, soil improvement, loess plateau

Hippophae rhamnoides is extensively distributed in the "three north" area of China and is a kind of shrub that can be used to plant water and soil conservation forests and windbreak or sand-fixing forests. As a result of its economic benefits, ecological benefits and alone medical value for the health, sea-buckthorn has caused the concerns related departments. In order to develop and use the resources of sea-buckthorn for the better so as to control rapidly the Loess Plateau, two plots were selected in Lingyou County of Shaanxi Province and Qing'an of Gansu Province, and the root amounts and nutrient status in the woodland of sea-buckthorn were determined, then the distributional status of its roots and its effects on soil improvement were studied.

1 A survey of studying plots

The experimental areas were chosen in Linyou County and Qing'an County, which are located in the typical region of the Loess Plateau. Qing'an is located at the east longitude 105°02'—106°02', north latitude 34°43'—35°10'. The climate there belongs to semi-moist and warm temperate zone, and annual average temperature is 10.4℃. In the hottest month, the average temperature is 22.8℃, while the temperature of the coldest month is –3.14℃. The cumulative temperature higher than 10℃ is 3510℃. Annual average rainfalls are 507.4 mm. The amount of annual average evaporation is 1,449.2 mm. Zonal soil is loess. Original natural vegetation had been destroyed while artificial forests, grasses and shrubs are mainly distributed there. Linyou is situated at east longitude 107°19'—108°02', north latitude 34°33'—34°58'. The climate belongs to the season-wind of continental type and semi-moist warm temperate zone. Annual average temperature is 9.2℃. The temperature of the hottest month is 21.8℃ and that of the coldest month is 4.2℃. The cumulative temperature higher than 10℃ is 2,935℃. Annual rainfalls are 640.4 mm. Zonal soil is loess and the natural vegetations are not existed anymore there but artificial forests, grasses and natural shrubs are in the area.

2 The methods of studying

First, in the studying area, the typical sea-buckthorn stands are chosen and sampling units by 10m×10m are set. The sampling units are classified by the stand-age into four class namely, Ⅰ(2-5 age), Ⅱ(6-10 age),Ⅲ(11-15 age),Ⅳ(>15 age). Then, the stands' factors are surveyed by the conventional methods, that is, 3-4 roots on average are dug at each sampling unit and the number of the roots is calculated according to the different soil layers and diameter classes. Generally the roots are divided into 6 classes, such as 1 class (0.1cm—0.5cm), 2 class (0.5cm—1.0cm), 3 class (1.0cm—2.0cm), 4 class (2.0cm—3.0cm), 5 class

(3.0cm—4.0cm) and 6 class (>4.0 cm). The samples of vegetations, leaf-litter and soil are chosen by setting a small square with 1m×1m and must be set on diagonal line. The soil samples are taken according to different layers, that is, 1cm—10cm, 10cm—30cm, 30cm—50cm. In addition, setting barren hillside, grassland and farmland are taken as the reference and all samples are ready to be used later after drying, smashing, filtering and putting them into the bottles. As for chemical analysis of soil samples, conventional methods are adopted, namely, determined the contents of whole N，whole P，whole K, quick-acting N, quick-acting P, Ca^{2+}, Mg^{2+} and value of CEC.

3 An analysis of results

3.1 The distribution and function of the sea-buckthorn roots

3.1.1 A spatial distribution of the roots

Although the roots of sea-buckthorn plantations are strong, the top roots aren't divided evidently and most of them grow up along the horizontal directions. The Table 1 shows that the roots' distribution of sea-buckthorn plantations form anti-pyramid, that is, the distribution of the topsoil (1cm—15cm) is as main part, taking up about 73.8%—84.55% in the amount of the roots. However, there is little the root's distribution in the subsoil (<35cm).

Table 1 The roots' distribution of the sea-buckthorn plantations in the different soil layers

Regions	Tree age	Roots' wet weight (t/hm^2)	Topsoil (%)	Mid soil (%)	Subsoil (%)
Qing'an	6	3.78	67.51	30.99	1.50
	8	6.98	78.16	21.84	0.00
	9	10.39	88.40	11.60	0.00
	11	3.22	65.66	34.43	0.00
Lingyou	4	4.53	74.16	20.43	5.41
	7	10.29	79.95	16.08	3.98
	13	5.84	67.50	24.22	8.28

Table 1 above shows that the number of Ⅰ age-class roots decides that of the topsoil but Ⅱ age-class roots decide the mid-soil roots.

3.1.2 A distribution of the roots with different length

The root length is one of an important indicator to study the roots because of its characteristics what can reflect the nature of the roots. According to the practical results of surveying in the sampling plots of sea-buckthorn plantations in Qing'an, the total length of sea-buckthorn roots on each unit area are calculated (Table 2).

Table 2 The distribution, surface area and the length of the sea-buckthorn roots in Qing'an

Tree age	Total root length (km/hm^2)	Topsoil (%)	Mid-soil (%)	Subsoil (%)	Surface area (m^2/hm^2)	Topsoil (%)	Mid-soil (%)	Subsoil (%)
6	160.076	59.39	38.14	2.48	2,965.66	56.20	40.65	3.16
8	442.973	63.49	36.51	0.00	6,377.97	66.17	33.83	0.00
9	472.611	90.00	10.00	0.00	8,775.47	85.80	14.20	0.00
11	182.066	72.43	27.57	0.00	3,018.56	66.28	33.72	0.00
Mean		71.33	28.06	0.61		68.61	30.6	0.79

The Table 2 shows that the distribution rules of different length of the roots on the different soil layers are that the longest is in the topsoil, the middle length is in the mid-soil and the least is in subsoil, taking up 71.33%, 28.06% and 0.61%, respectively.

The distribution rule of the roots' length in the different root-classes is that the root length obviously becomes shorter and shorter with the increasing of the roots' diameter. The results also show that the Ⅰ class roots give the most contribution to the root's length, accounting for 71.04% in the total length of the roots, but Ⅱ class roots and Ⅲ class roots just only take up 25.69%.

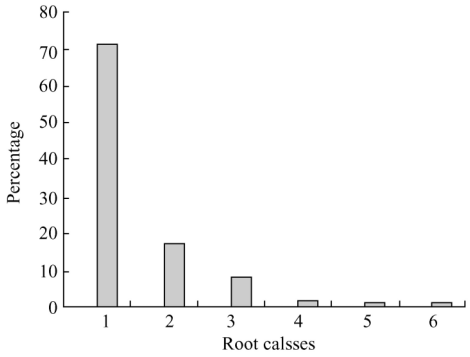

Fig. 1 The distribution rates of root legth on different root class of seabuckthorn plantations

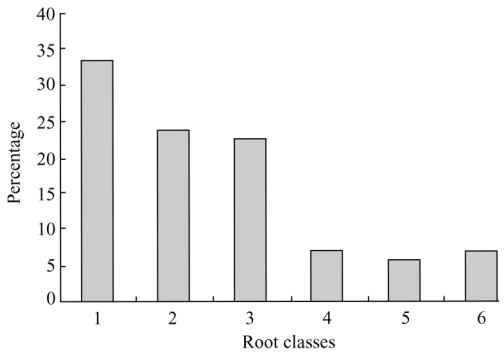

Fig. 2 The distribution rates of roots surface area on the different root class of seabuckthoen plantations

3.1.3 The distribution of the roots' surface

The root's surface is main interface which can conduct the exchange of energy between plants system and soil one, therefore, its distribution directly affect the amount of water and nutrition up-taking from soil and are related with the process of plant's life and its production force.

Seeing each root of sea-buckthorn as an approximate cylinder, its surface area is calculated respectively. Furthermore, reckoning the total area of the roots in the woodland on each unit. The observed value of the roots' length and diameter in the woodland of Qing'an is in Table 2.

The Table 2 shows that the distribution of root's surface in the different soil layers with anti-pyramid shape, but the rate of the roots' surface in the topsoil is smaller than that of the length and wet weight of the roots. In addition, as far as the root's surface area in each root class are conserved, the area of Ⅰ class root take up the most part of the whole area. Therefore, the order of effect on the matter's exchange between plant and soils is 1 class, 2 class and 3 class. 4,5,6 class roots are just a little in the area of surface area (Fig.2)

3.2 The functions of the roots

The roots are organs that plants directly touch soil. They not only grow up and respiration in soil but also suck up the moisture and the nutrition materials. In addition, roots, its dead body, falling matter and exudates abstract or stimulate the activities of the microbes in soil, especially the roots can produce the root nodule bacteria having a symbiotic relation with the roots, which can directly fix N in the air and make it become the organic compound for the plants. The dead bodies of the roots are one of sources that can produce the organic matters in soil, playing an important role in forming the soil structure.

3.2.1 The effect of the roots on soil nutrition

In the system of roots and soil, water, fertile, air and soil have directly influences on the roots' increment, and then further affect the change the physical and chemical characteristics of soil. In the process of the soil development, the exchange of the nutrient ions is done in the soil layers. This process is certainly related to the surface area of the roots. The results show the correlative analysis between the nutrient contents in the different layers of soil and the roots' surface area in the sea-buckthorn plantations (Table 3).

Table 3 The correlative analysis between nutrient contents and surface area in the different soil layers

Soil layers	Correlation coefficient					
0cm—15cm	Mg^{2+}	Ca^{2+}	K^{+}	CEC	P	N
	0.6989	0.6675	0.6473	0.6248	0.5828	0.4458
15cm—30cm	CEC	K^{+}	P	Mg^{2+}	Ca^{2+}	N
	0.6965	0.6842	0.6764	0.6754	0.6566	0.6524

The Table 3 shows that whether in the topsoil or subsoil, the order of the correlativity between the percentage contents of nutrient elements and the roots' surface area is K^{+}>P>N, Mg^{2+}>Ca^{2+}. However, the correlativity between in the topsoil and the surface area is much higher than that of them in the middle soil. This result is accord with the practical one. The reason for this is that K^{+} and P are exchanged by the surface of the roots, but N in soil mainly comes from the air after fixed by the root nodules. Therefore, the correlativity between K^{+}, P and the root's surface area is higher than that of N.

3.2.2 The amount of root nodules and its distribution in the woodland of sea-buckthorn plantations

The root nodules are matters like tumors produced by like-N microbes after they enter the roots, and these microbes have a symbiosis with sea-buckthorn. According to the survey of root nodules of sea-buckthorn plantations in Linyou and Qing'an, the results show that the most amounts of root nodules are in Ⅱage class (6—8 age), others are in Ⅰage class(2—5 age), but just a little is in Ⅲ age class (Table 4).

Talbe 4 The root nodules' distribution of the sea-buckthorn plantations in the different age class

Regions	Wet weight of the root nodules (kg/hm^2)			
Lingyou	4 age		7 age	13 age
	62.230		123.763	28.908
Qing'an	6 age	8 age	9 age	11 age
	81.600	151.700	106.080	22.052

In addition, the root nodules of sea-buckthorn plantations mainly distribute in the topsoil (0cm—15cm), taking up 83.43% in the total wet weight of the root nodules, but in the soil of 15cm—35cm and >35cm, the percentage of the root nodules are 13.52% and 3.05%, respectively. However, the symbiotic rates of root nodule bacteria are greatly different in the different root class, Ⅰ, Ⅱ, Ⅲ, Ⅳ, as the surveying, they are 69.08%, 21.25%, 9.41%, 0.269%, respectively.

3.3 The nutrient status of soil in the woodland of sea-buckthorn plantations

The sea-buckthorn, taking as an important species of trees for water and soil conservation, extensively distributing "three north" area of china, not only should be understood in its function of preserving water and fixing soil but also its effects on the nutrient status of soil. So through determination of the nutrient elements in the woodland of sea-buckthorn plantations, the nutrient status of soil in the different area and stands-age is understood and sea-buckthorn effects on it is also assessed.

3.3.1 The distribution of the nutrition in the woodland

As a result of sea-buckthorn effects on fixing N, the whole N contents in the woodland of sea-buckthorn plantations are very higher in the topsoil, taking up 49.71%—65.63%(Table 5). The quick-acting N takes up 0.78%—4.92% and its rate is greater and greater with the soil depth increasing.

Through comparing the N content in the woodland of sea-buckthorn plantations with that in the farmland and the grassland, the former is higher than the latter. Especially in the topsoil, the effects of

fixing N in the woodland of sea-buckthorn plantations can improve the soil fertility of the woodland.

The P and K contents in the woodland are just a little, taking up about 0.0975%—0.161% and 1.7615%—2.4630%.The P and K contents gradually decrease from the topsoil to the subsoil and regularly distribute in each soil layers. But the effect of P in the woodland of sea-buckthorn plantations is not stable, and no rules. The quick-acting K contents take up about 0.23%—1.57%, which decrease with the soil depth increasing. In addition, the quick-acting K contents in the woodland are obviously higher than that in the farmland and grassland, generally the former is 0.4—1.26, 0.71 times higher than the latter, respectively. Therefore, the sea-buckthorn plantations can improve the K availability in the woodland.

Table 5 The nutrient contents in the woodland of the sea-buckthorn plantations

Locations	Land type	Soil layers (cm)	Whole N (%)	whole P (%)	whole K (%)	Ca^{2+} (%)	Mg^{2+} (%)	Quick-acting N	Quick-acting P	Quick-acting K	CEC (mg/100g)	Organic matters （%）
								(mg/kg)				
Lingyou	Woodland	0—10	0.2273	0.1625	2.3589	0.0065	3.3707	36.946	0.9463	278.135	21.522	4.45
		20—30	0.0710	0.1412	2.4888	0.0089	3.6393	25.791	5.1301	104.037	17.527	1.40
		40—50	0.0511	0.1066	2.3951	0.0047	2.9104	23.654	6.1108	100.365	16.367	0.93
	Farmland	0—10	0.0551	0.1713	2.6510	0.0080	3.0255	35.000	2.855	137.434	18.044	0.79
		20—30	0.0442	0.1633	2.7527	0.0027	1.3375	33.833	5.796	119.134	16.238	0.38
		40—50	0.0306	0.1411	2.8207	0.0084	2.1815	23.217	6..776	126.454	15.981	0.36
	Grassland	0—10	0.1650	0.1299	2.4198			26.02	6.780	152.0	21.651	4.13
		20—30	0.1068	0.1100	2.4065			25.08	3.270	81.0	21.393	1.64
		40—50	0.0763	0.1015	2.4020			20.04	2.570	83.0	15.981	0.81
Qing’an	Woodland	0—10	0.1888	0.1595	2.1948	0.0091	4.1483	31.111	8.2547	252.114	13.489	3.12
		20—30	0.0730	0.1342	2.3047	0.0081	3.5625	20.300	6.2627	104.49	11.942	1.73
		40—50	0.0538	0.1202	2.3586	0.0099	3.8950	16.6057	4.6753	107.54	10.118	1.10
	Farmland	0—10	0.0646	0.1593	2.2893	0.0148	6.9385	23.917	11.257	117.304	10.310	1.01
		20—30	0.0503	0.1562	2.2264	0.0089	4.6387	19.833	9.577	93.519	10.053	0.88
		40—50	0.0384	0.1554	2.3555	0.0051	4.3298	16.333	6.216	89.853	8.506	0.62
	Grassland	0—10	0.0747	0.1674	2.2407	0.0061	2.6618	5.071	5.726	128.86	12.965	1.34
		20—30	0.0426	0.1502	2.3784	0.0086	3.6393	4.794	4.885	99.01	11.341	0.53
		40—50	0.0389	0.0353	2.4181	0.0071	3.7544	4.8855	9.2965	99.93	9.15	0.47

3.3.2 the contents of the organic matters and CEC

The organic matters in the woodland of sea-buckthorn mainly concentrate in the topsoil, about 2.65%—4.45%, and accounting for 52.44%—65.63% of the total amounts in the whole soil section. The contents of the middle soil and the subsoil are just a little, taking up about 0.93%—1.73%. The contents of organic matters in the woodland of sea-buckthorn plantations definitely improve after contrasting the farmland and grassland, and the former is 0.63—4.63,0.08—1.33 times higher than the latter, respectively.

CEC in the woodland of sea-buckthorn plantations is about 10.34m/100g—26.6067me/100g and increases by 20.58%—30.88% and 28.90%—31.73% after comparing with the farmland and the grassland.

In conclusion, sea-buckthorn plantations’ effects on the nutrient elements in the woodland have the definite improvement except for P, especially sea-buckthorn plantations have obvious effects on improving the soil N and the organic matters. The effect of K in the woodland of sea-buckthorn plantations mainly is concentrated in improving the K availability.

3.3 The soil improvement in the woodland of sea-buckthorn plantations

The Table 6 shows that the contents of nutrient elements in the woodland of sea-buckthorn plantations are clearly higher than that of farmland and barren hill, which show that sea-buckthorn

plantations is a good kind of trees for soil improvement because of its strong roots. The total amounts of roots reach 7,770kg/hm^2 at a stand in three years, and biological energy and chemical energy produced by the roots affect the physical and chemical nature in the soil. The root's death would increase the contents of organic matters in the soil. In addition, the sea-buckthorn is the no-bean-family plant with the ability of fixing N, therefore, it will increase the contents of nutrient elements.

Table 6 The contents of organic matters in the woodland of the sea-buckthorn plantations

Soil layers	Qing'an (8 age)			Lingyou (11 age)		
（cm）	Woodland	Farmland	Grassland	Woodland	Farmland	Grassland
0—10	3.12	1.01	1.34	4.45	0.79	4.13
20—30	1.73	0.88	0.53	1.40	0.38	1.64
40—50	1.10	0.62	0.47	0.93	0.36	0.81

The leaf-litter is abundant in the woodland of the sea-buckthorn plantations that are hardly disturbed by the natural and people. Its amounts of leaf litter can reach 22,200kg. The plants such as grass family, bean family and composite family can be changed into the organic matters by breaking down them. So this process makes the contents of organic matters higher and higher (Table 7).

Table 7 Correlative analysis of the nutrient contents and organic matters in the woodland of sea-buckthorn plantations

Locations	Whole N	Whole P	Whole K	Ca^{2+}	Mg^{2+}	Quick-acting N	Quick-acting P	Quick-acting K	CEC
QingO.M	0.9797③	0.4514	–0.7658	0.0558	–0.09536	0.9348③	0.7591②	0.6179①	0.7979③
LingO.M	0.9398③	0.5830②	–0.3087①	0.1484	0.2531	0.7971③	0.8710③	0.9862③	0.7066②

Note: ③reliability 95%, α=0.01 obviously correlation; ②reliability 95%, α=0.05 obviously correlation; ① reliability 95%, α=0.10 reliability.

The results show that the order of the correlation between the contents of the organic matters and the whole amounts of nutrient elements in the woodland of sea-buckthorn plantations is N_{whole} >CEC>P_{whole}> Ca^{2+}>K_{whole}>Mg^{2+}, but the order of the correlation between the contents of organic matters and that of the efficient components in the nutrient element in the soil in $N_{quick\text{-}acting}$>$P_{quick\text{-}acting}$>$K_{quick\text{-}acting}$.

The result shows that the nutrient elements of the most correlation between the contents of the nutrient elements and the organic matters is N and CEC, the next are P and K. In other words, the contents of the organic matters in the woodland directly affect that of N, P and K etc. in the woodland, less or more.

4 Summary

The root's distribution of sea-buckthorn plantations in soil is anti-pyramid form, and the increasingly trend of the roots is a parabola with the stand-age increasing. The root length and the surface area increase with the soil layers increasing, but they decrease with the root class increasing.

The contents of the nutrient elements such as N_{whole}, $N_{quick\text{-}acting}$, $P_{quick\text{-}acting}$ and CEC value in the woodland of sea-buckthorn plantations cut down from the topsoil to the subsoil. The $K_{quick\text{-}acting}$ contents in the topsoil are much higher than that in the middle and subsoil, but that of Ca^{2+} and Mg^{2+} are stable.

AS for the effects of sea-buckthorn plantations on the soil nutrition in the woodland, its effects on N, P, K in the woodland are higher than those in the farmland and the grassland. Especially sea-buckthorn plantations have an obvious role in improvement of N and the organic matters. But its effect on K is mainly improvement of the K availability.

Whole N and $K_{quick\text{-}acting}$ in the woodland of sea-buckthorn plantations can reach 1—2 class. The contents organic matters can reach 1—3 class.

For the contents of the nutrients elements in the woodland of sea-buckthorn plantations, N_{whole}, $N_{quick\text{-}acting}$ and CEC increase with the stand-age increasing while the $K_{quick\text{-}acting}$, P_{whole} contents in the topsoil are not only higher than those of the middle and subsoil but also increase with the stand-age increasing. The Ca^{2+} and Mg^{2+} change in the contents has not rules.

The N_{whole}, P_{whole}, $K_{quick\text{-}acting}$ and CEC value in the woodland of sea-buckthorn plantations are much higher than in the farmland and grassland, and their relation expression is as follows:

N_{whole}: woodland>grassland>farmland $N_{quick\text{-}acting}$: woodland>grassland>farmland

P_{whole}: woodland>farmland>grassland $P_{quick\text{-}acting}$: woodland>grassland>farmland

$K_{quick\text{-}acting}$: woodland>grassland>farmland Ca^{2+}: woodland>grassland>farmland

Mg^{2+}: woodland>farmland>grassland CEC value: woodland>grassland>farmland

The correlation between the organic matters and N, P, K in the woodland of sea-buckthorn plantations is very strong, and its order is N>P>K.

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