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Role of Seabuckthorn in Improvement of Soil Fertility in Cold Desert of Himalayas

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ABSTRACT

Seabuckthorn *(Hippophae* L.) is a winter hardy, deciduous shrub belonging to the family Elaeagnaceae. It is an actinorhizal plant characterized by its ability to form a symbiosis with the nitrogen fixing actinobacteria *Frankia* in the root nodules. It is found in the cold desert of north-western Himalayas at elevations ranging between 3200-4500 m above sea level. Extreme climate, scant rainfall, massive snowfall, high wind velocity, extreme temperature condition, sparse vegetation, high UV radiation, and extremely xeric conditions are the common features of this region. As it develops extensive root system making it ideal for soil binding and its strong root system and nitrogen fixing ability improves soil quality or fertility. An attempt has been made to study the effect of seabuckthorn on soil fertility in comparison to willow and wasteland in relation to increasing altitudes in cold desert of western Himalayas in Himachal Pradesh (India). In order to achieve the objective of the present study, soil samples were collected at six different altitudes, where *Hippophae rhamnoides* was found naturally and were chemically analyzed. The result showed that soil pH ranged from 8.2 to 7.8 in the soil top layer (0-10 cm) and decreased with an increase in altitude and increased with an increase in soil depth. Soil organic carbon ranged from 1.05 to 2.35 per cent in the soil top layer and increased with an increase in altitude and decreased with an increase in soil depth. The values of soil available macronutrients also varied, i.e. N (125 to 205 kg ha^{-1}), P (15 to 31 kg ha^{-1}), K (94 to 284 kg ha^{-1}), S (28 to 53 kg ha^{-1}), exchangeable Ca (8.56 to 10.20 cmol (p+) kg^{-1}) and Mg (2.3 to 3.6 cmol (p+) kg^{-1}), respectively, in the soil top layer and increased with an increase altitude and decreased with an increase in soil depth. Also, status of available micronutrients varied i.e. Fe (3.9 to 11.4 mg kg^{-1}), Cu (1.2 to 3.8 mg kg^{-1}), Zn (1.8 to 1.1 mg kg^{-1}) and Mn (4.5 to 2.3 mg kg^{-1}), in the soil top layer and decreased with an increase in soil depth. Available Fe and Cu increased and available Zn and Mn decreased with an increase in altitude. Values of organic carbon, available N, S, exchangeable Ca, Mg and available micronutrients Fe, Cu, Zn and Mn were in higher contents under seabuckthorn vegetation than willow and wasteland. Hence, seabuckthorn with its rich nodules and its increasing nutrient quality especially organic carbon, available N, P and K contents proved to be a wonder plant, which plays a significant role in increasing soil nutrients and improving the fertility in the soils of high altitude cold desert of Himalayas.

Keywords: Seabuckthorn, nitrogen fixing, soil fertility and cold desert of Himalayas.

INTRODUCTION

In India, cold desert comes under the trans Himalayan zone, which is approximately 1,03,113 sq. km. These are arid areas not affected by the Indian monsoons because they lie in the rain shadow of the Himalayan mountain systems. The bulk of the Indian cold desert lies in Ladakh region of Jammu and Kashmir, Lahaul & Spiti, Pooh sub division of Kinnaur, Pangi area of Himachal Pradesh and some areas of northern Uttaranchal and Sikkim. Extreme climatic conditions, scant rainfall, massive snowfall, high wind velocity, extreme temperature conditions from low to high, sparse vegetation, high UV radiation, intense solar radiation and extremely xeric conditions are the common features of the this region (Devi and Thakur, 2011).

The diverse climate and the varied environmental conditions prevailing in cold desert of Himalayas support diverse habitat and ecosystems with equally diverse life forms. But this unique and the most beautiful corner of the Himalayas is under threat due to various environmental problems prevailing in the region, which include the utilization of the slope, land resources for agriculture, poor water management, soil erosion and degradation of soil fertility. Erosion results in the degradation of productivity of soil in a number of ways.

It was found that seabuckthorn *(Hippophae rhamnoides* L.) plantation played a beneficial role in controlling soil erosion and improving soil fertility in Loess Plateau area of China (Qian, 1986). Zhao *et al.* (1990) proposed that utilization of seabuckthorn is superior to any other tree in afforestation, soil conservation and wasteland reclamation.

Seabuckthorn *(Hippophae* L.) a beautiful plant with multipurpose properties is a perennial, woody, nitrogen fixing and thorny, deciduous shrub or a form of tree covered with silvery scales belongs to family *Elaeagnaceae* (Rousi, 1971). It naturally grows in Europe and cold regions of Asia (Rongsen, 1992). Therefore, plant is naturalized in snowfall or low temperature conditions, which meet the chilling requirement of the plant. It tolerates temperature as low as -40^{o}C during winter. There is natural distribution of seabuckthorn in the regions with the temperature isolines over 25^{o}C on the average in the summer (Gupta *et al.*, 2001). It has been reported growing in about 40 countries like Russia, China, Indian Himalayas and Central Asia, Germany, Finland, Sweden, etc. It has also been introduced in Canada, USA, Bolvia, Korea and Japan (Singh, 2003).

Seabuckthorn is one of the most magical plant resources with higher value of economy and ecology. Its berry is a very rich source of vitamins and is called treasure of bio-activity substance because of its over 190 bioactivity substances possessing unique medicinal properties (Maertz, 2006). With help of scientific studies and researches, seabuckthorn has become the source of important medicinal and nutritional products in China, India, Russia, Germany, Finland, Sweden, etc. Yet seabuckthorn is much more than just a pretty plant with nutritious berries. It also has significant characteristics such as wide adaptation, fast growing rate, strong coppicing, suckering habits and efficient nitrogen fixation, this species is often the first woody species colonizing open areas (Rousi, 1965). Seabuckthorn is ecologically sound for soil and water conservation, land reclamation and rehabilitation, reforestation, establishment of wildlife habitats, fuelwood production, soil improvement, fixing of atmospheric nitrogen, and farmland protection (Schroeder, 1990). This plant is also equally important for firewood, fodder and serves as a soil binder species. Therefore, seabuckthorn should serve as a measure to safeguard medicinal and nutritional plants, to conserve biodiversity and environment and to generate sustainable income source for local people (Rousi, 1971).

Seabuckthorn has an outstanding ability to take roots even in poor soils, because of its ability to fix atmospheric nitrogen through the presence of symbiotic bacteria *Frankia (Actinomycetes)* in the root nodules of the plant. Root nodules of seabuckthorn have been found to fix 180 kg of nitrogen/ha/year, which generally improves soil fertility. The results improved root growth enhances the entire soil ecosystem in the form of rich organic matter, more oxygen and more soil organism, which means more soil biodiversity (Jike and Xiaoming, 1992).

Seabuckthorn *(Hippophae rhamnoides* L.) because of its strong canopy has the ecological function of protecting against wind and preventing sand from drifting, improving the biological diversity and also recovering and rebuilding the ecological system. Branching in seabuckthorn is intense and upward oriented. So its dense canopy intercepts rainfall and lessens the speed of rain drops. This releases the rainwater slowly on the ground canopy and thick layer thus, protect the soil from erosion (Chengjian and Daiqiong, 2002). For the farmers living in the mountains, seabuckthorn offers the opportunity to maintain a sustainable livelihood, providing healthy foods, variety of medicines and protecting their land from soil erosion (Lu Rongsen, 1992; Ansari, 2003).

It is well understood that the key to long-term success in increasing soil fertility in cold deserts is to encourage the seabuckthorn plantations. The present study summarizes the effect of seabuckthorn plantation on soil fertility. The results will help to provide a platform for future research into the role of seabuckthorn in improvement of soil fertility in cold desert of Himalayas. The main aim of the study was to examine the effect of seabuckthorn on soil fertility in the cold desert regions of Himalayas.

MATERIALS AND METHODS

Study Area

An investigation was conducted in Spiti cold desert of western Himalayas, which has a geographical area of 5,582 sq.km., situated between 32°05'55.1"-78°21'99.8" N latitude and 32°26'72.0"-77°53'81.1" E longitude in the extreme North-East region of Himachal Pradesh, India.

Field Study Experimental details

The field experiment was carried out in 6 places at different altitudes in an elevation range of 3390-4040 m above sea level in Spiti valley. Soil samples at the depths of 0-10 cm, 10-20 cm and 20-30 cm were collected under seabuckthorn *(Hippophae rhamnoides),* willow *(Salix daphnoides)* vegetation and control land. Soil samples were collected from the different locations such as Tabo (3390 m asl), Shichling (3520 m asl), Lingti (3560 m asl), Shego (3615 m asl), Rangrik (3790 m asl) and Hansa (4040 m asl) with increasing altitude.

Soil sampling

Soil samples were collected from various sites at soil depths of 0-10 cm, 10-20 cm and 20-30 cm from 5 different locations within 3 plots, each of 10 m * 10 m size, chosen randomly in every site with the help of a soil auger and were thoroughly mixed together making 5 replicates of each samples from each soil depth weighing about 200 g and subsequently stored in polythene bags for the determination of chemical properties.

Figure 1. Seabuckthorn *(Hippophae rhamnoides)* **forest, Spiti, HP.**

Laboratory analysis

The processed soil samples were analyzed chemical properties (soil organic matter, available N, P, K, S, exchangeable Ca

and Mg available micronutrients Fe, Cu, Zn and Mn) from the following standard methods.

a) Soil pH: The pH of soil water suspension was determined using electrode pH meter. 10 g soil sample was mixed with 25 ml distilled water in 1: 2.5 ratios. The suspension was stirred intermittently with glass rod and wait for 30 minutes. Then electrode was inserted into supernatant and pH was recorded (Jackson, 1967).

b) Organic carbon: A 1 g finely ground soil sample was taken into 500 ml conical flask, to which 10 ml of 1 N $K_2Cr_2O_7$ and 20 ml conc. H_2SO_4 were added. Then content was shaken for a minute and allowed to set aside for exactly 30 minutes. Then about 1.0 g sodium fluoride or 10 ml orthophosphoric acid, 200 ml distilled water and 10 drops of diphenylamine indicator were added and shaken vigorously to mix. The solution was titrated against N/2 ferrous ammonium sulphate from a burette, till the colour changes from violet to bright green and quantity of organic carbon of the soil was estimated (Walkey and Black, 1934).

c) Available N: A 2 g of soil sample was taken in Kjeldahl's distillation flask, to which 20 ml of $KMnO_4$ and 20 ml of NaOH was added and closed with the cork. Approximately 10 ml of Boric acid solution was taken in the 125 ml conical flask with help of pipette. Distill the ammonia gas at a steady rate and collect about 50 to 60 ml of distillate. Titrate the boric acid solution containing dissolved ammonia against 0.01 N H_2SO_4. The end point is reached when the colour changes from bluish green to wine red. Available N was calculated by alkaline potassium permanganate method (Subhaiah and Asija, 1956).

d) Available P: Available P was estimated in the soil by Alkali extraction. Alkali solution of 0.5 M $NaHCO_3$ (pH 8.5) is used, known as Olsen's reagent prepared by dissolving 42 gm $NaHCO_3$ in distilled water and making volume to 1 litre and adjusting pH of the solution to 8.5 by adding either NaOH or HCl solution (Olsen *et al,* 1954).

e) Available K: The most commonly used method for K determination is by flame photometry. A 5 g soil sample was taken in a pH bottle, to which 25 ml 1N NH_4OAc (pH 7.0) with a pipette (1: 10 ratio) was added. The contents were shaken for 5 minutes on a mechanical shaker and filtered immediately. Prepare a standard curve by adjusting 40 ppm K solution to 100 and 0, 5, 10, 15, 20 ppm K solution accordingly. Take the reading and compare this reading with standard curve and note down the concentration of K from it. Available K was calculated by neutral normal ammonium acetate extraction method (Jackson, 1967).

f) Available S: A 10 g soil sample was taken into a 150 ml Erlenmeyer flask and 50 ml of 0.15 % $CaCl_2$ extraction solution was added in the flask. The contents were shaken for 30 minutes on a mechanical shaker and filtered immediately. Then, 10 ml of aliquot from filtered solution and 10 ml of Morgan's reagent were transferred in 25 ml flask. Addition of 2 ml gum acacia and 1 g $BaCl_2$ was done in the flask and again shaken for 1 minute. After 5 minutes sulphur was calculated with reference to standard curve (Jackson, 1973).

g) Exchangeable Ca and Mg: A 5 g of air dried soil sample was taken in 500 ml conical flask, to which 50 ml of neutral normal ammonium acetate was added and was allowed to stand for 30 minutes. The contents were shaken on a mechanical shaker and filtered immediately and determine the Ca and Mg by using an Atomic Absorption Spectrophotometer after the removal of ammonium acetate (Jackson, 1967).

h) Available micronutrients: A 10 g soil sample was weighed in clean and dry pH bottle and 20 ml DTPA extracting solution was added in the same bottle. The contents were shaken on a mechanical shaker with a speed of approximately 120 cycles per minute continuously for 2 hours. Then soil suspension was filtered through and the estimation of micronutrients (Fe, Cu, Zn and Mn) in the soil was done by the DTPA method in the Atomic Absorption Spectrophotometer (Lindsay and Norvell, 1978).

i) Statistical analysis: Soil chemical properties were subjected to (ANOVA) analysis of variance. Simple correlation was worked out to establish the relationships between selected soil fertility parameters and along and within increasing altitudes and soil depths as per the procedure outlined by Gomez and Gomez (1984). Relationship was tested at 5% level of significance.

RESULTS AND DISCUSSION

Variation of different soil nutrients with altitude under seabuckthorn in Spiti

A perusal of Table 1 and Figures (2 and 3) showed that soil pH under seabuckthorn in Spiti significantly decreased with an increase in altitude and increased with an increase in soil depth, whereas, soil organic carbon significantly increased with an increase in altitude and decreased with an increase in depth of soil. Similarly, soil available N significantly increased with an increase in altitude and decreased with increasing depth.

Soil available P, available K and available S under seabuckthorn vegetation at different places in Spiti significantly increased with an increase in altitude and decreased with an increase in soil depth. Similarly, soil exchangeable Ca and Mg significantly increased with an increase in altitude and decreased with an increase in soil depth.

Soil available Fe and available Cu under seabuckthorn vegetation in Spiti significantly increased with an increase in altitude and decreased with an increase in soil depth. Whereas, soil available Zn and available Mn significantly decreased with increasing altitude and soil depth.

Variation of different soil nutrients with altitude under seabuckthorn in Spiti

From Table 2 it was found that different altitudes and the species interactions were significant (pd" 0.05) for the soil pH organic carbon, available N, P, K, S and exchangeable Ca, Mg and available Fe, Cu, Zn, Mn. Soil characteristics varied greatly under seabuckthorn than willow and wasteland soils. Compared with willow and wasteland, soil under seabuckthorn vegetation had higher values of pH, organic carbon, available N, S, exchangeable Ca, Mg and available micronutrients Fe, Cu, Zn and Mn. Also, the soil nutrients increased with an increase in altitude, except soil pH and available Zn and Mn.

As we know seabuckthorn *(Hippophae rhamnoides* L.) has an extraordinary capacity to grow and survive under adverse conditions (-40° to 40^{o} C) and has extensive subterranean rooting system with strong soil binding ability useful for soil stabilization, river bank control and water retention and also fixes nitrogen which improves soil quality or fertility. Above results indicated that much more soil nutrients enriched in the seabuckthorn soils than willow and wasteland soils. Soil pH was alkaline in reaction and the similar findings have been reported by Sharma and Kanwar (2010) and Sharma (2011). The soil organic carbon decreased with an increase in soil depth and increased with an increase in altitude and the results were corroborated with findings of Singh and Datta (1988), Lu (2009) and Gong *et al.* (2007).

Available macronutrients (N, P, K and S) increased with an increase in altitude and decreased with an increase in soil depth and similar results were shown by Guo (2003), Sharma (2011) and Zhao *et al.* (2013). Exchangeable ions (Ca and Mg) increased with an increase in altitude and decreased with an increase in soil depth and the similar findings have been reported by Singh and Raman (1982) and Xiaoning *et al.* (2002). Available micronutrients (Fe, Cu, Zn and Mn) decreased with an increase in soil depth, among which available Fe and Cu increased and available Zn and Mn decreased with an increase in altitude and the similar findings have been given by Jalali *et al.* (1989), Parmar (1999) and Sharma (2011).

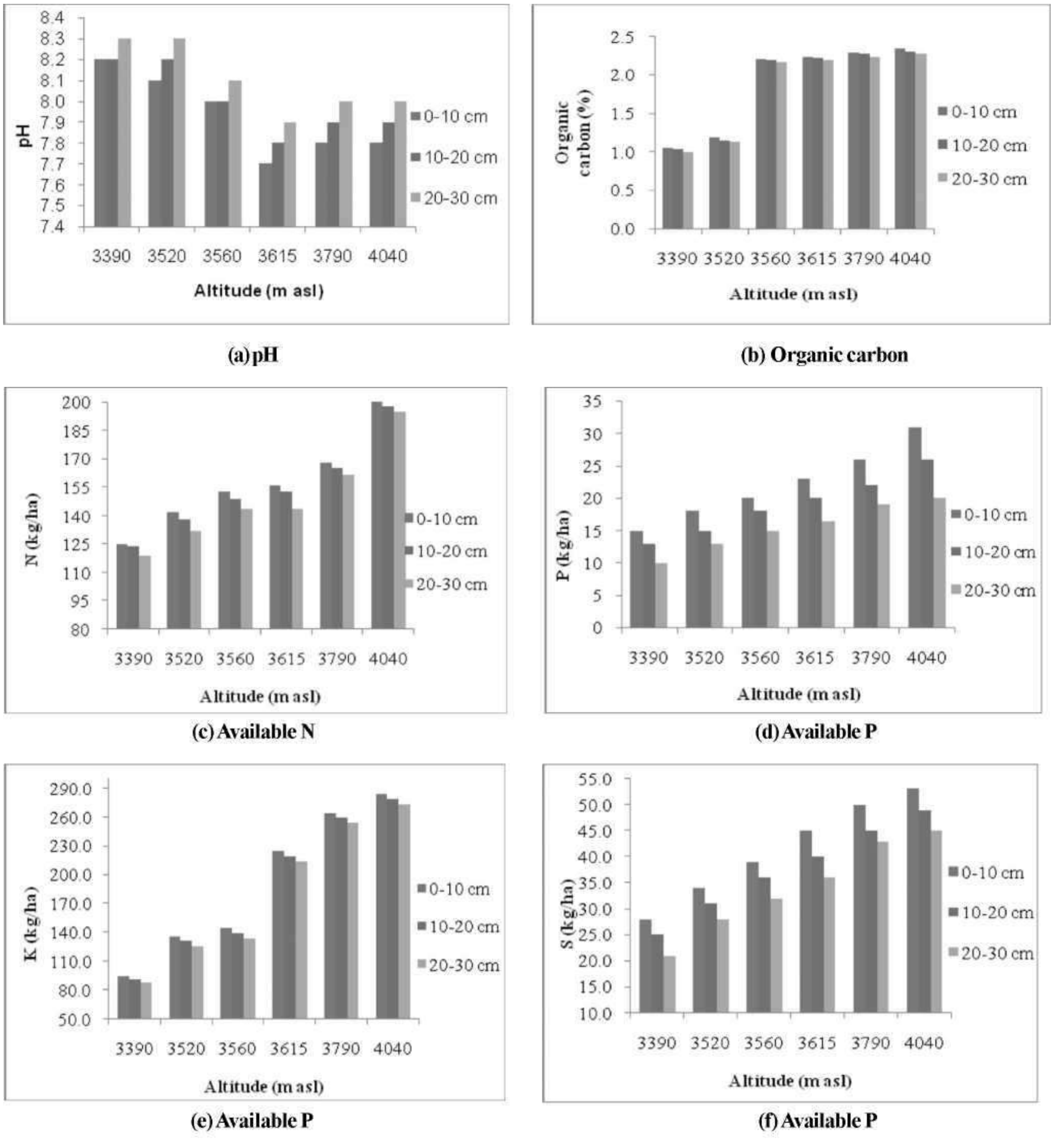

Figure 2. Variations of different soil nutrients in relation to altitude under seabuckthorn in Spiti. a) pH, b) Organic carbon, c) Available N, d) Available P, e) Available K, f) Available S.

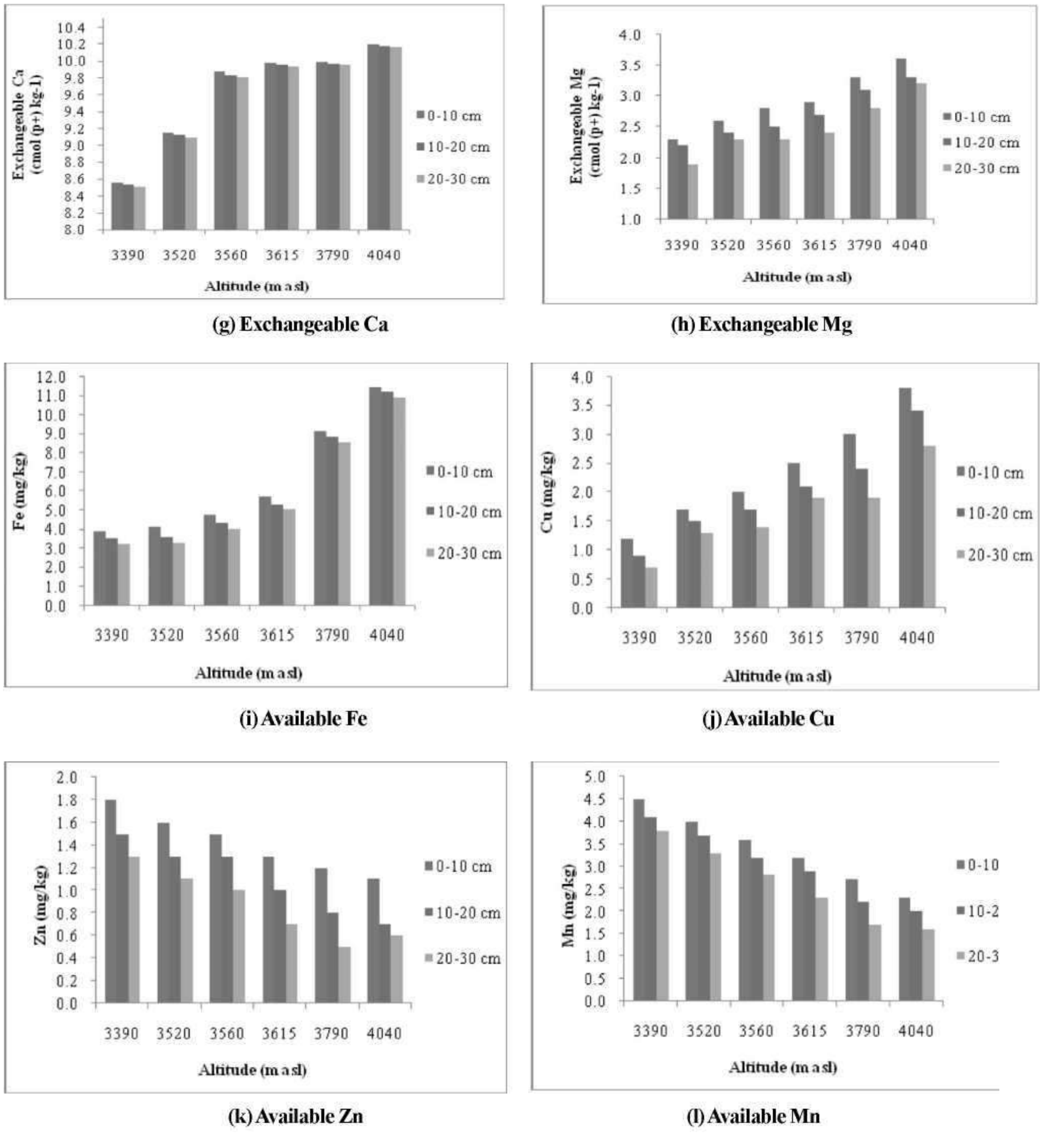

Figure 3. Variations of different soil nutrients in relation to altitude under seabuckthorn in Spiti. g) Exchangeable Ca, h) Exchangeable Mg, i) Available Fe, j) Available Cu, k) Available Zn, l) Available Mn.

Table 1. Integrated effects of the seabuckthorn (Hippophae rhamnoides) on the soil pH, organic carbon and other available nutrients

Locations	Altitude m asl	pH, depth (cm)			OC (%), depth (cm)			Ca (cmol(p+)kg^{-1}), depth (cm)			Mg (cmol(p+)kg^{-1}), depth (cm)		
		(0-10)	(10-20)	(20-30)	(0-10)	(10-20)	(20-30)	(0-10)	(10-20)	(20-30)	(0-10)	(10-20)	(20-30)
Tabo	3390	8.2±0.15	8.2±0.10	8.340.09	1.0540.03	1.0340.02	1.0040.03	8.5640.03	8.5340.03	8.5140.02	2.340.24	2.240.29	1.940.41
Shielding	3520	8.1±0.12	8.2±0.08	8.340.10	1.1840.04	1.1540.02	1.1340.03	9.1540.03	9.1240.01	9.0940.01	2.640.17	2.440.38	2.340.19
Lingti	3560	8.0±0.21	8.0±0.26	8.140.18	2.2140.05	2.1940.04	2.1740.02	9.8740.02	9.8340.02	9.8140.01	2.840.38	2.540.07	2.340.20
Shego	3615	7.7±0.18	7.8±0.18	7.940.19	2.2440.03	2.2240.02	2.240.06	9.9840.01	9.9540.03	9.9340.02	2.940.30	2.740.11	2.440.44
Rangreek	3790	7.8±0.13	7.940.15	8.040.20	2.2940.02	2.2740.02	2.2440.04	9.9940.02	9.9740.02	9.9540.03	3.340.28	3.140.08	2.840.24
Hansa	4040	7.8±0.29	7.940.12	8.040.19	2.3540.02	2.3040.05	2.2840.02	10.2040.02	10.1840.02	10.1640.01	3.640.33	3.340.22	3.240.29
CD($P_{0.05}$)		0.105			0.020			0.013			0.135		
		N (kg ha^{-1})			Ph (kg ha^{-1})			Fe (mg kg^{-1})			Cu (mg kg^{-1})		
Tabo	3390	125±4.03	12441.98	11943.87	1543.02	1341.97	1043.00	3.940.23	3.540.49	3.240.30	1.240.23	0.940.30	0.740.23
Shichling	3520	142±2.13	13844.98	13243.94	1844.03	1542.04	1342.07	4.140.16	3.640.58	3.340.23	1.740.43	1.540.49	1.340.30
Lingti	3560	153±3.03	14941.99	14444.02	2044.01	1842.10	1542.01	4.740.22	4.340.30	4.040.10	2.040.21	1.740.30	1.440.18
Shego	3615	156±2.24	15343.02	14443.97	2343.12	2042.98	1642.11	5.740.24	5.340.32	5.040.50	2.540.48	2.140.12	1.940.40
Rangreek	3790	168±2.28	16541.00	16242.03	2643.00	2243.00	1941.99	9.140.10	8.840.21	8.540.48	3.040.51	2.440.22	1.940.30
Hansa	4040	205±4.95	19845.12	19541.97	3141.01	2645.04	2042.03	11.440.39	11.240.40	10.940.31	3.840.40	3.440.38	2.840.22
CD($P_{0.05}$)		1.630			1.520			0.175			0.149		
		K (kg ha^{-1})			S (kg ha^{-1})			Zn (mg kg^{-1})			Mn (mg kg^{-1})		
Tabo	3390	94±3.98	9143.02	8842.03	2843.02	2542.98	2141.00	1.840.19	1.540.20	1.340.32	4.540.52	4.140.11	3.840.20
Shichling	3520	136±3.03	13140.99	12642.10	3444.10	3141.97	2842.03	1.640.23	1.340.33	1.140.30	4.040.29	3.740.38	3.340.28
Lingti	3560	145±4.98	13943.00	13343.04	3941.00	3643.02	3241.99	1.540.30	1.340.28	1.040.48	3.640.40	3.240.23	2.840.32
Shego	3615	225±2.98	21942.01	21442.03	4542.05	4044.00	3644.01	1.340.32	1.040.22	0.740.20	3.240.22	2.940.10	2.340.31
Rangreek	3790	26443.00	25941.02	25444.10	5045.02	4543.05	4343.17	1.240.21	0.840.19	0.540.18	2.740.37	2.240.21	1.740.29
Hansa	4040	284±4.04	27942.98	27342.98	5342.78	4941.23	4544.79	1.140.10	0.740.13	0.640.21	2.340.21	2.040.19	1.640.52
CD($P_{0.05}$)		4.720			1.590			0.122			0.165		

Table 2. Integrated effect of seabuckthorn, willow and wasteland on the soil pH, organic carbon and other soil nutrients

Locations	Altitude m asl	Seabuck-thorn	Willow	Wasteland	Seabuck-thorn	Willow	Wasteland	Seabuck-thorn	Willow	Wasteland	Seabuck-thorn	Willow	Wasteland
		pH			OC (%)			N (kg ha^{-1})			P (kg ha^{-1})		
Tabo	3390	8.2±0.10	8.1±0.23	8.0±0.18	1.02±0.032	0.96±0.041	0.86±0.034	122.7±4.09	104.7±4.06	91.0±3.96	12.7±3.20	16.0±3.20	8.7±2.00
Shichling	3520	8.2±0.10	8.0±0.18	8.0±0.22	1.15±0.035	1.11±0.036	0.92±0.057	137.3±5.50	120.7±4.41	111.0±5.20	15.3±3.27	17.7±3.16	11.7±2.12
Lingti	3560	8.0±0.23	8.1±0.24	8.0±0.22	2.19±0.038	2.08±0.047	1.20±0.03	148.6±4.74	137.7±3.67	134.0±4.61	17.7±3.27	19.3±3.77	12.3±3.00
Shego	3615	7.7±0.15	7.9±0.5	7.9±0.9	2.22±0.039	2.17±0.04	1.26±0.037	151.0±6.04	149.3±3.53	141.0±4.61	19.7±3.84	22.0±3.57	16.0±2.87
Rangrik	3790	7.9±0.25	7.8±0.25	7.8±0.27	2.26±0.033	2.17±0.042	1.54±0.049	165.0±3.31	157.3±3.96	151.3±4.06	22.3±4.33	25.0±4.03	16.0±3.64
Hansa	4040	7.9±0.20	7.7±0.15	7.8±0.18	2.31±0.042	2.29±0.037	2.01±0.045	199.3±5.76	167.3±4.41	157.3±3.84	25.7±5.50	32.3±3.42	17.7±3.27
CD($P_{0.05}$)		0.180			0.030			2.820			2.630		
		K (kg ha^{-1})			S (kg ha^{-1})			Ca (cmol(p+)kg^{-1})			Mg (cmol(p+)kg^{-1})		
Tabo	3390	91.0±3.74	101.3±6.38	85.1±4.93	24.7±3.74	20.7±2.87	18.0±3.31	8.53±0.031	7.35±0.023	6.50±0.021	2.1±0.30	1.9±0.33	1.7±0.27
Shichling	3520	131.0±4.71	151.3±3.27	147.3±4.87	31.0±3.57	25.3±4.45	22.6±4.00	9.12±0.016	9.03±0.026	7.92±0.018	2.4±0.27	2.1±0.20	1.8±0.13
Lingti	3560	139.0±6.14	161.2±3.56	150.0±4.03	35.7±3.57	27.7±4.21	25.3±4.09	9.84±0.020	9.05±0.024	8.28±0.021	2.5±0.23	2.3±0.15	2.0±0.27
Shego	3615	207.6±3.12	252.0±3.84	163.3±4.66	40.3±5.14	34.3±4.61	27.3±4.21	9.95±0.021	9.67±0.021	8.51±0.025	2.7±0.27	2.7±0.27	2.1±0.20
Rangrik	3790	259.0±5.19	280.3±4.27	180.0±3.90	46.0±4.52	39.7±4.61	36.0±3.77	9.96±0.023	9.75±0.025	8.80±0.026	3.1±0.20	2.8±0.17	2.6±0.17
Hansa	4040	278.7±5.59	300.3±5.14	203.7±5.47	49.0±4.55	43.3±4.69	42.0±3.00	10.18±0.016	10.09±0.018	9.62±0.021	3.4±0.28	3.0±0.20	3.1±0.23
CD($P_{0.05}$)		8.190			2.760			0.022			0.140		
		Fe (cmol(p+)kg^{-1})			Cu (cmol(p+)kg^{-1})			Zn (cmol(p+)kg^{-1})			Mn (cmol(p+)kg^{-1})		
Tabo	3390	3.53±0.43	3.30±0.33	2.6.0±0.36	0.93±0.30	0.83±0.26	0.70±0.23	1.53±0.30	1.20±0.32	0.93±0.24	4.13±0.40	3.20±0.33	2.80±0.30
Shielding	3520	3.70±0.47	3.50±0.35	2.97±0.40	1.50±0.39	1.07±0.25	0.80±0.25	1.33±0.32	1.13±0.33	0.80±0.28	3.67±0.42	2.98±0.32	2.37±0.36
Lingti	3560	4.33±0.35	3.93±0.40	3.47±0.36	1.70±0.33	1.33±0.38	0.80±0.20	1.27±0.39	0.97±0.30	0.73±0.20	3.20±0.43	2.53±0.28	2.00±0.30
Shego	3615	5.33±0.43	4.50±0.37	3.47±0.36	2.17±0.41	1.90±0.33	1.47±0.40	1.00±0.33	0.73±0.26	0.67±0.18	2.80±0.43	2.10±0.26	1.64±0.39
Rangrik	3790	8.80±0.37	5.97±0.36	5.37±0.32	2.43±0.56	2.13±0.39	1.70±0.32	0.83±0.35	0.70±0.22	0.57±0.17	2.20±0.51	1.60±0.37	1.37±0.32
Hansa	4040	11.17±0.38	8.23±0.46	6.47±0.33	3.33±0.52	3.10±0.30	1.80±0.36	0.80±0.26	0.70±0.25	0.53±0.15	1.97±0.41	1.17±0.32	1.30±0.26
CD($P_{0.05}$)		0.300			0.260			0.210			0.290		

Table 3. Correlation between pH, OC and other available soil nutrients with each other under seabuckthorn vegetation

Correlation	OC	N	P	K	S	Ca	Mg	Fe	Cu	Zn	Mn
pH	-0.653	-0.504	-0.689	-0.608	-0.598	-0.648	-0.506	-0.455	-0.558	0.322	0.356
OC		0.749	0.653	0.787	0.815	0.965	0.659	0.675	0.715	-0.527	-0.758
N			0.798	0.884	0.882	0.819	0.868	0.938	0.912	-0.473	-0.746
P				0.756	0.791	0.700	0.839	0.748	0.858	-0.159	-0.441
K					0.883	0.836	0.807	0.916	0.856	-0.601	-0.831
s						0.851	0.883	0.847	0.922	-0.398	-0.674
Ca							0.709	0.715	0.780	-0.563	-0.786
Mg								0.834	0.900	-0.202	-0.518
Fe									0.866	-0.501	-0.758
Cu										-0.284	-0.590
Zn											0.805

As indicated in Table 3, soil pH was found negatively and significantly correlated with organic carbon (r = -0.653), available N (r = -0.504), available P (r = -0.689), available K (r = -0.608), available S (r = -0.598), exchangeable Ca (r = -0.648), exchangeable Mg (r = -0.506), available Fe (r = -0.455), available Cu (r = -0.558) and was found positively and significantly correlated with available Zn (r = -0.322) and available Mn (r = -0.356).

CONCLUSION

Planting seabuckthorn in the cold desert has played a very significant role as the seabuckthorn soils accumulated higher values of soil nutrients than the willow and wasteland. Hence, has great potential for sustainable environmental protection in cold desert areas of Himalayas and because of its strong root system and nitrogen fixing ability improves soil quality or fertility. Overall results revealed that seabuckthorn is a wonder plant and suggest that planting seabuckthorn vegetation is more advantages for soil improvement and increasing soil fertility in the cold desert regions of Himalayas.

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