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Diksha Rana
Department of Biology and Environmental Science, CSK Himachal Pradesh Agricultural University, Palampur, Himachal Pradesh, India

Gourav
Department of Soil Science, CSK Himachal Pradesh Agricultural University, Palampur, Himachal Pradesh, India

Correspondence
Diksha Rana
Department of Biology and Environmental Science, CSK Himachal Pradesh Agricultural University, Palampur, Himachal Pradesh, India

Vertical characterization of soil under seabuckthorn (*Hippophae salicifolia* L.) in relation to age for sustainable development of cold arid Himalayas

Diksha Rana and Gourav

Abstract
Cold deserts of Himachal Pradesh support *Hippophae* L (seabuckthorn), which is a multipurpose plant. Seabuckthorn is a nitrogen fixer and can be used as an option to reclaim degraded lands. The present study was conducted to know about the soil fertility and its vertical distribution as affected by the seabuckthorn plantations of different ages. Soil samples were collected at Khangsar village at three depths, i.e., 0-15 cm, 15-30 cm and 30-45 cm, from one year to five years old seabuckthorn plantations and chemically analysed for pH, organic carbon, available N, P, K, S, exchangeable Ca, Mg and micronutrient cations following standard procedures. All the available nutrients organic carbon was higher in upper layer of soil in seabuckthorn plantation except available K, which was higher in control. With the increase in age, the increase in contents of all the available nutrients was observed and highest content was found in five years old plantation. All the nutrients were higher in seabuckthorn plantation as compared to control.

Keywords: seabuckthorn, age, macronutrients, micronutrients, soil fertility, cold arid himalayas

Introduction
Cold deserts have great extremes of hot and cold climate combined with excessive dryness. Temperature in these tracts normally ranges from -45°C during winters to 40°C in summers. Dryness in these areas is mainly due to the absence of monsoon rains as snowfall is the predominant source of precipitation. The soils are generally sandy in texture and grey in colour, characterized by low fertility status, poor water retention capacity and rare plant cover. Due to less rainfall and consequently less leaching there is accumulation of bases which results in alkaline reaction of soil. The total geographical area of cold deserts in India is approximately 74,809 sq. km and it lie in between 31°44’ to 36°0’ N latitude and 75°15’ to 80°15’ E longitude. Himachal Pradesh accounts for 6,488 sq. km area in Lahaul & Spiti districts (Tewari and Kapoor 2013) [35]. Lahaul is situated on the western side of district Lahaul-Spiti in Himachal Pradesh. This part of Himalaya is facing land degradation and fertile land is turning in to barren land. The major reason of land degradation and loss in soil fertility are deforestation, indiscriminate and unscientific management practices. Due to steep slopes cultivation is confined only to the flatter portions of the valley land and with possibilities of irrigation. Due to land degradation and increase in desertification there is a great need to have some technology or practice which can minimize the problem. Likewise, *Hippophae salicifolia* can also be recommended as the other option for carrying out the plantations, since the species has been found to be the most useful in the rural settings of the cold deserts. It is one of the most important shrubs or small trees, belonging to the family *Elaeagnaceae,* existing between 2500 m and 4500 m above sea level in high mountainous transect of the Pradesh (Singh 2003; Singh and Singh 2004) [33, 32]. It is an important fuel-wood and fodder tree of the region. Fruit and leaves being an important source of anti-oxidant (Geetha *et al*. 2002; Geetha *et al*. 2003) [7, 8], this plant has extraordinary economic benefits for the farmers, as it has a high potential in health, food, cosmetic and drug industries. Seabuckthorn is a nitrogen fixing shrub which can increase the nitrogen status of soil as well as overall fertility of soil. This plant also has an outstanding ability to conserve water and moisture, apart from fixing atmospheric nitrogen. Recent studies indicate that seabuckthorn plays an important role in improving the soil fertility

(Mao *et al*., 2010) [21]. By studying the seabuckthorn role in holding soil by its deep root system and in increasing soil fertility, it will help in managing cold deserts, which ultimately leads to sustainability.

By keeping in view the point that only little information is available in relation to forest and soil of cold desert of Himachal Pradesh (Singh and Gupta 1990) [31], and importance of seabuckthorn in the supporting forest system and livelihood of local residents of cold arid Himalayas the present study is devised with the title "Vertical characterization of soil under seabuckthorn (*Hippophae salicifolia* L.) in relation to age for sustainable development of cold arid Himalayas".

Materials and Methods

The present investigation was carried out in the Khangsar village and adjacent area in district Lahaul-Spiti of Himachal Pradesh state during the year of 2015-2016. The Lahaul ($31^0$44' 57''- $32^0$59' 57''N, $76^0$46'29''-$78^0$41' 34''E) is situated towards western side of Lahaul-Spiti district and covers an area of 6244 sq. km and is part of the proposed Cold Desert Biosphere Reserve of Himachal Pradesh (Fig. 1). Lahaul valley falls under dry temperate zone. The rainy season receives variable rainfall, which varies between 10 mm to 300 mm yr^{-1} depending upon the part of the valley. The winter season is comparatively a large period *i.e*., starts from November and ends by April. The temperature shows considerable variation throughout the year from a maximum of 25 ^{0}C in July and minimum of -1 ^{0}C in November (Fig. 2). Soil samples were collected with the help of a soil auger from different aged seabuckthorn (*Hippophae salicifolia*) plantation (from one year to five year plantation) varying from one year plantation to five year plantation, at soil depths of 0-15 cm, 15-30 cm and 30-45 cm from 5 different locations within 3 plots, each of 10 m × 10 m size, chosen randomly in every site and were thoroughly mixed together making 5 replicates of each samples from each soil depth weighing about 200 g. Soil samples were air dried, grinded by pestle mortar and passed through 2 mm sieve and then analysed for pH, organic carbon and nutrients by Standard procedures. The organic carbon was measured using $K_2Cr_2O_7$ method (Walkley and Black, 1934) [37] and the available N was estimated by using the method of Kjeldahl extraction given by Subbiah and Aseja (1956) [34], the available P was measured by Olsen's method with spectrophotometer (Olsen *et al*. 1954) [23], available K was estimated by using flame photometer and micronutrients (Fe, Cu, Mn and Zn) were estimated in atomic absorption spectrophotometer by DTPA method (Lindsay and Norvell 1978) [18]. Obtained results are then statistically analysed by the procedures given by Gomez and Gomez, 1984 [9].

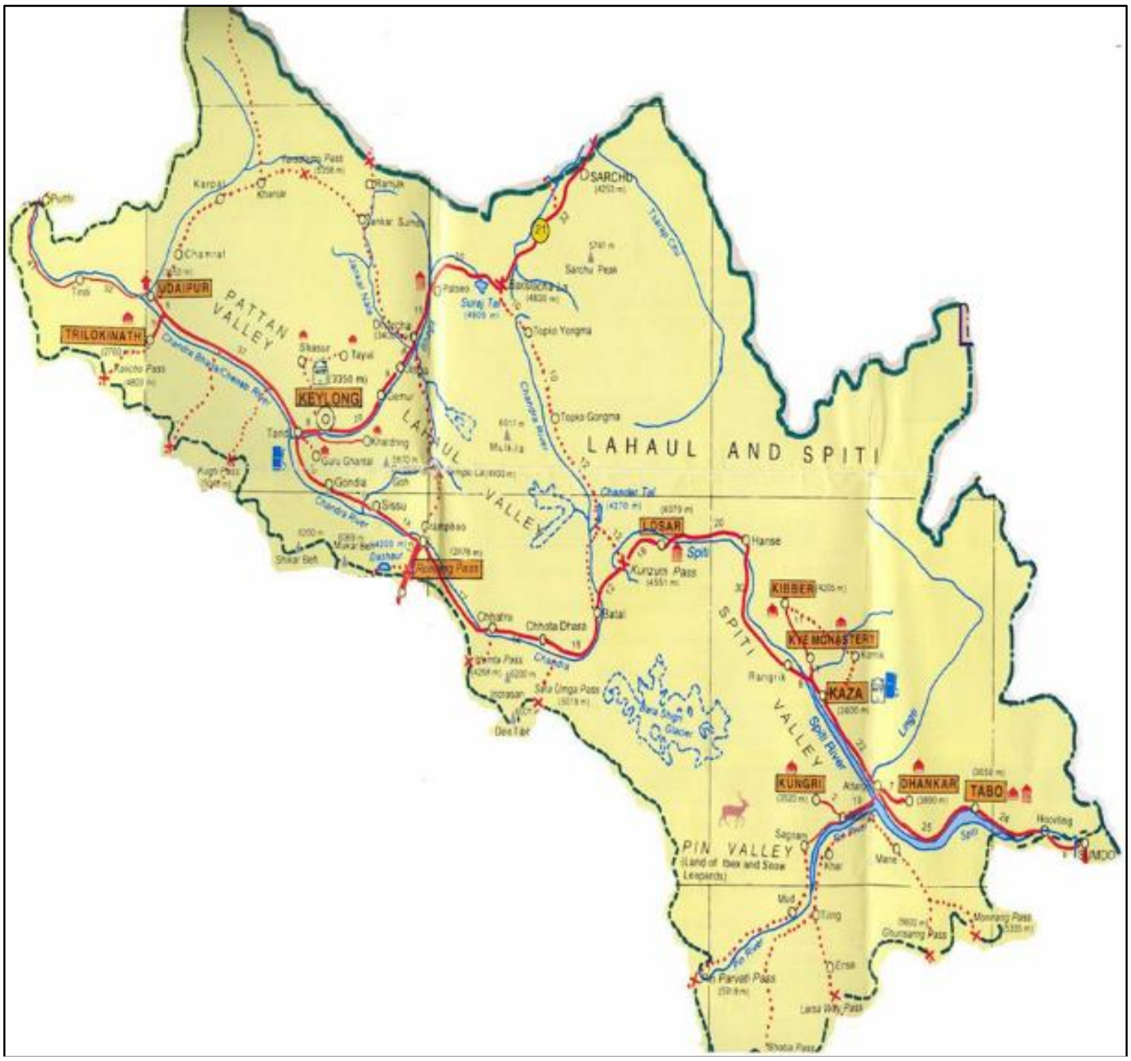

Fig 1: Geographical map of district Lahaul-Spiti of Himachal Pradesh

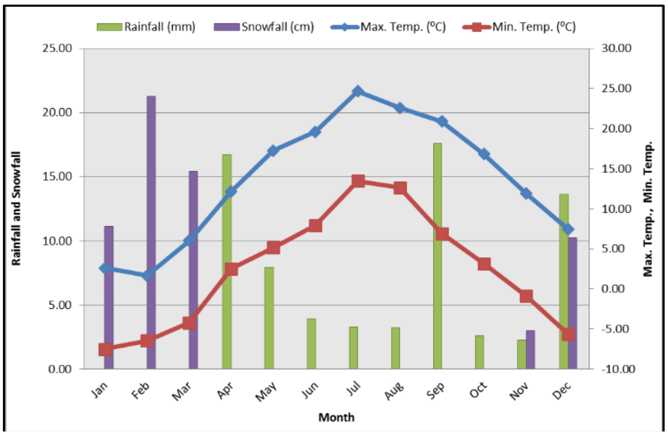

Fig 2: Variation in the temperature, rainfall and snowfall in Lahaul of Himachal Pradesh

Results and Discussion

pH

The reaction of the soil under seabuckthorn plantation is alkaline and varied from 7.5 to 7.9 in top soil layer 0-15 cm, 7.6 to 8.1 in 15-30 cm and 7.7 to 8.2 in 30-45 cm soil layers (Table 1). This showed that pH increased with increasing soil depth. The difference in pH at 0-15cm and 15-30 cm depth was non-significant, but at 0-15 cm it was significantly lower than 30-45 cm depth (Table 2). Higher pH in dry temperate zone may be due to more accumulation of $CaCO_3$ and other salts due to extremely low rainfall and high evaporation rate in this zone (Sharma and Kanwar 2010) [28]. Vertically there was an increase in pH which might be due to acidic parent material of soil, comparatively higher decomposition of organic residues, less percolation and leaching of organic materials to lower depths (Ali *et al*. 2013) [1]. Soil pH value varied significantly ($p \leq 0.05$) with age. Soil pH varied from a maximum value of 8.07 in 1st year plantations, followed by 7.97 in 2 years old plantations, 7.90 in 3 years old plantations, 7.80 in 4 years old plantations and a minimum value of 7.60 in 5 years old plantations (Table 2). Figure 3 shows that the soil pH significantly decreased with increasing age, this might be due to the accumulation of organic acids secreted or discharged from microorganisms, animals, plant roots and leaf litters on the surface soil (Bi and Zhang 2014) [4]. This way seabuckthorn also worked as a moderator to the soil pH.

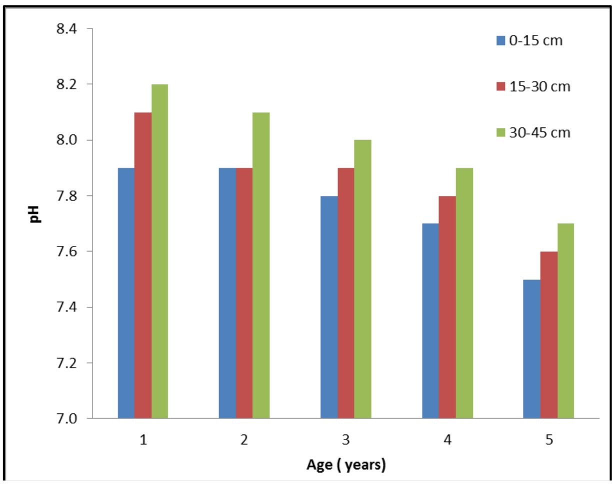

Fig 3: Variation of pH with age under seabuckthorn in Lahaul

Organic Carbon

Seabuckthorn's soil was found to have higher content of organic carbon than control and it varied from 1.85 to 2.30 percent in top soil layer 0-15 cm, 1.81 to 2.27 percent in 15-30 cm soil layer and 1.7 to 2.24 percent in 30-45 cm soil layer (Table 1). On an average, the difference in organic carbon of 0-15cm and 15-30 cm soil layer was non-significant, but in 0-15 cm depth, it was significantly higher than 30- 45 cm soil layer. Soil organic carbon varied significantly ($p \leq 0.05$) with age. Soil organic carbon varied from a minimum value of 1.81 percent in 1 year old plantations, followed by 2.06 per cent in 2 years old plantations, 2.19 per cent in 3 years old plantations, 2.22 per cent in 4 years old plantations and a maximum value of 2.27 per cent in 5 years old plantations (Table 2). This showed that soil organic carbon increased with increasing age of plantations. Lu (2009) [19] and Gong *et al*. (2007) [10] in China had also found the enrichment of soil with organic carbon in seabuckthorn plantation with increasing age. Figure 4 shows that soil organic carbon significantly increased with an increase in age and decreased with increasing depth of soil. Incorporation of seabuckthorn leaf litter and addition of decayed branches and roots in the upper layers and their further decomposition might have resulted in accumulation of organic carbon in the surface layers. Similar vertical distribution pattern of organic carbon have been reported by Singh and Datta (1988), Mandal *et al*. (1990) [20], Banerjee and Sharma (1990) [3], Sarkar and Sahoo (2000) [25], Singh *et al*. (2000) [30], Dhale and Prasad (2009) [6] and Sharma (2011) [26]. Organic carbon enriched soils are generally healthier one.

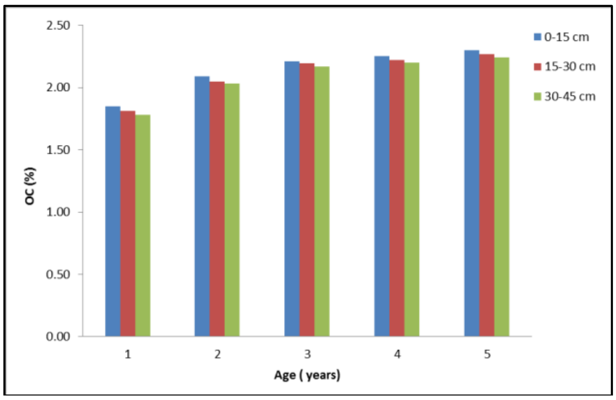

Fig 4: Variation of organic carbon with age under seabuckthorn in Lahaul

Available Nitrogen

Soil available nitrogen varied from 270 to 309 kg ha^{-1} in top soil layer 0-15 cm, 265 to 301 kg ha^{-1} in 15-30 cm soil layer and 261 to 295 kg ha^{-1} in 30-45 cm soil layer (Table 1). This showed that available N decreased with increasing depth. These results were concordant with the findings of Singh and Datta (1988), Kumar *et al*. (2006) [17] and Rajeshwar *et al*. (2009) [24]. The difference in available N content of 0-15cm and 15-30 cm depth was non-significant but in 0-15 cm depth, it was significantly higher than 30-45 cm soil depth and overall available N was higher in seabuckthorn plantation than in control. With age, nitrogen varied from a minimum value of 265.3 kg ha^{-1} in 1 year old plantations, followed by 283.7 kg ha^{-1} in 2 years old plantations, 291.0 kg ha^{-1}in 3 years old plantations, 295.7 kg ha^{-1} in 4 years old plantations and a maximum value of 301.7 kg ha^{-1}in 5 years old plantations (Table 2). Figure 5 shows that soil available N significantly increased with an increase in age and decreased with increasing depth of soil. Higher nitrogen content in soil with increase in age of seabuckthorn plantation is due to accumulation of organic matter and probably through nitrogen fixation by nitrogen fixing bacteria frankia in rhizosphere (Bi and Zhang 2014) [4]. Similar results were obtained by Zhao *et al*. (2013) [39] in China.

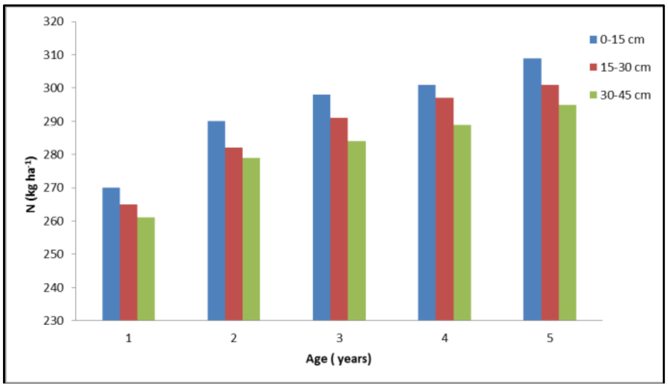

Fig 5: Variation of available N with age under seabuckthorn in Lahaul

Available Phosphorus

A perusal of the data given in table 1 showed that soil available P under seabuckthorn plantations varied from 18 to 32 kg ha^{-1} in top soil layer (0-15 cm), 14 to 25 kg ha^{-1} in 15-30 cm soil layer and 12 to 22 kg ha^{-1} in 30-45 cm soil layer. This showed that available P decreased with increasing depth. The content of available P varied significantly ($p \leq 0.05$) with soil depth with maximum value 23.8 kg ha^{-1} at soil top layer (0-15 cm), followed by 19.2 kg ha^{-1}at 15-30cm and a minimum of 15.8 kg ha^{-1} at 30-45 cm soil depth (Table 2). With age the soil available P varied significantly ($p \leq$ 0.05) having a minimum value of 14.7 kg ha^{-1} in 1 year old plantations, followed by 16.7 kg ha^{-1} in 2 years old plantations, 19.3 kg ha^{-1} in 3 years old plantations, 21.0 kg ha^{-1} in 4 years old plantations and a maximum value of 26.3 kg ha^{-1} in 5 years old plantations (Table 2). This showed that soil available P content increased with increasing age of plantations. Available P in seabuckthorn plantation of 5 years old was significantly higher than control. Figure 6 shows that soil available P significantly increased with an increase in age and decreased with increasing depth of soil. These results were in line with the findings of Zhang and Chen (2007) [38] and Lu (2009) [19].

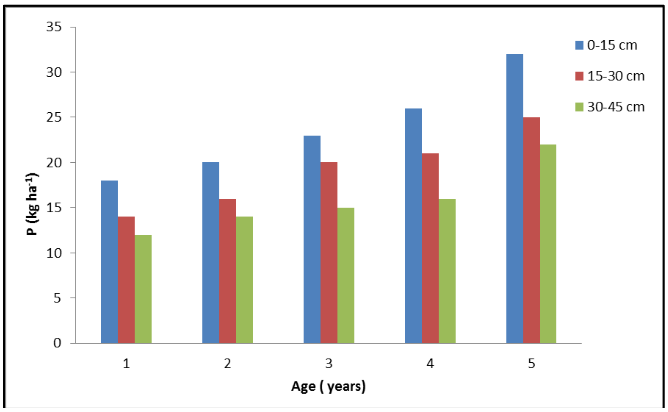

Fig 6: Variation of available P with age under seabuckthorn in Lahaul

Available Potassium

Soil available K under seabuckthorn plantations varied from 102 to 171 kg ha^{-1} in top soil layer of 0-15 cm, 100 to 165 kg ha^{-1} in 15-30 cm soil layer and 95 to 159 kg ha^{-1} in 30-45 cm soil layer (Table 1). This showed that available K decreased with increasing depth. The lower content of K in lower soil layers might be due to less root activity, microbial activity and low nutrient cycling in lower layers. Soil available K varied significantly ($p \leq$ 0.05) with age and varied from a minimum value of 99.0 kg ha^{-1} in 1 year old plantations, followed by 110.7 kg ha^{-1} in 2 years old plantations, 139.0 kg ha^{-1} in 3 years old plantations, 156.7 kg ha^{-1} in 4 years old plantations and a maximum value of 165.0 kg ha^{-1} in 5 years old plantations (Table 2). This showed that soil available K content increased with increasing age of plantations but remain lower than control might be due to higher uptake of potassium by seabuckthorn. Similarly, Figure 7 shows that soil available K significantly increased with an increase in age and decreased with increasing depth of soil, which might be due to higher root activity, microbial activity and nutrient cycling with increase in age. These findings were concordant with Gurung (2001) [12], Guo (2003) [11], Zhang and Chen (2007) [38] and Zhao *et al*. (2013) [39].

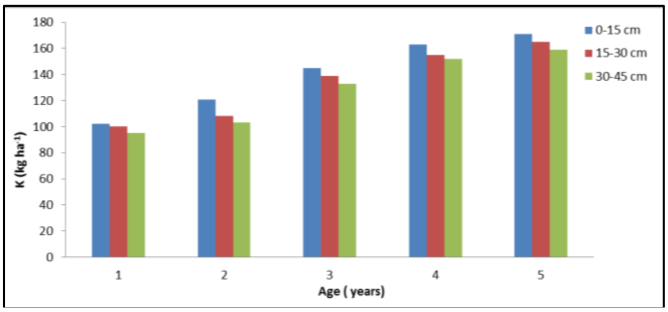

Fig 7: Variation of available K with age under seabuckthorn in Lahaul

Available Sulphur

Soil available S under seabuckthorn plantations varied from 19 to 32 kg ha^{-1} in top soil layer 0-15 cm, 17 to 29 kg ha^{-1} in 15-30 cm soil layer and 14 to 24 kg ha^{-1} in 30-45 cm soil layer (Table 1). This clearly indicated the decrease in available S with increasing depth. The content of available S varied significantly ($p \leq 0.05$) with soil depth. Soil available S at different depths was found to be significant and higher than control with maximum value 27.8 kg ha^{-1} at soil top layer (0-15 cm), followed by 23.8 kg ha^{-1}at 15-30cm and a minimum of 20.8 kg ha^{-1} at 30-45 cm soil depth (Table 2). Similar decreasing trend of available S with soil depth was also reported by Badiger (1985) [2], Tripathi *et al*. (1995) [36], Intodia and Sahu (1999) [14] and Kour *et al*. (2010) [16] which might be due to decreasing organic matter content with depth. With age also, the soil available S varied significantly ($p \leq$ 0.05), from a minimum value of 16.7 kg ha^{-1} in 1 year old plantations, followed by 23.7 kg ha^{-1} in 2 years old plantations, 25.3 kg ha^{-1} in 3 years old plantations, 26.0 kg ha^{-1} in 4 years old plantations and a maximum value of 28.3 kg ha^{-1} in 5 years old plantations (Table 2). Figure 8 also shows the increase in available S with increasing age and decrease with increasing soil depth, significantly, which might be due to higher addition of leaf litter and root exudates with increase ina the age of plantation.

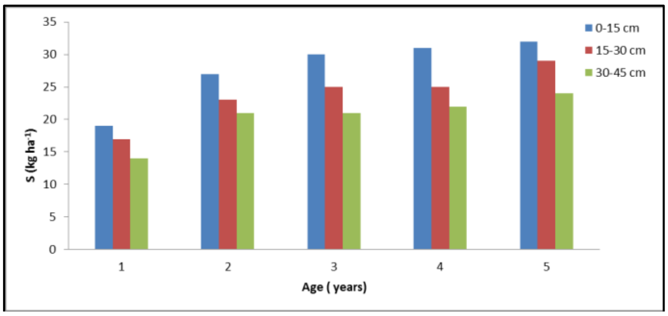

Fig 8: Variation of available S with age under seabuckthorn in Lahaul

Available Iron
Soil available Fe under seabuckthorn varied from 2.9 to 9.1 mg kg^{-1} in top soil layer 0-15 cm, 2.5 to 8.8 mg kg^{-1} in 15-30 cm soil layer and 2.2 to 8.5 mg kg^{-1} in 30-45 cm soil layer (Table 1). The content of available Fe varied significantly ($p \leq 0.05$) with soil depth having maximum value 5.0 mg kg^{-1} at soil top layer (0-15 cm), followed by 4.7 mg kg $^{-1}$ at 15-30 cm and a minimum of 4.4 mg kg $^{-1}$ at 30-45 cm soil depth (Table 2). The decrease in iron content with depth was also reported by Jalali *et al*. (1989) [15] and Kuldeep *et al*. (1990). Soil available Fe varied significantly ($p \leq 0.05$) with age, from a minimum value of 2.5 mg kg^{-1} in 1 year old plantations, followed by 2.6 mg kg^{-1} in 2 years old plantations, 4.1 mg kg^{-1} in 3 years old plantations, 5.4 mg kg^{-1} in 4 years old plantations and a maximum value of 8.8 mg kg^{-1} in 5 years old plantations (Table 2). Figure 9 also shows that soil available Fe significantly increased with increasing age and decreased with increasing soil depth.

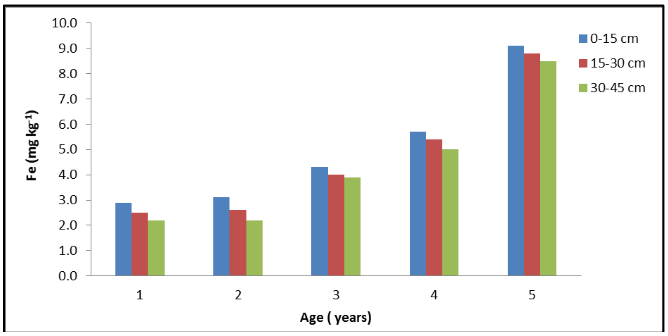

Fig 9: Variation of available Fe with age under seabuckthorn in Lahaul

Available Copper
Soil available copper was in sufficient content which varied from 1.2 to 2.5 mg kg^{-1} in top soil layer 0-15 cm, 0.9 to 2.1 mg kg $^{-1}$ in 15-30 cm soil layer and 0.7 to 1.9 mg kg^{-1} in 30-45 cm soil layer (Table 1). On an average, soil available Cu at different depths was found to be significant and higher than control with maximum value 1.8 mg kg^{-1} at soil top layer (0-15 cm), followed by 1.5 mg kg^{-1} at 15-30 cm and a minimum of 1.3 mg kg $^{-1}$ at 30-45 cm soil layer (Table 2). With age the soil available Cu varied significantly ($p \leq 0.05$), from a minimum value of 0.93 mg kg^{-1} in 1 year old plantations, followed by 1.40 mg kg^{-1} in 2 years old plantations, 1.47 mg kg^{-1} in 3 years old plantations, 1.70 mg kg^{-1} in 4 years old plantations and a maximum value of 2.17 mg kg^{-1} in 5 years old plantations (Table 2). Figure 10 also shows that soil available Cu significantly increased with increasing age and decreased with increasing soil depth. These findings were in line with the work of Jalali *et al*. (1989) [15], Sharma (2011) [26] and Sharma (2014) [27].

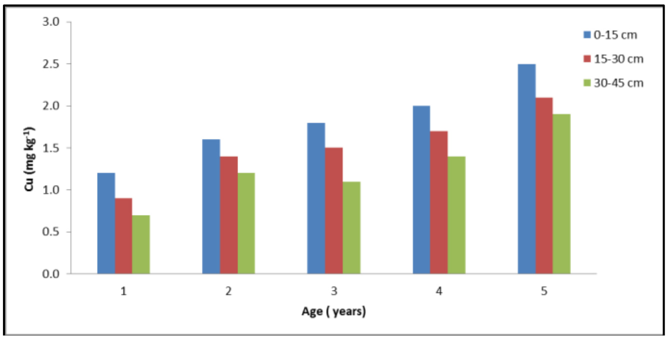

Fig 10: Variation of available Cu with age under seabuckthorn in Lahaul

Available Zinc
Soil available Zn under seabuckthorn plantations in Khangsar varied from 1.6 to 1.1 mg kg $^{-1}$ in top soil layer 0-15 cm, 1.4 to 0.6 mg kg^{-1} in 15-30 cm soil layer and 1.2 to 0.4 mg kg^{-1} in 30-45 cm soil layer. The content of available Zn varied significantly ($p \leq 0.05$) with soil depth. Soil available Zn at different depths was found to be significant with maximum value 1.34 mg kg^{-1} at soil top layer (0-15 cm), followed by 0.98 mg kg^{-1} at 15-30 cm and a minimum of 0.72 mg kg^{-1} at 30-45 cm soil depth (Table 2). With increasing age, the soil available Zn varied significantly ($p \leq 0.05$), from a maximum value of 1.40 mg kg^{-1} in 1 year old plantations, followed by 1.27 mg kg^{-1} in 2 years old plantations, 1.0 mg kg^{-1} in 3 years old plantations, 0.70 mg kg^{-1} in 4 years old plantations and a same content of 0.70 mg kg^{-1} in 5 years old plantations (Table 2). Figure 11 shows that soil available Zn significantly decreased with increasing age and decreased with increasing soil depth. The decrease in available content of zinc with increase in age of plantation might be attributed to increase in pH with age, which might converted the available form of micronutrients to unavailable forms.

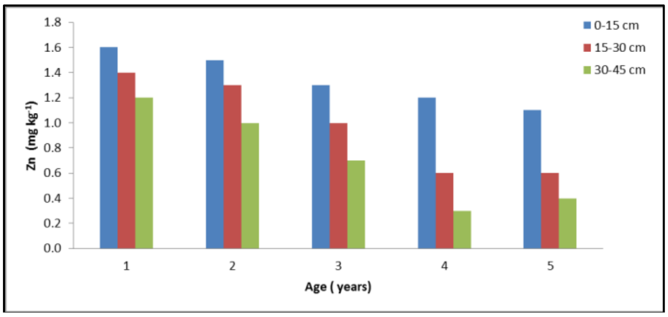

Fig 11: Variation of available Zn with age under seabuckthorn in Lahaul

Available Manganese
Available Mn were in sufficient range, which varied from 4.1 to 2.7 mg kg^{-1} in top soil layer 0-15 cm, 3.9 to 2.2 mg kg^{-1} in

15-30 cm soil layer and 3.6 to 1.9 mg kg^{-1} in 30-45 cm soil layer. The content of available Mn varied significantly ($p \leq 0.05$) with soil depth with maximum value 3.56 mg kg^{-1} at soil top layer (0-15 cm), followed by 3.14 mg kg $^{-1}$ at 15-30 cm and a minimum of 2.78 mg kg $^{-1}$ at 30-45 cm soil depth (Table 2). The decrease in micronutrient with depth may be attributed to low temperature which leads to lower rate of mineralization (Dar *et al*. 2012). With age, soil available Mn varied from a maximum value of 3.87 mg kg^{-1} in 1 year old plantations, followed by 3.67 mg kg^{-1} in 2 years old plantations, 3.27 mg kg^{-1} in 3 years old plantations, 2.73 mg kg^{-1} in 4 years old plantations and a minimum value of 2.27 mg kg^{-1} in 5 years old plantations (Table 2). Figure 12 shows that soil available Mn significantly decreased with increasing age and decreased with increasing soil depth. The higher content of micronutrient with age might be due to higher addition of leaf litter and ultimately soil organic matter (He *et al*. 2016) [13].

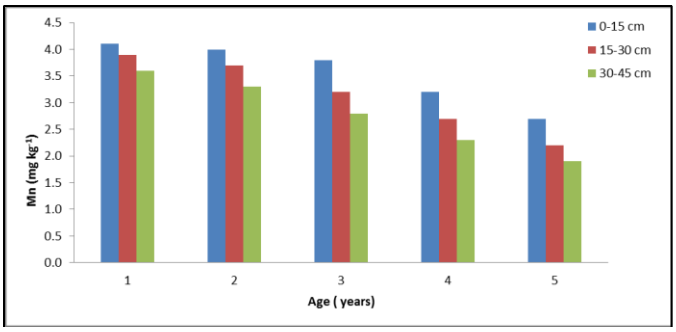

Fig 12: Variation of available Mn with age under seabuckthorn in Lahaul

Exchangeable Calcium

Soil exchangeable Ca under seabuckthorn plantations in Khangsar varied from 8.55 to 10.10 c mol (p^+) kg^{-1} in top soil layer 0-15 cm, 8.52 to 10.05 c mol (p^+) kg^{-1} in 15-30 cm soil layer and 8.51 to 9.95 c mol (p^+) kg^{-1} in 30-45 cm soil layer (Table 1). On an average Table 2 showed that exchangeable Ca decreased with increasing depth. Higher Ca in top soil is due to higher accumulation of Ca and less leaching (Nair and Chamuah, 1988; Singh and Raman, 1982) [22, 29]. Soil exchangeable Ca varied significantly ($p \leq 0.05$) with age, from a minimum value of 8.53 c mol (p^+) kg^{-1} in 1 year old plantations, followed by 9.12 c mol (p^+) kg^{-1} in 2 years old plantations, 9.83 c mol (p^+) kg^{-1} in 3 years old plantations, 9.95 c mol (p^+) kg^{-1} in 4 years old plantations and a maximum of 10.03 c mol (p^+) kg^{-1} in 5 years old plantations (Table 2). Figure 13 shows that soil exchangeable Ca significantly increased with increasing age and decreased with increasing soil depth. Old plants are adding more organic matter and hence higher Ca content, as a result.

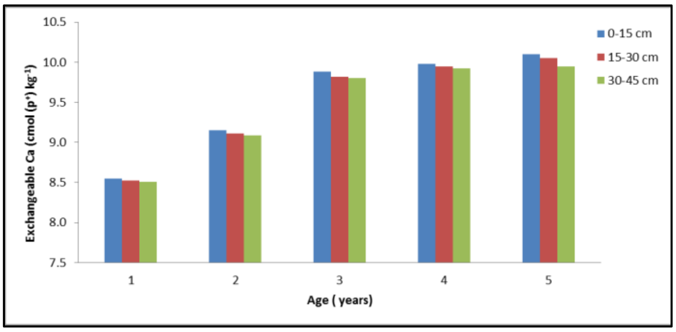

Fig 13: Variation of exchangeable Ca with age under seabuckthorn in Lahaul

Magnesium

Soil exchangeable Mg under seabuckthorn plantations varied from 2.20 to 3.30 c mol (p^+) kg^{-1} in top soil layer 0-15 cm, 2.00 to 3.10 c mol (p^+) kg^{-1} in 15-30 cm soil layer and 1.90 to 2.80 c mol (p^+) kg^{-1} in 30-45 cm soil layer (Table 1). Soil exchangeable Mg at different depths was found to be significant with maximum value 2.78 c mol (p^+) kg^{-1} at soil top layer (0-15 cm), followed by 2.62 c mol (p^+) kg^{-1} at 15-30 cm and a minimum of 2.44 c mol (p^+) kg^{-1} at 30-45 cm soil depth (Table 2). These findings were in line with the results of Nair and Chamuah, 1988 [22]; Singh and Raman, 1982 [29]. With age, the soil exchangeable Mg varied significantly ($p \leq 0.05$), from a minimum value of 2.03 c mol (p^+) kg^{-1} in 1 year old plantations, followed by 2.43 c mol (p^+) kg^{-1} in 2 years old plantations, 2.67 c mol (p^+) kg^{-1} in 3 years old plantations, 2.87 c mol (p^+) kg^{-1} in 4 years old plantations and a maximum of 3.07 c mol (p^+) kg^{-1} in 5 years old plantations(Table 2). Figure 14 shows that soil exchangeable Mg significantly increased with increasing age and decreased with increasing soil depth.

Table 1: Effects of the seabuckthorn (*Hippophae salicifolia*) on the soil fertility

		Depth(cm)				
Age(years)	**(0-15)**	**(15-30)**	**(30-45)**	**(0-15)**	**(15-30)**	**(30-45)**
		pH			**OC (%)**	
1st Year	7.9	8.1	8.2	1.85	1.81	1.78
2nd Year	7.9	7.9	8.1	2.09	2.05	2.03
3rd Year	7.8	7.9	8.0	2.21	2.20	2.17
4th Year	7.7	7.8	7.9	2.25	2.22	2.20
5th Year	7.5	7.6	7.7	2.30	2.27	2.24
		N (kg ha^{-1})			**P (kg ha^{-1})**	
1st Year	270	265	261	18	14	12
2nd Year	290	282	279	20	16	14
3rd Year	298	291	284	23	20	15
4th Year	301	297	289	26	21	16
5th Year	309	301	295	32	25	22
		K (kg ha^{-1})			**S (kg ha^{-1})**	
1st Year	102	100	95	19	17	14
2nd Year	121	108	103	27	23	21
3rd Year	145	139	133	30	25	21
4th Year	163	155	152	31	25	22
5th Year	171	165	159	32	29	24
		Fe (mg kg^{-1})			**Cu (mg kg^{-1})**	
1st Year	2.9	2.5	2.2	1.2	0.9	0.7

2nd Year	3.1	2.6	2.2	1.6	1.4	1.2
3rd Year	4.3	4.0	3.9	1.8	1.5	1.1
4th Year	5.7	5.4	5.0	2.0	1.7	1.4
5th Year	9.1	8.8	8.5	2.5	2.1	1.9
	Zn (mg kg^{-1})			**Mn (mg kg^{-1})**		
1st Year	1.6	1.4	1.2	4.1	3.9	3.6
2nd Year	1.5	1.3	1.0	4.0	3.7	3.3
3rd Year	1.3	1.0	0.7	3.8	3.2	2.8
4th Year	1.2	0.6	0.3	3.2	2.7	2.3
5th Year	1.1	0.6	0.4	2.7	2.2	1.9
	Ca (cmol (p$^+$) kg^{-1})			**Mg (cmol (p$^+$) kg^{-1})**		
1st Year	8.55	8.52	8.51	2.2	2.0	1.9
2nd Year	9.15	9.11	9.09	2.6	2.4	2.3
3rd Year	9.88	9.82	9.80	2.8	2.7	2.5
4th Year	9.98	9.95	9.92	3.0	2.9	2.7
5th Year	10.10	10.05	9.95	3.3	3.1	2.8

Table 2: Effect of different age and depth on the soil pH, organic carbon and other available nutrients in seabuckthorn

	pH	OC (%)	N (kg ha^{-1})	P (kg ha^{-1})	K (kg ha^{-1})	S (kg ha^{-1})	Fe (mg kg^{-1})	Cu (mg kg^{-1})	Zn (mg kg^{-1})	Mn (mg kg^{-1})	Ca (cmol (p+) kg^{-1})	Mg (cmol (p+) kg^{-1})
Age(years)												
1st Year	8.07	1.81	265.3	14.7	99.0	16.7	2.5	0.93	1.40	3.87	8.53	2.03
2nd Year	7.97	2.06	283.7	16.7	110.7	23.7	2.6	1.40	1.27	3.67	9.12	2.43
3rd Year	7.90	2.19	291.0	19.3	139.0	25.3	4.1	1.47	1.00	3.27	9.83	2.67
4th Year	7.80	2.22	295.7	21.0	156.7	26.0	5.4	1.70	0.70	2.73	9.95	2.87
5th Year	7.60	2.27	301.7	26.3	165.0	28.3	8.8	2.17	0.70	2.27	10.03	3.07
Control/Wasteland	7.67	1.73	144.2	17.6	243.8	14.9	3.1	1.11	0.69	1.36	8.35	2.28
SE(m±)	0.053	0.034	5.533	1.134	8.560	1.313	0.149	0.099	0.099	0.105	0.079	0.104
CD ($P \leq 0.05$)	0.155	0.100	15.980	3.278	24.723	3.793	0.431	0.288	0.289	0.305	0.230	0.303
Depth (cm)												
D_1 (0-15)	7.76	2.14	293.6	23.8	140.4	27.8	5.0	1.82	1.34	3.56	9.53	2.78
D_2 (15-30)	7.86	2.11	287.2	19.2	133.4	23.8	4.7	1.52	0.98	3.14	9.49	2.62
D_3 (30-45)	7.98	2.08	281.6	15.8	128.4	20.4	4.4	1.26	0.72	2.78	9.45	2.44
SE(m±)	0.041	0.026	4.285	0.878	6.631	1.017	0.115	0.077	0.077	0.081	0.061	0.081
CD ($P \leq 0.05$)	0.120	0.077	12.378	2.539	19.150	2.938	0.334	0.223	0.224	0.236	0.178	0.235

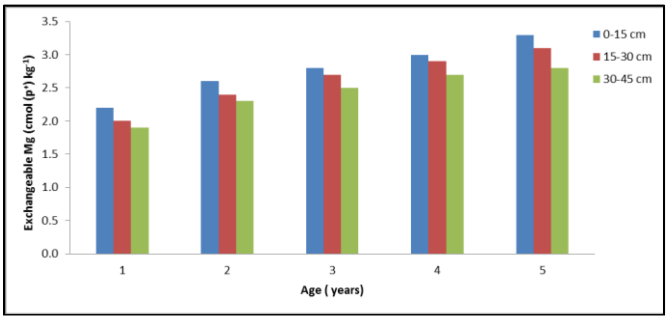

Fig 14: Variation of exchangeable Mg with age under seabuckthorn in Lahaul

Conclusion

Macro and micro nutrients in seabuckthorn plantation has a higher content than control or wasteland, which clearly indicates that seabuckthorn, can be used to maintain and sustain the soil fertility of the cold desert. Organic carbon content is also higher in seabuckthorn plantation, which is a good indicator of soil health. Vertically, the entire soil nutrients decreased due to decrease in soil organic matter. With increasing age, all the plant nutrients increased due to increase in organic matter. Hence, it can be concluded that seabuckthorn can be a good option to restore soil fertility and sustainable development of cold arid Himalayas.

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