Vol. 45, No. 3, pp 302-307, 2017
Indian Journal of Soil Conservation
Online URL : http://indianjournals.com/ijor.aspx?target=ijor:ijsc&type=home

Revegetation of muck dumping sites in Indian Himalayan region

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ARTICLE INFO

Article history :
Received : March, 2017
Revised : October, 2017
Accepted : November, 2017

Key words:
Muck dumping,
NHPC,
Pelleted seeds,
PGPR,
Tree species

ABSTRACT

Eco-restoration of the muck dumping sites in command area of a hydro-electric power generation project is a matter of serious concern from ecological and social points of view. Realizing the importance of the technological interventions under such situation, CSIR-Institute of Himalayan Bioresource Technology (IHBT), Palampur took up revegetation of 10 closed dumping sites (DS) of National Hydro-electric Power Corporation's (NHPC) Parbati Hydroelectric Project Phase-II in Kullu district, Himachal Pradesh, India, in 2010. These DS are located at 1400 to 2220 m above mean sea level (msl) covering about 9 ha area. Owing to steep slope of DS, a network of retaining walls of stacked stone-filled gabions tied together with mild steel wire-net was made throughout the DS for their stabilization. Considering the agro-climatic conditions of the DS, 11 tree species were selected for plantation. Nursery raised plants of the tree species were planted in gunny bags placed in pits at the sites containing garden soil, organic manure and peat moss. The consortium of selected plant growth promoting rhizo-bacteria (PGPR) was applied at collar level to the tree saplings. After plantation, pelleted seeds of potential herbs and shrubs were also broadcasted. After 1 year the survival rate was 85%. *R. pseudoacacia* followed by *Ailanthus excelsa* performed better than other planted tree species. Plant height was maximum in *R. pseudoacacia* at all the planting sites. The shrubs and herbs species planted in the targeted sites survived very well and helped in binding the soil over the slopes leading to support to tree species in their establishment and growth.

1. INTRODUCTION

Muck dumping has been a matter of serious concern to environmentalists for its adverse effect on habitation down stream in terms of threat to aquatic life, flora and fauna, as loose stratum of a dumping site is vulnerable to be washed down with heavy downpour triggering ecosystem degradation. Hence, restoration of such site becomes imperative from ecological and biodiversity angles. Dumping of muck creates the problem of management of all types of physical, chemical and biological disturbances of soil such as pH, fertility, microbial community and various soil nutrient cycles. The alteration of land forms thus produced is a high concern for society and it is desired that the pristine conditions are restored. The muck generally comprises the bare stripped area, loose soil piles, waste rock, overburden surfaces, subsided land areas. These waste rocks pose extreme stressful conditions for restoration because of destruction of existing vegetation and soil profile (Kundu and Ghose 1997). The overburden muck dumping include adverse factors such as elevated bio availability of metals, sand content, lack of moisture, lack of organic contents, etc. Overall effects of muck dumping can be multiple, as soil erosion, air and water pollution, toxicity, geo-environmental disasters, loss of biodiversity and ultimately loss of economic wealth (Wong, 2003; Sheoran *et al*., 2008 and Chaturvedi *et al.,* 2014). The restoration of such site requires the establishment of stable nutrient cycles for plants growth and microbial processes (Singh *et al.,* 2002; Lone *et al.,* 2008 and Kavamura and Esposito, 2010). The restoration of plants species on such dumps can fulfill the objectives of stabilization, pollution control, removal of threats to human beings (Wong, 2003). The revegetation strategies aims at improvement of soil structure, soil fertility, establishment of microbial population, top soil management and nutrient cycling in order to return the land as closely as possible to its pristine condition and continue as a self sustaining ecosystem. This present study was therefore executed to rationalize the technique for revegetation of a muck dumping site, and identify suitable tree species based on establishment for such eco-restoration approach.

2. MATERIALS AND METHODS

Study Site

The revegetation was attempted at 10 sites in Kullu district, Himachal Pradesh. The study sites were dumping muck by National Hydro-electric Power Corporation, Nagwain, Mandi, Himachal Pradesh. The detail of the study site is provided in Table 1. Total 8.774 ha area was covered for revegetation.

A preliminary survey of the target DS was conducted to know geological attributes of the sites, to identify the tree and shrub species growing in the vicinity of the sites, and to assess physico-chemical properties of the muck dumped on the sites (Table 2 and Table 3). The slope of the target sites is between 45° to 60° and the horizontal/vertical ratio of terrain ranged from 1.2 to 1.7. During the preliminary survey, separate composite samples of the surface soil or muck material (upto 15 cm depth) at all 10 DS were collected and analysed for pH, electrical conductivity, organic carbon, available N, P and K content (Table 2 and Table 3).

Plantation

Owing to the steep slope of the DS, a network of retaining walls of stacked stone-filled gabions tied together with mild steel wire-net was created throughout the DS for stabilizing muck across the slope (Fig. 1 and Fig. 4). Gunny bag of dimension 90 cm length and 45 cm lay-flat weighing 495 g m^{-2} was used as the planting bag. Soil for filling the gunny bag was collected from local forest. The planting medium was prepared by mixing forest soil with well

Table: 1
Salient aspects of the dumping sites of NHPC in Kullu, Himachal Pradesh

Site	Location	Valley	Altitude (m amsl)	Latitude	Longitude	Aspect
DS-01	Barshaini	Manikaran	2075	31°59'52.8"N	77°26'37.3"E	N
DS-02	Barshaini	Manikaran	2075	31°59'52.0"N	77°26'52.4"E	N
DS-03	Barshaini	Manikaran	2075	31°59'56.4"N	77°26'40.3"E	S
DS-06	Shilagarh	Garsa	2123	31°52'14.1"N	77°20'09.6"E	WS
DS-08	Rahla	Sainj	2027	31°47'23.0"N	77°18'43.8"E	NE
DS-09	Rahla	Sainj	2027	31°47'23.2"N	77°18'57.6"E	N
DS-12	Sund	Sainj	1403	31°47'35.6"N	77°19'55.5"E	SE
DS-13a	Sund	Sainj	1403	31°47'22.9"N	77°19'45.9"E	SE
DS-13b	Sund	Sainj	1403	31°47'24.4"N	77°19'42.3"E	SE
DS-14L	Sund	Sainj	1493	31°47'54.6"N	77°20'01.7"E	E, NE
DS-14U	Sund	Sainj	1493	31°47'55.2"N	77°20'00.3"E	E, NE
DS-16	Rahla	Sainj	2221	31°47'22.4"N	77°18'34.7"E	SE

Table: 2
Chemical properties of the muck material mixed with parent soil at the dumping sites

Site	Muck material					
	pH	Electrical Conductivity (m mhos cm^{-1})	Organic carbon (%)	Available N (kg ha^{-1})	Available P (kg ha^{-1})	Available K (ppm)
DS-01	8.8	0.494	0.51	72.1	15.5	64.2
DS-02	8.4	0.483	0.82	67.0	42.6	156.7
DS-03	8.2	1.110	0.69	65.9	13.0	212.4
DS-06	8.1	1.125	1.04	94.1	24.1	121.5
DS-08	7.6	2.085	0.93	83.7	18.5	87.1
DS-09	8.0	0.254	0.85	77.0	33.4	62.7
DS-12	8.5	0.251	0.60	76.8	17.3	115.5
DS-13	8.1	0.782	0.60	70.0	10.5	115.7
DS-14	8.7	0.222	0.80	67.4	16.7	105.8
DS-16	8.4	0.538	0.64	64.8	16.7	98.1

decomposed compost and peat moss in the ratio of 10:2:1. About 45 kg planting medium was filled in each planting bag. These forest soil used for each site was analyzed at CSIR-IHBT laboratory to assess its inherent chemical properties (Table 3). Considering the agro-climatic conditions and the existing flora in the vicinity of the DS; drought resistance, fast growth, soil binding quality, different tree, shrub and herbs species were selected for revegetation. The details of the species along with number and time of planting is given in Table 4.

For planting trees, 90 cm deep pits of dimension 45 x 45 cm^2 were made at 2.50 to 2.75 m spacing at the dumping site. The gunny bags filled with the planting medium as mentioned above were placed in the pits. The planting was done during August-September 2010, March-April and July-August in 2011, and March-April 2012. Total 14,370 tree saplings were planted for revegetation in all the 10 DS (Table 4).

Considering the physico-chemical condition of the DS, a consortium of selected plant growth promoting rhizobacteria (PGPR), formulated by CSIR-IHBT, was applied at collar level of the tree saplings. After planting trees, about 5 cm thick layer of forest soil was spread on the surface of the dumping site. Pelleted seeds, prepared using mixture of Calcium sulphate + Calcium carbonate + bavistin + adhesive,

Fig. 1. Dumping Site number 14 L before planting

Table: 3
Chemical properties of the soil used for making the planting medium

Site	Planting medium					
	pH	Electrical Conductivity (m mhos cm^{-1})	Organic carbon (%)	Available N (kg ha^{-1})	Available P (kg ha^{-1})	Available K (ppm)
DS-01	6.2	0.178	1.19	225.8	48.6	101.5
DS-02	5.5	0.064	1.77	163.1	49.0	219.0
DS-03	6.0	0.048	1.68	276.0	56.0	295.9
DS-06	6.4	0.062	1.91	282.2	56.0	28.8
DS-08	7.5	0.250	0.95	235.2	141.1	120.4
DS-09	6.6	0.058	1.43	210.1	72.7	37.7
DS-12	8.3	0.184	0.32	31.4	48.0	68.6
DS-13	7.1	0.217	0.92	185.0	50.9	100.5
DS-14L	8.8	0.151	0.26	138.0	53.8	81.5
DS-14U	8.8	0.160	0.35	34.5	47.1	99.5
DS-16	5.5	0.061	3.40	153.7	32.0	102.5

Table: 4
Time and number of tree saplings planted at the dumping sites

Site	DS-01	DS-02	DS-03	DS-06	DS-08	DS-09	DS-12	DS-13a	DS-13b	DS-14L	DS-14U	DS-16
Planting date	Apr 4-8, 2011	Sep 1-5, 2010	Jul 11-15, 2011	Jul 31-Aug 05, 2011	Mar 1-2, 2012	Mar 3-6, 2012	Aug 27-Sep 6, 2010	Sep 6-10, 2010	Sep 10-20, 2010	Aug 27-30, 2010	Sep 1-6, 2010	Mar 10-11, 2011
Aesculus indica	93	52	50	285	300							150
Ailanthus excelsa	116	77	100	100	750	270	500	52	460			100
Alnus nitida	350			100								
Bamboo	80	40		100				46				
Pinus wallichiana			100	200		200				176	150	50
Cedrus deodara		41	50	100	250	100						100
Punica granatum			300	620			1019	127	1140			
Quercus leucotrichophora			50	150		500				88	75	
Populus ciliata	116			110								
Robinia pseudoacacia	20	128	100	120	680	930	500		832	88	75	50
Salix alba	115	134	300	315								
Total	890	472	1050	2200	1980	2000	2019	225	2432	352	300	450

of the above mentioned shrub and herb species were sown in the soil spread on the surface. After plantation, the tree saplings planted at the DS were irrigated initially at every alternate day. Later the watering was done as and when required, depending upon the prevailing weather conditions. The water requirement was decided based on visual observations. The sites closer to water sources such as rivers required less water while sites away from rivers as well as those at higher elevation required frequent water. The wilting of leaves due to water scarcity also indicated for the water requirements of plants. For protecting the plantation from stray cattle the DS were fenced properly. The performance of the plantations was monitored at regular interval. Consequent upon the mortality of a tree sapling a vacant planting bag was replanted (infilled) at suitable time.

Observations were recorded on rate of survival or establishment of transplants, at 1 year after planting at each plantation-site (Table 5). Height of the tree species planted at the sites was recorded at 12 months interval after planting. Correlation coefficient between altitude of the plantation-site and rate of establishment of the transplants at 1 year after planting, and between the altitude and height of the target tree species at 2 and 3 years after planting was estimated, separately for each tree species.

3. RESULTS AND DISCUSSION

Among the 11 tree species used for revegetation, *Aesculus indica*, *Ailanthus excelsa*, *Pinus wallichiana*, *Cedrus deodara*, *Robinia pseudoacacia* and *Quercus leucotrichophora* were planted at least on six or more number of targeted sites (Table 4). Observations on establishment of the tree species used for revegetation at different sites revealed that the rate of survival at 1 year after transplanting ranged from 69.2% (at DS-01) to 96.6% (at DS-13b, Table 5). The average survival rate was 85.4%. There was a negative correlation between the altitude of the planting-site and the rate of establishment, however it was statistically non-significant (r= -0.35). The DS (DS-02 and DS-14L) before and two year after planting are shown in Fig. 1 to Fig. 4.

The plant height of the selected tree species after 3 years of planting is given in the Table 5. Results revealed that mean plant height of *R. pseudoacacia* (5.90 m) was higher than that of other target tree species followed by *Ailanthus excelsa* (1.39 m). Among the target tree species, being coniferous species, *P. wallichiana* and *C. deodara* showed

Fig. 2. Dumping Site number 14 L after planting (two years)

Table: 5
Plant height (m) of selected seven tree species at 3 years after planting at different sites

Site	Altitude (m amsl)	Survival (%) 1 year after planting	Mean plant height (m) at 3 years after planting						
			Aesculus	Ailanthus	Pinus	Cedrus	Robinia	Quercus	Salix
DS-01	2075	69.2	1.07		0.79	0.96	6.18		2.07
DS-02	2075	87.7	1.35	1.67		1.13	5.30		1.79
DS-03	2075	81.9	0.80		0.94	0.93	3.16	1.16	1.98
DS-06	2123	84.3	0.58	2.83	0.49	0.76		0.59	1.18
DS-08	2027	90.0	1.26	1.33	0.76	1.20	6.00	0.48	
DS-09	2027	88.0		1.00	0.71	1.05	5.77	0.69	
DS-12	1403	85.4		0.71			6.49		
DS-13a	1403	87.7					6.32		
DS-13b	1403	96.6		1.19			6.76		
DS-14L	1493	91.4		0.99	0.44		7.30	0.48	
DS-14U	1493	78.6			0.30	0.31	6.14	0.57	
DS-16	2221	84.5	1.30		1.13	1.50	5.52		
	Mean	85.4	1.06	1.39	0.69	0.98	5.90	0.66	1.75
Correlation Coefficient (r)*		-0.35	0.03	0.64	0.78**	0.82**	-0.62**	0.43	-0.96**

* Correlation Coefficient between altitude of the site with survival rate and plant height; ** Significant correlation

Fig. 3. Dumping Site number 02 before planting

Fig. 4. Dumping Site number 02 after planting (two years)

lower plant height of 0.69 m and 0.98 m, respectively (Table 5). The biofertilizers consisting of plant growth promoting rhizobacteria (PGPR) was applied to the soil. These are recognized as efficient soil microbes. They enhance the overall growth of plant species and are safe to the environmentally. It promotes plant growth, solubilization of P (Phosphorus), K (Potassium) uptake of N (Nitrogen) and some other elements. PGPR enhances root growth, leading to a root system with large surface area and increased number of root hairs. Nitrogen fixation and P-solubilization, production of antibiotics and other growth promoting substances was the main contribution in this plantation. The PGPR is also using in agro-ecosystem (Singh, 2013). Recent finding (Singh, 2013) treatment of PGPR inoculation significantly increases agronomic yield as compared to uninoculated soil. We have planted tree species separately and also observed the results. In our infilling tree species was the base of this observation. In our studies, it has played a major role in establishing plantation in all the DS.

Plant height of *R. pseudoacacia* and *P. wallichiana* indicated correlation with the altitude of the planting site (Table 5). While plant height of *R. pseudoacacia* significantly declined with increase in the altitude of the site (r= -0.62), *P. wallichiana* and *C. deodara* after 3 years showed increment in plant height with increase in altitude of the site (r= 0.78 and 0.82), though statistically it was significant. Remaining species showed no correlation between the plant height and the altitude of the site in the case of *Salix* and *Robinia*.

Consequent upon the mortality of a tree sapling a vacant planting bag was re-planted (infilled) at 5 to 17 months after initial planting date. Total 4,875 tree saplings were required to replant (infill) at the vacancies in all the 10 DS. About 1 year after planting the tree saplings, the rate of survival ranged from 69.2% (at DS-01) to 96.6% at DS-13b.

Revegetation has been proved to play an important role in protecting the soil surface from erosion as it acts as soil binders leading to accumulation of fine particles (Conesa *et al.*, 2007). Establishment of revegetation in the present study helped in development of extensive root system under culture medium (forest soil, peat moss and PGPR) thereby leading to prevention of erosion by stabilising the soil slopes. As observed from the physical appearance of the sites, the plantations were found to increase soil organic matter, lowered soil bulk density, moderated soil pH (Mendez and Maier, 2008). The selection of plants for revegetation at the DS was carried out by considering the local ecosystem and their ability to survive and regenerate under prevailing severe conditions and the nature of the dump material. Madcjon *et al.* (2006) also reported that dump surface can be stabilized effectively by replantation.

Tree species have potential to improve soil through numerous processes which includes soil organic matter addition, biological fixation (PGPR) uptake of nutrients from deeper soil layer, increase water filtration and storage, reduce loss of nutrients by erosion and leaching, improve soil properties, reduce soil acidity. In plantation *R. pseudoacacia,* tree species have the potential to improve the soil fertility (Gopichand, 2014). It has been recorded that new self sustaining top soils are created by tree species. As per our observations plant litter and root exudates provide nutrient cycling to soil. The results are in line with findings of Pulford and Watson, 2003; Coates, 2005; Padmavathiamma and Li, 2007 and Mertens *et al.,* 2007. Nitrogen is a major nutrient for the plant growth it was sufficient culture media for plant growth as our observations proved. Also nitrogen fixing species have a most significant effect on soil fertility through production of readily decomposable nutrient rich litter and turnover of fine roots and nodules. *R. pseudoacacia* is the main species to fix nitrogen through its root system. Yang *et al.*

(2003) and Song *et al.* (2004) also studied and observed the importance of nitrogen in plant growth.

4. CONCLUSIONS

Among the tree species evaluated for revegetation, *R. pseudoacacia* followed by *Ailanthus excelsa* performed better than remaining tree species, in terms of survival rate and plant height. The average survival rate was 85.4%. It was found that in terms of plant growth, *R. pseudoacacia* would be more suitable for lower altitudes up to 1493 m above (msl), while *P. wallichiana* and *C. deodara* should be selected for higher planting sites. The shrubs and herbs species planted in the targeted sites survived very well and helped in binding the soil over the slopes leading to support to tree species in their establishment and growth.

ACKNOWLEDGEMENTS

The authors are grateful to National Hydroelectric Power Corporation, Faridabad for financial support through project # SSP-0065 and CSIR, New Delhi for providing the facilities. We thank Er. Amit Kumar of High Altitude Biology division for his help during manuscript preparation.

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