Range Mgmt. & Agroforestry 31 (1) : 1-6, 2010
ISSN 0971-2070

Salix fragilis L.: Pollarding potential in dry temperate environment of the North-Western, Himalaya, India

Yashwant S. Rawat[1], Subhash C. R. Vishvakarma[1*], Santaram S. Oinam[2], N.P. Todaria[3] and Rakesh K. Maikhuri[4]
[1*]G.B. Pant Institute of Himalayan Environment and Development, Kosi-Katarmal, Almora-263 643, Uttarakhand, India.
corresponding author e-mail : ihedhima@yahoo.com, scrvishvakarma@hotmail.com
Received : 23rd August, 2008 Accepted :23rd March, 2010

Abstract

Willow (*Salix fragilis* L.) is an important fuel wood, fodder and small timber tree species in dry temperate environment of the Lahaul valley (HP), cultivated under agroforestry and forestry systems. It is widely cultivated on terraces of agricultural fields, wastelands, along with water channels (*kuhls)* and in around settlements through traditional shoot-cutting plantation. Increase in the length and diameter of coppices was noted with increase of DBH (diameter at breast height) category and trunk height of *S. fragilis*. Similarly, emergence of number of coppices in tree was found influenced by trunk height and DBH categories. Trunk height of 2.00 m to 2.50 m was most appropriate for pollarding of willow in cold desert environment of the Lahaul valley.

Key words: Coppicing potential, Dry temperate, Lahaul valley, Willow, North-Western Himalaya, Salix

Introduction

Twenty four species of willow (*Salix* sp.) are found in entire Indian Himalayan Region (IHR) (Troupe, 1986). Out of them, 10 shrubs of willow species are reported from dry temperate environment of the Lahaul valley (Aswal and Mehrotra, 1994). Two tree species (*Salix fragilis* L. and *S. alba* L.) of willow introduced from Jammu & Kashmir about 150 years ago are cultivated in the Lahaul valley under agroforestry and forestry system around the settlements (Rawat *et al.,* 2006). *S. fragilis* is widely cultivated through traditional shoot-cuttings method and is the best suitable tree species in the region, where no other plantation survives due to extremely low temperature in winter and xeric soil conditions during summer. The genus *Salix* with its fast growth rate and better pollarding potential is widely selected for Short Rotation Forestry (SRF) for renewable energy (Lindroth and Bath, 1999; Weigh and Nordh, 2002). Recent studies throughout the world have demonstrated that willow grown under Short Rotation Intensive Culture (SRIC), have potential for high biomass production (Weigh and Nordh, 2002). Though, *S. fragilis* is widely cultivated and pollarded for fuel wood, fodder and minor timber after three years of interval in the Lahaul valley, yet no scientific investigation has been carried out so far in terms of the pollarding potential of willow species in this region. The present study deals with pollarding potential of *Salix fragilis* trees in dry temperate environment of the Lahaul valley.

Materials and Methods

1. Study area and climate

The present study was carried out in dry temperate environment of the Lahaul valley, district Lahaul & Spiti, Himachal Pradesh in the North-Western Himalaya. The district is situated between 31° 44ô34ò N to 32° 59ô57ò N latitudes and 76° 46ô29ò E to 78° 41ô34ò E longitudes. This is a land locked area, approachable during summers months only through surface route *via* Rohtang pass (3978 m amsl). The present study was carried out at middle of the valley at Jahlma village (3000 m amsl). At the study site, maximum temperature reaches 27.8° C in July, while minimum temperature plunges down to -13.21° C in the month of January. The average annual rainfall and snowfall ranged from 241.5 to 272.4 mm and 693.2 to 466.2 mm, respectively.

2. Survey, sampling and measurement

A plot of pre established *Salix fragilis* plantation of 500 m x 500 m was demarcated at appropriate site (3000 m amsl) in the study area. In this plot, coppice producing potential of different sizes of willow trunk was assessed with respect to trunk height and DBH (diameter at breast height). Tree age was assessed with the help of owner of

[2]G.B. Pant Institute of Himalayan Environment and Development, Himachal Unit, Mohal-Kullu- 175 126, Himachal Pradesh, India.
[3]Department of Forestry, Post Box No.-59, H.N.B. Garhwal University, Srinagar (Garhwal)-246 174, Uttarakhand, India
[4]G.B. Pant Institute of Himalayan Environment and Development, Garhwal Unit, Srinagar Garhwal-246 174, Uttarakhand, India.

the plantation. Trees of the similar age within DBH category were selected for the study. Selected trees of 0.3-10 cm, 10-20 cm, 20-30 cm and > 30 cm DBH categories were, respectively 10, 20, 40 and >70 years old. All the trees of the same DBH category were of the similar age and were raised through traditional shoot-cutting propagation method. All the willow plantations are regularly irrigated after an interval of 15 days through traditional off-take water channels locally called *khul*. Ten willow trees were selected for each DBH category. Ten willow trees were selected for each trunk height such as small size (1.60 to 1.80 m), medium size (1.80 to 2.00 m) and large size (2.00 to 2.50 m). Trunk height was measured from base to top of trunk. Thus, 120 willow trees were sampled.

Number of coppices were counted from each tree, 6 coppices were marked in each tree and measured for further detailed growth study. Measurements included length and diameter of coppices. Length of coppices was measured from base to top of the coppices in meters with the help of measuring tape and properly graduated wooden rod. Diameter of coppice was measured at the base of coppices with the help of vernier caliper. The data were analyzed for correlation between trunk height and number of coppices for all DBH categories. All data of trunk height was pooled for each circumference category. Observations were recorded continuously for three years in the month of September every year.

Results and Discussion

At the end of first growth season under the DBH category of 0.3-10 cm, number of coppices were 69.80±2.98 under small trunk size, followed by medium trunk size (71.00 ±2.16) and maximum under large trunk size (71.50±5.67) (Table 1). Under 10-20 cm DBH category, number of coppices were 81.90±3.87, 103.40±9.29 and 116.00±10.24, respectively for small, medium and large size trunks. Similar pattern of increase in number of coppice with increase of trunk sizes was found under all the DBH categories. However, increase in the length of coppices and diameter of coppices was noted only with increase of DBH categories. Increase in the length and diameter of coppices was not significant with increase in trunk size under similar DBH category. There was no significant difference in the length and thickness of coppices emerging from small, medium and large size trunks during first, second and third years.

Number of coppices in trees was influenced by trunk height and DBH categories (Tables 1 & 2). Trunk height and number of coppices were correlated under all the DBH categories ($P<0.05$, r=0.386, 0.385, 0.421). However, under DBH category of > 30 cm the best correlation with trunk height and number of coppices ($P< 0.01$, r= 0.540) was found in the end of first year of growth. In second and third years of the growth correlations between trunk height and number of coppices were best under DBH category of 10-20 cm. In the third year of growth correlation values between trunk height and number of coppices were non-significant except DBH category of 10-20 cm. DBH category 20-30 cm and >30 cm and large trunk height of 2.00 m to 2.50 m was most appropriate for pollarding in dry temperate environment of the Lahaul valley.

At the end of first growth season, average length of coppices under DBH category of 0.3 -10 cm was more or less similar in all the three trunk sizes (Table 1). Similar trend was recorded for coppice length under DBH category of 10-20 cm. Average length of coppices under DBH category of 20-30 cm was maximum (1.37±0.02 m) in large sized trunk and on the lowest (1.28±0.04 m) in small sized trunk height. Similar trend was also recorded under DBH category of > 30 cm. Length of coppices at the end of second and third years growth season also showed the similar pattern; the longest coppices were in large sized trunk height followed by medium and small size. There was no significant difference in the coppice length under all the DBH categories.

At the end of first growth season, average diameter of coppices was highest in large trunk height (12.30±0.40 mm) followed by medium (11.72±0.26 mm) and small (11.42±0.16 mm) (Table 1). Diameter of coppices at the end of second and third years also showed similar patterns and height. Under all the circumference categories no significance difference was found at the end of same year in all the three sized trunk height.

The tree size and trunk height of willow trees vary under different DBH categories. The reserve food material stored in the stem is utilized for production of new leaves and branches (Vishwanatham *et al.,* 1999). The physiological processes are directly related to the climatic and edaphic conditions and management practices of willow cultivation in the region. Efficient metabolism and the production of new tissues are prerequisites for growth and development of willow plants and thus are important determinants for the competitive ability of the species.

Emergence of coppices increased with increasing DBH categories; large tree trunks produced more coppices as compared to small size tree trunks. Under all the DBH categories and under all the three trunk sizes mortality of coppices was recorded during second and third years.

Table 1: Coppice potential of *Salix fragilis* L. in dry temperate environment of the Lahaul valley

DBH	Trunk size								
Category (cm)	Small (1.65 m height)			Medium (1.86 height)			Large (2.25 m height)		
	First Year	Second Year	Third Year	First Year	Second Year	Third Year	First Year	Second Year	Third Year
0.3 to 10									
DBH (cm)	8.28±0.28			8.09±021			8.40±0.29		
Trunk height (m)	1.65±0.01			1.86±0.02			2.25±0.06		
No. of coppices	69.80±2.98	61.30±2.79	48.70±2.97	71.00±2.16	62.60±2.49	50.20±2.30	71.50±5.67	63.60±6.12	52.20±5.24
Coppice length (m)	1.04±0.02	3.15±0.05	4.68±0.08	1.05±0.01	3.19±0.04	4.72±0.03	1.05±0.03	3.20±0.08	4.75±0.13
Coppice diameter (mm)	9.23±0.13	23.96±0.32	51.24±0.80	9.28±0.16	24.20±0.32	51.60±0.75	9.30±0.38	24.43±0.79	51.69±1.96
10 to 20									
DBH (cm)	17.86±0.32			15.09±1.11			14.77±1.00		
Trunk height (m)	1.65±0.01			1.84±0.04			2.13±0.02		
No. of coppices	81.90±3.87	66.00±4.53	51.20±4.31	103.40±9.29	92.50±8.25	76.50±8.20	116.00±10.24	104.90±9.93	89.20±9.41
Coppice length (m)	1.09±0.01	3.26±0.02	4.92±0.03	1.09±0.02	3.50±0.17	5.19±0.22	1.10±0.02	3.53±0.03	5.26±0.04
Coppice diameter (mm)	10.18±0.27	25.44±0.54	56.01±1.49	10.72±0.29	27.21±0.64	58.94±1.61	10.95±0.35	27.84±0.63	60.23±1.90
20 to 30									
DBH (cm)	25.75±0.80			24.64±0.95			25.62±1.06		
Trunk height (m)	1.66±0.03			1.95±0.03			2.31±0.04		
No. of coppices	140.00±11.95	126.10±12.22	106.10±12.21	151.00±3.48	131.60±2.95	106.70±2.26	180.50±20.05	153.60±14.11	117.30±11.26
Coppice length (m)	1.28±0.04	3.80±0.11	5.76±0.18	1.34±0.04	4.05±0.13	6.05±0.20	1.37±0.02	4.15±0.05	6.16±0.08
Coppice diameter (mm)	10.78±0.10	26.78±0.20	59.31±0.56	10.92±0.31	28.00±0.65	60.04±1.69	11.28±0.39	28.29±0.53	62.06±2.15
>30									
DBH (cm)	32.090±1.10			30.53±0.68			34.98±1.49		
Trunk height (m)	1.65±0.02			1.95±0.02			2.48±0.09		
No. of coppices	149.50±9.87	127.10±8.36	107.90±7.66	183.50±17.95	143.90±15.48	113.30±2.48	237.00±22.45	158.80±11.58	121.50±9.04
Coppice length (m)	1.35±0.03	4.09±0.06	6.09±0.15	1.41±0.04	4.24±0.12	6.35±0.18	1.43±0.03	4.42±0.13	6.44±0.12
Coppice diameter (mm)	11.42±0.16	28.03±0.29	62.79±0.86	11.72±0.26	28.25±0.82	63.16±1.46	12.30±0.40	30.74±0.87	67.65±2.22

Sharma and Thakur (1995) found death of coppices due to competition for food materials as compared to diseases. Orians *et al.,* (1999) during their studies on *Salix sericea* and *S. eriocephala* concluded that availability of soil moisture, environmental stress, edaphic and biotic factors were responsible for growth and survival of coppices. Sachi and Price (1992) found low water availability was primary cause of mortality during the first 2 years of growth in *S. dasiolepis* Benth. These environmental factors are expected to act strongly, because xeric soil hampers nutrient uptake (Weigh, 2001). Under present study traditionally willow trees were regularly irrigated and soil moisture was not a limiting factor, mortality of coppices during second and third years seems more due to completion of food material. As the growth proceeded from first to second and third years demand of the food material increases, subsequently weaker coppices were eliminated. Growth rate and number of coppices also get reduced due to competition with other associated species and amongst coppices for existence or food materials (Richardson, 1993). Under all the DBH categories highest survival of coppices at the end of first year, second year and third year was maximum in medium and large trunk sizes under DBH categories of 20-30 cm and > 30 cm. Number of coppices showed direct relation with DBH of trunk and its height. With increase of DBH, coppices also increased in all the trunk sizes. At the end of first growth season number of coppices was highest in large trunk size than that of small and medium trunk size under the DBH categories; large trees produced more number of coppices than that of small and medium size trees. Thakur and Sehgal (2003) during their studies on pollarding of *Grewia optiva* and *Morus alba* trees found that both the branch wood and foliage production increased with increasing pollarding heights. The emergence of coppices mostly depends on tree size, altitude, edaphic factors, age of tree and management practices. Here cavity development in trees starts in about 70 years old trunks and subsequently, emergence of coppices declines with increase of cavity size. Under present study emergence of coppices showed increasing trend starting from 03-10 cm DBH to >30cm DBH. However, % changes in emergence of coppices showed the increasing trend upto 20-30 cm DBH categories (40 year old tree) and declining trend after that (Table 3). In other way upto the age of 40 years, percentage emergence of coppices was increasing after then it declines slowly. After age of 70 years emergence of coppices drastically declines as compared to 40 year old tree. Though variation in number of coppices is controlled by genetic constitution of the species but its number also depend on physiological processes and site related factors. Data of present study revealed that with increase in DBH and trunk height, number of coppices increases but after attaining the certain age percent emergence of coppices declines. Positive correlation between trunk height and number of coppices is clear cut evidence of relationship between trunk height and number of coppices during first year of growth. In second year of growth correlation was tilting toward non-significant values except DBH categories of 10-20 cm and 20-30 cm in second year and in 10-20 cm DBH category in third year of successive growth. High mortality of coppices in second and third year of growth could be the reason of lesser and

Table 2: Correlation between trunk height (TH) and number of coppices (NC) in dry temperate environment of the Lahaul valley

Diameter category(cm)	Correlation (TH vs NC Ist year of growth)	Correlation (TH vs NC IInd year of growth)	Correlation (TH vs NC IIIrd year of growth)
03 to 10	0.386*	0.071ns	0.172ns
10 to 20	0.385*	0.446***	0.451***
20 to 30	0.421*	0.384*	0.231ns
>30	0.540***	0.299ns	0.172ns

d.f.=28 *=Significant at 0.05 level ***= Significant at 0.01 level ns = not significant

Table 3 : Changes in pattern of emergence of coppices (%) from 0.3-10 cm to 10-20 cm, 10-20 cm to 20-30 cm and 20-30 cm to >30 cm DBH categories of willow trees in the Lahaul valley

DBH category	Age of tree	Trunk size			
	(year)	Small	Medium	Large	Average
0.3-10 cm	10	-	-	-	-
10ð 20 cm	20	17.34	45.63	62.24	41.74±13.11
20ð 30 cm	40	70.94	46.03	55.60	57.53±7.25
>30 cm	70	6.79	21.52	31.30	19.87±7.13

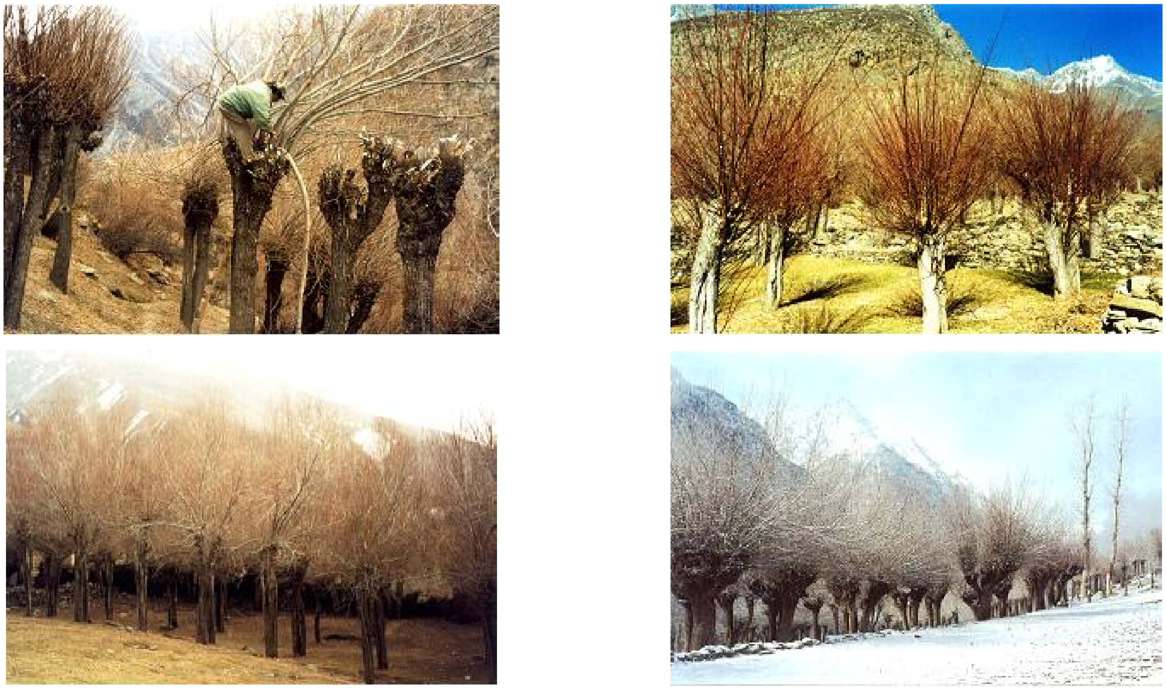

Fig. 1 (A-D) : Pollarding and subsequent growth of willow in the cold desert of the Lahaul valley. A. Pollard of three years coppice; B. One year old coppice; C. Two years old coppice; D. Three years old coppice

non-significant correlation values under 0.3-10 cm, 20-30 cm and >30 cm DBH categories of trunk during second and third year of successive growth. Coppices mortality was less under DBH category of 10-20 cm as compare to other DBH categories (Table 1).

In the present study, the length and diameter of coppices improved appreciably with increase in pollarding height. Harrington (1984) found higher sprout growth with increase in stump height in red alder (*Alnus rubra* Bong.). Khan and Tripathi (1989) reported similar pattern of increase of sprouts with increase of stump height for *Alnus nepalensis* and *Quercus griffithii* trees; in case of *A. nepalensis* increase of number of sprouts was higher as compared to *Quercus griffithii.* Inter specific variations for growth in height was a common phenomenon in multipurpose agroforestry tree species (Bisht and Tokey, 1993). Growth in diameter showed similar trend like growth in length of coppices. Diameter of coppices at the end of IInd and IIIrd years also showed similar pattern like diameter of Ist year. The growth behavior not only varies from species to species but within the same species with changing micro site environment. Growth process in tree species can be checked at any phenophase by any limiting factor; however, soil moisture often becomes the most important and unavoidable constraint. Environmental conditions, nutrients and moisture limit the growth of *Salix* (Lindroth and Bath, 1999). Plant growth is directly related to the biomass production. Inadequate food materials affect growth and emergence of sprouts (Khan and Tripathi, 1989). Under present study emergence of coppices were increasing both with increase of DBH and tree trunk height. Larger reserve of food material accumulated in the trunks promoted higher emergence and growth of coppices under ensured irrigated condition. The result of present study clearly suggests that 3 years rotation cycle is more appropriate for high biomass harvest as compared to one and two years cycle.

Conclusions

Production of fuel wood and fodder (particularly for winters) is important under severe harsh climatic conditions and barren landscape of the Lahaul valley. On the basis of the present study while raising willow plantation larger tree trunks of 2.00 m to 2.50 m height and 3 years pollarding interval should be considered for better foliage and woody biomass production.

Acknowledgements

Authors are thankful to the Director G. B. Pant Institute of Himalayan Environment and Development, Kosi-Katarmal, Almora, Uttarakhand for providing necessary facilities. Financial support for the study was provided by the Ministry of Environment and Forests, Govt. of India. First author also acknowledged CSIR, New Delhi for awarding Senior Research Fellowship.

References

Aswal, B. S. and B. N. Mehrotra. 1994. *Flora of Lahual- Spiti. A Cold desert in North West Himalaya.* Bishan Singh, Mahendra Pal Sigh, Dehradun, India.

Bisht, R. P. and O. P. Tokey. 1993. Growth pattern and architectural analysis of nine important multipurpose trees in an arid region of India. *Can. J. For. Res.* 23: 722-730.

Harrington, C. A. 1984. Factors influencing initial sprouting of red alder. *Can. J. For. Res.* 14: 357-361.

Khan, M.L. and R. S. Tripathi. 1989. Effect of stump diameter, stump height and sprout density on the sprout growth of four tree species in burnt and unburnt forest plots. *Acta Ecologica Ecol. Applic.* 10: 303-316.

Lindroth, A. and A. Bath. 1999. Assessment of regional willow coppice yield in Sweden on basis of water availability. *Forest Ecol. Manag.* 121: 57-65.

Orians, C. M., D. I. Bolnick, B. M. Roche, R. S. Fritz and T. Floyd. 1999. Water availability alters the relative performance of *Salix sericea, S. eriocephala*, and their F1 hybrids. *Can. J. Bot.* 77: 514-522.

Rawat, Y.S., S.S. Oinam, S.C.R. Vishvakarma, C.P. Kuniyal and J.C. Kuniyal. 2006. Willow (*Salix fragilis* Linn.): a multipurpose tree species under pest attack in the cold desert of Lahaul valley, north-western Himalaya, India. *Ambio* 35: 43-48.

Richardson, B. 1993. Vegetation management practices in Australia and New Zealand. *Can. J. For. Res.* 23: 1989-2005.

Sachi, C. F. and P. W. Price. 1992. The relative roles of abiotic and biotic factors in seedling demography of arroyo willow (*Salix lasiolepis*: Salicaceae). *Amer. J. Bot*. 79: 395-405.

Sharma, G. C. and J. R.Thakur. 1995. The giant willow aphid, *Tuberolachnus salignus* (Gmelin), a serious pest of *Salix* sp. in Spiti valley of Himachal Pradesh. *J. Aphidology* 5: 86-89.

Thakur, P. S. and S. Sehgal. 2003. Growth, Leaf Gas Exchange and production of Biomass in coppices and Pollarded Agroforestry Tree Species. *J. Tropical Forest Science* 15: 432-440.

Troupe, R. S. 1986. *The Silviculture of Indian Trees*. International Book Distributors, Dehradun, India. Vol. III.: 951-957.

Vishwanatham, M. K., J. S. Samra and A. R. Sharma. 1999. Biomass production of trees and grasses in a silvi-pasture system on marginal lands of Doon valley of north-west India. I Performance of tree species. *Agroforestry Syst.* 46:181-196.

Weigh, M. 2001. Evidence for increased sensitivity to nutrients and water tress in a natural willow clone. *Tree Physiology* 21: 1141-1148.

Weigh, M. and N. E. Nordh 2002. Characterizing willow for biomass and phytoremediation: growth, nitrogen and water use of 14 willow clones under different irrigation and fertilization regimes. *Biomass and Bioenergy* 23: 397-413.