

Impact of bark removal on survival of *Taxus baccata* L. (Himalayan yew) in Nanda Devi Biosphere Reserve, Garhwal Himalaya, India

Aditya Purohit[†], R. K. Maikhuri^{†,*}, K. S. Rao[‡] and S. Nautiyal[‡]

[†]Sustainable Development of Rural Ecosystem, G.B. Pant Institute of Himalayan Environment and Development, Garhwal Unit, P.B. 92, Srinagar (Garhwal) 246 174, India

[‡]Sustainable Development of Rural Ecosystem, G.B. Pant Institute of Himalayan Environment and Development, Kosi-Katarmal, Almora 263 643, India

The Himalayan yew (*Taxus baccata* L.) is widely but sparsely distributed along the cool temperate belt between 2600 and 3300 m asl of the Nanda Devi Biosphere Reserve (NDBR), Garhwal Himalaya. Traditionally, the bark of this plant is used for preparing beverages locally called *Namkin Chay*, medicines and its wood as a timber in various regions of the Himalaya. However, due to its excessive collection for use in anti-tumour and anti-cancer drugs, the population of this species has been reduced to a large extent. A study carried out between April 1997 and October 2000 showed that the trees with average girth of 10–90 cm were damaged through bark-stripping practices. The average consumption and collection of the bark was estimated to be 1.7 kg/family/year in the buffer zone villages of NDBR. It was noticed that the growth and survival of this species declined significantly when the bark was removed beyond a limit of average bark thickness (0.43 cm). Since bark collection is an important traditional activity and directly linked with the health and livelihood of the local people, it cannot be banned or stopped. It is suggested that if bark-removing practices are applied appropriately with minimum depth of 0.2–0.3 cm from around the circumference of the trees (> 40 cm cbh trunk) in a scattered manner, there will be minimum harmful effect on growth and survival of the trees. This paper describes the indigenous uses of *Taxus baccata*, impact of bark removal on survival and appropriate strategies for conservation/management of this species.

TAXUS baccata L., Himalayan yew, locally known as 'Thuner' in various parts of the Western Himalaya, has greater economic and medicinal values than the other gymnosperms in the region. *Taxus* as an understorey tree is found in temperate forests in the Pacific, north-west of North America, East Asia, North Africa and Europe^{1–4}. In India it is widely distributed in the temperate zone of Himalaya between 1800 and 3300 m above mean sea level¹. It is a late successional species and grows in its

natural habitat in Nanda Devi Biosphere Reserve (NDBR), Garhwal Himalaya, particularly on the north-north-west slopes. It is closely associated with *Betula utilis*, *Abies pindrow*, *Acer caesium* and *Pinus wallichiana*, and also found in small patches under the *Quercus semecarpifolia* and *Rhododendron arboreum* association in other parts of the Himalaya⁵. *T. baccata* received much attention during the recent past because its leaves and bark are the prime source of taxol, a potent anti-cancer drug^{6–8}. Taxol was first isolated from the bark of *Taxus brevifolia*⁹, but in India and other parts of the world pharmaceutical companies have succeeded in isolating it from the leaves. The presence of taxol has also been examined in the leaves, stem and bark of several *Taxus* species, including *T. baccata*¹⁰. In the Unani system of medicine, the extract from the bark and leaves of *T. baccata* was the source of a drug *Zarnab*, used for the treatment of various disorders¹. The paste prepared from its bark is applied as a plaster on fractured bone. It is also applied externally on the forehead to provide relief from headache¹¹. The extract from the bark and leaves is also used for the treatment of various diseases like bronchitis, asthma, poisonous insect bites and also as an aphrodisiac¹². The inhabitants of the buffer zone villages of NDBR have been collecting the bark of *T. baccata* mainly for making traditional tea and for curing cold and cough, for a long time. Tolchha and Marcha Bhotia sub-communities of NDBR and other traditional societies of the Himalaya used its leaves for thatching and wood carving, house construction and for the preparation of honey-bee shelter¹³. However, during the recent past, due to over-exploitation of this species legally or illegally for a variety of purposes, it is facing danger of extinction in different regions^{13–15}.

The main reasons for the decline of yew populations globally are widespread deforestation, selective felling of yew and grazing^{2,16,17}. *T. baccata* is very sensitive to forest fire and easily dries with ground fire¹⁸. Degradation of old populations and low regeneration in its natural habitat are the main problems in the conservation of *T. baccata*. Therefore, the present study was undertaken (i) to understand the patterns of its uses, quantify the bark extraction/collection and its impact on survival; and (ii) to develop strategies for conservation and management in its natural habitats.

The study area is located in the buffer zone of NDBR of Garhwal region (Central Himalaya). NDBR is situated between 30°17'N and 30°41'N latitude and 79°40'E and 80°05'E longitude and covers an area of 624.62 km² core zone and 1612.12 km² buffer zone. Recently, the total area of the NDBR has been increased from 2336.74 km² to 5800 km² (Figure 1). The climate of the area is typically temperate, monsoonal and divisible into three seasons, i.e. long winter, short summer and rainy. Average rainfall is 929 mm. About 47% of annual rainfall occurs over a short period of two months (July and August).

*For correspondence. (e-mail: rkmaikhuri@yahoo.com)

Monthly maximum and minimum temperature ranges between 24°–14°C and 7.5°–3°C, respectively. The area is geo-morphologically young and tectonically active¹⁹. Geologically, parent material is crystalline rocks, including mica schist, garnet mica quartz schist and mica quartz. The soil is generally friable, black-to-brown in colour, loam-to-sandy loam and well-drained. Frozen ice soil is also found in the valley or deep-shaded places in the months of April and May.

The people in these villages belong to two ethnic groups, viz. Indo-Mongoloid (Bhotiya tribals) and Indo-Aryan. The people inhabiting the buffer zone villages of NDBR located in the Chamoli part belong to the Tolchha community, which is one of the three sub-communities of the Bhotiyas. Except the residents of Reni, Peng, Lata and Tolma villages, all Tolchha–Bhotiya households have two permanent dwellings, one in the high altitudes between 2400 and 3500 m asl and other in the lower valleys (outside the buffer zone of NDBR) between 800 and 1500 m asl. This community has its own culture, tradition and religious beliefs. The major occupation of this community has been sheep rearing and agriculture, with the

latter gaining importance over pastoralism in contemporary time. The total number of households in ten buffer zone villages (Chamoli part) was 419, with a total population of 2253 of which 872 were adult male, 721 were adult female and 752 were children below 15 years of age. The average family size was 5–6 persons. In 2000–3500 m asl elevation zone, rainfed cultivation on terraced slopes is the common agricultural land use. Almost all the households are involved in agriculture through subsistence farming. Livestock comprises cows, bullocks, sheep, goat, horses and mules. The average number of animals per family was 19.5. All the households depend entirely on forests for fuel, fodder, timber and leaf litter for organic manure. Many plant species are used in traditional health care system.

A study has been carried out over a period of three years (April 1997 to October 2000) in the natural habitat of the *T. baccata* as well as in the buffer zone villages of NDBR. In nature, the *T. baccata* population regenerates through seeds¹. Seeds are surrounded by red, fleshy edible aril, have a long range of dispersal by means of birds, monkeys and sometimes through humans too. Seeds also

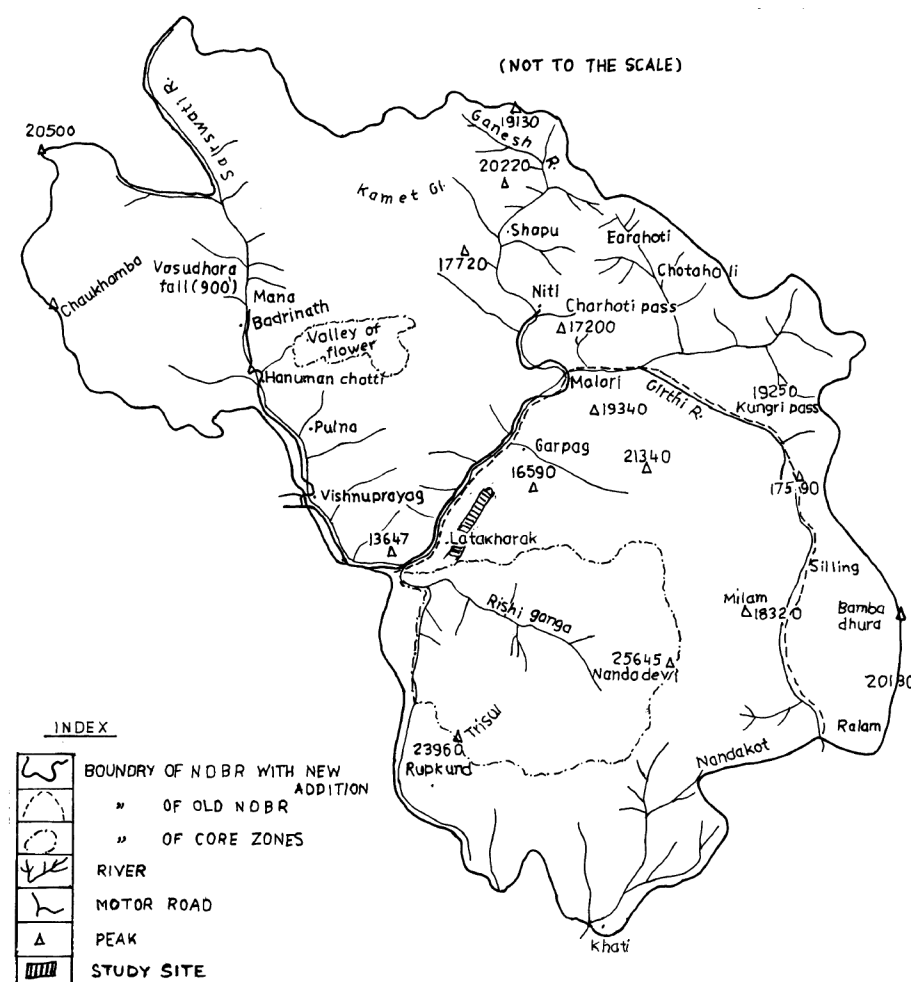


Figure 1. Map of Nanda Devi Biosphere Reserve with new addition.

Table 1. Average *Taxus baccata* bark collection kg/family/yr ($\bar{X} \pm \text{SD}$) on dry weight basis for preparation of traditional tea by the buffer zone villagers of NDBR. Values in parenthesis are the number of households surveyed in the study area

Family class	Small (1–4 persons)	Medium (5–8 persons)	Large (> 8 persons)
Poor	0.868 \pm 0.256 (35)	1.233 \pm 0.348 (45)	2.8 \pm 0.204 (10)
Medium	0.911 \pm 0.3 (42)	1.406 \pm 0.459 (70)	2.23 \pm 0.46 (15)
Rich	–	1.825 \pm 0.33 (15)	2.3 \pm 0.23 (8)

germinate in open canopy site between the forests, but do not survive. Low regeneration and recruitment of this species are because of grazing by goats, chilling injury, direct sunlight and fire, which are common in the Himalayan region. Data were collected to assess the consumption pattern of *T. baccata* bark used for traditional purposes by the Bhotiya tribal community. Anthropogenic pressure was also assessed, particularly on its bark, in the forest in terms of removed bark quantity (g/tree on dry weight basis) for different girth classes (10–50 cm and 50–90 cm cbh, i.e. circumference at breast height) during the study period. Besides, the total quantity of bark collected and consumed throughout the year by local people was quantified during the year on the basis of personal observations and by adopting weight survey method²⁰, in about 240 households which represent 60% of the total buffer zone villages. During the observation period, we visited each sampled household to collect information on the amount of *T. baccata* bark collected for the year. The dried bark was weighed using a top pan balance with the capacity of one kg. All these households were surveyed and grouped into three categories, i.e. (a) small family (with 1–4 members); (b) medium family (5–8 members); and (c) large family (> 8 members). These families were also categorized (viz. poor, medium and rich) based on their income earned through various sources as well as based on land holding, number and kinds of animals owned and employment status.

The two sites, each of 2 ha forests plots represented by *T. baccata* population and other associated species, i.e. *B. utilis*, *P. wallichiana*, *A. pindrow* and *Populus ciliata*, was selected near Lata and Tolama villages to assess the impact of bark removal on its survival. In each of the two sites, 5 transects (100 m length, 10 m width) along the slope were laid. Each transect was divided into 10 plots of 10 m \times 10 m size and in each plot, girth at breast height (i.e. 1.30 m above ground level) and the number of trees (cbh > 31.5 cm) were measured. Within a plot, one quadrat of 5 m \times 5 m was randomly laid to enumerate saplings (height > 20 cm and cbh < 31.5 cm) and within this, one quadrat of 1 m \times 1 m was randomly laid for enumeration of seedlings (height < 20 cm). Frequency, density and basal area values were calculated. Importance value index (IVI) was derived as a sum of relative frequency, relative density and relative basal area for each species²¹.

**Figure 2.** *Taxus baccata* tree from which a complete strip of bark was removed around the circumference.

Before initiating this study, a meeting was organized in these two villages and the villagers were requested to visit the area for bark collection in the presence of the researchers. Frequent visits, once in a month between April and October along with villagers to the study site were made to assess the actual quantity of bark removed and to see the process of debarking practised by the local people. From November to March, villagers usually do not collect the bark because of heavy snowfall in the area. It was noticed that the bark is removed from the main tree trunk in a different manner at various depths, which vary in quantity among the individuals. The volume of removed bark was estimated by measuring area and depth of bark on debarked trees; 30 individuals from different

girth classes were chosen. The measured volume of removed bark was converted into g/tree on dry weight basis and was averaged for two groups of girth classes, i.e. 10–50 and 50–90 cm.

An assessment was made to observe survival percentage of *T. baccata* tree, particularly among those individuals from which the bark was removed at various depths, i.e. up to 2 mm, 4 mm, 6 mm, and > 8 mm or beyond the maximum limit of bark depth. Along with depth, debarked area (25%, 50%, 75% and > 75% around the circumference up to a height of 2 m above the ground or depending on tree bole straightness) was also considered to assess its impact on survival. The observations were made for different girth classes from which the bark was removed.

The total (dried, uprooted and debarked) tree density of *T. baccata* ranged between 50 and 62 trees/ha. The average collection of bark per family per year was about 1.7 ± 0.318 kg dry weight (Table 1). Large-size families, belonging to all the income groups collect maximum bark compared to medium and small size families, throughout the year. Families of the poor income group totally depend on bark of *T. baccata* for tea all around the year, whereas rich families do not consume all the bark they have collected but distribute them to their kin living outside, particularly in the plains. While working on this aspect we found that there is no organized market available for selling *Taxus* bark in the area. However, due to the demand illegal extractions are going on.

The bark of *T. baccata* was peeled off from the main stem up to the height of 50–250 cm (depending on tree bole) from the ground, with the help of sharp sickle (Figure 2). The quantity of bark removed from the tree was measured as an average volume of 825 cm³/tree which is equal to 436 g dry weight for 10–50 cm girth classes and 1624 cm³/tree (966 g) for trees with 50–90 cm girth classes. The effect of debarking and browsing on *T. baccata* is poorly known though it is very susceptible to browsing and bark-stripping by deer and has a strong negative effect on recruitment and mature tree survival^{22–25}. Similar effect has been observed on *T. baccata* trees in NDBR, where bark-stripping has been done with the help of a sharp sickle by inhabitants of the buffer zone villages for traditional uses. They peeled off the bark from the trunk as a whole girdle of bark around the circumference or sometimes also in a scattered manner. During the study, it was also noticed (not monitored) that the browsing of *Taxus* seedlings by livestock, particularly sheep and goats was common, and had a negative impact on the growth of the seedlings.

Per cent survival after removing the bark from the trunk in different girth classes as well as at different thicknesses and areas is presented in Figure 3. Among the debarked *T. baccata* trees, survival was maximum when the bark was removed to a depth of 0.2 cm in a scattered manner. The maximum decline in survival was observed in those trees from which the bark was removed beyond the limit of

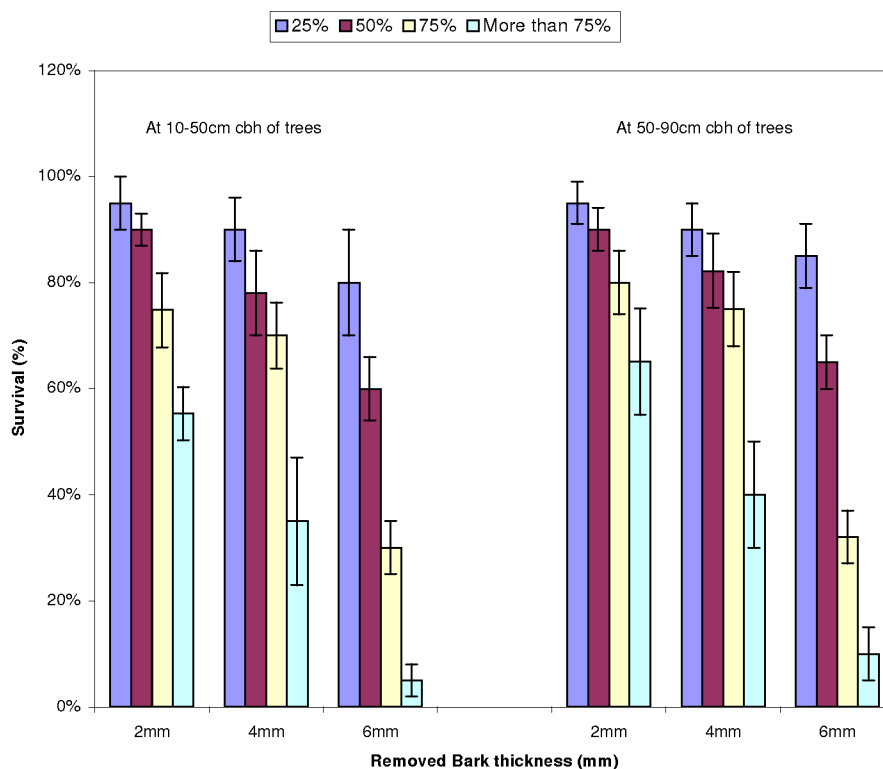


Figure 3. Survival percentage of *Taxus baccata* after removing bark from the tree trunk in different harvesting regimes.

average bark thickness (0.43 cm) or as a whole ring on the trunk. The effect of girdling on the tree trunk by removing bark from around the circumference was observed and it was noticed that the bark below the girdle dried and eventually died, which ultimately affects the growth and survival of the tree. Removal of bark (phloem) from the tree trunk usually blocks the translocation of materials, which is necessary for healthy growth and survival^{26–28}. Depth of bark removed is an important factor for the poor growth of the tree, because once the bark is stripped-off up to the cortex, the remaining part of the bark on the tree automatically splits up, even up to the top crown. Besides, bark-removing practices applied appropriately with minimum depth of 0.2–0.3 cm from around the circumference of the trees (> 40 cm cbh trunk) in a scattered manner, will have minimum harmful effect on growth and survival of the trees.

We have not found any correlation between bark removal depth and families of different income groups and sizes. Earlier, when there was not much demand traditionally, local people of the region used to collect/extract the bark usually from mature trees or trees with good growth, so as to not harm the trees. But, during the recent past, due to its legal or illegal extraction other than traditional uses, people do not even spare saplings or juvenile trees, which has a negative impact on the survival and growth of this species.

Taxus has very less or negative response to recovery or recruitment once the bark is peeled-off in a strip or as a whole ring from the trunk. The local population of NDBR buffer zone villages has been using bark of *Taxus* in traditional tea to cope with very cold climatic conditions of the area, for a long time. Since bark collection is an important traditional activity and directly linked with the health and livelihood of the people, it cannot be stopped or banned. However, in view of its large-scale collection legally or illegally, the people of the region should be made aware through conservation and environmental education programmes of sustainable harvest of bark and the harmful effect of debarking or girdling on the trees. Efforts in this direction are in progress. The regeneration and conservation of *Taxus* could be improved if all beneficiaries of the area participate and jointly act to protect, manage and adopt sustainable and appropriate techniques for the extraction/collection of bark and other useful parts.

1. Anon., *The Wealth of India*, Publication and Information Directorate, CSIR, New Delhi, 1976, vol. X, p. 591.
2. Tittensor, R. M., *Biol. Conserv.*, 1980, **17**, 243–265.

3. Watt, G., *A Dictionary of the Economic Products of India*, Gordhan and Company, Delhi, 1989, vol. 6, part 3, p. 479.
4. Lewandowsky, A., Burczyk, J. and Mejnartowicz L., *For. Ecol. Manage.*, 1995, **73**, 221–227.
5. Singh, J. S. and Singh, S. P., *Forests of Himalaya: Structure Functioning and Impact of Man*, Gyanodaya Prakashan, Nainital, 1992.
6. Kral, R., *Isoetaceae through Euphorbiaceae*, USDA Forest Service, Atlanta, Georgia, 1983, vol. 1.
7. Busing, R. T., Charls, B. H. and Thomas, A. S., *Conserv. Biol.*, 1995, **9**, 1199–1207.
8. Nemecek, S., *Sci. Am.*, 1996, 10.
9. Wani, M. C. and Taylor, H. L., *J. Am. Chem. Soc.*, 1976, **93**, 1325–1327.
10. Witherup, R. M., Look S. A., Slasko, M. W., Ghiorji, T. J., Muschik G. M. and Gragg, G. M., *J. Nat. Prod.*, 1990, **53**, 1294–1255.
11. Gaur, R. D., *Flora of the District Garhwal North West Himalaya with Ethnobotanical Notes*, Trans Media, Srinagar (Garhwal), 1999, p. 48.
12. Beckstrom-Sternberg S. M. and Duke, J. A., International Yew Resource Conference, Berkeley, USA, 1993, p. 3.
13. Maikhuri, R. K., Nautiyal, S. and Rao, K. S., *Curr. Sci.*, 1998, **75**, 152–157.
14. Gamble, J. S., *A Manual of Indian Timbers*, Simpson Low, Maston and Company Limited, London, 1992, p. 868.
15. Nandi, S. K., Rikhari, H. C., Nadeem, M. and Palni, L. M. S., *Physiol. Mol. Biol. Plant*, 1997, **3**, 15–24.
16. Bugala, W., in *The Yew-Taxus baccata L.* (ed. Bialobok, S.), Foreign Scientific Publications, Department of the National Center for Scientific, Technical and Economic Information, Warsaw, Poland, 1978, pp. 15–32.
17. Jahn, G., in *Temperate Deciduous Forests* (eds Rohrig, E., Ulrich, B.), Elsevier, Amsterdam, 1991, vol. 7, pp. 377–502.
18. Mc Cune, B. and Allen, T. F. H., *Can. J. Bot.*, 1985, **63**, 377–383.
19. Valdiya, K. S., *Geology of Kumaun Lesser Himalaya*, Wadia Institute of Himalayan Geology, Dehradun, 1980.
20. Maikhuri, R. K., *Bior. Techn.*, 1991, **35**, 291–296.
21. Curtis, J. T. and McIntosh, R. P., *Ecology*, 1950, **46**, 84–89.
22. Haeggstrom, C. A., *Acta Bot. Fenn.*, 1990, **141**, 1–28.
23. Gill, R. M. A., Gurnell, J. and Trout, R. C., in *The Ecology of Woodland Creation* (ed. Ferris Khan, R.), Wiley, Chichester, 1995, pp. 201–224.
24. Kelley, D. L., *J. Ecol.*, 1981, **69**, 437–472.
25. Sarmaja-Korjonen, K., Vasary, Y. and Haeggstrom, C. A., *Acta Bot. Fenn.*, 1991, **28**, 143–159.
26. Mason, T. G. and Maskell, E. J., *Ann. Bot.* 1928, **42**, 189.
27. Zimmermann, M. H., *Science*, 1961, **133**, 73–79.
28. Zimmermann, M. H. and Milburn, J. A., in *Encyclopaedia of Plant Physiology* (eds Pirson, A. and Zimmermann, M. H.), Springer-Verlag, Berlin, 1975, New Series, vol. I.

ACKNOWLEDGEMENTS. We are thankful to Dr L. M. S. Palni, Director, G.B. Pant Institute of Himalayan Environment and Development, Kosi-Katarmal, Almora for facilities. Financial support from the Ministry of Environment & Forests, Indian Council of Agriculture Research and Department of Biotechnology, Govt. of India is thankfully acknowledged. The views/opinions expressed in this article are those of the authors and not necessarily of the affiliated organization.

Received 26 December 2000; revised accepted 8 June 2001