The effect of disturbance levels, forest types and associations on the regeneration of *Taxus baccata*: Lessons from the Central Himalaya

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***Taxus baccata* L. subsp. *wallichiana* (Zucc.) Pilger has come into prominence in recent years because of its over exploitation from the Himalayan forests for pharmaceutical drugs. Despite wide elevational distribution (1770–3400 m elevation), it never forms extensive stretches and commonly occurs as undercanopy species. Further, it is an extremely slow-growing tree with poor seed germination. Along the disturbance gradient *Taxus* shows different population patterns. Least disturbed mixed broadleaf forest association shows stable population. The number of seedlings was related to crown cover and soil pH. The size class distribution of *T. baccata* population indicates that this species is on its way out at the study site. The threat is not only because of excessive harvesting but also due to degradation of forest sites for other reasons.**

TAXUS BACCATA (a small evergreen tree, family Taxaceae) is distributed between 1700 and 3400 m altitude, along west to east from Afghanistan to north-eastern Himalayan states in India. This tree commonly occurs in patches as under canopy associate of either conifers (*Abies pindrow* and *Cedrus deodara*) or broadleaf tree species (*Quercus semecarpifolia, Aesculus indica* and *Juglans regia*). Excessive harvesting to meet pharmaceutical requirements for taxol® (ref. 1) has caused severe threat to the survival of the species due to its slow-growing nature and poor seed germination[2]. The possible threat to *T. baccata* due to over exploitation was recognized at the beginning of this century[3], because of the multiple traditional uses. Consumption of seeds along with the aril (a sweet, fleshy cup-like structure surrounding the seed) by birds, monkeys and humans causes regeneration failure, as observed in a few areas. Further, the species is unlikely to reproduce in cleared forest areas or under large canopy gaps, as young plants require deep shade.

In recent years, information[1,4,5] has been generated on *T. baccata*, but very little is known about the regeneration of this species in comparison to other tree species of the region[6]. This study has been addressed to elucidate: (i) population structure of *T. baccata* in different forests and disturbance levels, (ii) regeneration status in different forests, and (iii) identification of associated factors that favour seedling recruitment.

The study area (Jageshwar) lies between 29°35′–29°39′N and 79°59′–79°53′E in the Kumaun Himalayan region of central Himalaya and occupies about 120 ha. The different forest associations sampled occur between 1810 and 2050 m altitude. *T. baccata* occurs in small groups of 5–10 individuals, in two associations: (i) Cedar forest (dominance of *Cedrus deodara* in canopy and a low occurrence of undercanopy tree associates, e.g. *Neolitsea pallens*), and (ii) mixed broadleaf forest (co-dominance of various tree species, e.g. *Juglans regia, Aesculus indica, Quercus leucotrichophora* and *Q. floribunda*). In these forests disturbance level was identified as least, moderate and heavy in terms of biomass removal, tree cutting and livestock grazing[1,5] (Table 1).

To depict population structure and regeneration trend all individuals of *T. baccata* were counted and measured

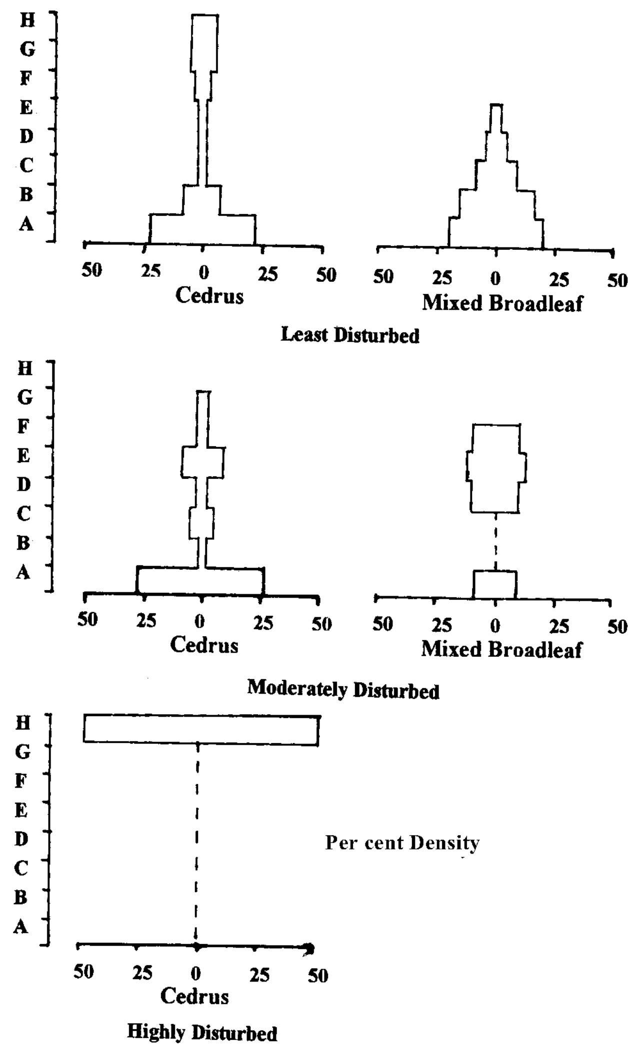

Figure 1. Representation of the size class distribution of *Taxus baccata* population in two types of tree associations. A, Seedling; B, Sapling; Trees: C, 10–30 cm; D, 30–50; E, 50–70; F, 70–90; G, 90–110; H, more than 110 cm CBH.

*For correspondence.

for circumference at breast height (CBH) in 7–14 randomly distributed 100 m^2 quadrates. Individuals up to 30 cm height were counted as seedlings, > 30 cm height but < 10 cm CBH as saplings and > 10.1 cm CBH as trees. Soil samples (40 cm depth) were collected from each forest site. The samples were analysed[7] for moisture, pH, organic carbon, total nitrogen and available phosphorus.

Along the disturbance gradient *Taxus* population shows different patterns. Least disturbed mixed broadleaf forest association shows stable population of *Taxus* as evident by greater number of small individuals than large individuals, termed[8] as Type I population (Figure 1). In contrast, saplings and some of the subsequent size classes of this species were not found in moderately disturbed sites of the same forest. Presence of greater number of plants in the older age classes (higher CBH class) indicates failure in conversion of seedlings to saplings during the recent past. This may be due to alteration in micro-site conditions by biotic disturbances.

A similar pattern was observed in the Cedar forest. At highly disturbed sites only the oldest tree category was present (Figure 1) with more individuals in higher than in lower size classes, indicating failure of regeneration in the past (termed as Type III population). Susceptibility of *Taxus* to biotic disturbances (as apparent from the absence of regeneration and lower girth class trees at highly disturbed site) is similar to its high altitude tree associate, brown oak, of the Central Himalaya[9]. At moderately disturbed sites, *Taxus* population structure with peaks and troughs was observed which indicates irregular seedling establishment along the time scale (termed as Type II population). In the cedar forest seedlings are abundant but their conversion into saplings is poor. Distribution of Type II population is common among late secondary species that depend on conspicuous canopy gap for regeneration[8]. A Type II population is characteristic of a light demanding, early pioneer species having a pool of dormant seeds in soil[8], while this pattern for a primary or late successional species, such as *T. baccata*, reflects no recruitment of seedlings to saplings. The three types of populations (as described earlier) occur in a single sequence through which the population passes on its way to extinction (from Type I to Type III), and *T. baccata* populations in the study area appear to be under such a transition.

Occurrence of only few seedlings and saplings in moderately and heavily disturbed forest sites suggests that *Taxus* requires shaded environment. Regression analysis also indicates that crown cover was positively related to seedlings and saplings number ($P < 0.05$). The undisturbed shaded environment has also a nutrient-rich soil with high moisture content (Table 2), and the nutrient concentrations (C, N and P) declined with increasing levels of disturbance. Nutrient-rich shaded forest stands may constitute natural habitat for regeneration of this species; however, soil carbon and N individually explain only 34% and 56% of the variation in the presence of seedlings, respectively. Soil pH has a reverse trend compared to the nutrients. Further, soil pH of a site was negatively related to the presence of *Taxus* seedlings ($P < 0.05$). The combined impact of all the nutrients along with pH describes 95% of the variation in seedling population. It seems that in the current chronic form of disturbances[10], gaps formed are too small but they have severe impact on regeneration of the species.

The failure of regeneration of a species would not be realized as long as old trees of *Taxus* will provide the raw material. Resulting from recent global awareness about this genus, a management plan has been suggested at the ecosystem level[11], which recommends protecting *Taxus*

Table 1. Some site details of *Taxus baccata* habitats

Forest type	Elevation (m)	Aspect	Canopy cover (%)	Disturbance status
Cedar	1810–1900	N, NWW	82.5	Least disturbed
Mixed broadleaf	1840–1910	E, EES, EES	86.7	Least disturbed
Cedar	1820–1930	SW, SE, SE	65.0	Moderately disturbed
Mixed broadleaf	1900–2050	NW, NW, NW	53.7	Moderately disturbed
Cedar	1860–2000	SW	26.0	Heavily disturbed

Table 2. Soil characteristics (up to 40 cm depth) of different forests

Forest type	Moisture (%)	pH	Carbon (%)	Nitrogen (%)	Phosphorus (%)
Cedar (LD)	34.1	6.01	1.88	0.27	0.10
Mixed broadleaf (LD)	35.7	5.87	1.51	0.23	0.13
Cedar (MD)	23.5	6.31	1.79	0.21	0.07
Mixed broadleaf (MD)	33.2	6.46	1.26	0.18	0.07
Cedar (HD)	10.0	6.73	1.12	0.10	0.09

LD, Least disturbed; MD, Moderately disturbed; HD, Heavily disturbed.

habitat to meet the genetic, population and ecosystem level objectives. Further, it has been emphasized that this practice should be at a scale large enough to buffer the disturbances because the undercanopy plants of old growth forests (like Cedar) require a considerably long disturbance-free period (as in the case of *Taxus*). It can be concluded that the Himalayan *Taxus* is under threat not only because of excessive harvesting but also due to degradation of forest sites due to other reasons. Biotic disturbances are apparent at the present study site but other factors like chilling temperatures, direct sunlight, warm and dry summer may also contribute to poor regeneration and subsequent recruitment processes.

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In vitro antibiotic susceptibilities of *Yersinia enterocolitica* and *Yersinia intermedia* isolated from sewage effluents

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Of the 31 strains comprising nineteen *Yersinia enterocolitica* (biotype 1A) and twelve *Yersinia intermedia* (biotypes 1, 2 and 4) isolated from sewage effluents, most (94-97%) were resistant to β-lactam antibiotics. The β-lactam antibiotic to which maximum number of isolates were sensitive was cefotaxime. With regard to susceptibility of isolates to non-β-lactam antibiotics, none was found resistant to amikacin, ciprofloxacin, cotrimoxazole and tetracycline. However, a varying pattern of sensitivity was observed with other non-β-lactams such as chloramphenicol, erythromycin, sulphafurazole, clindamycin, tobramycin and trimethoprim. In comparison to earlier reports, differences were observed in the antimicrobial susceptibilities of these isolates to ceftazidime, cefuroxime and piperacillin.

Yersinia enterocolitica, an important food- and water-borne enteric pathogen, causes acute gastroenteritis, enterocolitis and mesenteric lymphadenitis as well as a variety of extraintestinal disorders[1]. *Y. enterocolitica* has been isolated from a variety of zoonotic and environmental sources. However, pigs and water have generally been regarded as the most important reservoirs of this organism. *Y. enterocolitica* is highly adaptable to aquatic environment and is capable of surviving in water for longer periods[2]. Many water-borne outbreaks of yersiniosis have been documented[2]. A number of studies have reported the antimicrobial susceptibilities of *Yersinia* strains isolated from humans[3–5], animals[6,7] and food[6,8]. There is paucity of information about the antibiotic susceptibilities of *Y. enterocolitica* of aquatic origin. Hausnerova *et al.*[9] studied 64 strains of *Y. enterocolitica* isolated from river water and fish, and found these to be sensitive to chloramphenicol, tetracycline, neomycin and colistin. Recently, Tzelepi *et al.*[10] reported antibiotic susceptibilities of seven *Y. enterocolitica* and thirty *Y. intermedia* strains isolated from river and drinking water, and mussels harvested from sea water; these strains were found to be resistant to β-lactam antibiotics, viz. ampicillin, carbenicillin, ticarcillin, cephalothin, amoxycillin/clavulanate and cefoxitin. All strains, however, were sensitive to non-β-lactam antibiotics such as amikacin, tetracycline, chloramphenicol, gentamycin, tobramycin and cotrimoxazole. Further studies on isolates obtained from other aquatic sources and from different parts of the world would help in judiciously assessing the over-all susceptibilities of these isolates. Among the various aquatic sources, sewage and sewage effluents constitute an important source of *Y. enterocolitica* and other related species like *Y. intermedia*[11,12]. Their discharge in surface waters may play a significant role in the transmission of human yersiniosis. To the best of our knowledge, there is no report on the antibiotic susceptibilities of *Y. enterocolitica* and *Y. intermedia* isolated from the Indian subcontinent. Here we present the results of a study concerning *in vitro* antibiotic suscepti-

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