Shoolini University

Dr. Rachna Verma

Associate Professor

School of Biological and Environmental Sciences

Dated: 28/12/2022

Ref. No.: SUBMS/22/ 5330

To
Kireet Kumar
Scientist G & Nodal Officer,
NMHS-PMU,
G.B. Pant National Institute of Himalayan Environment and Sustainable Development,
Kosi-Katarmal, Almora
Uttarakhand- 263643

Subject: Final Technical Report for NMHS project

Dear Sir,

This is for your kind consideration that we have compiled the Final Technical Report of project sanctioned by National Mission on Himalayan Studies (NMHS) (Project Ref. No.: GBPNI/NMHS-2018-19/SG /210) entitled **"Returning Taxus to the Forests and the People: a study in Shimla and Kullu Districts of the Indian Himalayan Region"** worth 47 lakhs.

Please find attached five copies of FTR of NMHS project with all annexures duly completed along with this forwarding letter.

Further the arrear amount in salary was also mentioned to be given in letter (number GBPNI/NMHS-2018-19/SG/210/240, Dated: 17/12/2020) issued by NMHS.
So, kindly also assist in the same.

With kind regards

(Dr. Rachna Verma)
Principal Investigator

Shoolini University of Biotechnology & Management Sciences
Head Post Office: Solan (H.P.) • Post Box No. 9

Template/Pro forma for Submission

NMHS-Himalayan Institutional Project Grant

NMHS-FINAL TECHNICAL REPORT (FTR)

Demand-Driven Action Research and Demonstrations

NMHS Reference No.:	**GBPNI/NMHS-2018-2019/SG/210**

Date of Submission:	3	1	1	0	2	0	2	2
	d	**d**	**m**	**m**	**y**	**y**	**y**	**y**

PROJECT TITLE

RETURNING *TAXUS* TO THE FORESTS AND THE PEOPLE: A STUDY IN SHIMLA AND KULLU DISTRICTS OF THE INDIAN HIMALAYAN REGION

Project Duration: *from* (**01.02.2019**) *to* (**31.10.2022**).

***Submitted to*:**

Er. Kireet Kumar

Scientist 'G' and Nodal Officer, NMHS-PMU

National Mission on Himalayan Studies, GBP NIHE HQs

Ministry of Environment, Forest & Climate Change (MoEF&CC), New Delhi

E-mail: nmhspmu2016@gmail.com; kireet@gbpihed.nic.in; kodali.rk@gov.in

***Submitted by*:**

[*Dr. Rachna Verma*]

[*Associate Professor, School of Biological and Environmental Sciences, Shoolini University of Biotechnology and Management Sciences, Bhajhol, Solan, 173229*]

[*Contact No.:9816291543*]

[*E-mail: RachnaVerma@shooliniuniversity.com*]

GENERAL INSTRUCTIONS:

1. The Final Technical Report (FTR) has to commence from the date of start of the Project (as per the Sanction Order issued at the start of the project) till its completion. Each detail has to comply with the NMHS Sanction Order.
2. The FTR should be neatly typed (in Arial with font size 11 with 1.5 spacing between the lines) with all details as per the enclosed format for direct reproduction by photo-offset process. Colored Photographs (4-5 good action photographs), tables and graphs should be accommodated within the report or should be annexed with captions. Sketches and diagrammatic illustrations may also be given giving step-by-step details about the methodology followed in technology development/modulation, transfer and training. Any correction or rewriting should be avoided. Please give information under each head in serial order.
3. Training/ Capacity Building Manuals (with details contents of training programmed technical details and techniques involved) or any such display material related to project activities along with slides, charts, photographs should be brought at the venue of the Annual Monitoring & Evaluation (M&E) Workshop and sent at the NMHS-PMU, GBP NIHE HQs, Kosi-Katarmal, Almora 263643, Uttarakhand. In all Knowledge Products, the Grant/ Fund support of the NMHS should be duly acknowledged.
4. The FTR Format is in sync with many other essential requirements and norms desired by the Govt. of India time to time, so each section of the NMHS-FTR needs to duly filled by the proponent and verified by the Head of the Lead Implementing Organization/ Institution/ University.
5. Five (5) bound hard copies of the Project Final Technical Report (FTR) and a soft copy should be submitted to the **Nodal Officer, NMHS-PMU, GBP NIHE HQs, Kosi-Katarmal, Almora, Uttarakhand**.

The FTR is to be submitted into following two parts:

Part A – Project Summary Report

Part B – Project Detailed Report

Following Financial and other necessary documents/certificates need to be submitted along with Final Technical Report (FTR):

Annexure I	**Consolidated and Audited Utilization Certificate (UC) & Statement of Expenditure (SE)**, including interest earned for the last Fiscal year including the duly filled GFR-19A (with year-wise break-up)
Annexure II	**Consolidated Interest Earned Certificate**
Annexure III	**Consolidated Assets Certificate** showing the cost of the equipment in Foreign and Indian currency, Date of Purchase, etc. (with break-up as per the NMHS Sanction Order and year wise).
Annexure IV	**List of all the equipment, assets and peripherals** purchased through the NMHS grant with current status of use including location of deployment.
Annexure V	Letter of Head of Institution/Department confirming Transfer of Equipment Purchased under the Project to the Institution/Department
Annexure VI	**Details, Declaration and Refund of any Unspent Balance transferred through Real-Time Gross System (RTGS) in favor of NMHS GIA General**

NMHS-Final Technical Report (FTR) *template*

Demand-Driven Action Research Project

DSL: Date of Sanction Letter

DPC: Date of Project Completion

2	1	0	1	2	0	1	9
d	d	m	m	y	y	y	y

3	1	1	0	2	0	2	2
d	d	m	m	y	y	y	y

Part A: Project Summary Report

1. Project Description

i.	Project Reference No.	GBPNI/NMHS-2018-19/SG									
ii.	Type of Project	Small Grant	✓	Medium Grant		Large Grant					
iii.	Project Title	**Returning *Taxus* to the Forests and the People: a study in Shimla and Kullu Districts of the Indian Himalayan Region**									
iv.	State under which Project is Sanctioned	**Himachal Pradesh**									
v.	Project Sites (IHR States covered) (Maps to be attached)	Shimla and Kullu District of Himachal Pradesh									
vi.	Scale of Project Operation	Local		Regional	✓	Pan-Himalayan					
vii.	Total Budget/ Outlay of the Project	Rs. 47,00,000.00 (in Cr)									
viii.	Lead Agency	Shoolini University of Biotechnology and Management Sciences, Bhajol, Solan (HP) - 173229 Govind Ballabh Pant National Institute of Himalayan Environment and Sustainable Development, Himachal Unit, Mohal, Kullu (HP) -175126									
	Principal Investigator (PI)	Dr. Rachna Verma									
	Co-Principal Investigator (Co-PI)	Dr. K. S. Kanwal (GBPNIHESD, HRC, Mohal, Kullu, H.P) Er. R. K. Singh (GBPNIHESD, HRC, Mohal, Kullu, H.P.) Dr. Amita Kumari (Shoolini University of Biotechnology and Management Science, Bajhol, PO Sultanpur, Solan (HP) – 173229)									
ix.	Project Implementing Partners	Govind Ballabh Pant National Institute of Himalayan Environment and Sustainable Development, Himachal Unit, Mohal, Kullu (HP)-175126 Shoolini University of Biotechnology and Management Science, Bajhol, PO Sultanpur, Solan (HP) – 173229									
	Key Persons / Point of Contacts with Contact Details, Ph. No, E-mail	Dr. Rachna Verma Associate Professor, School of Biological and Environment Sciences, Shoolini University of Biotechnology and Management Science, Bajhol, PO Sultanpur, Solan (173229) E-mail: RachnaVerma@shooliniuniversity.com Contact No.: 9816291543									

2. Project Outcomes

2.1. Abstract (not more than 500 words) [it should include background of the study, aim, objectives, methodology, approach, results, conclusion and recommendations).

***Background*:** Western Himalayan yew (*Taxus contorta* Griff., Thuner, Rakhal) has severe range population decline of up to 90% in Indian Himalayan region. *Taxus contorta* is the natural species found in northeastern and northwestern Himalaya of India and categorized as endangered species in IUCN Red data list. Population of *Taxus contorta* is declining because of overexploitation, unscientific extraction and poor natural regeneration abilities. The anti-cancerous drug Taxine; extracted from bark and leaves of *Taxus*, is also precursor to the drug Taxol, is used in the preparation of Paclitaxel, and for the treatment of ovarian and breast cancer.

***Objectives/ Aim**:* Assessment and mapping of populations of *Taxus* in Shimla and Kullu district. Investigation of physicochemical and biotic factors associated with regeneration of *Taxus*. Development and standardization of protocols for mass multiplication of *Taxus* and comparison of its phyto-chemistry related to natural individuals.

Methodologies: Species distribution and modeling has been done by MaxEnt software. Forest community was also determined in the study area by quadrat method. Four conditions have been prepared Mother tree, Sapling and Seedling of *Taxus* and Non-*Taxus* plants. With every condition, we observed various factors like Soil Nitrogen, Phosphorus and Organic Carbon, Pitfall trap and soil monolith for soil macrofauna. Soil was also assessed for heavy metal presence. The mycorrhizal association was also determined in terms of biodiversity and association in roots. The phytochemistry of *Taxus contorta* at different sites was determined quantitatively and further by UHPLC analysis.

Approach: To sensitize target population through workshop/ training/ awareness campaign about importance of *Taxus* species and its mass multiplication.

***Results*:** Species distribution modelling has been done for study sites AUC value was observed as 0.905 and 0.86. Landcover showed the maximum percent contribution followed by temperature seasonality, precipitation of the driest month and annual mean temperature. *Taxus contorta* is expected to be found on the northern slopes but seedlings, saplings and adults of this species were observed also in the southwest aspect. *Cedrus deodara* was dominant in the northern region, *Quercus floribunda* was co-dominant in the north region and was the dominant species in the north-eastern aspect, where *Taxus contorta* was the co-dominant species. *Quercus oblongata* was dominant in the southern aspects, more so in the south-west aspect. Seventeen species of AMF were identified which were associated with *Taxus contorta*. Soil moisture, pH, Organic Carbon, Available Nitrogen, Available Potassium, were in sufficient amount for the development of *Taxus* at all the sites. After checking the heavy metal availability it was found that there is no heavy metal stress in the study area. Alkaloids and phenols were highest in the methanol extract and terpenoids and flavonoids were highest in chloroform extract. UHPLC analysis showed Taxol amount as highest in the plants grown in nurseries.

Conclusion: Most suitable niche areas identified through SDM for *Taxus contorta* have been chosen for reintroduction of *Taxus* seedlings. *Taxus contorta*, in the initial stages of the establishment had the high canopy cover (hence Low PAR), while at later mature stages low canopy cover (high PAR) seems to be favorable in establishment. disturbances like overgrazing and other activities hinders the growth of seedlings in different areas.

Recommendations: Place Himri of Shimla district is recommended as the best place for the *Taxus* growth.

2.2. Objective-wise Major Achievements

S. No.	Objectives	Major achievements (in bullets points)
1.	Assessment and mapping of populations of *Taxus* in Shimla and Kullu district	• AUC value observed 0.905 shows fitness of model for the entire state. • Landcover variable showed the maximum percent contribution followed by temperature seasonality, precipitation of the driest month and annual mean temperature.
2.	Investigation of the physicochemical and biotic factors associated with regeneration of *Taxus*	• Himri is the only place where seedlings were found. • *Taxus contorta* species was found on the northern slopes. • Lack of grazing could be one of the reasons that the seedlings got successfully established and survived to sapling stages, thereby showing good regeneration. • *Cedrus deodara* was dominant in the northern aspects, *Quercus floribunda* was co-dominant in the north aspect and was the dominant species in the north-eastregion, where *Taxus contorta* was the co-dominant species. *Quercus oblongata* was dominant in the southern aspects, more so in the south-west aspect. • In mycorrhizal studies *Glomus* spp. were dominant in the both the mother and seedling growth stages of *Taxus contorta*. • Investigations of the below ground soil fauna revealed that centipedes again, this time of the order Geophilomorpha, were closely associated with saplings of *Taxus contorta*, and very strongly preferred habitats of intermediate litter biomass. • Results of assessment of aboveground soil fauna showed that centipedes of the order Scolopendromorpha were closely associated with *Taxus contorta* seedlings, very strongly preferring habitats of very low soil compaction and less strongly preferring intermediate values of litter biomass. • The earthworms (order Haplotaxida) were closely associated with the mother trees of *Taxus contorta*, strongly preferring intermediate values of soil compaction. • Seedlings of *Taxus contorta* prefer habitats with low soil compaction and intermediate levels of canopy cover

3.	Development and standardization of protocols for mass multiplication of *Taxus* and comparison of its phytochemistry relative to natural individuals	• Development and standardization of mass multiplication methods for cultivating *Taxus* Department of Forest, Govt. of Himachal Pradesh has accorded permission to carry out field study for the assessment of *Taxus* population in the Kullu district. Mass multiplication of *Taxus* was carried out through branch cutting. The germplasm was collected from different locations of the Kullu and Shimla district. Stem cutting of *T. contorta* ranging 15-20 cm with 3-4 nodes and 0.5 to 1.0 cm in diameter were also used for mass multiplication. *Taxus contorta* was raised through mass multiplication at the Dohranala nursery of the institute and H.P. forest nurseries at Channi nala Sainj, Chutti, Bihal Hurla, Mohal nature park nursery, Khodu Bihal Nursery Dohra Nala. • While comparing the phytochemistry of natural plants and plantlets developed in polyhouse, amount of alkaloids and phenols were highest in the methanol leaf extract, while terpenoids and flavonoids were highest in chloroform leaf extract. Overall more phytochemicals were observed in the grown seedlings. • UHPLC chromatograph revealed that the amount of Taxol was higher in the seedlings grown in polyhouse conditions.

4.	Establishments of plantlets of *Taxus* involving forest department and the local communities.	• Establishing plantlets of seedlings involving forest department and local people were done in the Himiri region of Shimla district and . Awareness cum training program was also organised in seven villages and school. The meetings were organized in the following regions:
		  • Solangnala village on 18-09-2020
		  • Shangarh village on 01-10-2020
		  • Khokhan WLS on 08-10-2020
		  • Pulga village on 08-07-2021
		  • Bathad village on 04-08-2021
		  • Kamand village on 25-02-2022
		  • Tandari-2 on 02-03-2022
		  • Seri village on 21-03-2022
		  • Shairopa on 21-03-2022
		  • Kot village on 22-07-2022
		  • Theog on 25-11-2022
		
		• Around 20-30 participants were present in the meetings which included villagers, farmers, BMC members, forest department officials, and Panchayat Head. The participants were given a lecture on the Traditional knowledge and the medicinal properties of *Taxus contorta* and the threats it is facing leading to its endangerment in the wild.
		• Training programs cum workshops on propagation techniques for mass multiplication of *Taxus contorta* were organized
		  • Aloo ground nursey, Manali forest division on 28-04-2021
		  • Channi nala nursery, Sainj, Banjar Forest division on 04-03-2022
		  • Chuti Bihal nursery, Hurla, Parvati Forest division on 09-03-2022
		  • Nature Park nursery, Mohal, Kullu Forest division on 14-03-2022
		  • Conference hall, GHNP Tirthan wildlife range, Banjar, Kullu district on 21-03-2022.

2.3. Outputs in terms of Quantifiable Deliverables*

S. No.	Quantifiable Deliverables*	Monitoring Indicators*	Quantified Output/ Outcome achieved	Deviations made, if any, & Reason thereof:
1.	Develop the distribution map for *Taxus contorta*	Distribution map developed	About 14% area of Kullu district and 12% area in Shimla is suitable for species occurrence. Landcover, Precipitation of driest quarter, Annual mean temperature are the main drivers of species distribution.	
2.	Generation of Knowledge about different ecological factors affecting natural regeneration	Mass propagation of selected species (Nos.)	The seedlings of *Taxus contorta* prefer habitats with low soil compaction and intermediate levels of canopy cover, while the mother trees prefer low canopy cover and intermediate levels of soil compaction. Investigations of the below ground soil fauna revealed that centipedes of the order Geophilomorpha, were closely associated with saplings of *Taxus contorta*, and very strongly preferred habitats of intermediate litter biomass. *Glomus* spp. spores were dominant in both the mother and seedling growth stages of	

			Taxus contorta. Soil of studied forest is fertile which is good for the *Taxus* regeneration. There is no accumulation of heavy metals in the study areas	
3.	Development and standardization of mass propagation techniques for mass multiplication of *Taxus contorta*	Conservation Model developed (Nos.)	Rooting as observed in the stem cuttings treated with 500 ppm IBA.	
4.	New conservation Model for plantation drives through strengthening local nurseries and forest department, and community monitored plantations	Number of nurseries strengthened (No/ Area)	Training programs cum workshops on propagation techniques for mass multiplication of *Taxus contorta* were organized Aloo ground nursey, Manali forest division, Channi nala nursery, Sainj, Banjar Forest, Chuti Bihal nursery, Hurla, Parvati Forest division, Nature Park nursery, Mohal, Kullu Forest division, Conference hall, GHNP Tirthan wildlife range, Banjar, Kullu. Seedlings were provided to the forest division for plantation.	
5.	Manual and guidelines for conservation and	The number of Beneficiaries (Nos.)	E-Training Manual available on “Conservation and Cultivation practices of	

	sustainable use of target species		Endangered Himalayan Yew (Taxus contorta Griff.) in Himachal Pradesh"	
6.	Creating awareness among farmers in 10 villages	No. of Reports/Research articles/Policy documents/Manual prepared and published (Nos.)	An awareness cum training program was in seven villages and school. The meetings were organized in the following village. Solangnala village, Shangarh village, Khokhan WLS, Pulga village, Bathad village, Kamand village, Tandari-2, Seri village, Shairopa, Kot village, G(B)SSS Theog.	

(*) As stated in the Sanction Letter issued by the NMHS-PMU.

2.4. Strategic Steps with respect to Outcomes (in bullets)

S. No.	Particulars	Number/ Brief Details	Remarks/ Attachment
1.	New Methodology developed	-	
2.	New Models/ Process/ Strategy developed	-	
3.	New Species identified	-	
4.	New Database established	-	
5.	New Patent, if any	-	
	I. Filed (Indian/ International)	-	
	II. Granted (Indian/ International)	-	
	III. Technology Transfer (if any)	-	
6.	Others (if any)	-	

3. Technological Intervention

S. No.	Type of Intervention	Brief Narration on the interventions	Unit Details (No. of villagers benefited / Area Developed)
1.	Development and deployment of indigenous technology	Stem cutting technique was adopted	300 villagers benefitted
2.	Diffusion of High-end Technology in the region	NA	
3.	Induction of New Technology in the region	NA	
4.	Publication of Technological / Process Manuals	1	300
	Others (if any)	NA	

4. New Data Generated over the Baseline Data

S. No.	New Data Details	Status of Existing Baseline	Additionality and Utilisation New data
	NA		

5. Demonstrative Skill Development and Capacity Building/ Manpower Trained

S. No.	Type of Activities	Details with number	Activity Intended for	Participants/Trained			
				SC	**ST**	**Woman**	**Total**
1.	Workshops	**5**	**Mass multiplication of *Taxus contorta* in forest departments of Kullu**				**77**
2.	On Field Trainings	**11**	**Mass multiplication of *Taxus contorta* in forest departments of Kullu and Establishment of seedlings in the forest.**				**200**
3.	Skill Development	**11**	**Mass multiplication of *Taxus contorta***				**200**
4.	Academic Supports	**NA**					
	Others (if any)	**NA**					

6. Linkages with Regional & National Priorities (SDGs, INDC, etc)/ Collaborations

S. No.	Linkages /collaborations	Details	No. of Publications/ Events Held	Beneficiaries
1.	Sustainable Development Goal (SDG)	-		
2.	Climate Change/INDC targets	-		
3.	International Commitments	-		
4.	Bilateral engagements	-		
5.	National Policies	-		
6.	Others collaborations	-		

7. Project Stakeholders/ Beneficiaries and Impacts

S. No.	Stakeholders	Support Activities	Impacts
1.	Gram Panchayats	10	Learning of plant use and mass multiplication

			technique
2.	Govt Departments (Agriculture/ Forest)	-	
3.	Villagers	Workshops and training programs for development and establishment of *Taxus*.	Learning of mass multiplication technique
4.	SC Community	-	
5.	ST Community	-	
6.	Women Group	Workshops and training programs for development and establishment of *Taxus*.	Learning of mass multiplication technique
	Others (if any)	Awareness program with local school for highlighting the importance of biodiversity and its conservation.	Learning of medicinal importance of plant and mass multiplication technique

8. Financial Summary (Cumulative)

S. No.	Financial Position/Budget Head	Funds Received	Expenditure/ Utilized	% of Total cost
I.	Salaries/Manpower cost	1228662	1228662	100.00
II.	Travel	242000	342617	141.58
III.	Expendables &Consumables	1577742	1476900	93.61
IV.	Contingencies	242000	242338	100.14
V.	Activities & Other Project cost			
VI.	Institutional Charges	480000	480000	100.00
VII.	Equipments	860000	859887	99.99
	Total	4630404		
	Interest earned	38090 (Utilized) Details given in SE		
	Grand Total	4668494		

* Please attach the consolidated and audited Utilization Certificate (UC) and Year wise Statement of Expenditure (SE) separately, *ref*. **Annexure I.**

9. Major Equipment/ Peripherals Procured under the Project** (if any)

S. No.	Name of Equipments	Cost (INR)	Utilisation of the Equipment after project
1.	Printer	17,700	Installed in Biology Lab
2.	Scanner	10,502	Installed in Biology Lab
3.	27” LED	38,468	Installed in Biology Lab
4.	Computer	115,640	Installed in Biology Lab
5.	UPS	13,570	Installed in Biology Lab
6.	PAR Meter	40,061	Installed in Biology Lab
7.	Soil Compaction Meter	53,100	Installed in Biology Lab
8.	GPS Garmin etrex 30	15,576	Installed in Biology Lab
9.	Binocular 10* 50	5,791	Installed in Biology Lab
10.	Moultrie M40 game camera	13900	Installed in Biology Lab
11.	Moultrie MA series game camera	8999	Installed in Biology Lab
12.	DSLR and flash bundles	49,314	Installed in Biology Lab
13.	I button temperature logger + I button adaptor	309,438	Installed in Biology Lab
14.	Spherical Densiometer	22030	Installed in Biology Lab
15.	Soil Tensiometer	4225	Installed in Biology Lab
16.	Microscope MSZ + MagCam DC 10	141584	Installed in Biology Lab

Details should be provided in detail **(*ref* **Annexure III &IV).**

10. Quantification of Overall Project Progress

S. No.	Parameters	Total (Numeric)	Remarks/ Attachments/ Soft copies of documents
1.	IHR States Covered	*1*	*Shimla and Kullu districts of Himachal Pradesh*
2.	Project Site/ Field Stations Developed	*2 districts*	
3.	New Methods/ Modeling Developed	*NA*	
4.	No. of Trainings arranged	*11*	*Appendix 3*
5.	No of beneficiaries attended trainings	*Appx. 300*	
6.	Scientific Manpower Developed (Phd/M.Sc./JRF/SRF/ RA):	*4 JPF's, 3 Ph.D's*	
7.	SC stakeholders benefited	-	
8.	ST stakeholders benefited	-	
9.	Women Empowered	*26*	*Appendix 3*
10.	No of Workshops Arranged along with level of participation	*11*	
11.	On field Demonstration Models initiated	*NA*	
12.	Livelihood Options promoted	*NA*	
13.	Technical/ Training Manuals prepared	*Yes* -1	*https://nmhs.org.in/pdf/publication/Technical_Report/Dr.Mamta_Sharma/E-Training_manual_Taxus.pdf Appendix 5*
14.	Processing Units established	*NA*	
15.	No of Species Collected	*11 mycorrhizal species isolated*	*Added in the Part B Result section*
16.	New Species identified	*NA*	
17.	New Database generated (Types):	*NA*	
	Others (if any)	*NA*	

11. Knowledge Products and Publications:

S. No.	Publication/ Knowledge Products	*Number*		*Total Impact Factor*	*Remarks/* Enclosures
		National	International		
1.	Journal Research Articles/ Special Issue:		1 Published 1 communicated	1.57	https://doi.org/10.1007/s42965-021-00200-2
2.	Book Chapter(s)/ Books:		NA		
3.	Technical Reports		NA		
4.	Training Manual (Skill Development/ Capacity Building)		1		Appendix 5
5.	Papers presented in Conferences/Seminars		1		Attached
6.	Policy Drafts/Papers		NA		
7.	Others:		NA		

* Please append the list of KPs/ publications (with impact factor and further details) with due Acknowledgement to NMHS.

12. Recommendation on Utility of Project Findings, Replicability and Exit Strategy

Particulars	Recommendations
Utility of the Project Findings	• Helped in proper establishment of species by identifying the suitable habitat from MaxEnt modelling. • All habitat were found suitable in terms of physicochemical properties and associated species along with *Taxus* plant.
Replicability of Project	• Same model can be replicated in other districts of Indian Western Himalayan region

Exit Strategy	• The local people were trained for the species establishment and nursery techniques. • As a species has anticancerous activity, the plant can be commercially used for selling of leaves to pharma companies for production of anticancerous Taxol drug.

(PROJECT PROPONENT/ COORDINATOR)

(Signed and Stamped)

(HEAD OF THE INSTITUTION)

(Signed and Stamped)

Dean
Research & Development
Shoolini University
Post Box No. 9
Head Post Office
Solan - 173212 (H.P.)

Place: Solan

Date: 28 / 12 / 2022

PART B: PROJECT DETAILED REPORT

The Detailed report should include an Executive Summary and it should have separate chapters on (i) Introduction (ii) Methodologies, Strategy and Approach (iii) Key Findings and Results (iv) Overall Achievements (v) Project's Impacts in IHR (vi) Exit Strategy and Sustainability (vii) References and (viii) Acknowledgement (It should have a mention of financial grant from the NMHS, MoEF&CC)

Further, description of Technical Activities, List of Trainings/ Workshops/ Seminars with details of trained resources, list of New Products developed under the project, Manual of Standard Operating Procedures (SOPs) developed, Technology developed/Transferred etc should be enclosed as Appendix.

1 EXECUTIVE SUMMARY

The Executive Summary of the project should not be more than 3–5 pages, covering all essential features in precise and concise manner as stated in Part A (Project Summary Report) and Part B (Comprehensive Report).

The West Himalayan Yew (*Taxus contorta* Griff.) has suffered a severe range wide population decline of up to 90% in the Indian Himalayan Region (IHR), mainly because of overexploitation for its medicinal properties, especially for the commercial extraction of the anti-cancer drug Taxol. Hence, there is an urgent requirement of understanding the causes of decline in regeneration and to try to decipher the factors that have resulted in the successful regeneration, in the few habitats where *Taxus* has been able to establish itself. Habitat destruction, changing climate, pollution, invasion of alien species and pathogens, overexploitation and increasing human population are the most important factors responsible for ecosystem degradation worldwide that alter the structural and functional integrity of the ecosystems. Such alterations have brought approximately one fifth of the plant species to the brink of extinction. The species re-introduction is a successful ecological technique for recovering and maintaining the position of degraded species populations, degraded habitats and ecosystems. For the successful re-introduction and rehabilitation of species in an ecosystem, a detailed knowledge on the potential habitats and distribution of species is essential. Conserving plant biodiversity requires consistent and sound qualitative as well as quantitative records of botanical data on regular basis and robust phyto-sociological techniques are essential to achieve this. The critical review of literature indicated that, in the IHR, a large number of studies have been conducted on the quantitative assessment of economically important species. But very few studies are available on the quantitative assessment. However, a very few studies on structure and composition of ecologically and economically important species of Indian Himalaya Region are available. Therefore, in the present study attempt has been made to assess the populations of *Taxus contorta* in Kullu district of Himachal Pradesh.

2 INTRODUCTION

2.1 Background of the Project (max. 500 words)

Out of 12 species of *Taxus* found in the world two species are found in India in the Indian Himalayan Region, East Himalayan Yew i.e. *Taxus* wallichiana Zucc. found in the eastern Himalayas in the states of Arunanchal Pradesh, Sikkim and Assam and the west Himalayan Yew i.e. *Taxus contorta* Griff., found in western Himalayas in the states of Jammu and Kashmir, Himachal Pradesh and Uttarakhand. Both the species have declared endangered in the IUCN red data list.*Taxus* is commonly known as Western Himalayan yew. In Hindi/ Sanskrit it is called as thuner, in Kullu region of Himachal Pradesh it is called as Rakhal. *Taxus* is a very useful medicinal plant, which is used to cure fever, cold, headache and also used to treat gastrointestinal problems and the major use of the *Taxus* is to treat the cancer, majorly the ovarian and breast cancers. *Taxus* has the anticancer properties and also used by indigenous communities in the Himalayas. Herbal tea and paste of the bark of *Taxus* are used indigenously. It is mainly found in the European countries, Himalayan ranges of Pakistan, India, Nepal, Myanmar and Asian countries such as Indonesia, China and Japan. As *Taxus* species has very low regeneration capacity, that is why its population is decreasing and climate change and anthropogenic activities are also the reasons. *Taxus* needs the moist soil conditions for growing and regeneration. *Taxus* grows in the vicinity of *Abies pindrow* (Himalayan fir), *Quercus semecarpifolia* (ban), *Quercus leucotrichophora* (kharshu), *Betula utilis* (bhojpatra), *Acer caesium* (Himalayan maple), *Pinus wallichiana* (kail) and *Rhododendron arboreum* (buransh). Flowering of *Taxus* occurs during March and May. Fruiting occurs during September and October. *Taxus contorta* has very thin bark as compared to some other yew species, which makes it more susceptible to forest fires. *Taxus* regenerates very poorly form the seed which germinates nearly after 18 months due to its long dormancy period. There exist a number of causes for the decline in their populations starting from over exploitation associated with its medicinal importance to over collection for fuel wood and fodder. Some other factors have also been implicated. In the Indian Himalaya, *Taxus* is locally called 'Rakhal' or 'Thuner'. *Taxus* is a medicinal plant crucial importance especially for its Taxin and DAB (10-deacetyl baccatin III) content. The bark and leaves of this tree is a source of taxine, a precursor to the drug Taxol, which is one of the best anticancer agents and is used in preparation of Paclitaxel, for treatment of ovarian cancer. The west Himalayan yew is a source of the Unani drug Zarnab. This tree has a wide variety of ethno medicinal uses. Additionally, the wood of this tree is in demand for making furniture and as fuel. Pharmaceutical companies pay villagers to bring them bark and leaves of *Taxus* for making Paclitaxel. A large damage to the population has already been done in the Indian Himalayan Region because of this short term economic benefit the locals got interested in.

2.2 Overview of the Major Issues to be Addressed (max. 1000 words)

2.3 Baseline Data and Project Scope (max. 1000 words)

2.4 Project Objectives and Target Deliverables (as per the NMHS Sanction Order)

• Assessment and mapping of populations of *Taxus* in Shimla and Kullu district.

• Investigation of physicochemical and biotic factors associated with regeneration of *Taxus*.

• Development and standardization of protocols for mass multiplication of *Taxus* and comparison of its Phyto-chemistry related to natural individuals.

• Plantlets of *Taxus* are established with the help of forest department and the local communities.

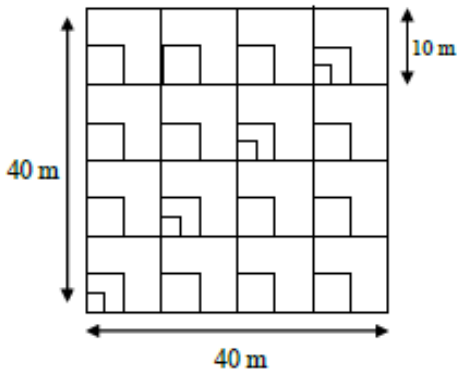
3 METHODOLOGIES, STARTEGY AND APPROACH

3.1 Methodologies used for the study (max. 1000 words)

Species distribution modelling has been done for MaxEnt model. All the bioclimatic layers and occurrence data process under the MaxEnt result in the knowing the probability of occurrence of species. All bioclimatic layers were downloaded from http://worldclim.org/version2. The environmental variables were filtered to remove redundant variables that were correlated with other variables within the Maxent program. Shapefiles of Himachal Pradesh, Shimla and Kullu were obtained from the GADM website (GADM, 2019).

The forest community was studied in the following aspects: North, North-east, South-east and South-west considered as sites. In each site 6 plots of 40 x 40 m were laid out. Within each plot 16 sub-plots of 10 x 10 m were laid out systematically within which nested quadrats of 5 x 5 m and 1 x 1 m were placed, the latter quadrats being placed in the diagonal quadrats of 5 x 5 m (Fig. 7). The individuals were classified as trees: ≥31.5 cm CBH; saplings: 10.5 to <31.5 cm CBH; and seedlings: <10.5 cm CBH and those having heights less than 30 cm. Within each 10 x 10 m plot the CBH of all the trees were measured and all the saplings of all the tree species were counted. Within each 5 x 5 m quadrat the shrubs and seedlings of all the tree species were enumerated. The herb species were listed in the nested 1 x 1 m quadrats of the diagonal 5 x 5 m quadrats. The 40 x 40 m plot size has been chosen to compare the ground data with Landsat satellite imagery having spatial resolution of 30 x 30 m and to include the standard plot size used in forestry which is 0.1 ha. The distribution pattern was determined by calculating the ratio of abundance to frequency (A/F) for different species of mature trees, saplings, seedlings, shrubs and herbs. Values of the ratio <0.025 indicates regular distribution, 0.025–0.05 random and >0.05 contagious distribution (Whitford, 1949). The Shannon-Weiner's index (Shannon and Weaver, 1949), Simpson's concentration of dominance and Gini-Simpson's index (Simpson, 1949; Izsák and Papp, 2000) were calculated to evaluate diversity. ANOVA and post hoc Tukey's HSD tests were conducted when the F test was

significant (P< 0.05) to see significant differences between quantitative ecological characters studied in the four aspects.



In each aspect viz., north, north-east, south-east and south-west of the study sites in Shimla District, the following conditions were separate in triplicates of 5x5 m quadrats:

(1) Mother tree: Containing a mother tree of *Taxus contorta* at the center

(2) Sapling: Containing a sapling of *Taxus contorta* at the center

(3) Seedling: Containing a seedling of *Taxus contorta* at the center

(4) Non-*Taxus*: Containing no individual of *Taxus contorta*, but within the forest

Within the above conditions the following parameters were assessed:

i) Soil compaction
ii) PAR
iii) Canopy cover
iv) Litter biomass
v) Soil Nitrogen
vi) Soil organic carbon
vii) Available Phosphorus
viii) Available Pottasium
ix) Heavy metals: Cadmium, Chromium, Copper, Lead, Manganese and Zinc.
x) Above-ground soil macrofauna through pit fall traps in triplicates randomly within each condition.
xi) Below-ground soil macrofauna through soil monolith in triplicates randomly within each condition.
xii) Mycorrhizal investigation

There are some methods for propagation, such as stem cuttings, in vitro seed germination and air layering techniques. As per the studies, propagation through Stem cuttings and air layering are the most feasible and shows the best results in shorter time then other methods. Trails for mass multiplication of *Taxus* was carried out through IBA, IAA and NAA treated branch cuttings.

Concentration of 500 ppm, 1000 ppm, 1500 ppm of IBA, IAA and NAA were used to treat the cuttings of *Taxus contorta*. The cuttings were sown in the poly bags containing potting media viz.: forest soil + sand + humus/vermin-compost (at 2:1:1). To make the soil slightly acidic, pine leaves were added in top of the poly bag for mulching. Another method for propagation is air layering technique in which new trees and shrubs are propagated from the live parent plant. The mature healthy plants are selected for air layering.

Phytochemicals were investigated from the fresh leaves of *Taxus*. Plants of lower and higher elevation were compared to plantlets grown in polyhouse. Two solvents were used for the extraction of phytochemicals from fresh leaves i.e., Methanol and Chloroform. The plant extract was further investigated for Alkaloids, Terpenoids, Saponins, Phenols and Flavonoids. UHPLC were used for Taxol quantification in the plant extract.

Workshops cum training programs were organized at forest departments, local schools and meetings were organized at villages. Division forest officer, range forest officer, deputy ranger, block officer, Forest Guards and nursery workers of forest department were present in the workshops. Local villagers, farmers, BMC members, forest department officials, and Panchayat Head were present in the meetings held in villages.

3.2 Preparatory Actions and Agencies Involved (max. 1000 words)

3.3 Details of Scientific data collected and Equipment Used (max 500 words)

Collected data was processed on DIVA-GIS and Q-GIS to create a map of the occurrence points of *Taxus contorta* in Kullu district. Points of occurrence (Coordinates) of *Taxus contorta* were marked with the help of GPS Garmin etrex – 30 by visiting various sites. Points were taken for mapping and Species Distribution Modeling (SDM). Soil compaction meter were used for checking the soil compaction. PAR meter was used for observing photosynthetically active radiation during field. Spherical Densiometer was used for checking the canopy cover in the forest. Soil corer were used for collecting soil samples during the field survey.

3.4 Primary Data Collected (max 500 words)

3.5 Details of Field Survey arranged (max 500 words)

3.6 Strategic Planning for each Activities (max. 1000 words)

3.7 Activity wise Time frame followed [using Gantt/ PERT Chart (max. 1000 words)]

4 KEY FINDINGS AND RESULTS

4.1 Major Research Findings (max. 1000 words)

- **Niche Model of *Taxus contorta* for Shimla district.**

  Niche Model of *Taxus contorta* for Shimla district. The Maxent model shows the probability of occurrence of *Taxus contorta* in Shimla district of Himachal Pradesh.The model AUC was 0.967,

which is greater than the minimum acceptable value of 0.75 (Elith, 2000). Landcover showed the greatest relative contribution to the model.

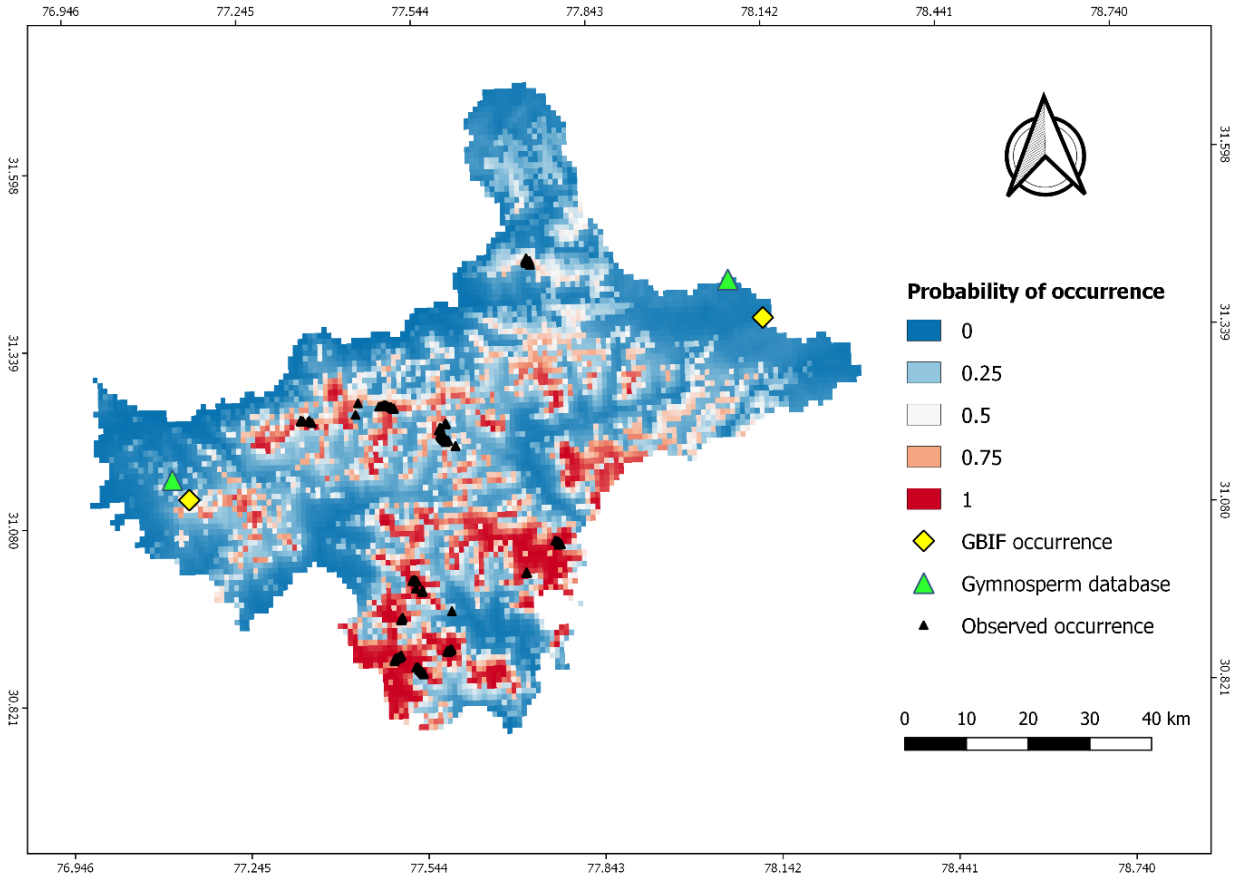


Fig. 1: Map showing species distribution model and sampled occurrence of *Taxus contorta* in Shimla district of Himachal Pradesh. Projection: WGS 84/ UTM zone 43 N (EPSG: 32643).

- **Ecological niche modeling of *Taxus contorta* in Kullu district**

The Maxent model shows the probability of occurrence of *Taxus contorta* in Kullu district of Himachal Pradesh (Fig. 3). The model AUC was 0.860. BIO13 showed the greatest relative contribution to the model. BIO7 showed the highest Permutation importance.

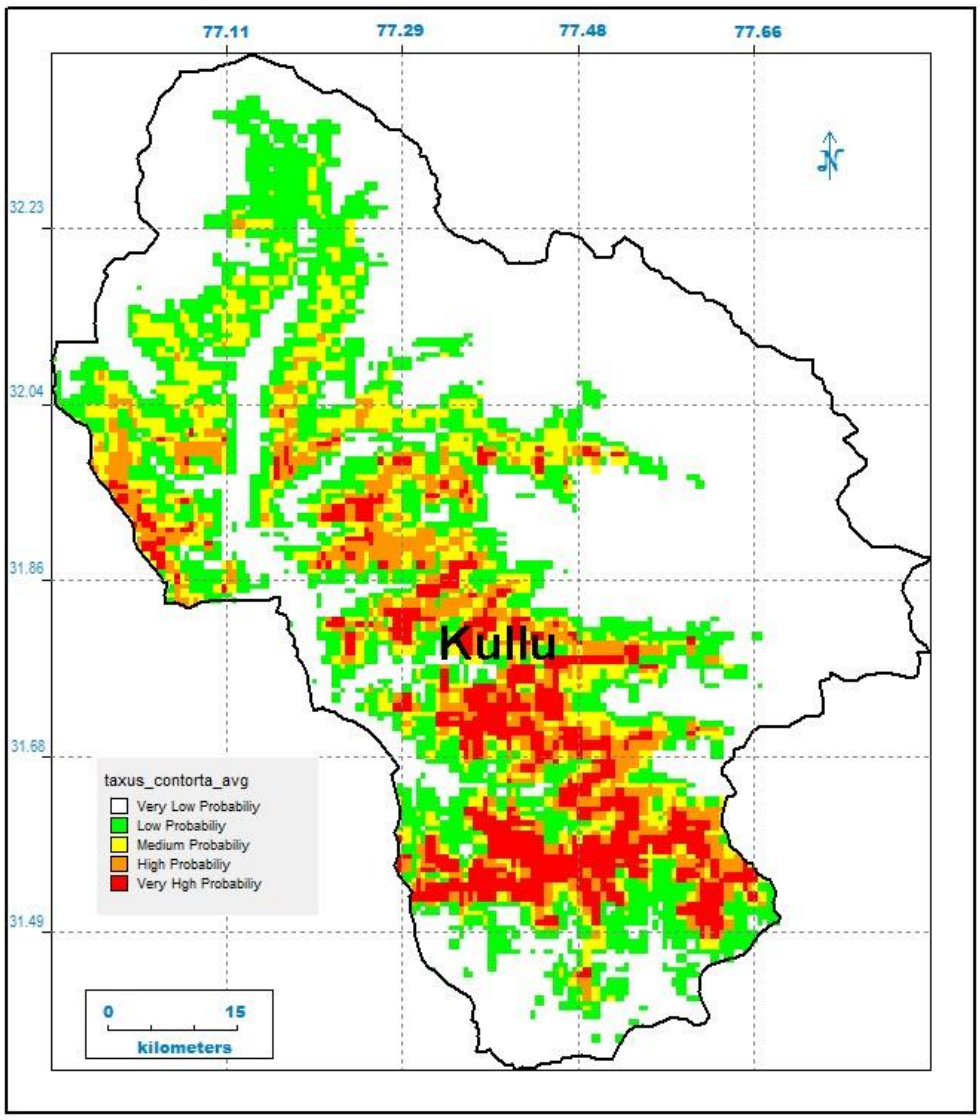


Fig. 3. Habitat suitability and distribution Map of *Taxus contorta* in Kullu district

Fig. 3. Picture shows the results of the jackknife test of variable importance Fig. 9. Picture shows the results of the jackknife test of variable importance

IVI based community analysis and Diversity indices of the forests at Narkanda and Himri.

In Narkanda, the Shannon-Wiener diversity index values did not significantly differ aspect wise, In Himri the north aspects were not significantly different from each other in terms of the Shannon-Wiener index and the Gini-Simpson index and so was the trend in the south aspects, while the north and south aspects differed significantly from one another, the former having greater diversity than the latter. In terms of dominance the south-west *Q. oblongata* dominated community had higher dominance than the south-east community, indicating that the south-west aspect was probably more favourable for *Q. oblongata* trees compared to that of the south-east aspect. Dominance values of the north and south communities in general did not significantly differ from each other.

Regeneration Status:

Table 1: Site wise regeneration criteria of *Taxus contorta* in Shimla district

Site	Aspect	Seedling (ind. ha^{-1}) Mean ± S.D.	Sapling (ind. ha^{-1}) Mean ± S.D.	Tree (ind. ha^{-1}) Mean ± S.D.	Regeneration category
Narkanda	North	0	0	25 ± 25.62)	None
	North East	0	0	40.63 ± 20.44	None
	South West	0	1.04 ± 2.55	8.33 ± 10.21	Poor
	South East	0	0	0	Species absent
Himri	North	450 ± 248.50	70.833 ± 92.76	50 ± 54.63	Good
	North East	458.33 ± 153.03	141.67 ± 138.33	63.54 ±63.54	Good
	South West	79.17 ± 128.86	5.20 ± 12.75	1.04 ± 2.55	Good
	South East	0	0	0	Species absent

[Only Himri showed good regeneration for *Taxus contorta.* Hence this site should be given formal protection and studied as a model system for the conservation of this species]

Physicochemical properties of soil:

The soil investigation for the study areas showing the soil is good for the *Taxus* growth. The *Taxus* needs slightly acidic soil for its growth. The organic carbon is in good amount. Amount of available nitrogen, phosphorus and potassium are in plenty of amount, which showing the soil is fertile (Fig. 4). Heavy metals were also investigated which shows the soil is stress free (Fig. 5). The amount of various metals like Cadmium, Chromium, Copper, Lead, Manganese and Zinc are in satisfactory amount. The soil analysis reveals that studied area is good for *Taxus* plantation.

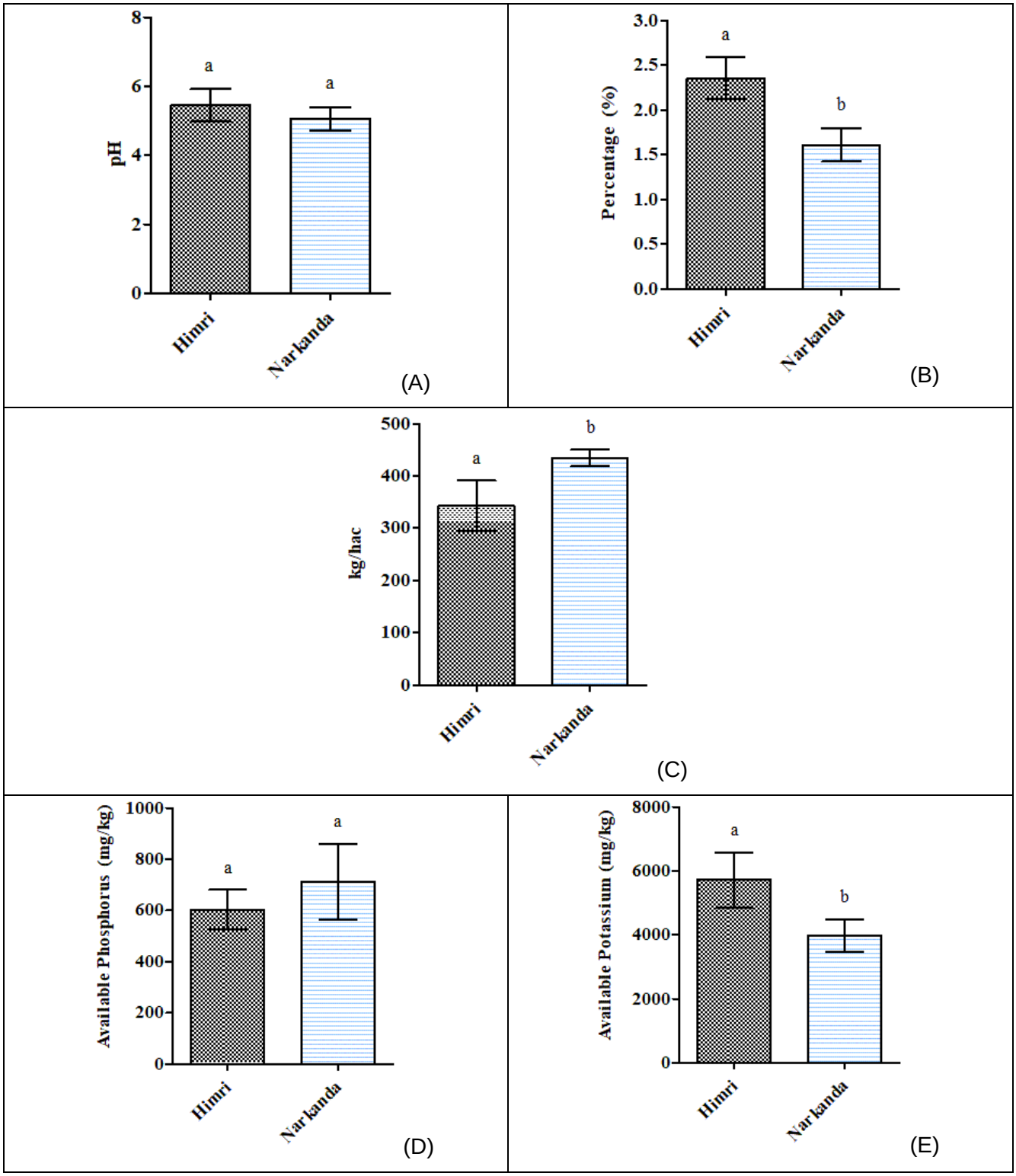


Fig. 4: A – E depicts the physicochemical properties of soil showing pH, soil organic Carbon. Available Nitrogen, available Phosphorus and Available potassium respectively. Different letters on the bar graph shows the significant difference at $p<0.05$.

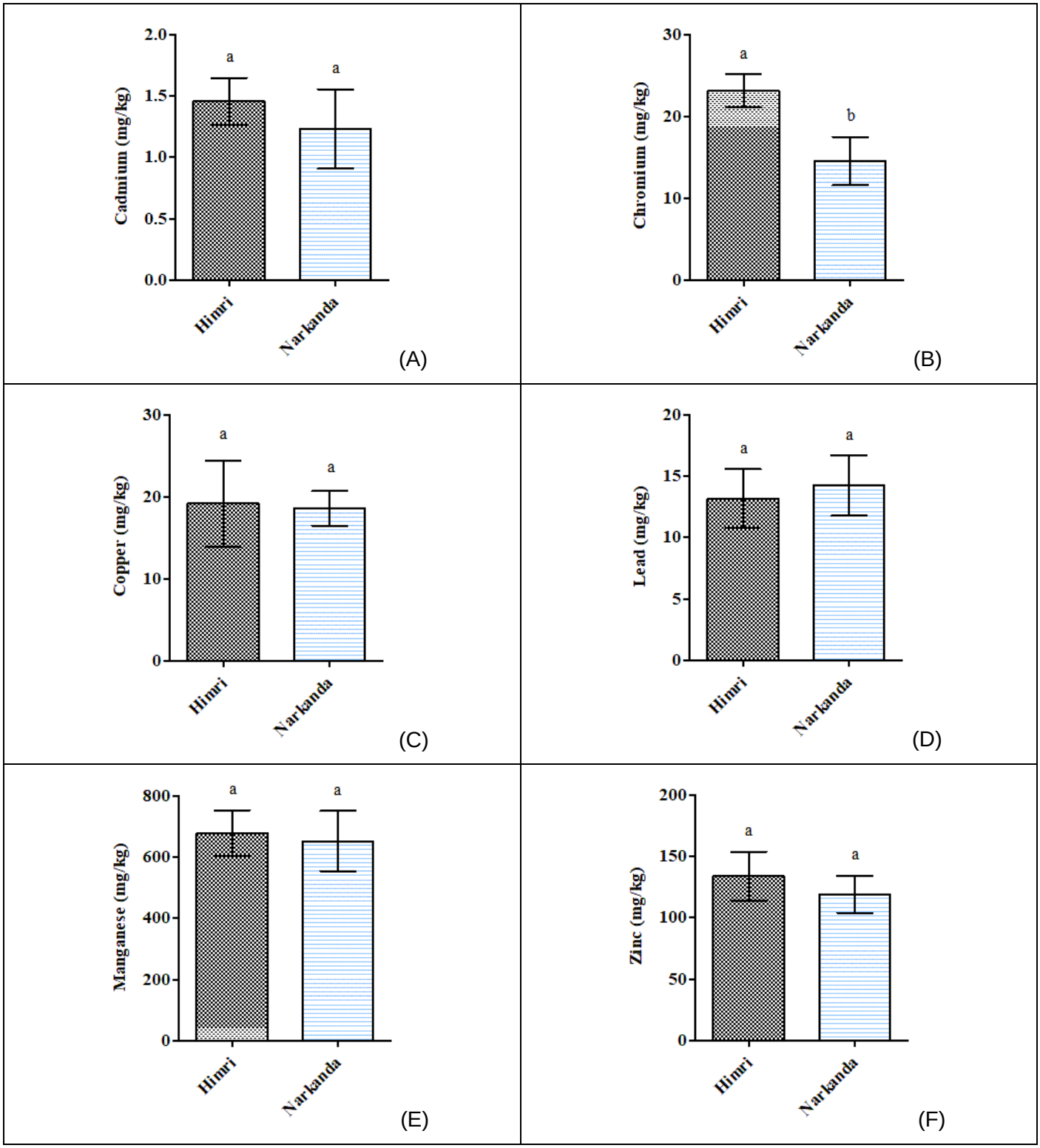


Fig. 5: A – F shows the amount of metals available in the soil. Different letters on the bar graph shows the significant difference at $p<0.05$.

Abiotic factors like light availability and compaction:

We have observed that seedlings of *Taxus contorta* prefer habitats with low soil compaction and intermediate levels of canopy cover (Fig. 6), while the mother trees prefer low canopy cover and intermediate levels of soil compaction. The non-*Taxus* category was found in conditions of high PAR and much lower canopy cover than the mother trees and relatively higher values of soil compaction than seedlings, thereby implying that these are conditions bad for seedling establishment of *Taxus contorta* (Fig. 6). This implies that the conditions necessary for seedling establishment and successful growth of adult trees are totally different and this is one of the serious causes of lack of regeneration of this species. It also implies that different management steps should be taken to protect seedlings and the adult trees.

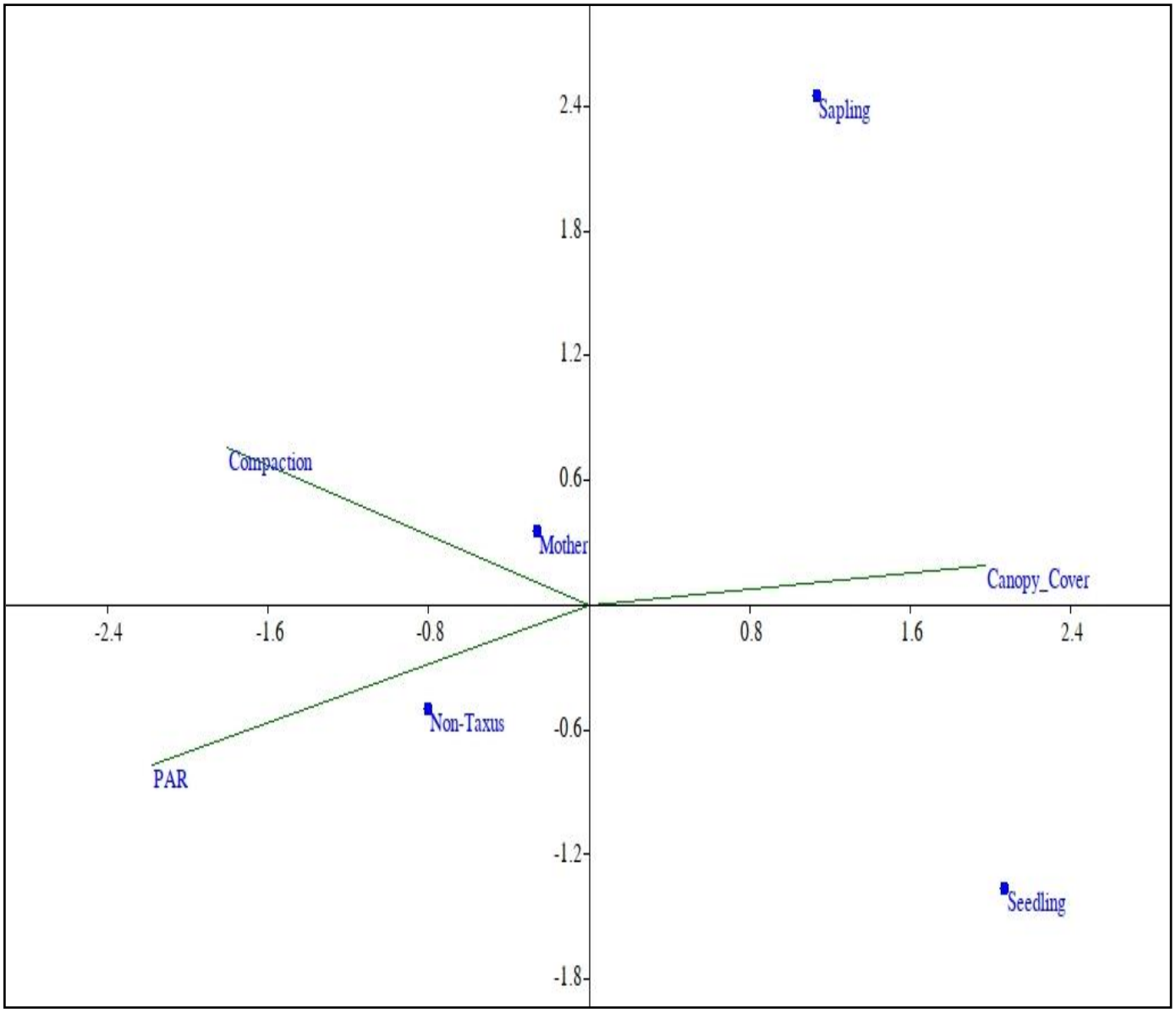


Fig. 6. CCA plot of species-environment relationship of different conditions of *Taxus contorta*

3.6.2 Above-ground soil macrofauna

The soil macrofauna were identified in the laboratory to order level. Interestingly, results of assessment of aboveground soil fauna showed that centipedes of the order Scolopendromorpha were closely associated with *Taxus contorta* seedlings, very strongly preferring habitats of very low soil compaction and less strongly preferring intermediate values of litter biomass (fig. 4). The earthworms (order Haplotaxida) were closely associated with the mother trees of *Taxus contorta*, strongly preferring intermediate values of soil compaction (Fig. 7)

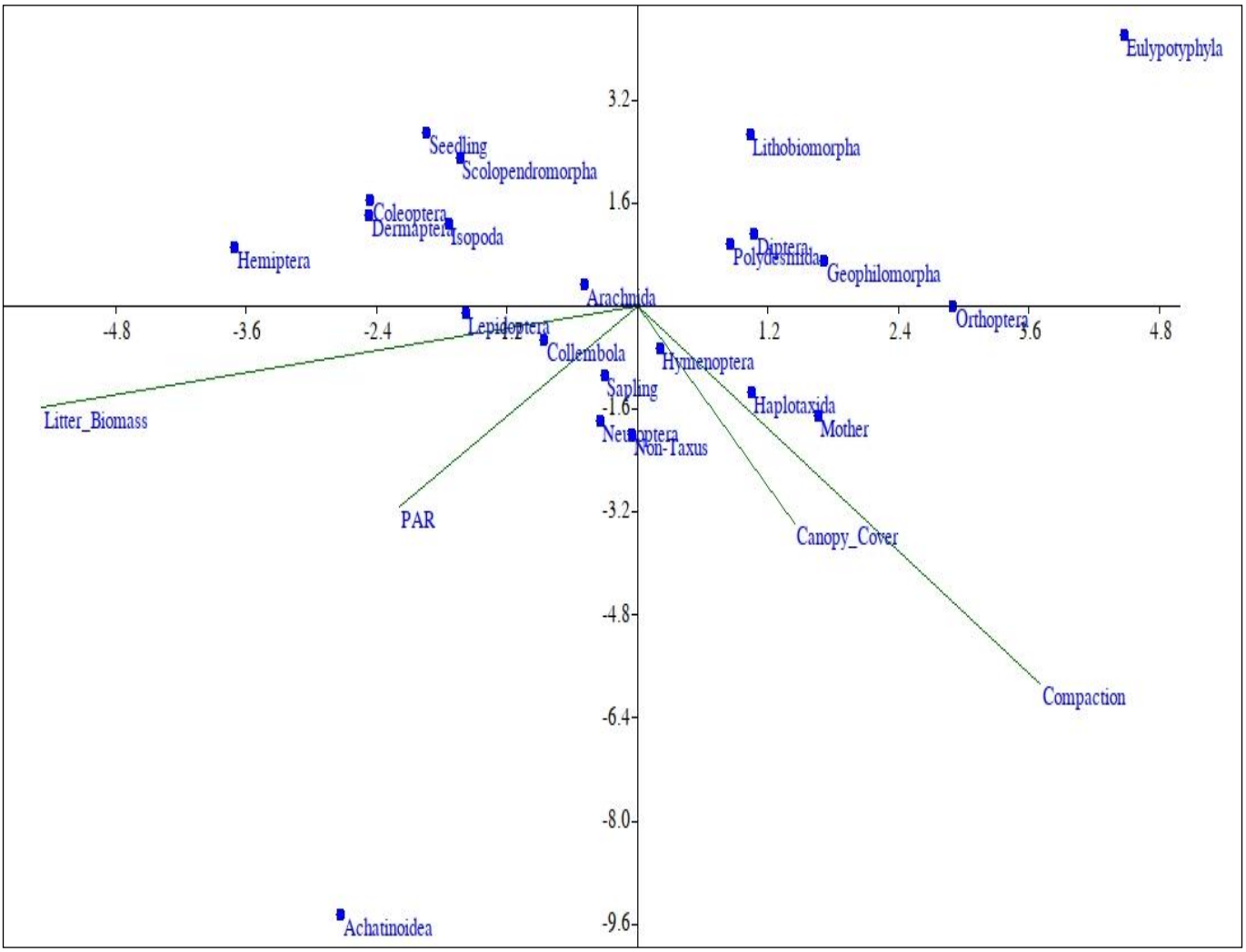


Fig. 7. CCA plot of species-environment relationship of above-ground soil faunal orders along with the different conditions of *Taxus contorta*

3.6.3 Below-ground soil macrofauna

Investigations of the below ground soil fauna revealed that centipedes again, this time of the order Geophilomorpha, were closely associated with saplings of *Taxus contorta*, and very strongly preferred habitats of intermediate litter biomass (Fig. 8).

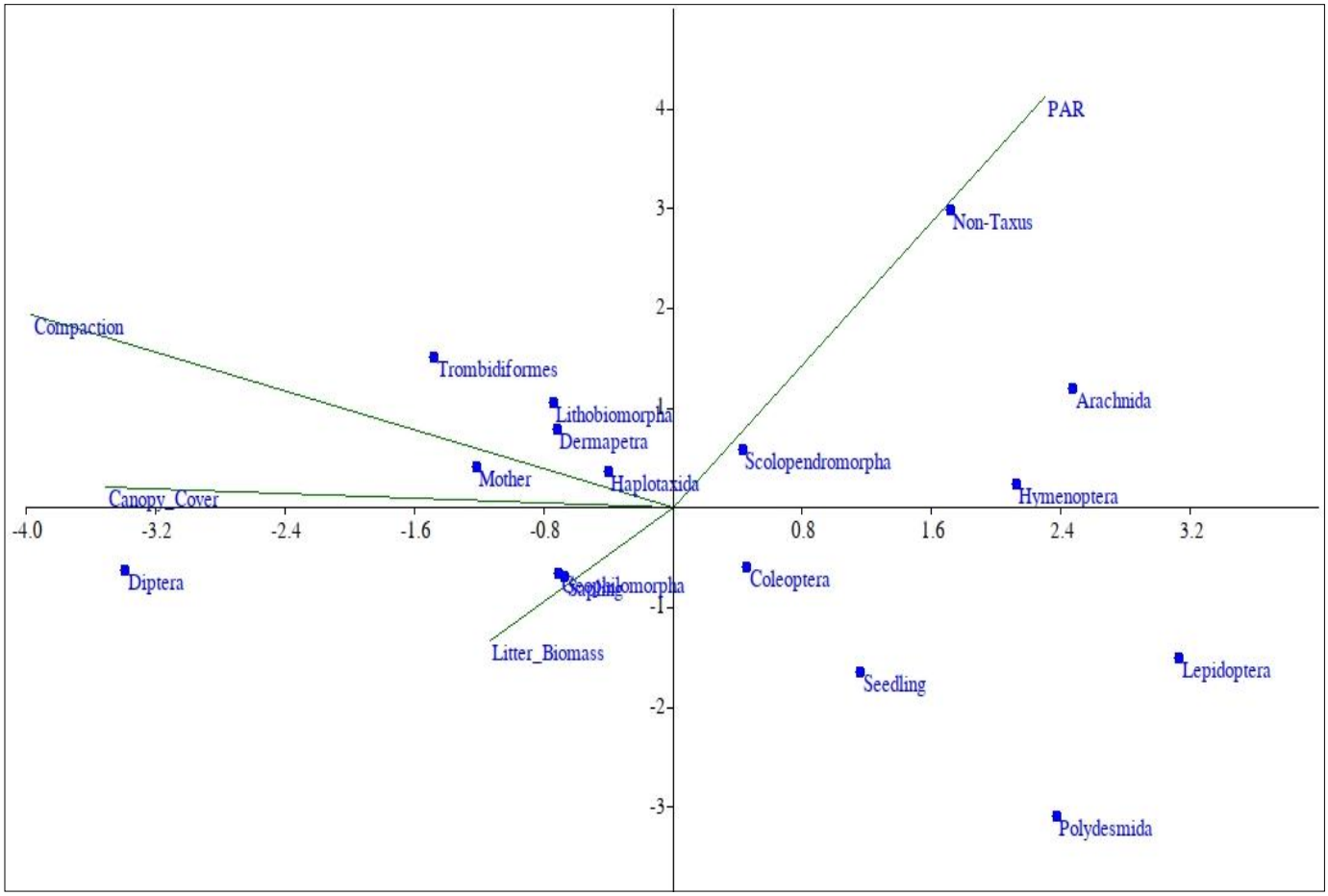


Fig. 8. CCA plot of species-environment relationship of below-ground soil faunal orders along with the different conditions of *Taxus contorta*

Mycorrhizal association:

Seventeen species of AMF were identified which were associated with *Taxus contorta* (Fig. 9). *Glomus* spores were dominant in the both the mother and seedling growth stages of *Taxus contorta* (Table 2) (Fig. 10). Present root colonization also seen higher at Himri than Narkanda (Table 3).

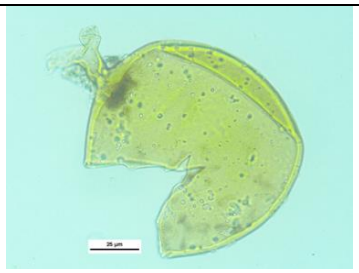
Table 2: Mycorrhizal spores present (+) and absent (-) in study sites

Sr. No.	Spores	Himri	Narkanda
1	*Acaulospora lacunosa*	-	+
2	*Claroideoglomus etunicatum*	+	+
3	*Entrophospora* sp. *1*	+	-
4	*Entrophospora* sp. *2*	-	+
5	*Glomus aggregatum*	+	+
6	*Glomus caledonium*	+	-
7	*Glomus clarum*	+	-
8	*Glomus fasciculatum*	+	-
9	*Glomus glomerulatum*	+	-
10	*Glomus macrocarpum*	+	+
11	*Glomus microcarpum*	-	+
12	*Glomus rubiforme*	+	-
13	*Paraglomus* sp.	+	-
14	*Rhizoglomus clarum*	-	+
15	*Rhizophagus clarus*	+	+
16	*Rhizophagus intraradices*	-	+
17	*Scutellospora* sp. *1*	+	-

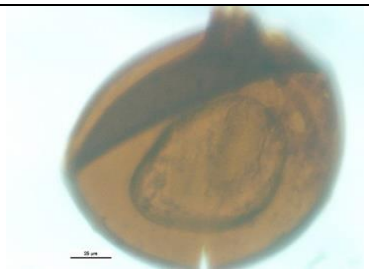
Table 3: Site wise percent root colonization of VAM fungus in *Taxus contorta* roots (Superscript letters show significant difference)

Sr. No.	Study Site	Root Colonization (%) (Mean ± SD)
1	Himri	72.89 **±** 2.79[a]
2+	Narkanda	64.58 **±** 2.95[b]

a. Scutellospora sp. 1



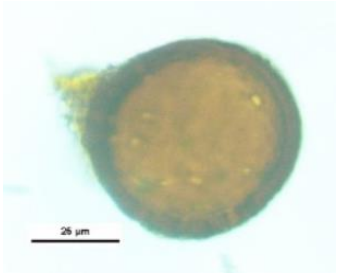
b. Glomus caledonium



c. Entrophospora sp. 1

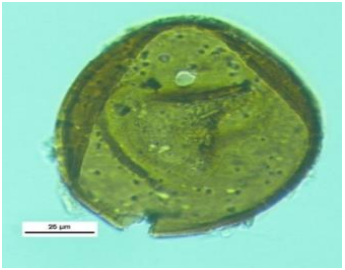
d. Acaulospora lacunosa

e. Glomus macrocarpum



f. Glomus aggregatum

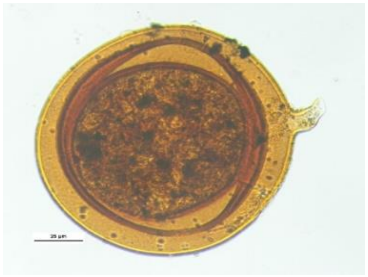
g. Paraglomus sp. 1



h. Rhizoglomus clarum

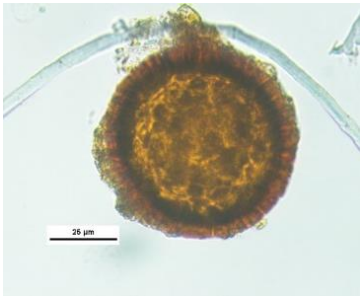
i. Rhizophagus clarus

j. Entrophospora sp. 2



k. Glomus clarum

i. Glomus glomerulatum



j. Glomus fasciculatum

k. G*lomus microcarpum*

l. Glomus rubiformе

m. Claroideoglomus etunicatum

Fig. 9: a – p shows the mycorrhizal fungus associated with *Taxus* rhizosphere.

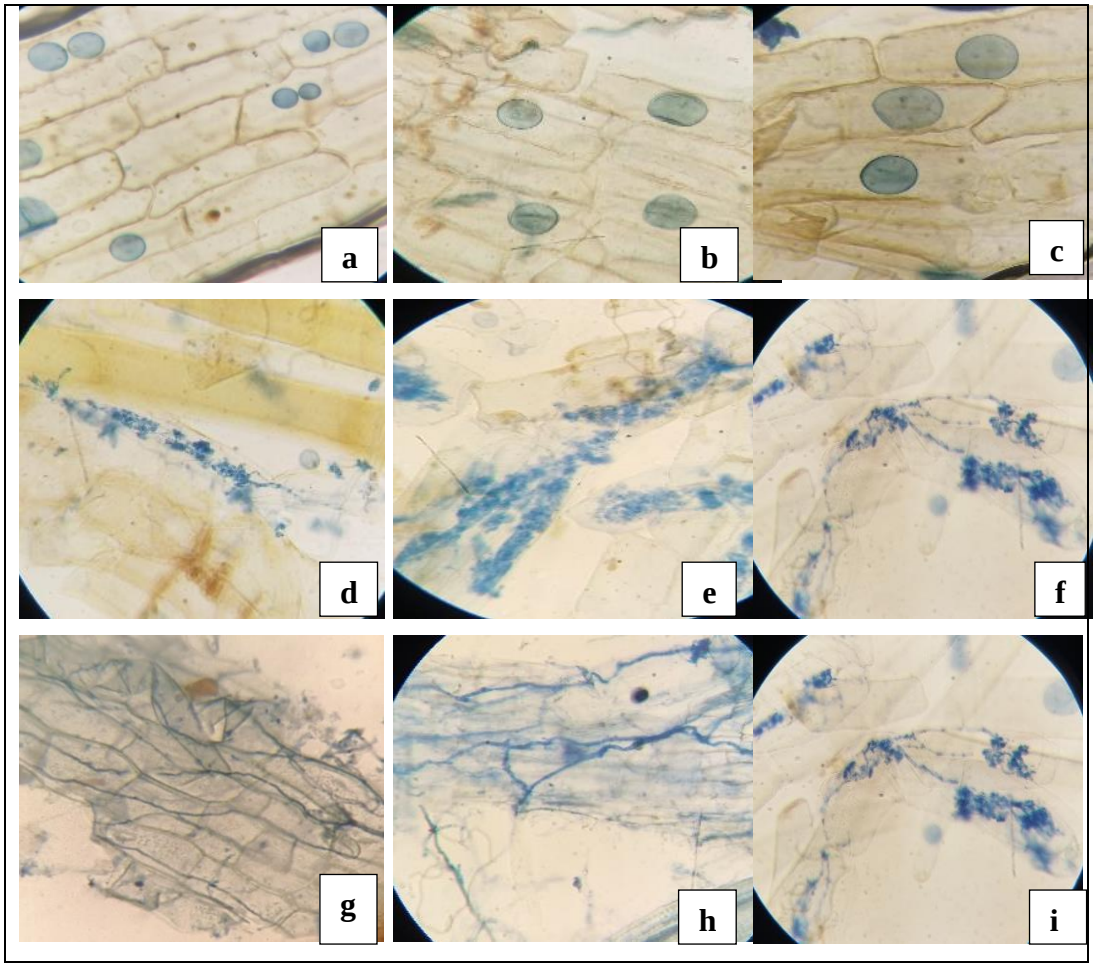


Fig. 10: Mycorrhizal colonization in roots of *Taxus contorta* in the form of Vesicles (a-c), Arbuscules (d-f) and Infection thread (g-i).

Phytochemical analysis and comparison of natural population with polyhouse seedlings:

All the phytochemicals like alkaloids, phenols, saponins, terpenoids and flavonoids were present in both the solvents i.e., methanol and chloroform except Tannins which were absent (Table 4). Alkaloids and phenols were comparatively higher in methanolic extract and in chloroform leaf extract terpenoids and flavonoids were in higher amount. Saponins content were almost same in both (Fig. 11). While comparing in sites, alkaloids content was higher at lower elevation site i.e., Himri in both the extracts. The results are significantly different for alkaloid quantification. Phenols were observed highest in seedlings which were grow in polyhouse and almost same amount of phenols were quantified at lower and higher elevations. Terpenoids and flavonoids are usually higher in chloroform extract. In case of polyhouse seedlings, the terpenoids are higher amongst all and flavonoids were observed highest in the higher elevation site i.e., Narkanda. Saponins are almost same in both solvent with same condition. Higher elevation is showing the higher amount of saponins from other sites.

UHPLC analysis were done for detection of Taxol in the leaf extract. The quantity of Taxol in both the methanolic and chloroform extract is almost similar. The retention time of elution is 4.117 minutes. The amount of Taxol is higher in the leaf extract of polyhouse seedlings Table 5 and Fig 12 & 13.

Table 4: Qualitative analysis of phytochemicals from leaf extract of *Taxus contorta* in different solvents.

Sr. No.	Solvent	Methanol			Chloroform		
	Phytochemicals	Himri	Narkanda	Polyhouse	Himri	Narkanda	Polyhouse
1.	Phenols	++	++	+++	+	+	++
2.	Tannins	-	-	-	-	-	-
3.	Flavonoids	+++	++	+	++	+++	++
4.	Terpenoids	++	+	++	+++	++	+++
5.	Alkaloids	+++	+	++	+++	+	++
6.	Saponin	++	+++	++	+	+++	++

Table 5: Amount of Taxol in the leaf extract of *Taxus contorta*

Sr. No.	Solvent	Site	Taxol Amount (ppm)
1.	Methanol	Himri	6.976
2.		Narkanda	6.091
3.		Polyhouse	10.809
4.	Chloroform	Himri	6.180
5.		Narkanda	4.529
6.		Polyhouse	10.984

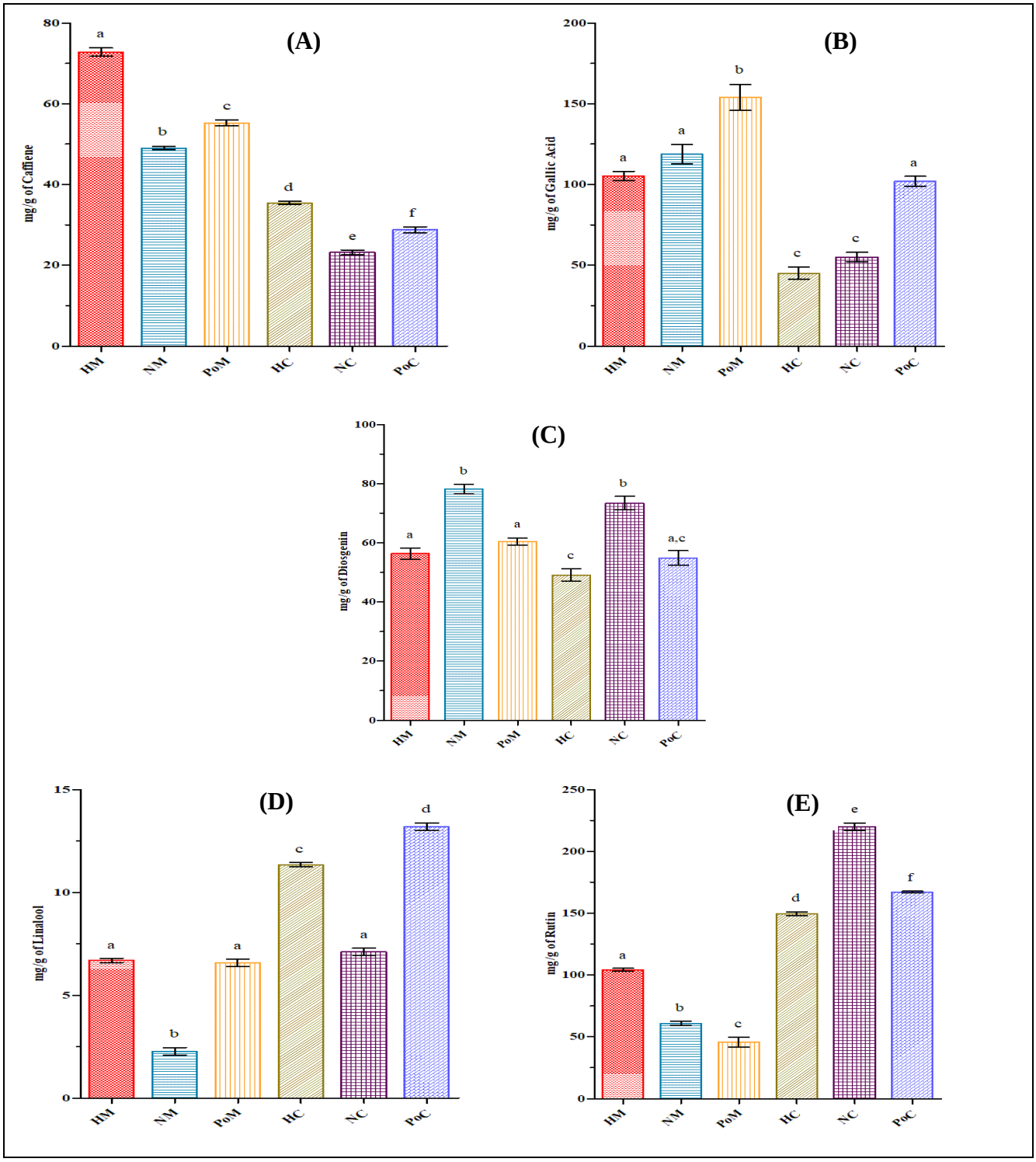


Fig 11: A – E depicts the quantification of alkaloids, phenols, saponins, terpenoids and flavonoids respectively. Different letters on bar graphs depicts significant difference at $p<0.05$. (where HM: Himri Methanol, NM: Narkanda Methanol, PoM: Polyhouse Methanol, HC: Himri Chloroform, NC: Narkanda Chloroform, PoC: Polyhouse Chloroform).

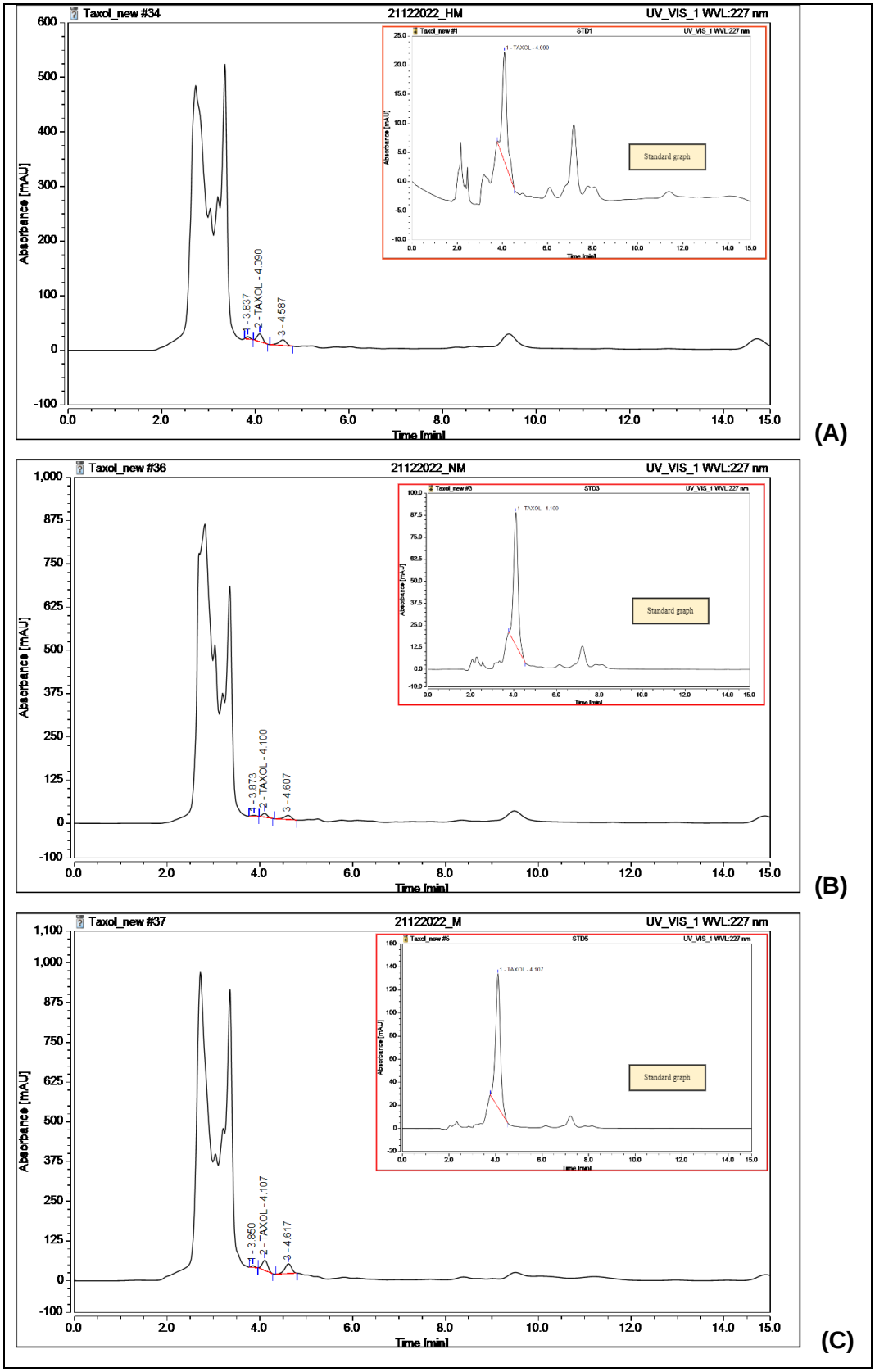


Fig. 12: A – C showing the UHPLC chromatograph for Taxol of methanolic leaf extract of *Taxus* from site Himri, Narkanda and Polyhouse respectively.

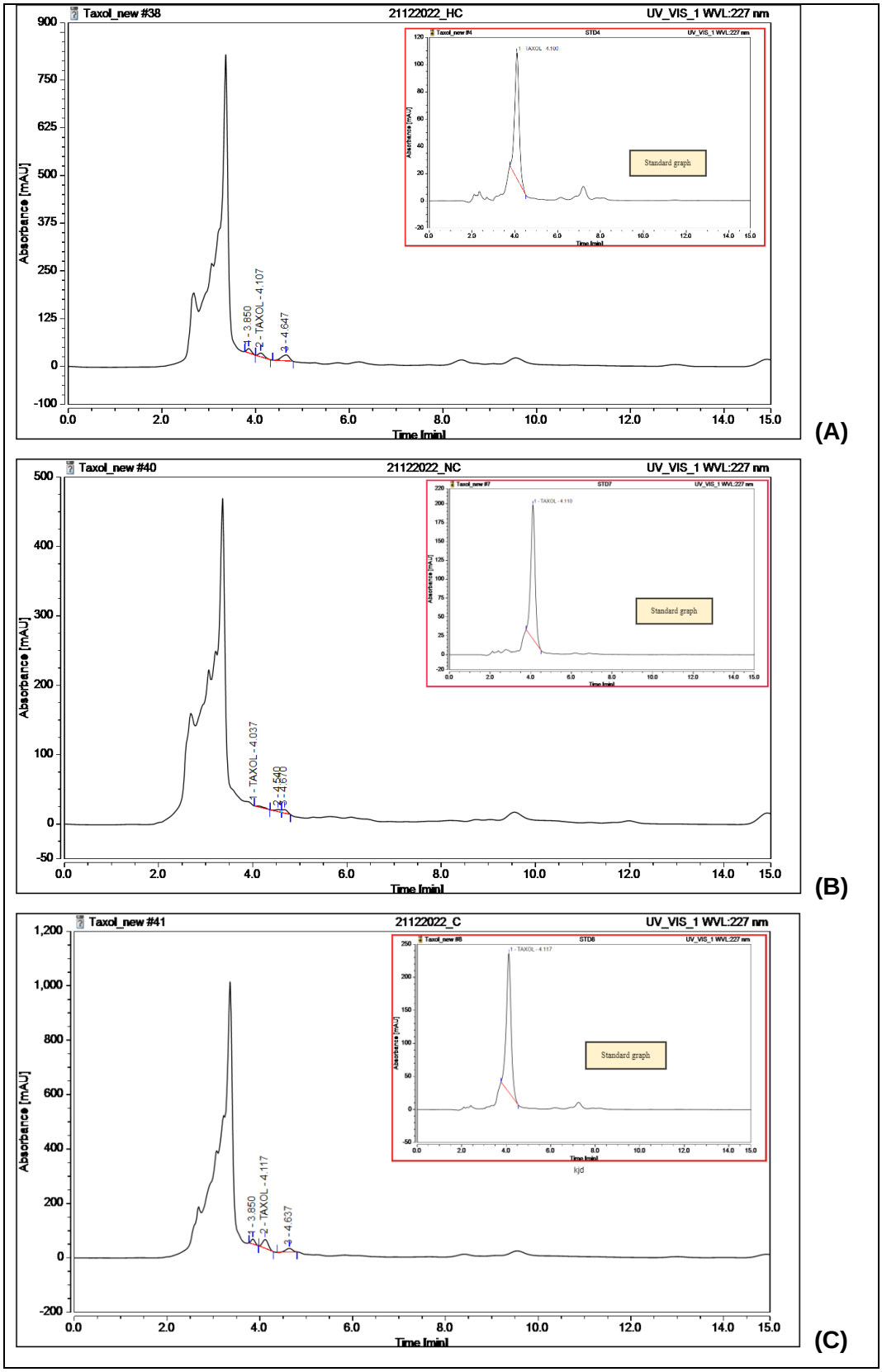


Fig. 13: A, B, C showing the UHPLC chromatograph for Taxol of chloroform leaf extract of *Taxus* from site Himri, Narkanda and Polyhouse respectively.

4.2 Key Results (max 1000 words in bullets covering all activities)

- The Maxent model shows the probability of occurrence of *Taxus contorta* in Shimla district of Himachal Pradesh. The model AUC was 0.967, which is greater than the minimum acceptable value of 0.75. Landcover showed the greatest relative contribution to the model. The present occurrence records fitted well with the model.

- The Maxent model shows the probability of occurrence of *Taxus contorta* in Kullu district. Based on habitat suitability for *Taxus contorta*, the map shows that the area with very high probability is 419 Km^2 (7.60%) and area with high probability is 429Km^2 (7.79%).

- *Taxus contorta* showed good regeneration with the classic reverse J-shaped density-diameter distribution, in the Himri forest of Shimla district. Rest of the study sites showed poor regeneration i.e., no record of seedling and sapling.

- Elevation did not have any effect on the tree densities of this species. In general, the North-east aspect had higher tree densities of *Taxus contorta* than that of the southern aspects.

- The seedlings of *Taxus contorta* prefer habitats with low soil compaction and intermediate levels of canopy cover. while the mother trees prefer low canopy cover and intermediate levels of soil compaction. The non-*Taxus* category was found in conditions of high PAR and much lower canopy cover than the mother trees and relatively higher values of soil compaction than seedlings, thereby implying that these are conditions bad for seedling establishment of *Taxus contorta*.

- The assessment of aboveground soil fauna showed that centipedes of the order Scolopendromorpha were closely associated with *Taxus contorta* seedlings, very strongly preferring habitats of very low soil compaction and less strongly preferring intermediate values of litter biomass. The earthworms (order Haplotaxida) were closely associated with the mother trees of *Taxus contorta*, strongly preferring intermediate values of soil compaction.

- Investigations of the below ground soil fauna revealed that centipedes again, this time of the order Geophilomorpha, were closely associated with saplings of *Taxus contorta*, and very strongly preferred habitats of intermediate litter biomass.

- Seventeen species of AMF were identified which were associated with *Taxus contorta*. *Glomus* spores were dominant in the both the mother and seedling growth stages of *Taxus contorta*.

- The alkaloid, phenols, flavonoids, terpenoids and saponins were present while the qualitative analysis of phytochemicals from leaf extract of *Taxus* in methanol and chloroform extract.

- Alkaloids and phenols were highest in the methanol leaf extract and flavonoids and terpenes were in highest amount in chloroform leaf extract. Saponins were approximately same in both methanol and chloroform leaf extracts.
- UHPLC analysis shows the amount of Taxol is highest in the methanol and chloroform extract of polyhouse plants.
- After soil analysis it has been revealed that the soil of studied forest were good for the *Taxus* regeneration. The dispersal rate is slow or less significantly hinders the population of plant.
- The participants were given a lecture on the Traditional knowledge and the medicinal properties of *Taxus contorta* and the threats it is facing leading to its endangerment in the wild.
- An open discussion was held with the local people about the traditional uses for which they have been using *Taxus* plant (locally called as Rakhal) and the changes they have been observing in its population over the years.
- The plantlets of *Taxus* plant were distributed among the participants and a plantation drive was initiated in and around the villages with the help of forest department officials.

Fig. 14: Rooting as observed in the stem cuttings treated with 500 ppm IBA

Fig. 15: Treatment of the cuttings in laboratory and transferring them to the shade house

Fig. 16: Mass multiplication trials

- Establishing plantlets of seedlings involving forest department and local people. An awareness cum training program was in seven villages and school. The meetings were organized in the following villages:
    - Solangnala village on 18-09-2020
    - Shangarh village on 01-10-2020
    - Khokhan WLS on 08-10-2020
    - Pulga village on 08-07-2021
    - Bathad village on 04-08-2021
    - Kamand village on 25-02-2022
    - Tandari-2 on 02-03-2022
    - Seri village on 21-03-2022
    - Shairopa on 21-03-2022
    - Kot village on 22-07-2022
    - G(B)SSS Theog on 25-11-2022
- Training programs cum workshops on propagation techniques for mass multiplication of *Taxus contorta* were organized
    - Aloo ground nursey, Manali forest division on 28-04-2021
    - Channi nala nursery, Sainj, Banjar Forest division on 04-03-2022
    - Chuti Bihal nursery, Hurla, Parvati Forest division on 09-03-2022
    - Nature park nursery, Mohal, Kullu Forest division on 14-03-2022

- Conference hall, GHNP Tirthan wildlife range, Banjar, Kullu district on 21-03-2022.

-
- E Training manual for conservation and cultivation has been established entitled “Conservation and Cultivation practices of Endangered Himalayan Yew (*Taxus contorta* Griff.) in Himachal Pradesh”.

- Figure 17: Awareness meeting cum Plantation drive at Solangnala village

- Figure 18: Awareness meeting cum Plantation drive at Shangarh village

- Figure 19: Awareness meeting cum Plantation drive at Khokhan WLS

- Figure 20 : Meeting held at Pulga village

- 
- Figure 21: Meeting held at Bathad village
- 

- Fig. 22: Awareness workshop at G(B)SSS Theog

4.3 Conclusion of the study (maximum 500 words in bullets)

- The west Himalayan yew (*Taxus contorta* Griff.) has suffered a severe range wide population decline of up to 90% in the Indian Himalayan Region (IHR), mainly because of overexploitation for its medicinal properties, especially for the commercial extraction of the anti-cancer drug Taxol. The west Himalayan yew (*Taxus contorta* Griff.) has been warranted with the endangered status in the IUCN Red List (Thomas & Farjon, 2011). The main reasons for the decline of population of *Taxus* are overexploitation of the tree because of its commercially important medicinal use and the lack of regeneration. To reduce the overexploitation of the species, research would be conducted to successfully establish plantlets of *Taxus* in the village lands for its ex-situ conservation.

- The species distribution modelling predicted the best suitable conditions are landcover and mean annual temperature for the *Taxus* growth in these regions. The tree generally found the north facing aspect which shows positive relation with abundance of population.

- Low Soil compaction and shady area is best for the seedling growth, later the canopy is not required at tree stage.

- Various factors affecting the regeneration of *Taxus contorta* like population of centipedes and earthworms and low soil compaction are associated with successful establishment.

- Various abiotic factors like soil pH and litter biomass have potential for the seedling growth. The slightly acid soil considered as best for the species growth. By the analysis of organic carbon and available Nitrogen we can conclude the soil is fertile and best for the seed settlement and further growth. The main problem with the species is the seed settlement, the seeds were not dispersed properly that's why the regeneration status is poor in the studied area.

- The *Glomus* species shows the highest association with *Taxus* which help in root growth and absorption of water and minerals. It acts as microbial fertilizers which promotes growth and Taxol accumulation.

- The elevation change also affects the phytochemicals content of the plants. It has been observed that quantity of phenols, alkaloids, terpenoids, flavonoids and saponins were higher in low elevation of plants. While comparing with nursery plants, the phytochemical accumulation is almost similar with plants of low elevation. UHPLC analysis showed that amount of Taxol were higher in the nursery plants.

- The population of *Taxus* is at declining state. The environmental factors and modeling suggest the forest of temperate regions are best for the plant growth. We can identify various suitable sites for the plantation drive in these regions. By studying various abiotic and biotic factors we can create

same microclimatic conditions for the seedling settlement which help in saving the important tree species of our Himalayan region.

5 OVERALL ACHIEVEMENTS

5.1 Achievement on Project Objectives [Defining contribution of deliverables in overall Mission (max. 1000 words)]

Assessment and mapping of populations of Taxus in Shimla and Kullu district:

AUC value observed 0.905 and 0.860 shows fitness of model for study area. Landcover showed the maximum percent contribution followed by temperature seasonality, precipitation of the driest month and annual mean temperature. About 14% area of Kullu district and 12% area of Shimla district is suitable for species occurrence. Jacknife prediction shows that landcover, precipitation of driest quarter, annual mean temperature are main drivers of species distribution. The area which were suitable for species occurrence can be used as best place for plantation.

Investigation of the physicochemical and biotic factors associated with regeneration of Taxus:

Taxus contorta was abundantly found at the northern slopes. Lack of grazing could be the reason that the seedlings got successfully established and survived to sapling stages, thereby showing good regeneration. *Cedrus deodara* was dominant in the northern aspects, *Quercus floribunda* was co-dominant in the north aspect and was the dominant species in the north-east aspect, where *Taxus contorta* was the co-dominant species. *Quercus oblongata* was dominant in the southern aspects, more so in the south-west aspect too. *Glomus* spp. spores were dominant in the both mother and seedling growth stages of *Taxus contorta*. Investigations of the below ground soil fauna revealed that centipedes of the order Geophilomorpha, were closely associated with saplings of *Taxus contorta*, and very strongly preferred habitats of intermediate litter biomass. Results of assessment of aboveground soil fauna showed that centipedes of the order Scolopendromorpha were closely associated with *Taxus contorta* seedlings, very strongly preferring habitats of very low soil compaction and less strongly preferring intermediate values of litter biomass. The earthworms (order Haplotaxida) were closely associated with the mother trees of *Taxus contorta*, strongly preferring intermediate values of soil compaction. Seedlings of *Taxus contorta* prefer habitats with low soil compaction and intermediate levels of canopy cover. The soil of these areas is fertile, all the conditions which are suitable for the *Taxus* growth is present in these sites. The heavy metals also shows accumulation below their toxic level in these areas.

Development and standardization of protocols for mass multiplication of Taxus and comparison of its phytochemistry relative to natural individual:

The germplasm was collected from different locations of the Kullu and Shimla district. Stem cutting of *T. contorta* ranging 15-20 cm with 3-4 nodes and 0.5 to 1.0 cm in diameter were also used for mass multiplication. *Taxus contorta* was raised through mass multiplication at the Dohranala nursery of the institute and H.P. forest nurseries at Channi nala Sainj, Chutti, Bihal Hurla, Mohal nature park nursery, Khodu Bihal Nursery Dohra Nala. Rooting were observed in the stem cuttings treated with 500 ppm IBA. E-Training Manual available on "Conservation and Cultivation practices of Endangered Himalayan Yew (Taxus contorta Griff.) in Himachal Pradesh". The phytochemistry of natural plants and plantlets developed in polyhouse were compared. It has found that amount of alkaloids and phenols were highest in the methanol leaf extract, while terpenoids and flavonoids were highest in chloroform leaf extract. UHPLC chromatograph reveals the amount of Taxol quantified higher in the seedlings grown in polyhouse conditions i.e., 10ppm.

Establishment of Taxus plantlets with the help of forest department and the local communities:

Establishing plantlets of seedlings involving forest department and local people through an awareness cum training program was done in seven villages and school. Around 20-30 participants were present during each meeting which included villagers, farmers, BMC members, forest department officials, and Panchayat Head. The participants were given a lecture on the Traditional knowledge and the medicinal properties of *T. contorta* and the threats it is facing leading to its endangered status in the wild.

5.2 Establishing New Database/Appending new data over the Baseline Data (max. 1500 words, in bullet points)

- The MaxEnt modelling were not done previously in these areas. Species Distribution Modelling shows the suitable area for species where it can grow and can do more plantations.
- The soil was tested as fertile soil for proper growth of the plant.
- There were no traces of heavy metals found.
- The phytochemistry comparison of natural population and polyhouse seedlings reveals the Taxol quantity of seedlings were higher.
- The soil under flora and above ground flora helps the circulation of nutrients, they also helping in the reducing compaction of soil. The low compaction establishes the species better.
- Low light and dense canopy helping in the species establishment at initial stages.

5.3 Generating Model Predictions for different variables (if any) (max 1000 words in bullets)

MaxEnt model were used for predicting species distribution along the study area. The environmental variables and occurrence points were correlated with each other and results are obtained in the form of probability of occurrence of species in an area.

5.4 Technological Intervention (max 1000 words)

Tissue culture and nursery techniques were used for the seedling development.

Tissue culture:

• The shoot cuttings were washed using Tween 20 (two drops) under running tap water for 15-20 minutes

• Cuttings were then sterilized with a solution of 0.05% Bavistin for 10-20 minutes and rinsed thoroughly 3 times using distilled water.

• 0.1% Mercuric chloride treatment is then given for 30sec-2 minutes and rinsed thoroughly 3 times with distilled water under laminar air flow cabinet.

• The cuttings were then blotted on to a tissue paper.

• The cuttings were inoculated into the culture media flask using a sterile forceps.

• 5 cuttings were inoculated per culture media flask and total 30 flasks were prepared.

• The flasks were then placed in the culture room (25-27° C temperature, 16hr light 8hr dark conditions)

Nursery:

• The needles were removed from the basal 2 cm region and the cuttings were dipped in the following four solutions of different concentration of growth regulators for 24h at 20°C

Indole-3-butyric acid (IBA) – 500ppm, 1000ppm

Naphthalene Acetic cid (NAA) – 500ppm, 1000ppm

• Following the chemical treatment, cuttings were vertically planted in polythene bags containing rooting medium (sand, soil and farmyard manure in the ratio 1:2:1).

The seedlings were kept in Nursery (shade house)

• The cuttings were watered daily and were protected from direct sunlight and high humidity under a shade house.

5.5 On field Demonstration and Value-addition of Products (max. 1000 words, in bullet points)

Workshop data

The field workshops were organized to demonstrate the propagation and plantation of *Taxus* to villagers. The Taxus is important for its drug “Taxol”. Traditionally people use it as pain reliever by consuming tea, which is prepared from the bark of plant. The plant is also important for its toxicity. Study showed that the plant was used for poisoning. It is necessary to aware people about the importance of the species. The workshop organized in these areas help the people for establishing new seedlings and sell commercially for the financial benefit.

5.6 Promoting Entrepreneurship in IHR

The natural regeneration is very low of *Taxus*. The seed dispersal rate is also low. These two effects the number of seedlings are very low or zero for this plant. Although plants can also be established by vegetative propagation. It can help locals for developing their own nurseries. They can develop and sell the plantlets for the locals and forest department. Thus it helps in developing entrepreneurship for nursery development at commercial level. On the other hand people can also use the leaves of plant to sell it to pharma companies for Taxol production.

5.7 Developing Green Skills in IHR

The status of the species in the western Himalayas is at declining state. The IUCN categorized it as endangered plant species of western Himalayas. The main reason of low population is lack in establishment of new plants naturally. The species is distributed by frugivorous birds like Jujurana (Western Tragaphon). The seed coat of the plant is very hard which takes so many years for breaking naturally. The development of Taxus nurseries coupled with number of plantation drive to different areas can assist in increasing the green cover of Taxus. It helps to rejuvenate the species and establish the new population for the forest ecosystem. Thus the development of green skills like letting people know the techniques of nursery development and also awaring them about the medicinal significance of plants can them in becoming enterpreneur.

5.8 Addressing Cross-cutting Issues (max. 500 words, in bullet points)

- The species were restricted to northern face steep slopes. It is tough to reach the plant.
- During the tissue culture experiment, temperature fluctuations caused damage to the new ones.
- Improper shade or direct sunlight effects the seedlings in nurseries.

6 PROJECT’S IMPACTS IN IHR

6.1 Socio-Economic Development (max. 500 words, in bullet points)

The project promotes the socio economic development in various ways:

- Skills provide the chance for villagers to earn money.
- Development of nurseries help in giving a new startup to the villagers, they can develop nurseries thereon and sell it to locals and forest department.
- The bark and leaves contain high amount of Taxol drug. By selling the plant leaves people can earn money.

6.2 Scientific Management of Natural Resources In IHR (max. 500 words, in bullet points)

- Fencing of the forests where *Taxus* forests are present.
- Scared groove is one of the approaches.
- The microscossum technique is best for seedling establishment, by creating small environment conditions like with adult trees help in proper establishment of seedlings.
- Tissue culture and vegetative propagation helps in raising new plantlets without any damage to parent plant.

6.3 Conservation of Biodiversity in IHR (max. 500 words, in bullet points)

The conservation is one of the important concerns to protect any ecosystem and species in different areas. The *Taxus* population is in declining state, so if the conservation strategies will not be followed then it will extinct in coming years. The conservation of one species parallelly conserve other associated species with it. Not even the plants it helps in the conserving the birds species, microorganisms which are all associated with species. The threatened to the one species indirectly threatened the ecosystem.

- The distribution modeling helps in identify suitable area for species plantation.
- The seeds of *Taxus* plants were distributed by Jujurana which is also endangered to the Himalayan region.

6.4 Protection of Environment (max. 500 words, in bullet points)

Plantation to these areas sustain the environment. The loss of any species in the ecosystem can cause huge damage to ecosystem and also effects more to the closely associated species. The conservation to this species not only provide benefit to human kind but also cope up the previous damage. The species help in protecting the natural habitat of temperate region which is the home place of several other important species which are not explored. We also provide direct protection to unexplored species. The protection to one provide protection to whole environment.

6.5 Establishing New Database/Appending new data over the Baseline Data (max. 1500 words, in bullet points): Physicochemical & phytochemical analysis was done in the sampling sites along with assessment of mycorrhizal biodiversity study.

6.6 Generating Model Predictions for different variables (if any) (max 1000 words in bullets)
Helped in proper establishment of species by identifying the suitable habitat from MaxEnt modelling

6.7 Technological Intervention (max 1000 words): Quantitative analysis of phytochemicals was done through UHPLC technique for the detailed phytochemical analysis. Further Stem cutting was done for mass propagation of Taxus seedlings

6.8 On field Demonstration and Value-addition of Products (max. 1000 words, in bullet points): NA

6.9 Promoting Entrepreneurship in IHR: Trained locals for mass multiplication of Taxus

6.10 Developing Green Skills in IHR: Aware locals about the significance of Taxus and trained locals for mass multiplication of Taxus

6.11 Addressing Cross-cutting Issues (max. 500 words, in bullet points): Overgrazing and other activities were the reasons for the absence of seedlings and saplings from different regions of study site.

7 PROJECT'S IMPACTS IN IHR

7.1 Socio-Economic Development (max. 500 words, in bullet points): Awaring locals about the significance of plants can lead them not only to conserve Taxus but also to mass propagate it.

7.2 Scientific Management of Natural Resources In IHR (max. 500 words, in bullet points) : NA

7.3 Conservation of Biodiversity in IHR (max. 500 words, in bullet points): Mass multiplication and plantation of Taxus was done in different areas of study site.

7.4 Protection of Environment (max. 500 words, in bullet points): Mass multiplication and establishment of species is related with preventing biodiversity and protecting environment which was one of the main aspect of the project

7.5 Developing Mountain Infrastructures (max. 500 words, in bullet points): NA

7.6 Strengthening Networking in IHR (max. 700 words, in bullet points): NA

8 EXIT STRATEGY AND SUSTAINABILITY

8.1 How effectively the project findings could be utilized for the sustainable development of IHR (max. 1000 words)

The project point out the factors influencing the regeneration rate of *Taxus*. For establishing community monitored plantations and rejuvenation of *Taxus* population in the forests, the panchayats, Joint Forest Management Committees (JFMCs), H.P. and the forest department was involved. The saplings were allowed to grow by the local people, thereby generating a source of sustainable harvesting of the plant parts for extraction of important medicinal compounds.

8.2 Efficient ways to replicate the outcomes of the project in other parts of IHR (Max 1000 words): As use of The Maxent model shows the probability of occurrence of species in study area. So, with its use potential areas should be identified for the propagation/growth of desirable species

8.3 Identify other important areas not covered under this study needs further attention (max 1000 words)

The similar study could be conducted in the other left out regions of Indian Himalaya where Taxus is already growing.

8.4 Major recommendations for sustaining the outcome of the projects in future (500 words in bullets)

Plantation drive should be carried further in other temperate areas of Western Himalaya.

9 REFERENCES/BIBLIOGRAPHY

1. Bodh, M. 2017. Study on floristic diversity assessment, monitoring and prioritization in Great Himalayan National Park, North Western Himalaya for management implications. Ph. D. Thesis. Kumaun University, Nainital, Uttarakhand, India.
2. Ecological Assessment and Conservation Prioritization of Floristic Diversity of the Tirthan Wildlife Sanctuary in Himachal Pradesh, North Western Himalaya (Ms Shalu Thakur: Awarded, 2012)
3. Elith J. Quantitative methods for modeling species habitat: comparative performance and an application to Australian plants. InQuantitative methods for conservation biology 2000 (pp. 39-58). Springer, New York, NY.
4. GADM. GADM maps and data [Internet]. GADM. [cited 2019Jun30]. Available from:
5. GBIF. GBIF [Internet]. GBIF. [cited 2019Jun30]. Available from: https://www.gbif.org/en/
6. Gemma, JN, Koske, RE, Roberts, EM, & Hester, S. (1998). Response of *Taxus* times media var. densiformis to inoculation with arbuscular mycorrhizal fungi. Canadian journal of forest research , 28 (1), 150-153.
7. Gerdemann, J. W., & Nicolson, T. H. (1963). Spores of mycorrhizal Endogone species extracted from soil by wet sieving and decanting. Transactions of the British Mycological society, 46(2), 235-244.
8. Gibji Nimasow, Oyi Dai Nimasow, Jawan Singh Rawat, Gendan Tsering, and Takom Liting, 2016. Remote sensing and GIS based suitability modeling of medicinal plant (*Taxus* baccata Linn.) in Twang district, Arunachal Pradesh, India.
9. Iglesias, M. I., Sainz, M. J., Vilariño, A., López Mosquera, M. E., Pintos, C., & Mansilla, J. P. (2002, August). Mineral nutrition of *Taxus* baccata L. as affected by inoculation with arbuscular mycorrhizal fungi. In XXVI International Horticultural Congress: Nursery Crops; Development, Evaluation, Production and Use 630 (pp. 225-229).

10. Izsák, J., & Papp, L. (2000). A link between ecological diversity indices and measures of biodiversity. Ecological Modelling, 130(1-3), 151-156.
11. Kramer-Schadt S, Niedballa J, Pilgrim JD, Schröder B, Lindenborn J, Reinfelder V, Stillfried M, Heckmann I, Scharf AK, Augeri DM, Cheyne SM. The importance of correcting for sampling bias in MaxEnt species distribution models. Diversity and Distributions. 2013 Nov;19(11):1366-79.
12. Lal, M. 2007. Assessment of floristic diversity and conservation status of plants in Kais Wildlife Sanctuary of Himachal Pradesh in North Western Himalaya. Ph. D. Thesis. Kumaun University, Nainital, India
13. Misra, A., Gupta, M. L., & Singh, U. B. (2004). Occurence of Vesiculararbascular mycorrhizal fungi in *Taxus* wallichiana Zuccarini. J. Plant Biol, 31, 1-3.
14. Pankaj Sharrma, 2013. Ecological assessment of floristic diversity and possible impacts of hydropower projects in Kullu District of Himachal Pradesh, North Western Himalaya. Ph. D. Thesis Kumaun University, Nainital, Uttrakhand, India.
15. Rana, M.S. 2007. Assessment of floristic diversity and conservation prioritization of communities for conservation in Manali Wildlife Sanctuary of Himachal Pradesh in Northwestern Himalaya. Ph. D. Thesis, Kumaun University, Nainital, Uttarakhand.
16. Sainz, M. J., Iglesias, I., Pintos, C., Mansilla, J. P., & Vilarino, A. (2000, September). Improved production of nursery stock of *Taxus* baccata L. through management of the arbuscular mycorrhizal symbiosis. In XIVth International Symposium on Horticultural Economics 536 (pp. 379-384).
17. Samant, S. S., Joshi, H. C., Arya, S. C., & Pant, S. (2002). Studies on the structure, composition and changes of the vegetation in Nanda Devi Biosphere Reserve of West Himalaya – FinalTechnical Report Submitted to Ministry of Environment and Forests, New Delhi, India.
18. Scagel, C. F., Reddy, K., & Armstrong, J. M. (2003). Mycorrhizal fungi in rooting substrate influences the quantity and quality of roots on stem cuttings of hick's yew. HortTechnology, 13(1), 62-66.
19. Schickhoff, U. (1996). Contributions to the synecology and syntaxonomy of West Himalayan coniferous forest communities. Phytocoenologia, 537-581.
20. Shankar, U. (2001). A case of high tree diversity in a sal (Shorea robusta)-dominated lowland forest of Eastern Himalaya: Floristic composition, regeneration and conservation. Current Science, 776-786.
21. Shannon CE, Weaver W. The mathematical theory of communication, 117 pp. Urbana: University of Illinois Press. 1949.
22. Sharma, A. 2008. Studies on Floristic diversity and prioritization of communities for conservation in Hirb and Shoja Catchments, District Kullu of Himachal Pradesh, North Western Himalaya. Ph. D. Thesis, Kumaun University, Nainital, Uttarakhand, India.
23. Shiv Paul, 2018. Population assessment and ecological niche modeling of economically important species of north western Himalaya. Ph.D. Thesis, Kumaun University, Nainital, Uttrakhand, India

24. Shreekar Pant and S.S. Samant, 2008. Population Ecology of the endangered Himalayan Yew in Khokhan Wildlife Sanctuary of North Western Himalaya for Conservation Management.
25. Simpson EH. Measurement of diversity. nature. 1949 Apr;163(4148):688-. The Gymnosperm Database. [Internet]. *Taxus contorta* (West Himalayan yew) description. [cited 2019Jun30]. Available from: https://www.conifers.org/ta/*Taxus*_contorta.php
26. The Gymnosperm Database. [Internet]. *Taxus contorta* (West Himalayan yew) description. [cited 2019Jun30]. Available from: https://www.conifers.org/ta/*Taxus*_contorta.php
27. Thomas P. *Taxus contorta* . The IUCN Red List of Threatened Species. 2011: e.T39147A10170545. https://dx.doi.org/10.2305/IUCN.UK.2011 2.RLTS.T39147A10170545.en. Downloaded on 29 September 2019.
28. Whitford, P. B. (1949). Distribution of woodland plants in relation to succession and clonal growth. Ecology, 30(2), 199-208.Mueller-Dombois, D., & Ellenberge, H. (1974). *Aims and methods of vegetation ecology*. John Willey and Sons, New York.

10 ACKNOWLEDGEMENT

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- Director, G.B. Pant National Institute of Himalayan Environment, Kosi- Katarmal, Almora, Uttarakhand
- Chancellor, Registrar, Shoolini University of Biotechnology and Management Sciences, Bhajol, Solan, Himachal Pradesh

- **APPENDICES**

Appendix 1 – Details of Technical Activities

Appendix 2 – Copies of Publications duly Acknowledging the Grant/ Fund Support of NMHS

Appendix 3 – List of Trainings/ Workshops/ Seminars with details of trained resources and dissemination material and Proceedings

Appendix 4 – List of New Products (utilizing the local produce like NTFPs, wild edibles, bamboo, etc.)

Appendix 5 – Copies of the Manual of Standard Operating Procedures (SOPs) developed

Appendix 6 – Details of Technology Developed/ Patents filled

Appendix 7 – Any other (specify)

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Annexure-I

Consolidated and Audited
Utilization Certificate (UC) and Statement of Expenditure (SE)

For the Period: from (01.02.2019) to (31.10.2022)

1.	Title of the project/Scheme/Programme:	**RETURNING TAXUS TO THE FORESTS AND THE PEOPLE: A STUDY IN SHIMLA AND KULLU DISTRICTS OF THE INDIAN HIMALAYAN REGION**
2.	Name of the Principle Investigator & Organization:	Dr. Rachna Verma] Associate Professor, School of Biological and Environmental Science, Shoolini University of Biotechnology and Management Sciences, Bhajhol, Solan, 173229
3.	NMHS-PMU, G.B. Pant National Institute of Himalayan Environment, Kosi-Katarmal, Almora, Uttarakhand Letter No. and Sanction Date of the Project:	GBPNI/NMHS-2018-2019/SG/210 21/01/2019
4.	Amount received from NMHS-PMU, G.B. Pant National Institute of Himalayan Environment, Kosi-Katarmal, Almora, Uttarakhand during the project period (Please give number and dates of Sanction Letter showing the amount paid):	**46,30,404**
5.	Total amount that was available for expenditure (Including commitments) incurred during the project period:	**46,68,494***
6.	Actual expenditure (excluding commitments) incurred during the project period:	**46,68,494**
7.	Unspent Balance amount refunded, if any (Please give details of Cheque no. etc.):	**Nil**
8.	Balance amount available at the end of the project:	**Nil**
9.	Balance Amount:	**Nil**
10.	Accrued bank Interest:	**38,090**

***The interest amount is also included.**

Certified that the expenditure of **Rs. 46,68,494/- (Rupees: Forty-six lakh sixty-eight thousand four hundred and ninety four)** mentioned against Sr. No. 6 was actually incurred on the project/scheme for the purpose it was sanctioned.

Date: 28/12/2022

(Signature of Principal Investigator)

(Signature of Registrar/ Finance Officer)

Comptroller (Finance)
Shoolini University of Biotechnology
& Management Sciences
Bajhol Campus, Solan (H.P.)

(Signature Head of Institution)

Dean
Research & Development
Shoolini University
Post Box No. 9
Head Post Office
Solan - 173212 (H.P.)

OUR REF. No.
GBPNI/NMHS/2018-2019/SG/210

ACCEPTED AND COUNTERSIGNED

Date:

COMPETENT AUTHORITY
NATIONAL MISSION ON HIMALAYAN STUDIES (GBP NIHE)

Statement of Consolidated Expenditure

[Institution Name here]

Statement showing the expenditure of the period from 01/02/2019 to 31/10/2022
Sanction No.: GBPNI/NMHS-2018-19/SG/210 and Date: 21/01/2019

1. Total outlay of the project : 47,00,000

2. Date of Start of the Project : 01/02/2019

3. Duration : 3 years, 8 months

4. Date of Completion : 31/10/2022

a) Amount received during the project period : 46,30,404

b) Total amount available for Expenditure : 46,68,494 (Included interest)

S. No.	Budget head	Amount received	Expenditure	Amount Balance/ excess expenditure
1.	Salaries	1228662	1228662*	0
2.	Permanent Equipment Purchased	860000	859887**	+113
3.	Travel	242000	342617**	-100617
4.	Consumables	1577742	1476900**	+100842
5.	Contingency	242000	242338**	-338
6.	Institutional charges	480000	480000	0
7.	Accrued bank Interest	38090	38090*	0
8.	Total	4668494	4668494	0

*The amount 30,256 out of 38,090 is adjusted against the arear amount of salaries as per NMHS sanction letter no. GBPNI/NMHS-2018-19/SG/210/240, Dated: 17/12/2020 and remaining amount of Rs.7834 was utilized in consumables.
**The excess expenditure done under travel and contingency head was compensated with balance left from equipment head, consumables head and interest accrued head.

Certified that the expenditure of **Rs. 46,68,494/- (Rupees: Forty-six lakh sixty-eight thousand four hundred and ninety four)** mentioned against Sr. No.8 was actually incurred on the project/ scheme for the purpose it was sanctioned.

Date:28/12/2022

(Signature of Principal Investigator)

(Signature of Registrar/ Finance Officer)

Comptroller (Finance)
Shoolini University of Biotechnology
& Management Sciences
Bajhol Campus, Solan (H.P.)

(Signature of Head of the Institution)

Dean
Research & Development
Shoolini University
Post Box No. 9
Head Post Office
Solan - 173212 (H.P.)

OUR REF. No.: GBPNI/NMHS-2018-19/SG/210

ACCEPTED AND COUNTERSIGNED

Date:

COMPETENT AUTHORITY
NATIONAL MISSION ON HIMALYAN STUDIES (GBP NIHE)

GFR 19 – A

(See Rule 212 (1))

Form of Utilization Certificate

S.No.	Letter Date and No.	Amount (Rs.)
	GBPNI/NMHS-2018-2019/SG/210	11,88,660
	Total	11,88,660

Certified that out of Rs. 11,88,660 of Grants-in aid sanctioned during the years 2021-22 in favor of Shoolini University under this Ministry/ Department letter No. given in the margin and Rs. Nil on account of unspent balance of the previous year, a sum of Rs. Nil has been utilized for the purpose of R&D Project for which it was sanctioned and that the balance of Rs. Nil remaining un utilized at the end of the year has been surrendered to Government (vide No. NA dated NA) will be adjusted towards the grants-in-aid payable during the next year 2022-23.

1. Certified that I have satisfied myself that the conditions on which the grants-in-aid was sanctioned have been duly fulfilled/are being fulfilled and that I have exercised that following checks to see that the money was actually utilized for the purpose for which it was sanctioned.

Kinds of checks exercised.

1. Verification of book of Accounts
2. Verification of vouchers
3 P{hysical verification

Signature_____

Designation (Senior Controller Finance

Shoolini University of Biotechnology & Management Sciences
Bajhol Campus, Solan (H.P.)

Date: 28/12/2022

Annexure-II

Consolidated Interest Earned Certificate

Certificate

This is to certify that an amount of **38,090 (Thirty-eight thousand and ninety)** was earned under the project entitled "RETURNING TAXUS TO THE FORESTS AND THE PEOPLE: A STUDY IN SHIMLA AND KULLU DISTRICTS OF THE INDIAN HIMALAYAN REGION" sanctioned vide NMHS number : GBPNI/NMHS-2018-2019/SG/210 and dated: 21/01/2019 during the period of implementation.

(FINANCE OFFICER)

(Signed and Stamped)
Comptroller (Finance)
Shoolini University of Biotechnology
& Management Sciences
Bajhol Campus, Solan (H.P.)

Annexure-III

Consolidated Assets Certificate

Assets Acquired Wholly/ Substantially out of Government Grants

(Register to be maintained by Grantee Institution)

Name of the Sanctioning Authority: National Mission on Himalayan Studies Name of Grantee Institution: Shoolini University

1. Sl. No.: Nil
2. No. & Date of sanction order: **GBPNI/NMHS-2018-2019/SG/210 and 01/02/2019**
3. Amount of the Sanctioned Grant: **47,00,000.00 (Actual received: 46,30,404)**
4. Brief Purpose of the Grant: **Study on *Taxus* species in the Shimla and Kullu district of Indian Himalayan Region**
5. Whether any condition regarding the right of ownership of Govt. in the property or other assets acquired out of the grant was incorporated in the grant-in-aid Sanction Order: **No**
6. Particulars of assets actually acquired **NA**
7. Value of the assets as on: Rs. 859887/-
8. Purpose for which utilised at present: **Research work**
9. Encumbered or not **NA**
10. Reasons, if encumbered **NA**
11. Disposed of or not **NA**
12. Reasons and authority, if any, for disposal **NA**
13. Amount realised on disposal **NA**

Any Other Remarks: **NA**

(PROJECT INVESTIGATOR)

(Signed and Stamped)

Shoolini University of Biotechnology & Management Sciences Head Post Office, Solan (H.P.) Post Box No. 9

(FINANCE OFFICER)

(Signed and Stamped)

Comptroller (Finance)
Shoolini University of Biotechnology
& Management Sciences
Bajhol Campus, Solan (H.P.)

(HEAD OF THE INSTITUTION)

(Signed and Stamped)

Dean
Research & Development
Shoolini University
Post Box No. 9
Head Post Office
Solan - 173212 (H.P.)

Annexure-IV

List or Inventory of Assets/ Equipment/ Peripherals

S. No.	Name of Equipment	Quantity	Sanctioned Cost	Actual Purchased Cost	Purchase Details (Invoice number)
1.	Printer	1	17,700	17,700	MCS/CHD/0152
2.	Scanner	1	10,502	10,502	MCS/CHD/0152
3.	27" LED	2	38,468	38,468	MCS/CHD/0152
4.	Computer	2	115,640	115,640	MCS/CHD/0152
5.	UPS	2	13,570	13,570	MCS/CHD/0152
6.	PAR Meter	1	40,061	40,061	164
7.	Soil Compaction Meter	1	53,100	53,100	13549
8.	GPS Garmin etrex 30	1	15,576	15,576	GST-1148
9.	Binocular 10* 50	1	5,791	5,791	BOM1-5311
10.	Moultrie M40 game camera	1	13900	13900	ANIPL/19-20/0665
11.	Moultrie MA series game camera	1	8999	8999	ANIPL/19-20/0665
12.	DSLR and flash bundles	1	49,314	49,314	0235
13.	I button temperature logger + I button adaptor	88	174943	309,438	G1272/20-21
14.	Spherical Densiometer	1	22030	22030	164
15.	Soil Tensiometer	1	4225	4225	164
16.	Microscope MSZ + MagCam DC 10	1	141584	141584	37

(PROJECT INVESTIGATOR)

(Signed and Stamped)

(FINANCE OFFICER)

(Signed and Stamped)

Comptroller (Finance)
Shoolini University of Biotechnology
& Management Sciences
Bajhol Campus, Solan (H.P.)

(HEAD OF THE INSTITUTION)

(Signed and Stamped)

Shoolini University
Think Learning. Think Success.

Annexure-V

To,

The Convener, Mountain Division
Ministry of Environment, Forest & Climate Change (MoEF&CC)
Indira Paryavaran Bhawan
Jor Bagh, New Delhi-110003

Sub.: Transfer of Permanent Equipment purchased under Research Project titled "RETURNING *TAXUS* TO THE FORESTS AND THE PEOPLE: A STUDY IN SHIMLA AND KULLU DISTRICTS OF THE INDIAN HIMALAYAN REGION" funded under the NMHS Scheme of MoEF&CC – reg.: GBPNI/NMHS-2018-2019/SG/210

Sir/ Madam,

This is hereby certified that the following permanent equipment purchased under the aforesaid project have been transferred to the Implementing Organization/ ~~Nodal Institute~~ after completion of the project:

1. Printer
2. Scanner
3. 27" LED
4. Computer
5. UPS
6. PAR Meter
7. Soil Compaction Meter
8. GPS Garmin etrex 30
9. Binocular 10* 50
10. Moultrie M40 game camera
11. Moultrie MA series game camera
12. DSLR and flash bundles
13. I button temperature logger + I button adaptor
14. Spherical Densiometer
15. Soil Tensiometer
16. Microscope MSZ + MagCam DC 10

Head of Implementing Organization:
Name of the Implementing Organization: Shoolini University, Solan
Stamp/ Seal:
Date:

Research & Development
Shoolini University
Post Box No. 9
Head Post Office
Solan - 173212 (H.P.)

Copy to:

1. The Nodal Officer, NMHS-PMU, National Mission on Himalayan Studies (NMHS), G.B. Pant National Institute of Himalayan Environment (NIHE), Kosi-Katarmal, Almora, Uttarakhand-263643

Annexure-VI

Details, Declaration and Refund of Any Unspent Balance

Please provide the details of refund of any unspent balance and transfer the balance amount through RTGS (Real-Time Gross System) in favor of **NMHS GIA General** and declaration on the official letterhead duly signed by the Head of the Institution.

Not applicable

Kindly note the further Bank A/c Details as follows:

Name of NMHS A/c:	NMHS GIA General
Bank Name & Branch:	Central Bank of India (CBI), Kosi Bazar, Almora, Uttarakhand 263643
IFSC Code:	CBIN0281528
Account No.:	3530505520 (Saving A/c)

In case of any queries/ clarifications, please contact the NMHS-PMU at e-mail: nmhspmu2016@gmail.com

(PROJECT INVESTIGATOR)

(Signed and Stamped)

Shoolini University of Biotechnology & Management Sciences, Post Box No. 9, Solan (H.P.)

(FINANCE OFFICER)

(Signed and Stamped)
Comptroller (Finance)
Shoolini University of Biotechnology
& Management Sciences
Bajhol Campus, Solan (H.P.)

Tropical Ecology
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International Society for Tropical Ecology

RESEARCH ARTICLE

Ecological niche modelling for predicting the habitat suitability of endangered tree species *Taxus contorta* Griff. in Himachal Pradesh (Western Himalayas, India)

Saurav Chauhan[1] · Shankharoop Ghoshal[1,2] · K. S. Kanwal[3] · Vikas Sharma[3] · G. Ravikanth[2]

Received: 21 April 2021 / Revised: 6 September 2021 / Accepted: 16 October 2021

Abstract
The West Himalayan Yew (*Taxus contorta* Griff.) is an extremely important tree species as its bark and leaves are the source of the anti-cancer medicine Taxol® used in chemotherapy for the treatment of a number of different cancers. Unfortunately, the species is endangered because of unsustainable harvesting and over grazing coupled with a very low natural regeneration potential. The Maxent modelling algorithm was used to model the ecological niche and predict the habitat suitability of this species in the Western Himalayas of Himachal Pradesh. The purpose of the modelling was basically to restore the species in its native habitat. The model output had a reasonable area under the receiver operating characteristic curve (AUC) value of 0.905. The *jackknife* test showed that the land cover and the annual mean temperature were the most important environmental predictors that individually affected the information gain. The results suggested that the Great Himalayan National Park Conservation Area had the highest area (134.14 km^2) under the very highly suitable category. Being an International Union for Conservation of Nature (IUCN) category II protected area, it would be an ideal place to preserve and reintroduce the species. Among Wildlife Sanctuaries, the Kais Wildlife Sanctuary had the highest proportion of its area (92.46%) under very highly suitable category for *T. contorta*. Additionally, Churdhar and Tirthan Wildlife Sanctuaries are predicted to have more than 60% of their geographic areas as very highly suitable for the species. Overall, only 6% of the geographic area of Himachal Pradesh was predicted to be very highly suitable.

Keywords Bioclimatic layers · Conservation · Endangered species management · Geographic Information System (GIS) · Reintroduction and Maxent · World Database on Protected Areas (WDPA)

Introduction

The analysis of species-environment relationships is a very important research tool in ecology, biogeography, evolutionary, and conservation biology (Guisan and Zimmermann 2000; Guisan and Thuiller 2005). Ecological Niche Modelling (ENM) helps formulate maps of the potential distribution of species based on empirical correlations between species occurrences and environmental conditions of the habitat (Guisan et al. 2007; Franklin 2010). These maps could be interpreted as the suitability of each pixel to support the occurrence of the species (Guisan and Thuiller 2005; Zurell et al. 2020). An understanding of which habitats would be most suitable for a particular species is extremely beneficial for population supplementation and restoration projects especially for that of threatened species (Wilson et al. 2011).

Maxent is a software very popular among ecologists for ENM, with thousands of articles published since 2006 (Phillips et al. 2006; Kumar and Stohlgren 2009; Merow et al. 2013). Maxent is a general-purpose method for maximizing information entropy (Jaynes 1957). When used in ENM, Maxent acts as a maximum entropy based machine learning algorithm that estimates the smoothest probability distribution for the occurrence of a species that matches the

✉ Shankharoop Ghoshal
shankharoop@gmail.com

[1] Environmental Geomatics Lab, Faculty of Basic Sciences, Shoolini University of Biotechnology and Management Sciences, Solan 173229, Himachal Pradesh, India

[2] Ashoka Trust for Research in Ecology and the Environment, Bengaluru 560064, Karnataka, India

[3] G. B. Pant National Institute of Himalayan Environment and Sustainable Development, Himachal Unit, Mohal, Kullu 175126, Himachal Pradesh, India

Published online: 14 January 2022

environmental constraints (Phillips et al. 2006; Elith et al. 2011). Maxent predicts on the basis of species occurrence data and predictor variables such as topography, climate, soil etc. (Phillips et al. 2006; Elith et al. 2011). It specializes in the usage of presence-only data and that is one advantage of Maxent over other statistical modelling techniques that require both presence and absence data (Phillips et al. 2006), because absence data is difficult to obtain and has uncertainties (Anderson et al. 2003). Further, both continuous and categorical environmental data could be used and the built-in *jackknife* test evaluates the performance of the environmental variables, which makes Maxent highly useful for ENM (Phillips and Dudík 2008).

Taxus contorta Griff. commonly known as west Himalayan yew is listed as an endangered species by IUCN (Thomas 2011). The bark and leaves of *Taxus* spp are a source of taxine, a precursor to the drug Paclitaxel, sold under the brand name Taxol®, one of the best anticancer agents used in the treatment of different kinds of cancer (Lanker et al. 2010). This tree has a wide variety of ethnomedicinal uses, its wood is used in making furniture and it is also used as fuel (Beckstrom-Sternberg et al. 1993; Gaur 1999; Purohit et al. 2001; Joshi 2009; Lanker et al. 2010). Pharmaceutical companies pay villagers to bring them the bark and leaves of *Taxus* for manufacturing Paclitaxel (Poudel et al. 2013). A large proportion of the populations have already been severely harvested in the Indian Himalayan Region (IHR) because of short-term economic gain. As a result of all these multifarious uses, this species has been over-exploited to such levels that about 90% of its population in the IHR has been lost (Thomas 2011). Another problem of this species is its intrinsic poor natural regeneration ability (Rikhari et al. 1998; Pant and Samant 2008). Pant and Samant (2008) predicted that *Taxus* may soon be eradicated from Khokhan Wildlife Sanctuary, Himachal Pradesh if indiscriminate harvesting continues. During the past decades unsustainable use of this species, accompanied with its regeneration problems has neared it towards eventual extinction, which if happens would be a terrible loss to humankind given the medicinal importance of this species (Nimasow et al. 2015). Any measure taken to preserve this tree species would not only help the local communities that use it for traditional medicine, but also for the global human community, at a time when cancer has become a leading cause of death worldwide and its instances have been rising of late (Torre et al. 2015). Protection of existing habitats and well planned reintroduction of *T. contorta* in suitable habitats is highly imperative. In this regard, the present study was aimed at identifying potential sites for conservation and reintroduction of *T. contorta* through ecological niche modelling. Attempts were made to identify areas suitable for mass planting of this tree species throughout the Western Himalayas by ecological engineering.

Ecosystem restoration projects are required globally and in March 2019 the United Nations General Assembly declared 2021–2030 as the decade on ecosystem restoration (https://www.decadeonrestoration.org/about-un-decade). Apart from the ecological significance, ecosystem restoration can also improve the health of human populations, integrate national and ethnic cultures and ultimately lead to holistic social well being (Aronson et al. 2020). Lopping, bark peeling, logging, and grazing severely damage the growth and natural regeneration of *T. contorta* (Purohit et al. 2001; Perrin et al. 2006; Lanker et al. 2010). This study aimed at identifying areas which are least impacted by anthropogenic disturbances such as logging, lopping, firewood extraction and especially grazing such that planting of seedlings or propagules can be taken up. In that regard protected areas would be the best place for the reintroduction of this species. Various factors like poor regeneration, slow growth, loss of suitable habitat, and anthropogenic pressures do not allow *T. contorta* to occupy all of its suitable habitat and that is in fact leading to the decline in the populations of *T. contorta* (Samant 1999). ENM helps to identify the potential area that would satisfy the ecological requirements of the species and this knowledge is essential for reintroduction. Ecological niche modelling has already proven to be an effective tool for carrying out conservation efforts (Hill et al. 2017; Hernández-Quiroz et al. 2018; Zhang et al. 2019) and in developing habitat suitability maps (Zhang et al. 2012) and hence would be immensely beneficial to recover threatened species. Keeping in view the above pressing issues, the present research had the following objectives:

1. Characterize the ecological niche of *T. contorta,* and identify the environmental variables that are most important for this species,
2. Generate a habitat suitability map for *T. contorta* in Himachal Pradesh, and
3. Identify areas within the protected areas in Himachal Pradesh where *T. contorta* could be planted.

Materials and methods

Study area

Himachal Pradesh (30˚22′40″N–33˚12′40″N and 75˚45′55″E–79˚04′20″E) is a mountainous state of India situated in the Western Himalayas covering an area of 55,673 km^2 (India Planning Commission 2005; Himachal Pradesh GOI 2021). Elevations range from 350 to 6975 m asl and hence supports diverse habitats and vegetation (Himachal Pradesh GOI 2021; Samant et al. 2007; Upgupta et al. 2015). The annual rainfall averages 1800 mm and the temperatures range from sub-zero to around 35 ˚C.

The forest cover as of 2017 constitutes 27.72% of the geographic area of the state (Forest Survey of India 2019). All the 12 districts in the state are located in the mountainous regions (Fig. 1). Five national parks, 28 wildlife sanctuaries and three conservation reserves constitute the protected area network covering 15.10% of the geographic area of the state (Forest Survey of India 2019). Himachal Pradesh has been reported to harbour populations of *T. contorta* in the wild (Fig. 2).

Data sources

Occurrence data of *T. contorta* were collected from both primary and secondary sources (Table 1). Ecological field survey was done in Kullu and Shimla districts of Himachal Pradesh from April-November, 2019 and the occurrence points of *T. contorta* were marked with a Garmin eTrex 10 Global Positioning System (GPS) receiver with ± 5 m accuracy. Various location points for the different districts were collected from published literature, herbarium records, Gymnosperm Database (https://www.conifers.org/ta/Taxus_contorta.php) and Global Biodiversity Information Facility database (GBIF) (https://www.gbif.org/en/). The occurrence data totalling 533 were manually observed on QGIS version 3.4 (QGIS Development Team 2019) with an underlying Google satellite layer (Google 2015) through the QuickMapServices plugin (NextGIS 2019) and the locations that were illogical were removed. Only those points within the state of Himachal Pradesh were considered. To remove sampling bias (Kramer-Schadt et al. 2013) the occurrence data totalling to 519 points after filtering were subsequently spatially thinned using the SpThin package (Aiello-Lammens et al. 2015) on R Studio version 1.2.5042 (RStudio Team 2020) running a base R version 3.6.3 (R Core Team 2019). The thinning was run once with the thin distance set at 5 km and another time with that set to 10 km. Spatial thinning using the 5 km distance reduced the data points to 33 observations, while setting it to 10 km reduced the observations to 15. Models were run using both datasets.

For predicting the habitat suitability of *T. contorta* 23 variables were initially gathered, out of which the nineteen Bioclimatic layers (Hijmans et al. 2005) Bio1 to Bio19 of WorldClim version 2 (average monthly climate data for minimum, mean, and maximum temperature

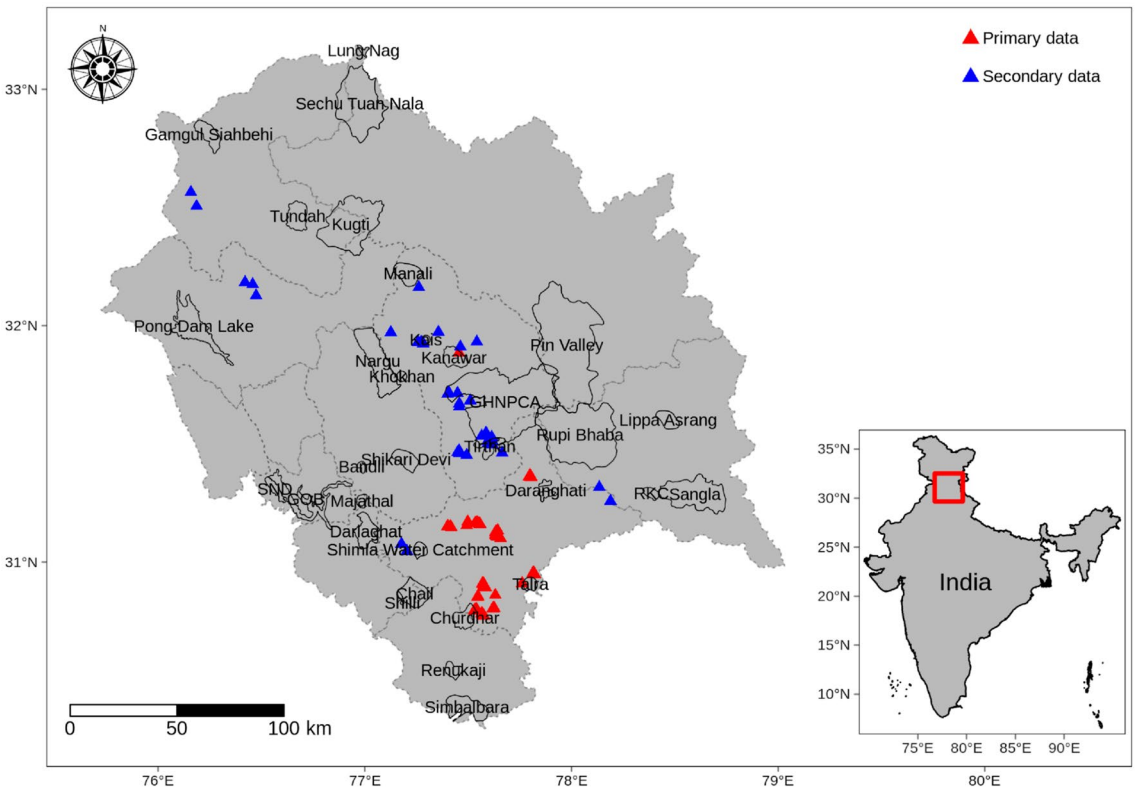

Fig. 1 Map of Himachal Pradesh showing the districts and its location in India (inset). Shown in red and blue are the primary and secondary data points respectively, collected for the modelling procedure. Internal boundaries with dotted lines represent the districts while the ones with thick continuous lines represent protected areas along with their names. *GHNPCA* Great Himalayan National Park Conservation Area, *GOB* Gobindsagar, *RKC* Raksham Chitkul, *SND* Shri Nainadevi

Fig. 2 **a** Foliage and aril with seed of *T. contorta* in a natural forest in Shimla district, and **b** Propagules of *T. contorta* raised by stem cutting based macro-propagation for reintroduction at G.B. Pant National Institute of Himalayan Environment and Sustainable Development, Himachal unit, Kullu. **c** *T. contorta* in its natural habitat in Shimla district. Pic credits: (**a**) Dr. S. Ghoshal, (**b**) Dr. K. S. Kanwal, and (**c**) Mr. Saurav Chauhan

Table 1 Occurrence data of *Taxus contorta* used in the modelling procedure

District	Primary data	Secondary data	Sources
Shimla	490	4	GBIF, Gymnosperm database
Kullu	3	31	Bodh (2017), GBIF, Gymnosperm database, Lal (2007), Rana (2007), Sharma (2008), Sharma (2013), Thakur (2012)
Kangra		3	GBIF, Gymnosperm database
Chamba		2	GBIF, Gymnosperm database

and precipitation for 1970–2000) were downloaded from WorldClim (http://worldclim.org/version2) with a spatial resolution of 30 arc-seconds (ca. 1 km^2). The Bioclimatic layers were converted from BIL to the Maxent compatible ASCII format using QGIS. The Shuttle Radar Topographic Mission (SRTM) digital elevation model (DEM) with a spatial resolution of 90 m was downloaded from Earth Explorer website (https://earthexplorer.usgs.gov). As *T. contorta* have been reported to be predominantly distributed in northern aspects (Schickhoff 1996; Thomas 2011), slope and aspect data were extracted from the SRTM DEM using QGIS and were included as environmental predictor variables. Global 300 m land cover data GlobCover 2009 (Arino et al. 2012) was downloaded from http://due.esrin.esa.int.

All the variable layers were clipped to the shapefile of Himachal Pradesh, downloaded from the Database of Global Administrative Areas (GADM) (https://gadm.org/download_country_v3.html).The elevation, slope, aspect, and the land cover data were resampled to the spatial resolution of

the Bioclimatic layers (30 arc-seconds) using the bilinear interpolation method for all the layers except for land cover for which the nearest neighbour interpolation method was used. All the above environmental predictor variables were examined for multicollinearity by the Pearson Correlation Coefficient (r) and the variables having cross-correlation value beyond ± 0.75 were excluded from analysis. Eleven remaining variables were used in the model (Table 2).

The protected areas shapefiles for India were downloaded from the World Database on Protected Areas (WDPA) (WDPA 2020). The protected area polygons lying within the state boundary of Himachal Pradesh were clipped for analysis.

Niche modelling

Maxent software (version 3.4.1) was downloaded from http://www.cs.princeton.edu/~schapire/Maxent/. Selected variables and occurrence data were processed in Maxent software by using 10 replicates using the subsampling method and 5000 iterations were used. Random Test percentage was set to 30% based on the formula 1/(1 + (*P*-1)^0.5, where *P* implies the number of predictor variables used (Huberty 1994). The maximum number of background points was set to 10,000. Linear and quadratic features were used (Phillips et al. 2004) and all the other values were kept as default. The generated models were evaluated based on AUC value (Area Under ROC (Receiver Operating Characteristics) Curve). AUC, a threshold-independent parameter that is used widely to evaluate model performance by a single value, ranges between 0 and 1. The AUC value is based on the ROC curve, which is the plot of the proportion of observed presences predicted correctly (sensitivity) against the proportion of observed absences predicted incorrectly (1-specificity). Sensitivity and specificity are used as they account for all the true and false presences and absences and subtracting specificity from 1 makes both the metrics vary in the same direction (Pearce and Ferrier 2000). A model that predicts very accurately will form an ROC curve that is close to the left axis and the top, while on the other hand a model that predicts no better than random would closely follow the 1:1 line (Pearson 2007). The quality of the model was evaluated and graded following the categorization based on AUC values by Swets (1988). Values less than 0.5

Table 2 Environmental predictor variables and their relative contribution in the model

Code	Environment Variables	Unit	Percent contribution
Bio1	**Annual mean temperature**	**°C**	**19.9**
Bio2	**Mean diurnal range (mean of monthly (max temp-min temp)**	**°C**	**0.1**
Bio3	**Isothermality (Bio2/Bio7) (*100)**	**Dimensionless**	**0.0**
Bio4	**Temperature seasonality (standard deviation *100)**	**Percent**	**26.7**
Bio5	Max temperature of warmest month	**°C**	
Bio6	Min temperature of coldest month	**°C**	
Bio7	Temperature annual range (Bio5-Bio6)	**°C**	
Bio8	**Mean temperature of wettest quarter**	**°C**	**0.2**
Bio9	Mean temperature of driest quarter	**°C**	
Bio10	Mean temperature of warmest quarter	**°C**	
Bio11	Mean temperature of coldest quarter	**°C**	
Bio12	Annual precipitation	mm	
Bio13	Precipitation of wettest month	mm	
Bio14	**Precipitation of Driest Month**	**mm**	**20.4**
Bio15	Precipitation seasonality (coefficient of variation)	Dimensionless	
Bio16	Precipitation of wettest quarter	mm	
Bio17	**Precipitation of driest quarter**	**mm**	**0.8**
Bio18	Precipitation of warmest quarter	mm	
Bio19	Precipitation of coldest quarter	mm	
Land cover	**Land cover**	**Categorical**	**31.5**
Elevation	**Elevation**	**m asl**	**0.3**
Slope	**Slope gradient**	**Degree**	**0.0**
Aspect	**Slope aspect**	**Degree**	**0.3**

Note: Bold letters show the environmental variables used in the model

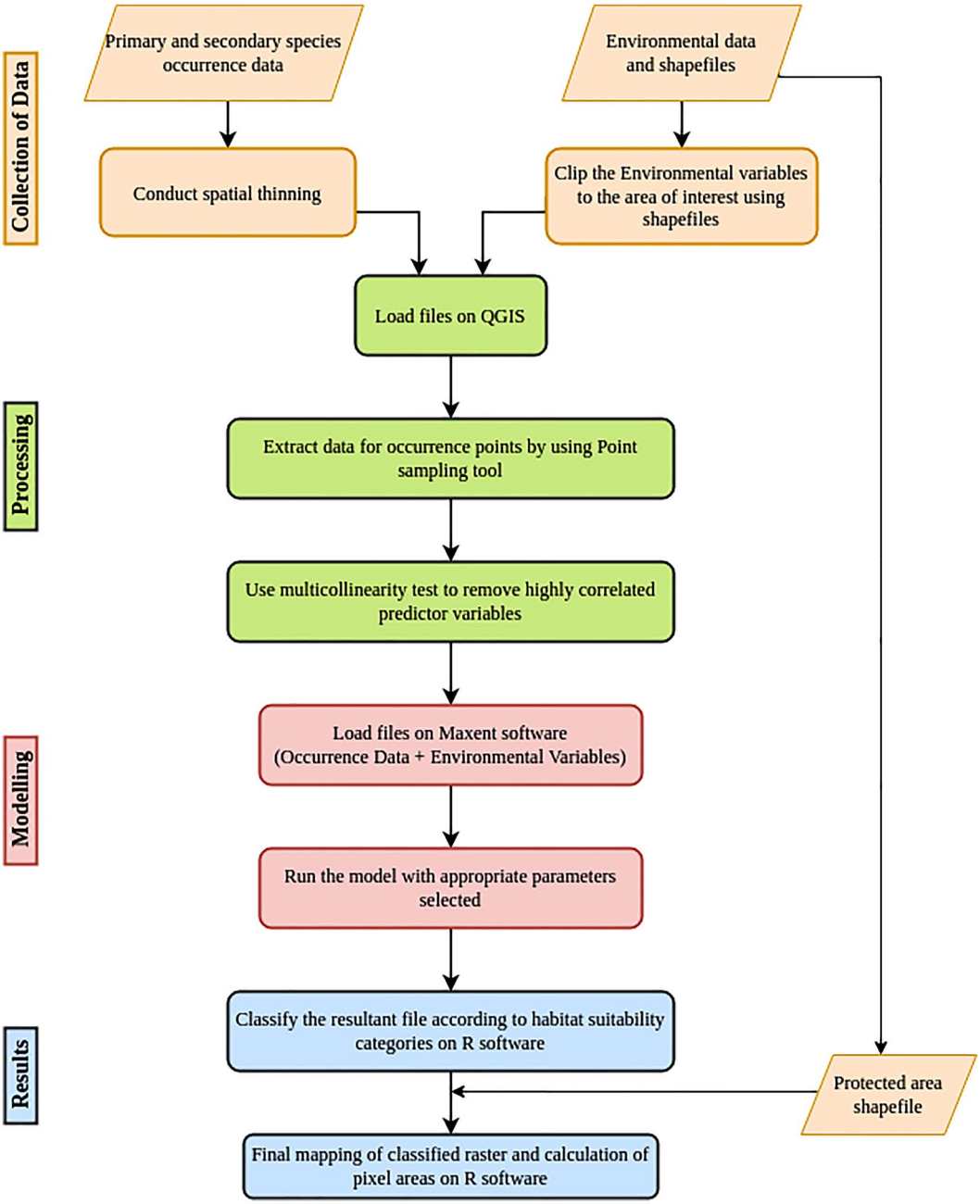

Fig. 3 Flowchart of the ecological niche modelling methodology

imply that the model performed worse than random chance, which is when the value equals 0.5. Beyond that the AUC values were graded as failed (0.5–0.6), poor (0.6–0.7), fair (0.7–0.8), good (0.8–0.9), and excellent (0.9–1). The relative importance of the variables were evaluated by the *jackknife* procedure. The cloglog output was selected. The Maxent output so generated directly predicts the species habitat suitability in a range from 0 to 1. Further, potential areas of distribution were categorized into five classes namely very low (0.0-0.10), low (0.10-0.30), medium (0.30-0.50), high (0.50-0.70), and very-high (0.70-1.0) based on the logistic threshold of 10 percentile training presence (Adhikari et al. 2012; Barik et al. 2012; Paul et al. 2019). The pixels showing the very high category of habitat suitability and falling inside the protected area polygons were extracted for each protected area and the counts were summed up and converted to km^2 to generate the total area, based on the spatial resolution of the pixels. Maxent models predict the habitat suitability and not the actual distribution and hence the predicted output is not a species distribution model in the

Table 3 Model performance under different sample sizes due to different spatial thinning distances used

Spatial thinning distance (km^2)	Resulting sample size	AUC
10	15	0.905
5	33	0.867

strict sense of the term and hence ecological niche modelling or habitat suitability modelling are appropriate terms to describe the current research (Guisan and Zimmermann 2000; Peterson and Soberón 2012). A flowchart of the methodology in brief is shown in Fig. 3.

Maps and projections

The maps were prepared on R-studio (RStudio Team 2020) using the tmap package (Tennekes 2018). The study area map was projected to Oblique Lambert azimuthal equal-area projection (Fig. 1), while the habitat suitability maps were projected to Lambert Conformal Conic projection.

Results and discussion

Model performance and contribution of variables

The AUC is widely used to estimate the predictive accuracy of the distributional models derived from species presence–absence data. The two datasets differing in number of occurrence points (15 and 33) showed different AUC values (Table 3). The one with 15 data points had the higher AUC indicating the effect of increased bias with increased sample size and that may have lead to over-fitting when using the larger dataset. A sample size of 15 falls within the range of the lower limits for sample size discussed in van Proosdij et al. (2016). The model with the higher AUC value was considered for preparing the habitat suitability map (Fig. 4). Figure 5 shows the results of the *jackknife* test. Figure 6 displays the test omission rate and predicted area as a function of the cumulative threshold, averaged over the replicate runs. Considering the definition of the cumulative threshold, the omission rate should be close to the predicted omission. For the current model the test omission rate was found to be acceptably close to the predicted omission. Figure 7 shows the ROC curve averaged over the replicate runs. ROC curve summarizes model performance overall conditions a model could operate using all information provided by the predictive model (Swets 1988). The ROC curve was reasonably close to the left axis and the top and far from the 1:1 line (Fig. 7) and hence is acceptable.

Maxent predicted the habitat suitability for *T. contorta* with an excellent level of accuracy as per Swets (1988) having the average test AUC of 0.905 (Fig. 7). AUC value (of more than 0.8) exhibits the satisfactory performance of the model in predicting species distribution with higher discrimination of input data (Lobo et al. 2008). Among the environmental layers, land cover had the highest contribution (31.5%) followed by Bio4: temperature seasonality (26.7%) and Bio14: precipitation of the driest month (21.4%) (Table 2). Forested habitats are extremely important for *T. contorta* as its seedlings require shade in the initial stages (Giertych 2000). The climatic factors are important at larger spatial extents, while at the local level land cover is generally the limiting factor for species distributions (Pearson et al. 2004; Cord et al. 2014). Hence, the importance of land cover was expected. According to the response curves (Fig. 8), GlobCover land cover categories 40 and 100 showed the highest importance in predicting the presence of *T. contorta* followed by 70. These categories are 40: Closed to open (> 15%) broadleaved evergreen and/or semi-deciduous forest (> 5 m), 100: Closed to open (> 15%) mixed broadleaved and needle leaved forest (> 5 m), and 70: Closed (> 40%) needle leaved evergreen forest (> 5 m) (Arino et al. 2012). Examples of the above three categories where *T. contorta* have been found to occur are *Quercus semecarpifolia* Sm. dominated forest community, *Q. floribunda* Lindl. ex A.Camus—*T. contorta* mixed forest community, and *Abies pindrow* (Royle ex D.Don) Royle and *Picea smithiana* (Wall.) Boiss. dominated forest communities respectively (personal observation). So these communities would be appropriate for reintroduction of *T. contorta* in the western Himalayas. Interestingly, Yang et al. (2013) had also observed that land cover was the most important variable for predicting the ecological niche of *Justicia adhatoda,* another Himalayan medicinal plant. The response curves (Fig. 8) predict that areas having annual mean temperature values (Bio1) between 7.5 and 10 °C, and precipitation of the driest month greater than 25 mm should be highly suitable areas for potential distribution of *T. contorta.* According to the *jackknife* test of the regularized training gain, Bio1: annual mean temperature seemed to be the most important variable by itself as it had the highest gain when used in isolation. Conversely, the environmental predictor that

Table 4 Area covered by the different habitat suitability classes of *Taxus contorta* in Himachal Pradesh

Habitat suitability	Area (km^2)	Proportion of total state area (%)
Very low	35,347.31	63
Low	7973.47	14
Moderate	4746.02	9
High	4506.17	8
Very High	3208.49	6

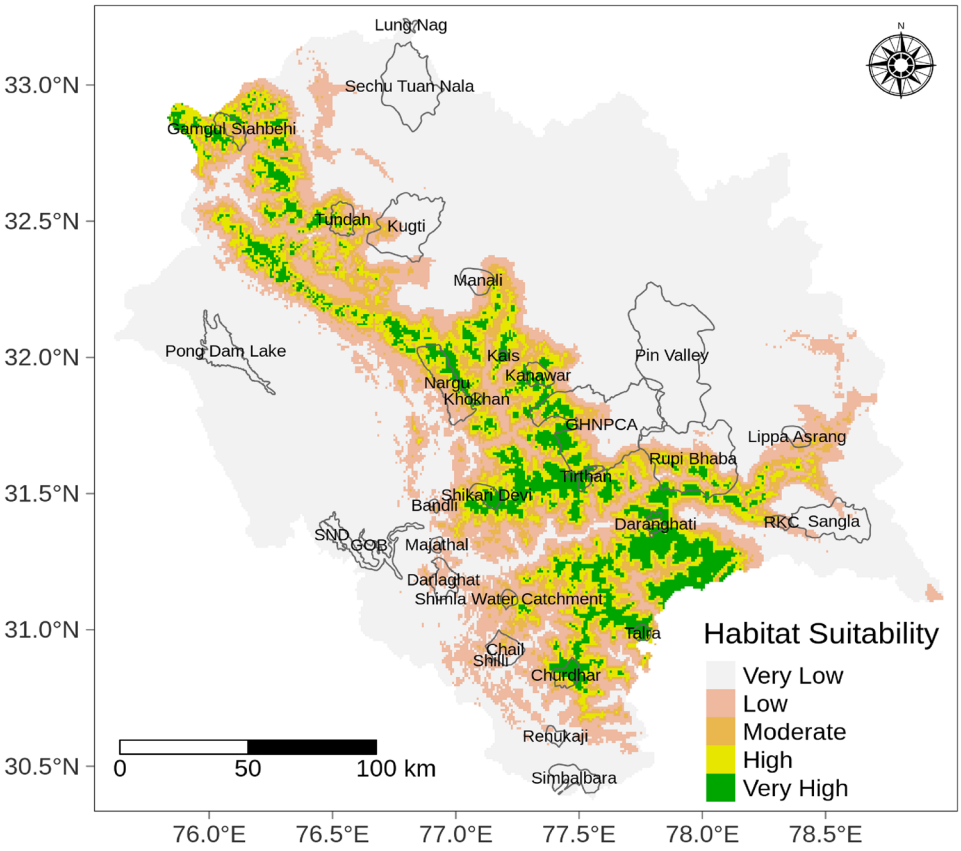

Fig. 4 Habitat suitability map of *Taxus contorta* in Himachal Pradesh. Internal boundaries represent protected areas along with their names. *GHNPCA* Great Himalayan National Park Conservation Area, *GOB* Gobindsagar, *RKC* Raksham Chitkul, *SND* Shri Nainadevi

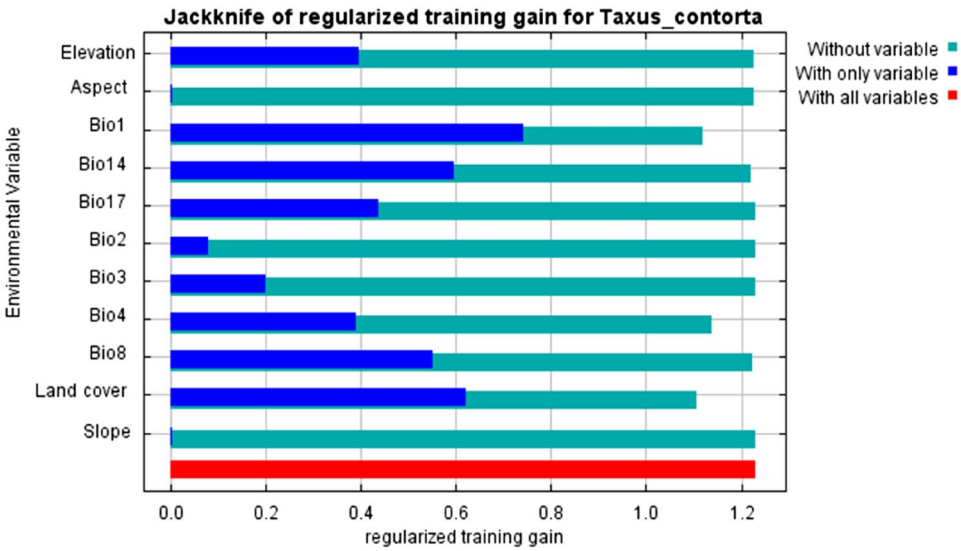

Fig. 5 Jackknife test of regularized training gain for evaluating the relative importance of environmental variables for modelling habitat suitability of *Taxus contorta* in Himachal Pradesh

decreased the gain the most when it was omitted was land cover, which therefore seems to have the most information that is absent in the other variables (Fig. 5). Slope and aspect showed zero and near zero contribution to the model respectively (Table 2) as was also observed by Glen (1999). This could be explained by the fact that slope and aspect are local variables and as the model was working on pixels of coarser resolution, these variables could not contribute to the model performance. Even though elevation did not contribute much in the model, but when used by itself, it predicted the presence of *T. contorta* between 2200 and 3000 m asl, peaking around 2600 m asl (Fig. 8), which is consistent with the average elevation in which the species have been reported (Thomas 2011). The influence of elevation would always be important and its low contribution in the model could

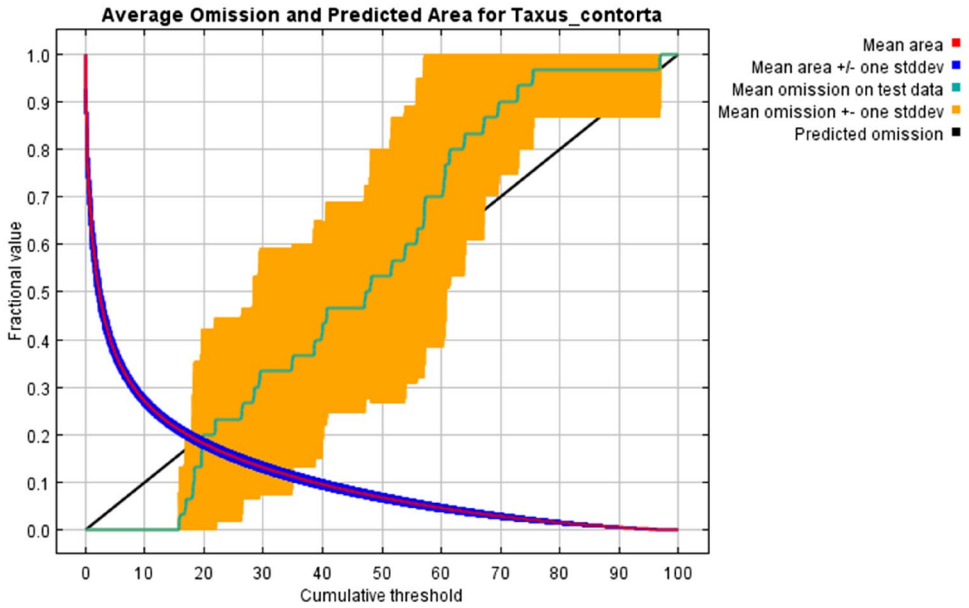

Fig. 6 The test omission rate and predicted area as a function of the cumulative threshold, averaged over the 10 replicate runs of the Maxent output for *Taxus contorta* in Himachal Pradesh

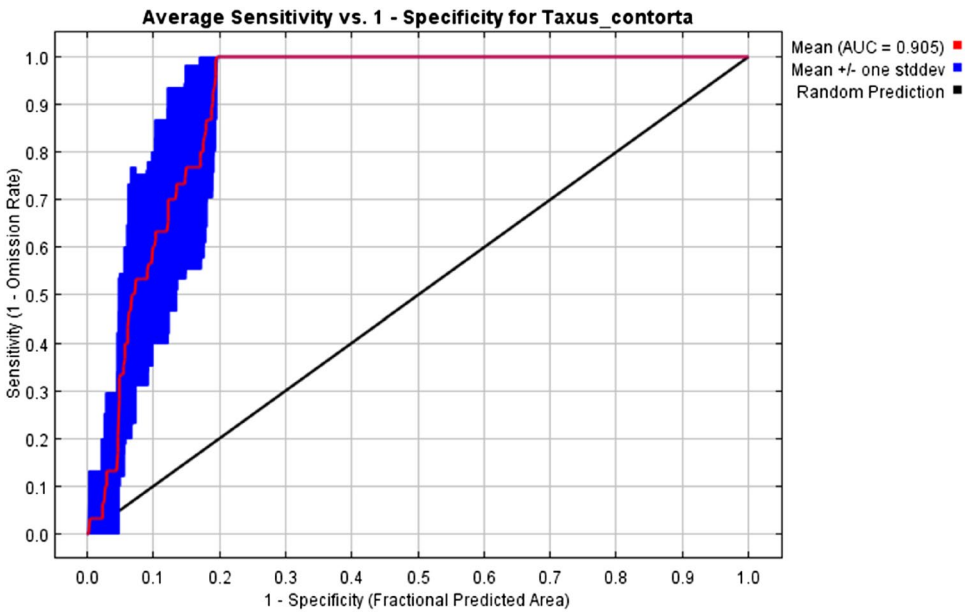

Fig. 7 The receiver operating characteristic (ROC) curve showing Average Sensitivity vs 1-Specificity averaged over the 10 replicate runs of the Maxent output for *Taxus contorta* in Himachal Pradesh

be explained by it being correlated with the other climatic variables.

Protected areas suitable for reintroduction of *Taxus contorta*

Only 6% of the total geographic area of the state could be very highly suitable (habitat suitability > 0.70) while another 8% could be highly suitable for *T. contorta* (Table 4). The ecological niche may be over-predicted in some areas by Maxent (Pearson 2007), in which case the proportion of highly suitable sites is likely to actually go further down. Because *T. contorta* is very sensitive to anthropogenic disturbances and specificity of habitat (Giertych 2000; Perrin et al. 2006; Pant and Samant 2008; Lanker et al. 2010), it would be crucial to plant the tree seedlings or saplings only in the very highly suitable sites so as to reduce the uncertainties in its establishment. The habitat suitability model overlaid with the vector layers of the protected area shapefiles downloaded from WDPA, clearly shows which protected areas fall under the predicted very highly suitable category (Fig. 4). The largest area (132.68 km^2) of predicted suitable habitat has been found to be in the Great Himalayan National Park Conservation Area (GHNPCA) (Table 5), which is a National Park and also a World Heritage site, declared in 2014 by the United Nations Educational

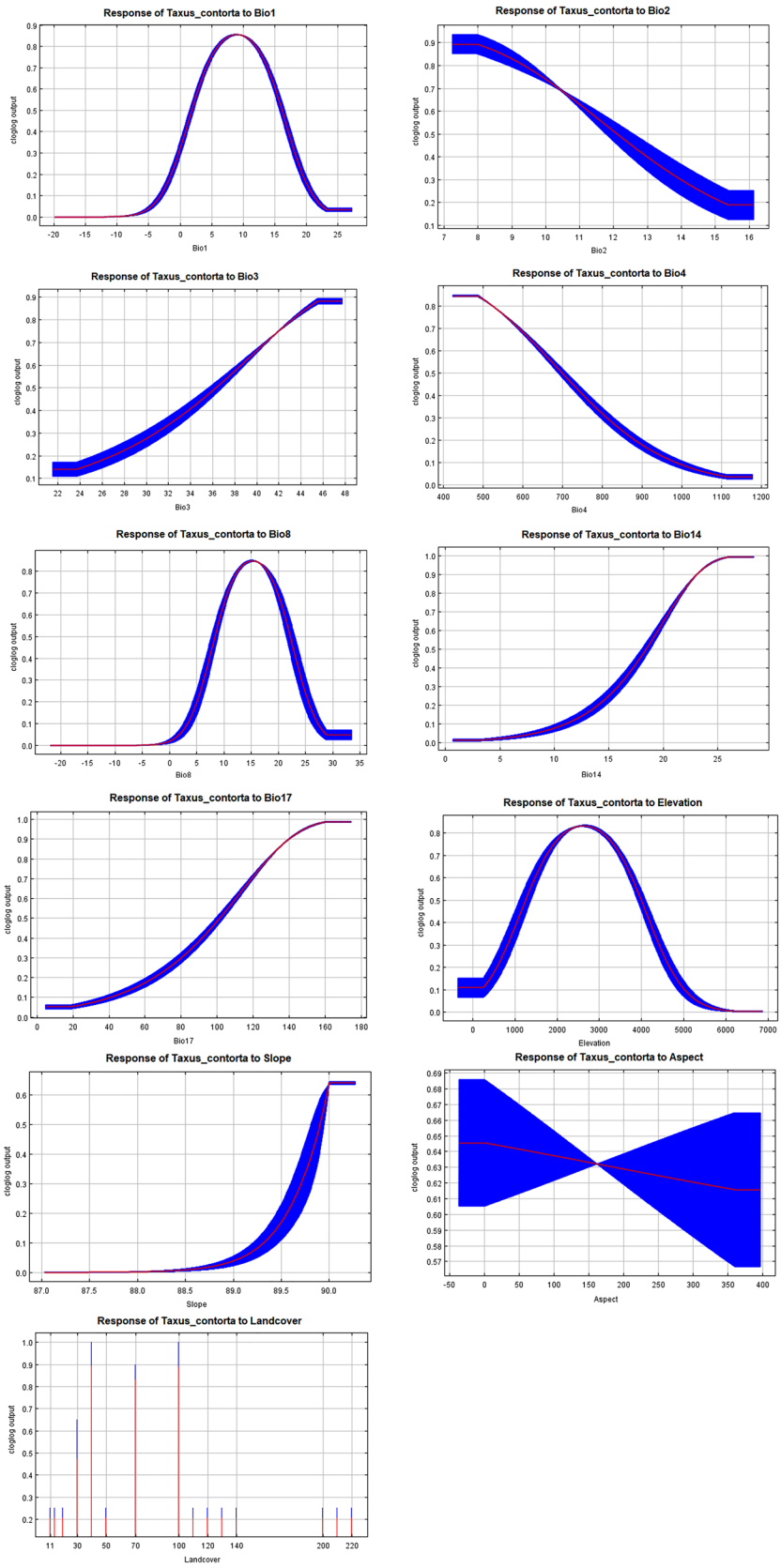

Fig. 8 Response curves obtained when running the Maxent model with only the corresponding variable. The curves show the mean response of the 10 replicate Maxent runs (red) and and the mean ± one standard deviation (blue, two shades for categorical variables e.g., landcover)

Table 5 Protected areas of Himachal Pradesh which are very highly suitable for *Taxus contorta*

Protected area	District	Suitable area (km^2)	Proportion of protected area suitable (%)
Great Himalayan National Park Conservation Area[II*]	Kullu	134.14	11.65
Rupi Bhaba Wildlife Sanctuary[IV]	Kinnaur	70.72	9.58
Nargu Wildlife Sanctuary[IV]	Mandi	55.41	17.42
Churdhar Wildlife Sanctuary[IV]	Sirmour and Shimla	43.74	66.27
Tirthan Wildlife Sanctuary[IV]	Kullu	43.01	70.37
Shikari Devi Wildlife Sanctuary[IV]	Mandi	40.10	55.69
Talra Wildlife Sanctuary[IV]	Shimla	24.79	53.89
Daranghati Wildlife Sanctuary[IV]	Shimla	24.79	14.08
Kanawar Wildlife Sanctuary[IV]	Kullu	24.06	19.76
Kais wildlife Sanctuary[IV]	Kullu	13.12	92.46
Tundah Wildlife Sanctuary[IV]	Chamba	8.75	13.63
Gamgul Siahbehi Wildlife Sanctuary[IV]	Chamba	8.02	6.47
Khokhan Wildlife Sanctuay[IV]	Kullu	4.37	19.40

Superscripts indicate the IUCN category of protected areas

* → Includes a World Heritage Site

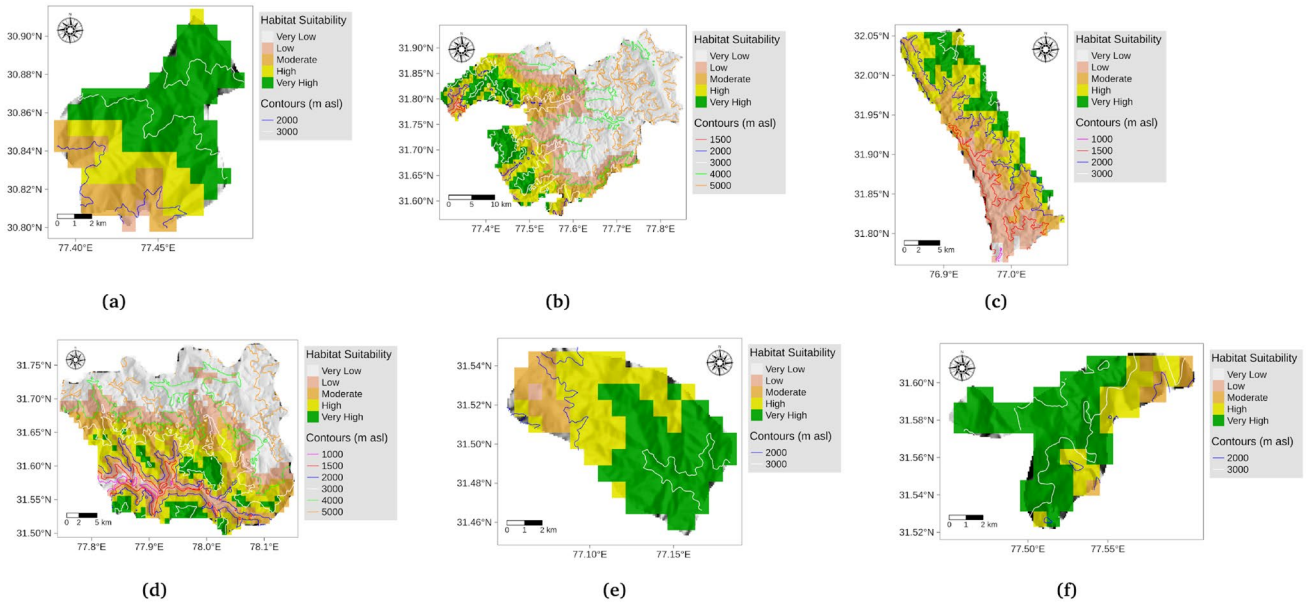

Fig. 9 Habitat suitability map of *Taxus contorta* in protected areas of Himachal Pradesh with a considerable area under the highly suitable category. **a** Churdhar Wildlife Sanctuary, **b** GHNPCA, **c** Nargu Wildlife Sanctuary, **d** Rupi Bhaba Wildlife Sanctuary, **e** Shikari Devi Wildlife Sanctuary, **f** Tirthan Wildlife Sanctuary. The habitat suitability raster has been overlaid over a hillshade created using SRTM 90 m DEM. All the layers have been projected to Lambert Conformal Conic projection

Scientific and Cultural Organization (UNESCO) for its outstanding role in the conservation of Biodiversity (UNESCO,2014). The GHNPCA has a lot of riparian coniferous forests (ASI 2020), which happens to be a very suitable habitat for *T. contorta* (Thomas 2011). The GHNPCA was the only National Park in Himachal Pradesh where Maxent predicted very highly suitable habitats for *T. contorta.* It is an IUCN category II protected area (WDPA 2020) and hence there is no extraction of resources and no grazing is legally permitted (Bawa et al. 2011), which makes it an ideal place to reintroduce *T. contorta*, given its sensitivity to anthropogenic disturbance (Giertych 2000; Perrin et al. 2006; Pant and Samant 2008; Lanker et al. 2010). As is evident from Fig. 9b the western areas of the National Park near the slopes with elevation contours between 2500 and 3000 m asl (white lines) could be the best sites to re-introduce *T. contorta.* The

other protected areas, where very high suitability of habitats were predicted, are all wildlife sanctuaries, which are IUCN category IV protected areas (WDPA 2020). In such areas some controlled harvesting is legally permitted (Bawa et al. 2011), therefore any planting of *T. contorta* in such areas would need clear demarcations (including fencing the sites for a certain time period) and discussions with the local communities to maintain grazing free conditions. A considerable area of suitable habitats for *T. contorta* were predicted in Rupi Bhaba, Nargu, Churdhar, Tirthan and Shikari Devi Wildlife Sanctuaries (Table 5). In these wildlife sanctuaries, the best areas for enrichment planting of *T. contorta* could again be the areas between 2500 and 3000 m asl (Fig. 9), the stretches being north-eastern for Nargu Wildlife Sanctuary, north- and south-western for Tirthan Wildlife Sanctuary, central and south-eastern for Shikari Devi Wildlife Sanctuary and distributed in patches at the mountain tops of central and southern areas separated by a valley in the Rupi Bhaba Wildlife Sanctuary. The Kais Wildlife Sanctuary in Kullu district had the highest proportion (92.46%) of its protected area falling under the very highly suitable category, followed by Tirthan Wildlife Sanctuary (Kullu district) and Churdhar Wildlife Sanctuary (Sirmaur and Shimla districts), both having more than 60% of its area as being very highly suitable. These Wildlife Sanctuaries would be very important for concentrated reintroduction of *T. contorta.* In the highly suitable areas predicted for *T. contorta,* any enrichment planting should be done only within the GlobCover land cover categories 40, 70 and 100 following the response curve (Fig. 8). These protected areas would be easy to maintain and may serve as future reserves of genetic stocks of *T. contorta,* if given proper protection from anthropogenic disturbances. The other protected areas of Himachal Pradesh, that are not included in Table 5, did not contain any pixel having a predicted very highly suitable habitat. To completely restore *T. contorta*, concerted efforts are required on the part of both State Forest Department as well as the forest fringe communities and other stakeholders to enact regulations, and to reach agreements to protect the species (Ravikanth et al. 2018). Adequate legal mechanisms must be put in place to manage species especially those where the population size of the species is small so that it can be recovered from the brink of extinction.

Conclusion

The Maxent modelling algorithm was used in the ENM of *T. contorta*. The model output should be reasonable, provided that the AUC value was in the excellent category (Swets 1988). The model could be improved in the future by collecting more occurrence points from the different sites predicted to have high to very high suitability for *T. contorta*, that shall also validate how well the model had predicted the ecological niche of the species. Further research to evaluate the dispersal characteristics of the species and inclusion of disturbance layers could help in predicting the actual distribution of the species. The most important factors that characterize the ecological niche of *T. contorta* are land cover, annual mean temperature (Bio1), temperature seasonality (Bio4) and precipitation of the driest month (Bio14). Land cover had the greatest percent contribution to the model. The response curves using only one variable at a time, predicted the land cover categories: Closed to open (> 15%) broadleaved evergreen and/or semi-deciduous forest (> 5 m), Closed to open (> 15%) mixed broadleaved and needle leaved forest (> 5 m), and Closed (> 40%) needle leaved evergreen forest (> 5 m) to be highly suitable for enrichment planting of *T. contorta.* Additionally, the model predicted that the reintroduction areas for *T. contorta* should have annual mean temperature values (Bio1) between 7.5 and 10 °C, and precipitation of the driest month greater than 25 mm. This research has highlighted the protected areas and the proportion of their areas that are very highly suitable for the establishment of *T. contorta*. The western stretches of the GHNPCA along the elevation contours of 2500–3000 m asl could be the best places for the enrichment planting and for long-term secure preservation of this species in its natural habitat. Wildlife Sanctuaries such as Rupi Bhaba, Nargu, Churdhar, Tirthan and Shikari Devi have also been predicted to be highly suitable for reintroduction of *T. contorta,* but in such areas protection from anthropogenic disturbances, especially grazing would be extremely important. This information shall be potentially beneficial for *in-situ* conservation of this endangered tree species, by demarcating and protecting areas predicted to have very high suitability and for initiating reintroduction operations for *T. contorta* by the state Forest Department and other conservation agencies.

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Author contributions Dr. SG conceived the research idea, supervised the work, prepared the final maps and contributed in their analysis and interpretation. Mr. SC conducted the collection of primary data in Shimla district, performed the initial data processing and model runs of Maxent, and wrote the first draft. Mr. VC and Dr. KSK provided the primary and secondary data respectively from Kullu district. Dr. GR proofread the manuscript. All the authors contributed in the writing of the final manuscript.

References

Adhikari D, Barik S, Upadhaya K (2012) Habitat distribution modelling for reintroduction of *Ilex khasiana* Purk., a critically endangered tree species of northeastern India. Ecol Eng 40:37–43

Aiello-Lammens ME, Boria RA, Radosavljevic A, Vilela B, Anderson RP (2015) spThin: An R package for spatial thinning of species occurrence records for use in ecological niche models. Ecography 38:541–545

Anderson RP, Daniel L, Peterson AT (2003) Evaluating predictive models of species' distributions: criteria for selecting optimal models Robert. Ecol Modell 162:211–232

Arino O, Ramos Perez JJ, Kalogirou V, Bontemps S, Defourny P, Van Bogaert E (2012) Global land cover map for 2009 (GlobCover 2009). © European Space Agency (ESA) & Université catholique de Louvain (UCL), PANGAEA

Aronson J, Goodwin N, Orlando L, Eisenberg C, Cross AT (2020) A world of possibilities: six restoration strategies to support the United Nation's decade on ecosystem restoration. Restor Ecol 28:730–736

ASI (2020) World Heritage Site – Great Himalayan National Park Conservation Area, Archaeological Survey of India. https://asi.nic.in/great-himalayan-national-park-conservation-area.

Barik S, Appraisal D (2012) Predicting the geographical distribution of an invasive species (*Chromolaena odorata* L. (King) & HE Robins) in the Indian subcontinent under climate change scenario. Invasive alien plants: an ecological appraisal for the Indian subcontinent 77:88

Bawa K, Primack R, Oommen MA (2011) Conservation biology: a primer for South Asia. Bookshelf, UMass Boston

Bodh M (2017) Study on floristic diversity assessment, monitoring and prioritization in Great Himalayan National Park, North Western Himalaya for management implications. PhD Dissertation. Kumaun University, Nainital, Uttarakhand, India

Elith J, Phillips SJ, Hastie T, Dudík M, Chee YE, Yates CJ (2011) A statistical explanation of Maxent for ecologists. Divers Distrib 17:43–57

Forest Survey of India (2019) India State of Forest Report Volume-II-chapter: Himachal Pradesh. https://fsi.nic.in/isfr19/vol2/isfr-2019-vol-ii-himachal-pradesh.pdf

Franklin J (2010) Mapping species distributions: Spatial inference and prediction. spatial inference and prediction. Cambridge University Press, Cambridge

Gaur RD (1999) Flora of the District Garhwal, North West Himalaya. TransMedia.

Giertych P (2000) Factors determining natural regeneration of yew (*Taxus baccata* L.) in the Kórnik Arboretum. Dendrobiology 45:31–40

Glen (1999) *Taxus canadensis* in Prince Edward Island: an examination of factors affecting distribution and abundance. Prince Edward Island Department of Agriculture and Forestry Management Notes 21

Google (2015) Map data ©2015 Google. https://about.google/brand-resource-center/ (accessed 1.6.21).

Guisan A, Thuiller W (2005) Predicting species distribution: offering more than simple habitat models. Ecol Lett 8:993–1009

Guisan A, Zimmermann NE (2000) Predictive habitat distribution models in ecology. Ecol Modell 135:147–186

Guisan A, Zimmermann NE, Elith J, Graham CH, Phillips SJ, Peterson AT (2007) What matters for predicting the occurrences of trees: Techniques, data, or species' characteristics? Ecol Monogr 77:615–630

Guisan A, Thuiller W, Zimmermann NE (2017) Habitat suitability and distribution models: with applications in R. Cambridge University Press, Cambridge

Hernández-Quiroz NS, Badano EI, Barragán-Torres F, Flores J, Pinedo-Álvarez C (2018) Habitat suitability models to make conservation decisions based on areas of high species richness and endemism. Biodivers Conserv 27:3185–3200

Hijmans RJ, Cameron SE, Parra JL, Jones PG, Jarvis A (2005) Very high resolution interpolated climate surfaces for global land areas. Int J Climatol 25:1965–1978

Hill L, Hector A, Hemery G, Smart S, Tanadini M, Brown N (2017) Abundance distributions for tree species in Great Britain: a two-stage approach to modeling abundance using species distribution modeling and random forest. Ecol Evol 7:1043–1056

Himachal Pradesh GOI (2021) At a Glance—Government of Himachal Pradesh, India. https://himachal.nic.in/en-IN/at-a-glance.html (accessed 8.30.21).

Huberty C (1994) Applied discriminant analysis. Wiley Interscience, New York

India Planning Commission (2005) Himachal Pradesh, Development Report. Acad Found https://www.google.co.in/books/edition/Himachal_Pradesh_Development_Report/Jl0qdJYU3LgC?hl=en&gbpv=1&dq=Himachal+Pradesh++%2B+Area&pg=PA60&printsec=frontcover (accessed 1.5.21).

Jaynes ET (1957) Information theory and statistical mechanics. Phys Rev 106:620–630

Joshi K (2009) *Taxus wallichina* (Himalayan Yew; Loth salla) in Nepal: indigenous uses, conservation and agenda for sustainable management. Ethnobot Leafl 13:1504–1508

Kramer-Schadt S, Niedballa J, Pilgrim JD, Schröder B, Lindenborn J, Reinfelder V, Stillfried M, Heckmann I, Scharf AK, Augeri DM, Cheyne SM, Hearn AJ, Ross J, Macdonald DW, Mathai J, Eaton J, Marshall AJ, Semiadi G, Rustam R, Bernard H, Alfred R, Samejima H, Duckworth JW, Breitenmoser-Wuersten C, Belant JL, Hofer H, Wilting A (2013) The importance of correcting for sampling bias in Maxent species distribution models. Divers Distrib 19:1366–1379

Lal M (2007) Assessment of floristic diversity and conservation status of plants in Kais Wildlife Sanctuary of Himachal Pradesh in North Western Himalaya PhD Dissertation. Kumaun University, Nainital, Uttarakhand, India

Lanker U, Malik AR, Gupta NK, Butola JS (2010) Natural regeneration status of the endangered medicinal plant, *Taxus baccata* Hook. F. syn. *T. wallichiana*, in northwest Himalaya. Int J Biodivers Sci Ecosyst Serv Manag 6:20–27

Lobo JM, Alberto JV, Raimundo R (2008) AUC: a misleading measure of the performance of predictive distribution models. Glob Ecol Biogeogr 17:145–151

Merow C, Smith MJ, Silander JA (2013) A practical guide to Maxent for modeling species' distributions: What it does, and why inputs and settings matter. Ecography 36:1058–1069

NextGIS (2019) QuickMapServices. https://nextgis.com/ (accessed 1.6.21).

Nimasow G, Tsering G, Dai Nimasow O (2015) Vanishing *Taxus baccata* L. Due to unsustainable exploitation and climate change in West Kameng and Tawang Districts of Arunachal Pradesh. Earth Sci 4:11–18

Pant S, Samant SS (2008) Population ecology of the endangered Himalayan Yew in Khokhan Wildlife sanctuary of North Western Himalaya for conservation management. J Mt Sci 5:257–264

Paul S, Samant SS, Lal M, Ram J (2019) Population assessment and habitat distribution modelling of high value *Corylus jacquemontii* for in situ conservation in the state of Himachal Pradesh. India Proc Indian Natl Sci Acad 85:275–289

Pearce J, Ferrier S (2000) Evaluating the predictive performance of habitat models developed using logistic regression. Ecol Modell 133:225–245

Pearson RG (2007) Species' distribution modeling for conservation educators and practitioners. Synth 50:54–89

Pearson RG, Dawson TP, Liu C (2004) Modelling species distributions in Britain: a hierarchical integration of climate and land-cover data. Ecography 27:285–298

Perrin PM, Kelly DL, Mitchell FJG (2006) Long-term deer exclusion in yew-wood and oakwood habitats in southwest Ireland: natural regeneration and stand dynamics. For Ecol Manage 236:356–367

Peterson AT, Soberón J (2012) Species distribution modeling and ecological niche modeling: getting the concepts right. Nat Conserv 10:102–107

Phillips SJ, Dudík M (2008) Modeling of species distributions with Maxent: new extensions and a comprehensive evaluation. Ecography 31:161–175

Phillips SJ, Dudík M, Schapire RE (2004) A maximum entropy approach to species distribution modeling. Proc Twenty-First Int Conf Mach Learn ICML 2004:655–662

Phillips SJ, Anderson RP, Schapire RE (2006) Maximum entropy modeling of species geographic distributions. Ecol Modell 190:231–259

Poudel RC, Gao LM, Möller M, Baral SR, Uprety Y, Liu J, Li DZ (2013) Yews (*Taxus*) along the Hindu Kush-Himalayan region: exploring the ethnopharmacological relevance among communities of Mongol and Caucasian origins. J Ethnopharmacol 147:190–203

Purohit A, Maikhuri RK, Rao KS, Nautiyal S (2001) Impact of bark removal on survival of *Taxus baccata* L. (Himalayan yew) in Nanda Devi Biosphere Reserve. Garhwal Himalaya India Curr Sci 81:586–590

QGIS Development Team (2019) QGIS Geographic Information System. Open Source Geospatial Foundation Project. https://qgis.org/en/site/ (accessed 1.6.21).

R Core Team (2019) R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. https://www.r-project.org/ (accessed 1.6.21).

Rana MS (2007) Assessment of floristic diversity and conservation prioritization of communities for conservation in Manali Wildlife Sanctuary of Himachal Pradesh in Northwestern Himalaya. PhD Dissertation. Kumaun University, Nainital, Uttarakhand, India.

Ravikanth G, Jagadish MR, Vasudeva R, Uma Shaanker R, Aravind NA (2018) Recovery of critically endangered plant species in India: need for a comprehensive approach. Curr Sci 114:504–511

Rikhari HC, Palni LMS, Sharma S, Nandi SK (1998) Himalayan yew: stand structure, canopy damage, regeneration and conservation strategy. Environ Conserv 25:334–341

RStudio Team (2020) RStudio: Integrated Development for R. RStudio, Inc., Boston, MA. https://rstudio.com/ (accessed 1.6.21).

Samant SS (1999) Diversity, nativity and endemism of vascular plants in a part of Nanda Devi biosphere reserve in west Himalaya I. Himalayan Biosphere Reserve (biannual Bulletin) 1:1–28

Samant SS, Pant S, Singh M, Lal M, Singh A, Sharma A, Bhandari S (2007) Medicinal plants in Himachal Pradesh, north western Himalaya. India Int J Biodivers Sci Manag 3:234–251

Schickhoff U (1996) Contributions to the synecology and syntaxonomy of West Himalayan coniferous forest communities. Phytocoenologia 1:537–581

Sharma A (2008) Studies on Floristic diversity and prioritization of communities for conservation in Hirb and Shoja Catchments, District Kullu of Himachal Pradesh, North Western Himalaya. PhD Dissertation, Kumaun University, Nainital, Uttarakhand, India

Sharma P (2013) Ecological Assessment of floristic diversity and Possible impacts of hydropower projects of in Kullu district of Himachal Pradesh in North Western Himalaya. PhD Dissertation, Kumaun University, Nainital, Uttarakhand, India

Swets JA (1988) Measuring the accuracy of diagnostic systems. Sci 240:1285–1293

Tennekes M (2018) tmap: thematic maps in R. J Stat Softw 84:1–39

Thakur S (2012) Ecological Assessment and Conservation Prioritization of Floristic Diversity of the Tirthan Wildlife Sanctuary in Himachal Pradesh, North Western Himalaya. PhD Dissertation. Kumaun University, Nainital, Uttarakhand, India.

Thomas P (2011) *Taxus contorta* (West Himalayan Yew). https://www.iucnredlist.org/species/39147/10170545. Accessed 1.5.21.

Torre LA, Bray F, Siegel RL, Ferlay J, Lortet-Tieulent J, Jemal A (2015) Global cancer statistics, 2012. CA Cancer J Clin 65:87–108

Upgupta S, Sharma J, Jayaraman M, Kumar V, Ravindranath NH (2015) Climate change impact and vulnerability assessment of forests in the Indian Western Himalayan region: a case study of Himachal Pradesh. India Clim Risk Manag 10:63–76

van Proosdij ASJ, Sosef MSM, Wieringa JJ, Raes N (2016) Minimum required number of specimen records to develop accurate species distribution models. Ecography 39:542–552

WDPA (2020) World Database on Protected Areas (WDPA) IUCN. https://www.iucn.org/theme/protected-areas/our-work/quality-and-effectiveness/world-database-protected-areas-wdpa. Accessed 1.6.21.

Wilson CD, Roberts D, Reid N (2011) Applying species distribution modelling to identify areas of high conservation value for endangered species: a case study using *Margaritifera margaritifera* (L.). Biol Conserv 144:821–829

Yang XQ, Kushwaha SPS, Saran S, Xu J, Roy PS (2013) Maxent modeling for predicting the potential distribution of medicinal plant, *Justicia adhatoda* L. in Lesser Himalayan foothills. Ecol Eng 51:83–87

Yang XQ, Kushwaha SPS, Saran S, Xu J, Roy PS (2013) Maxent modeling for predicting the potential distribution of medicinal plant, *Justicia adhatoda* L. Lesser Himalayan foothills. Ecol Eng 51(83):87

Zhang MG, Zhou ZK, Chen WY, Ferry Slik JW, Cannon CH, Raes N (2012) Using species distribution modeling to improve conservation and land use planning of Yunnan, China. Biol Conserv 153:257–264

Zurell D, Franklin J, König C, Bouchet PJ, Dormann CF, Elith J, Fandos G, Feng X, Guillera-Arroita G, Guisan A, Lahoz-Monfort JJ, Leitão PJ, Park DS, Peterson AT, Rapacciuolo G, Schmatz DR, Schröder B, Serra-Diaz JM, Thuiller W, Yates KL, Zimmermann NE, Merow C (2020) A standard protocol for reporting species distribution models. Ecography 43:1261–1277

Training cum Awareness program on conservation and cultivation of *Taxus contorta*

Figure 1: Training cum Awareness program on conservation and cultivation of *Taxus contorta*

Figure 2: Training cum Awareness program on conservation and cultivation of *Taxus contorta*

On field demonstration of protocol of Mass Multiplication of Taxus contorta cuttings at Forest Department nursery at Aloo ground nursery

Figure 3: On field demonstration at Aloo ground, Manali

Figure 4: Mass multiplication trials at Aloo ground, Forest Department nursery, Manali

Training cum Awareness program on conservation and cultivation of *Taxus contorta*

Figure 5: Awareness meeting cum Plantation drive at Solangnala village (18-09-2020)

Annexure V

Figure 6: Awareness meeting cum Plantation drive at Shangarh village (01-10-2020)

Figure 7: Awareness meeting cum Plantation drive at Khokhan WLS (10-10-2020)

Figure 8 : Meeting held at Pulga village

Figure 9 : Meeting held at Bathad village

Figure 10: Awareness workshop at G(B)SSS Theog

Table 1: Participant list for meeting at Solangnala village.

S.No.	Participant's name	Gender
1	Sonam	F
2	Maan Chand	M
3	Tej Ram	M
4	Ratan Thakur	M
5	Darshanu Devi	F
6	Kaushalya Devi	F
7	Tikmi Devi	F
8	Shabnam	F
9	Balraj	M
10	Krishan Thakur	M
11	Anil Goyal	M
12	Durgi Devi	F
13	Gehri Devi	F
14	Nupi Devi	F
15	Poonin Devi	F
16	Tikam Ram	M
17	Tirath Raj Thakur	M

Table 2: Participant list for meeting held at Shangarh village.

S.No.	Participant's name	Gender
1	Narayan Singh	M

2	Manoj Jambal	M
3	Mohar Singh	M
4	Tulu Ram	M
5	Tara Chand	M
6	Savitri Devi	F
7	Balam Kund	M
8	Satish Thakur	M
9	Khem Raj	M
10	Chandra Devi	F
11	Veena Devi	F
12	Heera Devi	F
13	Raamdei	F
14	Girdhari Lal	M
15	Surat Ram	M

Table 3: Participant list for meeting held at Khokhan WLS.

S.No.	Participant's name	Gender
1	Ram Dass	M
2	Ram Chand	M
3	Rubina Thakur	F
4	Dinesh Kumar	M
5	Shiv Chand Negi	M

6	Gorkhu Ram	M
7	Suresh	M
8	Urmila Thakur	F
9	Aashu	F
10	Sunita	F
11	Neha Bharti	F
12	D.P. Singh	M
13	Rakesh	M
14	Dharamveer Singh	M
15	Pratap Singh	M
16	Ram Lal	M
17	Dola Ram	M
18	Rita Devi	F
19	Meena Kumari	F
20	Kanchan Patial	F

Table 4: Participant list for meeting held at Bathad village

S. No	Name	Gender
1	Kehar Singh	M
2	Ses Ram	M
3	Dhani Ram	M
4	Moti Ram	M

6	Chaman lal	M
7	Bheem Sain	M
8	Chaman lal	M
9	Duni Chand	M
10	Dhani Ram	M
11	Poonam Kumari	F
12	Norma Devi	F
13	Anoop Ram	M
14	Kaur Singh	M
15	Tilak Raj	M
16	Pege Ram	M
17	Pradeep Chauhan	M
18	Tikam Ram	M
19	Mool Chand	M
20	Theva Ram	M
21	Jeeva Singh	M
22	Dhave Ram	M

Table 5: Participant list for meeting held at Pulga village

S.No.	Name	Gender
1.	Aadesh Kumar	M
2.	Aakash Duggal	M
3.	Amit Dhouchak	M
4.	Prajit Vohra	M
5.	Yogesh Trehan	M
6.	Heera Singh	M

7.	Jhabe Ram	M
8.	Tara Chand	M
9.	Sher Singh	M
10.	Yash Pal	M
11.	Ramesh Bharti	M
12.	Ramesh Chand	M
13.	Bodh Raj	M
14.	Shobha	F
15.	Neha	F
16.	Dharma Kashi	M
17.	Uma Devi	F
18.	Meena	F
19.	Loohi Devi	F
20.	Maiti Devi	F
21.	Kokila Devi	F
22.	Ishwari Devi	F

Table 6: Participant list for meeting at Sharchi village

Name of Participants	**Address**	**Contact No/ Adhar Number**
Pingla Devi	Jamala	9418694678
Hari Singh	Jamla	7807050557
Reetam		9805343484
Roshan lal	Jamala	8988648991
Thakur Singh	Jamala	9816298915
Dola Ram	Jamala	8627893956
Heera lal	Jamala	7807516594
Heera Devi	Sarchi	8894912570

Dinu Ram	Jamala	9418720434
Tejender Singh	Sarchi	8219626049
Rameshwari	Talihar Pradhan Gram panchayat Sarchi	7876020782
Kushhal Sharma	Bandal (B.M.C)	8580508395
Neerat Singh	Jamala	9418132826
Goyla Devi	Jamala	
Uttam Singh	Sarchi	
Dola Ram	Jamala	
Chander Sen	Jamala	
Dhyan Singh	Jamala	
Tape Ram	Jamala	
Meera Devi	Jamala	
Surma Devi	Jamala	

Table 7: Participant list for meeting at Sainj Ropa, Sainj Valley

Name of Participants	**Address/Village**	**Contact No/ Adhar Number**
Khimi Ram	Raila	8894118746
Bal Mukand	Upper Raila	9805188083
Shanta Devi	Sharan	7807194617
Rajender Chauhan	Deohari	9418045362
Tek Singh	Kathiari	8219732837
Durga Dhami	Raila	9816953333
Ved Ram	Shukari	9816016100
Prem Chand	Bijal	9857955773
Shaina Thakur	Raila	8626812252
Koyla Dhami	Raila	9805721718
Mahender Singh	Narwali	8679115044
Leeladhar	Ropa	7807608129
Aemna Devi	Banogi	8091096465

Sita vati	Narwali	88945450388
Prakash Chand	Ropa	9015281314
Man Singh	Ropa	8679878076
Jai Singh Thakur	Sharan	9816617652
Chatar Das	Jilhinahi	
Tara bati	Ropa	
Dole Singh	Sarahan	9816714984
Kali Ram	Sarahan	9805285838
Thakur Das	Sarahan	9816776514
Jaya Dasi	Devgarh	
Dharampal	Shanshar	
Manoj Kumar	Barshangar	9459782660
Ramesh chand	Majhan	

Table 8: Participant list for meeting at Dhoranala nursery

Name of Participants	**Address/Village**	**Contact No/email id**
Teji devi	Bhiyachak	9015060038
Reshma	Pachali	7018924715
Hardyal	Kamand	8219965171
Nirti Devi	Bhiyachak	8580505981
Mamta	Bhiyachak	7876255067
Ritu devi	Bhiyachak	8894500058
Chetri devi	Bhiyachak	8278718511
Leela devi	Pachali	9816646126
Noma devi	Sharanagg	7876628414
Kanta devi	Pachali	8894572696
Tubanti devi	Bhiyachak	9816371619
Ahilya	Pachali	9816276136
Leela devi	Pachali	8219974118
Neelam Sharma	Khadhidhar	8279206196

Baniya Prasad	Dohranala	9805721734
Kamla	Pachali	8263839966
Ramkali	Bhiyachak	
Budhi singh	Kamand	9816910361
Bhag chand	Kamand	8580968328

E-Training Manual

Conservation and Cultivation practices of Endangered Himalayan Yew (*Taxus contorta* Griff.) in Himachal Pradesh

Developed under

National Mission on Himalayan Studies (NMHS) Funded Project

"Returning Taxus to the Forests and the People: a study in Shimla and Kullu Districts of the Indian Himalayan Region"

Year-2021

Compiled by

Dr. K. S. Kanwal, Ms. Shivani Parmar & Er. R.K. Singh

G. B. Pant National Institute of Himalayan Environment
(An Autonomous Institute of Ministry of Environment, Forest & Climate Change, Govt. of India)
Himachal Regional Centre, Mohal, Kullu- 175126, Himachal Pradesh

COMPILED BY: K.S. Kanwal, Shivani Parmar and R.K. Singh

- Dr. K. S. Kanwal, Scientist-D, G.B. Pant National Institute of Himalayan Environment, Himachal Regional Centre, Mohal, Kullu-175 126, Himachal Pradesh
- Ms. Shivani Parmar, Junior Project Fellow, Himalayan Senior Project Fellow, G.B. Pant National Institute of Himalayan Environment, Himachal Regional Centre, Mohal, Kullu-175 126, Himachal Pradesh
- Er. R.K. Singh, Scientist-F & Head, G.B. Pant National Institute of Himalayan Environment, Himachal Regional Centre, Mohal, Kullu-175 126, Himachal Pradesh

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- Director, G.B. Pant National Institute of Himalayan Environment, Kosi-Katarmal, Almora, Uttarakhand

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Contents

About the NMHS-Taxus Project

Project title "Returning *Taxus* to the Forests and the People: a study in Shimla and Kullu Districts of the Indian Himalayan Region"

Funded by National Mission on Himalayan Studies (NMHS), Govt. of India

The west Himalayan yew (*Taxus contorta* Griff.) previously known as *Taxus wallichiana or baccata* has suffered a severe range wide population decline of upto 90% in the Indian Himalayan Region (IHR), mainly because of overexploitation for its medicinal properties, especially for the commercial extraction of the anti-cancer drug Taxol (Thomas & Farjon, 2011; Aslam, 2016). The last population assessment of *Taxus* in Himachal Pradesh was conducted in 2008 in Khokhan Wildlife Sanctuary (Pant & Samant, 2008) and the current extent and possible locations of this species is not known. Hence there is a need to assess and map the current distribution using species niche modeling technique. Pant & Samant (2008) reported a very poor situation of regeneration of this species and have predicted the extirpation of this species from the sanctuary. Hence, there is an urgent requirement of understanding the causes of decline in regeneration and to try to decipher the factors that have resulted in the successful regeneration, in the few habitats where *Taxus* has been able to establish itself. Hence this project would focus on trying to establish those conditions, be it nurse shrubs, shrubs or trees to which the birds responsible for the dispersal of *Taxus* seeds are attracted, or inoculating the soil with mycorrhizae that help in the early establishment of the seedlings, litter thickness that provides the appropriate temperature, soil fauna that aid in creation of the ideal soil environment and help to prevent seed predation, and the soil compaction, pH level, temperature and litter C:N ratio that ultimately help to establish *Taxus* seedlings in the habitat for in situ conservation. At the same time it is important to reduce the dependency of the indigenous people on the forest individuals of *Taxus* by helping them in establishing *Taxus* plantlets in their gardens and community lands. This is where we need to develop and standardize mass multiplication protocols and plantlet establishment involving the forest department and the local people for successful planting for ex situ conservation of this endangered medicinal tree. Such community monitored plantations and trees planted in forests would generate livelihood and income for the local people, creating an incentive for conserving the species for extraction of plant parts for medicinal uses, and this would develop into a self-sustaining conservation strategy. Without undertaking these steps it would be impossible to save this species from extinction from wild in the IHR and an important source of anti-cancer medicines would be lost forever.

Considering the above, G. B. Pant National Institute of Himalayan Environment Mohal, Kullu - 175 126, Himachal Pradesh, India in collaboration with Shoolini University, Bajhol, PO Sultanpur, Solan - 173229, India is implementing a project entitled "Returning Taxus to the Forests and the People: a study in Shimla and Kullu Districts of the Indian Himalayan Region" funded by National Mission on Himalayan Studies (NMHS) of G.B. Pant "National Institute of Himalayan Environment"(NIHE), Kosi-Katarmal, Almora, Uttarakhand.

Project Objectives, Deliverables and Monitoring Indicators

The Project Objectives, Quantifiable Deliverables and Monitoring Indicators are as follows:

Project Objectives	Quantifiable Deliverables	Monitoring Indicators
• Assessment and mapping of populations of *Taxus* in Shimla and Kullu district. • Investigation of the physicochemical and biotic factors associated with regeneration of *Taxus*. • Development and standardization of protocols for mass multiplication of *Taxus* and comparison of its phytochemistry relative to natural individuals. • Establishment of plantlets of *Taxus* involving the forest department and the local communities.	• Develop the Distribution map for *Taxus contorta* • Generation of knowledge about different ecological factors affecting natural regeneration of *Taxus*. • Development and standardization of mass propagation techniques for mass multiplication of *Taxus contorta* (production of >100000 propagules) • New conservation Model for plantation drives through strengthening local nurseries and forest department, and community monitored plantations • A manual and guidelines for conservation and sustainable use of target species • Creating awareness among farmers in 10 villages	• Number of distribution map developed (Nos.) • Mass propagation of selected species (Nos.) • Conservation Model developed (Nos.) • Number of nurseries strengthened (No/ Area) • The number of Beneficiaries (Nos.) • No. of Reports/Research articles/Policy documents/Manual prepared and published (Nos.)

The role and responsibilities of project partners

The role and responsibilities of project partners are as follows

S.No.	Name of organizations	Roles & Responsibilities
1.	Shoolini University, Bajhol, PO Sultanpur, Solan - 173229, India	• Collection of invertebrates and soil fauna associated with Taxus. • Identification of fauna and analysis of soil nutrients. • Studying the role of seed dispersers and seed predators. • Studying the extent of herbivory and the associated animals. • Statistical analysis of data. • Guiding a project fellow for collection, identification, soil analysis, statistical analysis and • local community participation and outreach activities.
2.	G. B. Pant National Institute of	• Mapping the distribution of Taxus in Kullu district. • Identification of plants associated with Taxus.

	Himalayan Environment and Sustainable Development Mohal, Kullu - 175 126, Himachal Pradesh, India	• Development and standardization of mass multiplication methods for cultivating Taxus. • Establishing plantlets of seedlings involving forest department and local people. • Guiding a project fellow for mass multiplication of seedlings and • local community participation and outreach activities.
3.	Shoolini university of Biotechnology and Management Sciences, Solan, Himachal Pradesh	• Isolation and identification of mycorrhizae associated with Taxus. • Phytochemistry of mass multiplied saplings and its comparison to naturally propagated individuals. • Outreach activities.

Context of the project:

Biodiversity Conservation and Management*:* The west Himalayan yew (*Taxus contorta* Griff.) has been warranted with the endangered status in the IUCN RedList (Thomas & Farjon, 2011). The main reasons for the decline of population of *Taxus* are overexploitation of the tree because of its commercially important medicinal use and the lack of regeneration. To reduce the overexploitation of the species, research would be conducted to successfully establish plantlets of *Taxus* in the village lands for its ex situ conservation. For in situ conservation, the factors responsible for successful regeneration of *Taxus* in the wild would be investigated, such that establishing those conditions should aid in successful germination and growth of the seedlings in the forest. The current distribution of the species would be mapped using niche distribution modeling, which would help in recognizing potential areas where this species is growing or could grow, so that those areas could be given protection.

Skill Development and Capacity Building: There would be involvement of the local communities in establishment of the plantlets in the community lands, with proper training so that employment opportunities if created for planting *Taxus* in forest lands, would help in generating some income to the local people. This would also empower the local people for identification, monitoring and protection of the species, creating conditions conducive to the regeneration of the species, and for generating nurseries for growing the species and establishing plantations for sustainable exploitation. The people will also be trained as to how to harvest the bark so as to not kill the tree.

Livelihood options and Employment Generation: Once the local people get trained in establishing the plantlets of *Taxus*, they can plant it in their own lands and after some years, they would be able to generate income by extracting plant parts is a sustainable way for utilizing the medicinal properties of this tree, thereby generating income continually in the future and also saving the species from extinction.

General Introduction about *Taxus contorta*

Scientific name - *Taxus contorta*

Family - Taxaceae

Local name - Rakhal, The Himalayan Yew, Thuner

Useful parts - Leaves and bark

Medicinal uses - It is a prime source of taxol, a potent anticancer drug; used for the treatment of high fever and painful inflammatory conditions; consumed as decoctions, herbal tea for treating cold, cough, respiratory infections, indigestion.

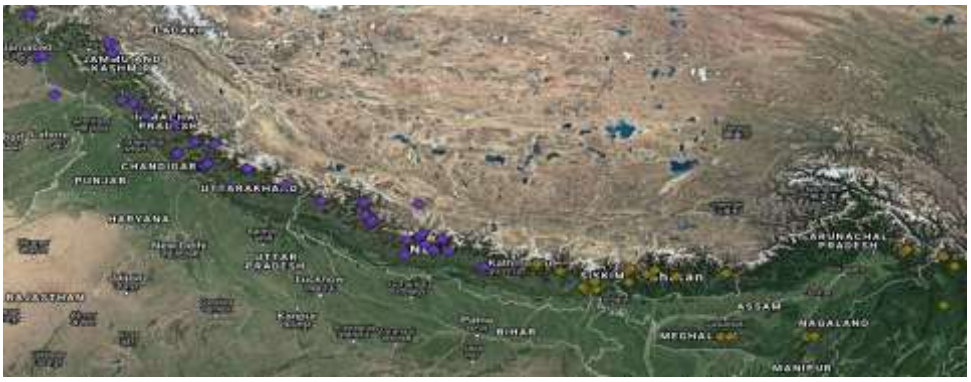
General details

- It is a medium-sized, temperate, endangered, native high value medicinal plant of the Indian Himalayan region.
- It attains a height of 9-20 meters with a massive trunk.
- The leaves are flat, dark green, 1–4 centimeters (0.39–1.57 in) long and 2–3 millimeters (0.079–0.118 in) broad, twisted at the base and arranged spirally on the stem.
- The stem is profusely branched and remains covered with a thin brown-colored bark.
- Plants are mainly dioecious with globose male flowers and female flowers appearing as small stalked conical buds in the leaf axils.
- Seeds are brown and nut-like and are covered with a red fleshy aril, ripening in the first year.
- It is closely associated with *Abies pindrow*, *Quercus semecarpifolia*, *Q.floribunda*, *Q.leucotrichophora*, *Betula utilis*, *Acercaesium*, *Pinus wallichiana*, *Rhododendron arboreum* and *Betula alnoides*

Conservation approach for Taxus contorta in Himachal Pradesh

Taxus contorta Griff. (Western Himalayan Yew, locally known as Rakhal/Thuner), belonging to family Taxaceae, is an endangered native high value medicinal plant species of the North Western Himalaya (as per IUCN red list). Total ten species under the genus *Taxus* were recorded globally. Out of which *T. contorta* is native to Indian Himalayan Region (IHR) covering the temperate and sub-alpine zones. In India, it covers the area of J&K, Himachal Pradesh, Uttarakhand, Meghalaya, Nagaland and Manipur.

The native population in the IHR has been using its bark for making herbal tea concoctions, for treating cold, cough, fever and headache. It is well known for it's anti-cancerous product Taxol, which is obtained from the leaves and bark of tree. High anthropogenic pressure; particularly over exploitation from its natural habitats, biotic pressure on yew from lopping, peeling bark and grazing, several medicinal properties of the bark and leaves of this species has led to a drastic decrease in its population. Due to over-harvesting of its bark and leaves, most wild populations are threatened with extinction and are endangered in the Himalayas. Himalayan yew is a very slow growing plant, with poor natural regeneration potential primarily due to low seed production and germination. It was observed that the population of *Taxus* has been decreasing drastically in the last few years in the Western Himalayan Region. The forest has been cut down by the local communities for domestic uses like, for timber wood, fuel wood. Local people also use its branches for support and for decorative purposes.



Distribution of Taxus in Indian Himalayan Region

Climate change is projected to alter species' natural distribution and drive biodiversity loss in forest ecosystems. Habitat destruction, changing climate, pollution, invasion of alien species and pathogens, overexploitation and increasing human population are the most important factors responsible for ecosystem degradation worldwide that alters the structural and functional integrity of the ecosystems. Such alterations have brought approximately one fifth of the plant species to the brink of extinction. To mitigate the effects of climate change on forest ecosystems, effective target conservation strategies such as modeling species distributions to identify areas where sensitive species exist or are likely to exist will be needed. To effectively model species distributions, detailed and reliable information about the spatial distribution of species is required.

The present study is focused on (i) to investigate population size and altitudinal distribution of *T. contorta* in Kullu district of Western Himalaya, (ii) to test which bioclimatic parameters influence the species presence (iii) to test species distribution models and compare the species' extent of occurrence under current climatic situation and under climate change scenarios and (iv) to make a conservation strategy for its protection.

To remodel the forest of *Taxus contorta*, it is important to understand distribution of the species, its current status, and to assess the vegetation related to it. The species do not regenerate well from seed and that is another risk factor. The objective of this research is to investigate the population ecology of the species as a foundation for its conservation and to remodel the forest communities of Kullu valley in order to understand the distribution of the species, and its current status. The species re-introduction is a successful ecological technique for recovering and maintaining the position of degraded species populations, degraded habitats and ecosystems. For the successful re-introduction and rehabilitation of species in an ecosystem, a detailed knowledge on the potential habitats and distribution of species is essential. Species Distribution Models (SDMs) are commonly used to predict the geographic range of a species, given presence-only occurrence data and environmental variables assumed to influence its distribution.

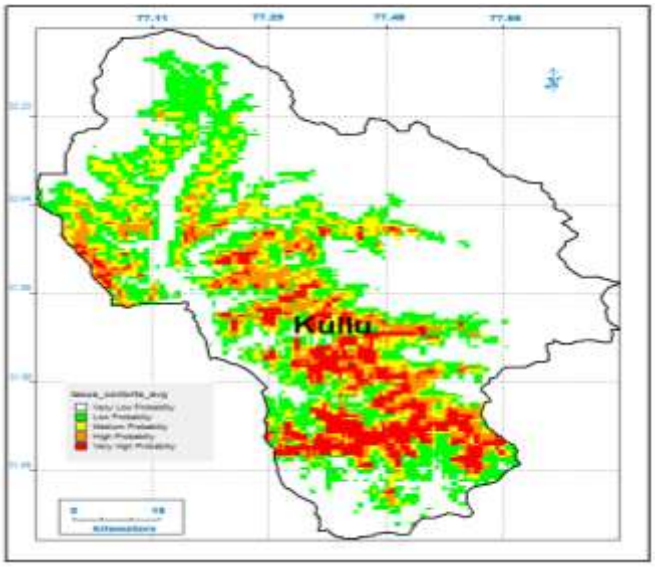
Of many species distribution model algorithm methods, Maxent (Maximum Entropy, Phillips, 2004) has proved powerful when modeling rare species with narrow ranges and scarce presence-only occurrence data. Twenty eight (28) secondary and 3 primary occurrence points (Ground control points) were collected through field survey and literature review. Remotely sensed data on elevation and bioclimatic variables in highest resolution (*i.e.*, ~1km) were downloaded in BIL format, converted to ACS II raster grids and rescaled to ~250 m resolution in Arc GIS 10.5 software. The 31 occurrence points and environmental layers – current global climate (19 bioclimatic variables), altitude, slope and aspect were used for the MaxEnt modeling. The Maxent model shows the probability of occurrence of *Taxus contorta* in Kullu district of Himachal Pradesh. The model AUC was 0.860, which is greater than the minimum acceptable value of 0.75 and the standard deviation was 0.138. BIO13 showed the greatest relative contribution to the model. BIO7 showed the highest Permutation importance. On the basis of habitat suitability for *Taxus contorta*, the areas with very high, high, medium, low and no probability were identified; the area with very high probability is 419 Km^2 (7.60%) and area with high probability is 429 Km^2 (7.79%). The information from collection sites of the herbarium specimens and some of our own collections were used to validate model predictions. Predictions on potential sites of *Taxus contorta* could help in the conservation of this species. The model with eco-physiologically important bioclimatic variables seems to perform best, covering most potential sites of *Taxus contorta*. This study also revealed that the most suitable

altitudinal range was from 2600-3000 m a.s.l., while temperature and precipitation played important role in the species. Results from our models can be utilized for developing conservation strategies for the species in the Himalayan region. Mass multiplication of *Taxus contorta* cutting was also carried out in the institute nursery. These mass multiplied saplings have been transplanted in most suitable area/high probability areas marked by the Maxent model with the support of local communities and state forest department.

A conservation strategy of *Taxus contorta* has been formulated under the project. It will provide a template for conservation in other locations where the species is at risk. The study thus suggests that there is an immediate need to protect *Taxus* forests from harvesting (lopping, peeling bark, etc.), grazing and other destructive activities. Using efficient biotechnological tools (like tissue culture), artificial regeneration of this species needs to be promoted in nurseries to produce healthy planting material on a large scale. Besides in-situ conservation and management, large-scale afforestation with the participation of local communities and

forest department would also be needed for conservation of endangered and valuable *Taxus contorta* species in the Himalayan region.

Unsustinable harvesting threats to Taxus contorta in Kullu, Himachal Pradesh



Habitat suitability for *Taxus Contorta* in Kullu district of Himachal Pradesh

Mass multiplication Package of Practice of Taxus contorta

1. **Name of medicinal plant**

a) **Scientific name:** *Taxus contorta* Zucc.

b) **Pharmacopoeial name:** Sthauneya [1]

c) **Local name (specify language):** English: Himalayan Yew; Hindi : Thuner, Talispatra Bhed; Bengali: Birmi, Bhirmie, Talish Patra, Bhada Getela; Gujarati: Gethela Barmi; Oriya: Talisabhed, Chalisa Patra; Tamil: Talisapatri-Bhedam; Telegu: Taleesa Patri Bhedamu and in Sanskrit: Sukapuspa, Vikarna [1].

d) **Varieties/Germplasm authentication**

e) **Characteristics/Diagram and Herbaria:**

Taxus contorta is a native evergreen non-resinous gymnosperm tree up to 20−28 m, often with multiple trunks and spreading, rounded or pyramidal canopy. It is capable of producing leafy branches from old branches and trunks, and sometimes from stools. Root system is shallow with extensive horizontal roots, often above ground on calcareous substrates. Branches long, not whorled. Twigs green and irregularly alternate; buds very small, bud scales dark-brown, rounded, imbricate and closely appressed. Leaves spirally attached but on lateral shoots twisted more or less into two ranks, can live for up to 8 years; 1–3(−4.5) cm long and 2–3 mm wide. It is normally dioecious, rarely monoecious; reproductive structures green, borne in leaf axils near the end of the previous summer's growth. Seed ovoid, smooth and shiny, brown-yellow, 6–7 × 5 mm at maturity, with a tough seed coat, partly surrounded by a fleshy red aril typically 9 × 7 mm which falls with the seed at maturity, the 'fruit' ripening in the first year. [2]

2. **Plant to be employed as the medicinal plant material (Description of the part of the plant used for medicinal purposes):**

Bark and Leaves

Himalayan yew has been used traditionally for the treatment of high fever and painful inflammatory conditions. It is consumed as decoctions, herbal tea, and juice for treating cold, cough, respiratory infections, indigestion, and epilepsy. As poultice, it is used locally on the infected wounds and burns. [3] Its **bark and leaves** are used in steam baths to treat rheumatism, and the paste made from its bark is used to treat fractures and headaches. Extracts from the tree are also used in medicinal hair oils. The **bark and leaves** of ***T. wallichiana*** are used in Unani medicine as a source of the drug Zarnab, which is prescribed

as a sedative, aphrodisiac, and as a treatment for bronchitis, asthma, epilepsy, snake bite, and scorpion stings.[6] **Young shoots** of the plant are used in Ayurveda to prepare a tincture for the treatment of headache, giddiness, feeble and falling pulse, coldness of extremities, diarrhea, and severe biliousness.[5] **Leaf paste** is used for the treatment of asthma and bronchial disorders. Tea, made out of the **stem bark** of Himalayan yew, has been popular in Himalayan tribal communities for curing cold, cough and hypertension.

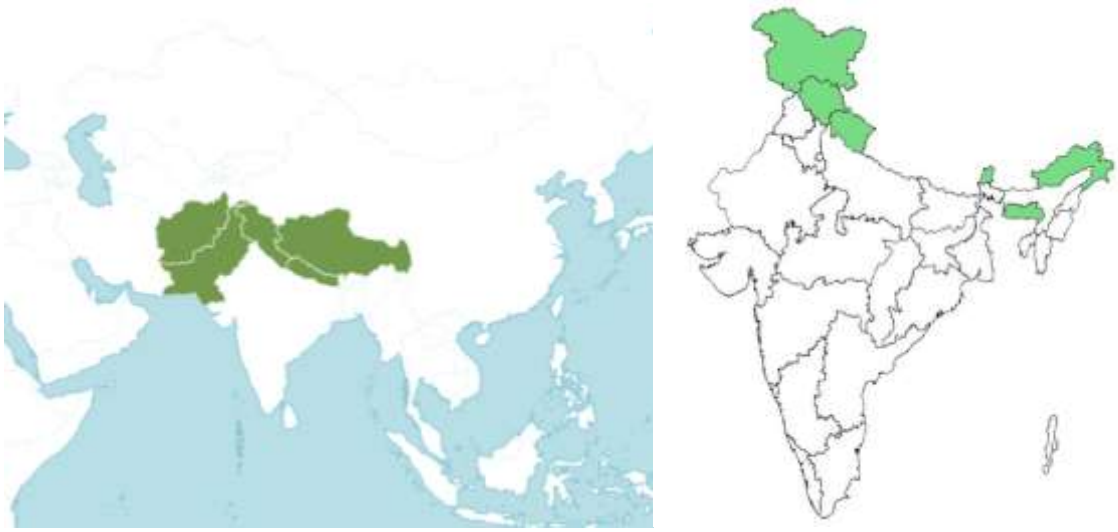
3. **Characteristics of the medicinal plant (Describe the ago-morphological characteristics including the key character following standard descriptors and descriptor state)**

T. wallichiana commonly known as 'Yew' is an evergreen tree attaining a height of 9-20 meters with a massive trunk. The stem is profusely branched and remains covered with a thin brown-coloured bark.

- **Leaves** - The leaves are linear, small, only 2-3 cm. long and 2–3 mm wide spirally arranged. Each leaf possesses a single strong vein and recurved margins, tapering to a petiole-like base. The upper surface is dark green while the lower surface is pale or rusty red in color. The stalk broadens into a flat persistent base which shows a slight twist.
- **Seed -** Taxus seeds are covered by a three-layered seed coat. The outermost layer is thin, brown and detaches soon. The middle layer is hard and stony while the innermost layer is fleshy. The mature seeds are covered by a red-coloured aril. The aril serves to attract birds and help in dissemination.
- **Stem** – It is profusely branched and remains covered with a thin brown-collared bark.
- **Flowering** - Plants are mainly dioecious with globose male flowers and female flowers appearing as small stalked conical buds in the leaf axils. The female flower resembles an axillary vegetative bud, but is usually decurved or pendent and is easily recognized on close inspection by the micropyle opening in the exposed ovule. The male flower or pollen cone has several sterile scales at the base, with a stalked globose head of 6 to 14 scales, each with 5 to 9 microsporangia or pollen sacs. [8]
- **Fruit** – It is a soft, bright red berry-like structure which is known as aril and they are long and wide open at the end. Subsequent to pollination, the aril matures within 6 to 9 months. Having a jelly-like consistency, the aril is not poisonous and is sweet to taste.

4. **Distribution of the species including map in Himalaya…; in India..; in world…;**

It is distributed from Pakistan to southwest China, Nepal and Bhutan, mainly at elevations of 1800–3300 m a.s.l. In Indian Himalaya, it is found in temperate and sub-alpine zone; Jammu and Kashmir, Himachal Pradesh, Uttarakhand, Meghalaya, Nagaland and Manipur.



(A) **(B)**

Figure (A) Species distribution in the world

(http://www.plantsoftheworldonline.org/taxon/urn:lsid:ipni.org:names:263797-1)

Figure (B) Species distribution in India

(http://envis.frlht.org/maps/Taxus-18b10da2df66b026beeb71cfa4b4023c-wallichiana)

5. **Characteristics of accessions for cultivation**

i. **Key identification marks:** Similar to its agro-morphological characteristics.

ii. **Major chemical compound responsible for drug value along with chemical profile:** The diterpenoid alkaloid, Taxol (paclitaxel), was first isolated from the bark of *Taxus brevifolia*. Subsequently, taxol and taxoid derivatives were reported from foliage and bark of several other species of Taxus including *Taxus contorta*. The species is well recognized as source of anti-cancerous drug taxol for treating various forms of cancers. The needles, stem and bark have been reported to contain taxol, baccatin 111, and 10-deacetylbaccatin 111, a precursor for taxol synthesis. [7]

iii. **Preferred growing conditions**

a) **Soil conditions** (pH, Water retention capacity, nutrient status as per soil test report etc.)

In order to keep the soil moist and to suppress weed growth spread a 3-inch-thick layer of mulch in a 20-inch radius around the base of the yew tree. Use pine bark or other mildly acidic, lightweight mulch. It can tolerate frost, drought and strong winds, and usually grows on limestone-derived moist soil

b) Soil type: loamy soils of a slightly acidic or neutral pH having adequate moisture.

c) Shade requirement, if any: It is suitable for shady places as well as sunny spots. However, optimal is a half-shady location. If it is too dark, the growth rate decreases. In sunny locations, especially with alternating rain/snow and strong sun radiation, it can result in the drying up.

6. Cultivation methods [12]

i. Land preparation: The land is ploughed twice or thrice to make the soil more permeable. The weeds and stones are separated from the soil and let the land under the exposure of sun for a week.

ii. Propagation methods: The plant can be propagated through seeds and vegetative means (Air layering).

a) Seed: The seeds are collected from a medium-aged, healthy, and disease free tree.

- Time of year to collect seed: Autumn; Time of year to sow seed: Summer; Seeds should be covered with 1/2 inch of soil and proper cultural controls such as mulching and shading should be maintained to ensure proper moisture and temperature.
- It is best sown as soon as it is ripe when it should germinate 18 months later. Stored seed may take 2 years or more to germinate. For ideal germination conditions, seeds should be given 5-7 months of warm stratification at 65º F, followed by 2-4 months of cold stratification at 34º-40º F.

b) Cutting

- **Stem cutting**

➢ **Selection of Stem cuttings**

- 15 – 20 cm long and 4 – 5 cm in diameter
- Juvenile stem cuttings with leaves from lower part of the canopy of mature Taxus trees.
- At least 3 – 4 nodes.

Too many leaves in the cutting give negative effect because of higher transpiration rate and water deficiency that cause leaf shedding. At the same time, cuttings without leaves root poorly.

- **Preparation of Stem cuttings**
  - The base of each cutting is given a slanting cut and dipped in 0.1% aqueous solution of Bavistin for 5-10 min to protect cuttings from any chances of fungal infection, subsequently washed with distilled water.
  - 18 hours prior to planting, the cuttings are dipped in a hormonal solution of 500 ppm IBA.
- **Nursery Technique**
  - These cuttings are planted in the locally prepared beds in a slanting 45° position.
  - The cuttings should be protected from direct sunlight and high humidity (>70 percent) should be maintained by a thatch covering.
  - They require a lot of water. The soil should never dry out and should be kept appropriately wet. Make sure that no water logging occurs which a yew does not tolerate.
  - Spreading a layer of gravel or bark mulch on the surface of the soil or substrate is helpful especially for warm days. This prevents the evaporation of moisture and keeps the moisture longer inside the soil.
  - The cuttings are planted in the prepared beds during July-August.
  - 70-80% cuttings produced roots in the bed during September–October and they can then be transplanted in the field in early June.
- **Air layering:** The mature healthy plants are selected for air layering. The air layering experiment is carried out usually during rainy season. The layered shoots are treated with various concentrations test chemicals (500, 1000, 2000 and 5000μM) of indol-3-butyric acid (IBA), Indole-3-acetic acid (IAA) and α-naphthalene acetic acid (NAA) and systematic fungicide Bavistin. The shoots of 5-8 mm diameter (250-320 cm, CBH trees) are used for each treatment and untreated is used for control. The careful removal of bark (1.5-2cm width) with sharp knife at the node of shoot is followed by application of various test chemicals mixed with soil paste or directly by using test solution dipped cotton plug around the layer. The layer is then covered by moss pad and wrapped with perforated polythene sheet, tied with thread at both the end and observations are taken at 20-25days intervals. Afterwards well rooted shoots are cut 5 cm below the girdle with help of sharp secateurs. Out of these 50% rooted cuttings are directly planted in their natural habitat and 50% are transported in laboratory in wet cotton sheets. These rooted cuttings are transferred in pots containing mixture of soil and farmyard manure and kept inside mist chamber. [13]

- **Tissue culture:** The shoot cuttings of *T. wallichiana* are taken and washed using detergent solution (Tween 20, two drops) under running tap water for 15-20 minutes. Afterwards, they are sterilized with a solution of 0.1% Bavistin for 10-20 minutes and Mercuric chloride 0.05 % for 30sec-2 minutes and rinsed with distilled water thoroughly under laminar air flow cabinet. They are then cultured in Murashige and Skoog (MS) medium containing various concentrations and combinations of BA – Benzyl adenine, NA - 1-Naphthaleneacetic acid, and GA3 - Gibberellic acid and then placed in the culture room (25-27° C temperature, 16hr light 8hr dark conditions).

c) Sowing methods

- **Seed:** Time of year to sow seed: Summer; Seeds should be covered with 1/2 inch of soil and proper cultural controls such as mulching and shading should be maintained to ensure proper moisture and temperature.
- **Transplanting:** The seedlings are very slow-growing and will probably require at least 2 years of pot cultivation before being large enough to plant out.

d) Manures & fertilizers including microbial fertilizers

1.5 inches of soil, 1.5 inches of sand, and 1.5 inches of organic fertilizer.

- **Irrigations:** They require a lot of water. The soil should never dry out and should be kept appropriately wet. Make sure that no water logging occurs which a yew does not tolerate.

e) Pest managements including diseases

i) Pest / disease type:

Disease	Symptoms	Pathogen/Cause
Bleeding canker	Sap oozes from the lower trunk near the soil line. Needles yellow and fall as branches die back.	*Phytophthora*
Dieback	Needles on branches yellow as the branch dies.	Excessive soil moisture.
Edema	Bumps of scab-like tissue form on the underside of needles. [15]	Excessive soil moisture.

ii) Control measures used:

Remove the infected plant and do not replace it with a Taxus or other *Phytophthora*-susceptible plant. Do not plant *Taxus* in poorly drained locations, especially in areas of heavy clay. [11]

Viii. Harvesting stage, time & procedures:

- **Stage of Maturity:** Only harvest from trees with a trunk diameter of more than 20cm
- **Time of Harvesting:** Conventionally, harvesting time of Himalayan Yew can be variable depending on the component, the plant collected for. Collection of leaves for essential oil can be done early in the morning before the day temperature starts increasing due to strong essential oil activity in morning.
- **Method of harvesting**: Only harvest from trees with a trunk diameter of more than 20cm. Ensure that the branch which the twig was taken from has been pruned. Never completely remove a branch of its twigs. These methods ensure that the branch can quickly recover, and not kill the tree. Snip a small twig from the tree approximately 10-15cms.

(a) Postharvest handling & processing:

(i) Cleaning & washing: The harvested material should be washed with clean water... Do not use contaminated water for washing. Do not wash seeds and delicate parts of the medicinal plants. All excess water should be drained from the herb before drying.

(ii) Drying: Small branches with leaves and the collected leaves are shade dried during sunlight on a tarpaulin / cement floor for 3 - 4 days and protect them from fog and frost.

(iii) Storage: Leaves can be stored when wrapped in appropriate packing in air tight bags. For long term storage leaves should be dried well and drying should avoid any breakage to avoid loss of essential oil and taxanes.

(iv) Packaging: leaves are then tied up in bundles and put in gunny bags to avoid fungal attack.

(b) Expected yield with desired quality: depends on the age of the plant, a 10-year-old plant gives a yield of 200kg/ 0.61 acres, for paclitaxel extraction a yield of 0.1% - 0.45% per kg.

7. Quality evaluation of the medicinal plant material

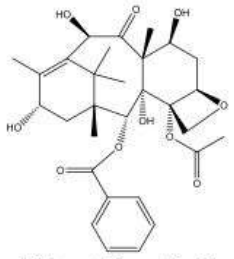
i) National quality standard of the medicinal plant material API (defined as the quality and quantity standard) [1]

- **Foreign matter -** Not more than 2 Per cent, Appendix 2.2.2
- **Total ash -** Not more than 6 Per cent, Appendix 2.2.3
- **Acid-insoluble ash -** Not more than 1.5 Per cent, Appendix 2.2.4
- **Alcohol-soluble extractive -** Not less than 10 Per cent, Appendix 2.2.6
- **Water-soluble extractive -** Not less than 16 Per cent, Appendix 2.2.7

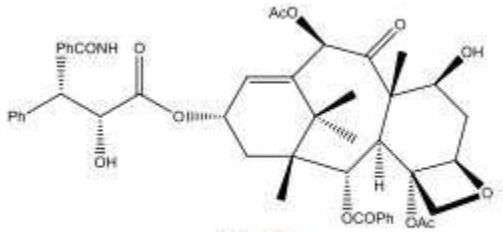
ii) Name of major chemical/chemicals constituents and its percentage

Taxol (a diterpenoid alkaloid) is the major taxoid which is mainly obtained from bark and varies in concentration from 0.007 to 0.01%, in different Taxus species. Other potent taxoids found in Taxus *contorta* include baccatin-III (0.084%), cephalo mannine (0.031%), and 10-deacetyl baccatin-III. Another important class of compounds (lignans) is found in heartwood of plant. These include isoliovil, conidendrin, α-conidendrin, hydroxymatairesinol, texiresinol, β-conidendrin, (–)-secoisolariciresinol, isotexiresinol. These lignans have anticancer as well as antiulcer potentials. Major bioflavonoids found in T. wallichiana include sciadopitysin and amentoflavone. Phytosterols (daucosterol, 4-desmethylsterol type, and βsitosterol), and phytoecdysteroids (ponasterone and ecdysone), have also been reported from T. wallichiana bark. [9]

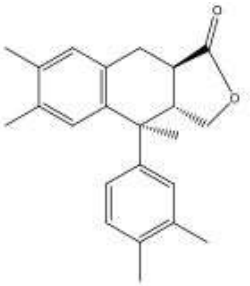
iii) Chemical structure of selected major constituents [9]



10-deacetyl baccatin-III

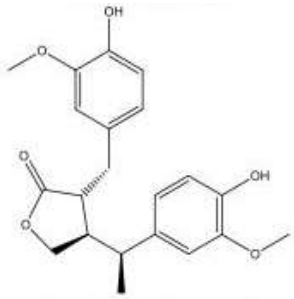


Taxol

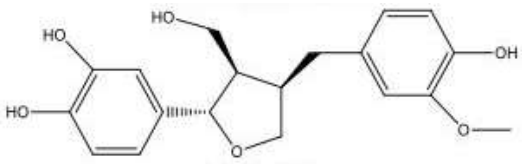


α –conidendrin

(A) (B) (C)



Hydroxymatairesinol



Texiresinol

(D) (E)

Figure: Major chemical constituents of *Taxus contorta*

A) 10-deacetyl baccatin-III B) Taxol C) α-conidendrin D) Hydroxymatairesinol E) Texiresinol

8. Cultivation calendar

A tabulated schedule of cultivation practices whichever to be followed indicating the type of care and management work/actions and their timing during the entire growing period.

Cultivation practices	Month	Course of work [12]
Seed collection	October- November	Collect seeds from the natural forest of Taxus. Clean seeds with drinking water by removing the outer fleshy part and dry them in shade. Store dry seeds in a cold but not damp place. While storing protect them from fungus, insects and mice.
Nursery bed preparation	March	Create a bed, containing 3 levels. 1.5 inches of soil, 1.5 inches of sand, and 1.5 inches of organic fertilizer
Seed sowing	March-April	Seeds should be covered with 1/2 inch of soil and proper cultural controls such as mulching and shading should be maintained to ensure proper moisture and temperature.
Seed germination	First week of June	After 20-25 days of sowing, the seeds start germinating; keep them in the nursery bed for one month and then transfer to polybags where they remain for 8-12 months
Transplanting	July-August	Seedlings will take one and half year before being ready to plant in the field.

Harvesting	August to October	Only harvest from trees with a trunk diameter of more than 20cm. Ensure that the branch which the twig was taken from has been pruned. Never completely remove a branch of its twigs. These methods ensure that the branch can quickly recover, and not kill the tree. Snip a small twig from the tree approximately 10-15cms. You can also dry the twigs - they fetch a higher price. Dry the twigs in open sunlight and away from livestock or wildlife. This can be done by fencing or elevating the twigs.

Mass multiplication method of *Taxus contorta*

Stem cuttings treated with IBA 500 ppm

9. Background data and other information, if any

Photographs of plant and plant material;

1. (B) (C) (D)

Figure: A) Leaves, B) Aril, C) Male Flower, D) Dried leaves

10. Extract attributes, if applicable

A. Plant part: Leaves

B. Extraction method: Four types of solvent extraction methods (ultrasound and microwave assisted extraction, pressurized liquid extraction, and extraction in the Soxhlet apparatus) for paclitaxel, cephalomannine, and 10-deacetylbaccatin, taxoids can be employed for extraction process. [14]

11. Quality parameter for certifications

Quality parameter addressing below is based on Ayurvedic Pharmacopoeia of India part 1 volume IX. It suggests the parameter should be used in Compliance with the prescribed limits which are shown in the appendix section of the book. [10]

A. Pesticide residue (if pesticides used, any)

B. Heavy metal:

S. No.	Heavy metal	Permissible limits
1.	Lead	10 ppm
2.	Arsenic	3 ppm
3.	Cadmium	0.3 ppm
4.	Mercury	1 ppm

C. Microbial load:

Microbial Contamination Limits:

Sl. No.	Parameters	Permissible limits for herbal extracts and Powders	Permissible limits for plant materials which will be treated before use
1	Staphylococcus aureus/g	Absent	-
2	Salmonella sp./g	Absent	-

3	Pseudomonas aeruginosa/g	Absent	-
4	Escherichia coli	Absent	10
5	Total microbial plate count (TPC)	10^5/g	10^7/kg
6	Total Yeast & Mould	10^5/g	10^7/kg

D. Aflatoxin:

Permissible Limit of Aflatoxins:

Aflatoxin	Permissible Limit
B1	< 2 ppb
B1+B2+G1+G2	< 5 ppb

Pictorial representation of various activities of NMHS- Taxus project

On field demonstration *Taxus contorta* mass multiplication at Aloo ground nursery of Forest Department, Manali

Mass multiplication of *Taxus contorta* at GBNIHE, HRC

Awareness meeting cum Plantation of Taxus contorta at various locations of Kullu district

Bibliography/References

1. The Ayurvedic Pharmacopoeia of India, Part I, Volume – III, Ministry of Health and Family Welfare, Department of Ayush, New Delhi, pp 204-205.
2. Thomas, P. A., & Polwart, A. (2003). Taxus baccata L. *Journal of Ecology*, *91*(3), 489-524.
3. Nisar, M., Khan, I., Ahmad, B., Ali, I., Ahmad, W., & Choudhary, M. I. (2008). Antifungal and antibacterial activities of Taxus wallichiana Zucc. *Journal of enzyme inhibition and medicinal chemistry*, *23*(2), 256-260.
4. Gonzalez, J. (1980). Medicinal plants in Colombia. *Journal of ethnopharmacology*, *2*(1), 43-47.
5. Khan M, Verma SC, Srivastava SK, Shawl AS, Syamsundar KV, Khanuja SP, et al. Essential oil composition of *Taxus wallichiana Zucc*. from the Northern Himalayan region of India. *Flavour Frag J.* 2006;21:772–5.
6. Purohit A, Maikhuri RK, Rao KS, Nautiyal S. Impact of bark removal on survival of *Taxus baccata* L.(Himalayan yew) in Nanda Devi Biosphere Reserve, Garwhal Himalaya, India. *Curr Sci.* 2001;81:586–90.
7. Adhikari, P., & Pandey, A. (2017). Taxus wallichiana Zucc.(Himalayan Yew) in antimicrobial perspective. *Advances in Biotechnology and Microbiology*, *5*(4), 1-5.
8. Chadwick, L. C., & Keen, R. A. (1976). study of the genus taxus.
9. H. Sharma, M. Garg. (2015). A review of traditional use, phytoconstituents and biological activities of Himalayan yew, Taxus wallichiana. Journal of integrative medicine. 13(2): 80-90
10. https://main.ayush.gov.in/sites/default/files/Ayurvedic%20Pharmacopoeia%20of%20India%20part%201%20volume%20IX.pdf
11. https://extension.psu.edu/taxus-diseases
12. https://2019.igem.org/wiki/images/2/23/T--UNSW_Australia--IHP-Himalayan-Yew-Tree-Guideline.pdf
13. Kishor, K., Upreti, B. M., Pangtey, Y. P. S., Tewari, A., & Tewari, L. M. (2015). Propagation and conservation of Himalayan Yew (Taxus baccata L.) through air layering: a simple method of clonal propagation. *Ann. Plant Sci*, *4*(04), 1064-1067.
14. Wianowska, D., Hajnos, M. Ł., Dawidowicz, A. L., Oniszczuk, A., Waksmundzka-Hajnos, M., & Głowniak, K. (2009). Extraction methods of 10-deacetylbaccatin III, paclitaxel, and cephalomannine from Taxus baccata L. twigs: A comparison. *Journal of Liquid Chromatography & Related Technologies®*, *32*(4), 589-601.
15. https://extension.psu.edu/taxus-diseases

G.B. PANT NATIONAL INSTITUTE OF HIMALAYAN ENVIRONMENT

KOSI-KATARMAL, ALMORA-263643, UTTARAKAHND, INDIA

G.B. Pant National Institute of Himalayan Environment (GBPNIHE) was established in 1988-89, during the birth centenary year of Bharat Ratna Pt. Govind Ballabh Pant, as an autonomous Institute of the Ministry of Environment, Forest and Climate Change (MoEF&CC), Govt. of India. The Institute has been identified as a focal agency to advance scientific knowledge, to evolve integrated management strategies, demonstrate their efficacy for conservation of natural resources, and to ensure environmentally sound management in the entire Indian Himalayan Region (IHR). The Institute has Headquarters at Kosi-katarmal, Almora (Uttarakhand) and six Regional Center, namely, Himachal Regional Center at Mohal (Kullu, HP), Garhwal Regional Center at Srinagar (Garhwal, Uttarakhand), Sikkim Regional Center at Pangthang (Sikkim), North East Regional Center at Itanagar (Arunachal Pradesh), and Mountain Division Regional Center at MoEF&CC New Delhi. More recently Institute has made functional its Ladakh Regional Centre at Leh (Ladakh UT).

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HIMACHAL REGIONAL CENTRE, MOHAL, KULLU- 175126, HIMACHAL PRADESH, INDIA

The focus of the HRC is entire Himachal Pradesh state covering parts of north western Himalayan bio-geographic province. The region is recognized for its ecological and economic values manifested by ecosystem integrity, adaptability and ecosystem services. Its protective and productive functions for both upland and lowland dwellers are well known. The major thrust areas of activities include: (i) vulnerability assessment of biodiversity of the ecosystems in Trans and North Western Himalaya under biological, anthropogenic and climate scenarios and developing strategies for conservation management, (ii) assessment, monitoring and management of agricultural crops/farming systems for sustainability under chemical contamination and climate change scenarios along an altitudinal gradient in North Western Himalaya, (iii) assessment, characterization and valuation of ecosystem services for sustainable development of the native communities, (iv) development of strategies for monitoring and management of water resources under climate change scenario, (v) assessment and sustainable management of eco-tourism through entrepreneurship development, (vi) assessment, monitoring and analysis of the anthropogenic and natural environmental impacts for developing management strategies, and (vii) development and strengthening of institutional mechanism for information sharing and capacity building of the stakeholders for environmental management.

For more information, please contact:

Er. Kireet Kumar
Director In-charge
G. B. Pant National Institute of Himalayan Environment
(Autonomous Institute of Ministry of Environment, Forest & Climate Change, Government of India)
Kosi-Katarmal, Almora-263643, Uttarakhand, India

Er. Rakesh Kumar Singh
Regional Head
G. B. Pant National Institute of Himalayan Environment
(Autonomous Institute of Ministry of Environment, Forest & Climate Change, Government of India)
Himachal Regional Center, Mohal, Kullu-175126, Himachal Pradesh, India

Dr. K.S. Kanwal
Scientist-D & Principal Investigator (NMHS-Taxus Project)
G. B. Pant National Institute of Himalayan Environment
(Autonomous Institute of Ministry of Environment, Forest & Climate Change, Government of India)
Himachal Regional Center, Mohal, Kullu-175126, Himachal Pradesh, India

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G. B. Pant National Institute of Himalayan Environment
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