

**Tribhuvan University**  
**Institute of Science and Technology**  
**Central Department of Botany**

**M.Sc. Botany Syllabus**

**Third Semester**

**2074**

## Course Outline

### SEMESTER III: Theory + practical (Lab/field work)

**Credits: 18; Full marks: 450**

#### 1. Compulsory Paper – 6credits

Course No	Title	Credit	FM
BOT 601	Research Design and Biological Data Analysis (theory)	3	75
BOT 602	Research Design and Biological Data Analysis (practical)	2	50
BOT603	Dissertation Proposal and Seminar	1	25
<b>Total</b>		<b>3+3</b>	<b>150</b>

#### 2. Special Paper [any one group]\*– 8 credits

Course No	Title	Credit	FM
	<b>Group A</b>		
BOT 611	Functional Plant Ecology (theory)	3	75
BOT 612	Functional Plant Ecology (practical)	1	25
BOT 613	Landscape and Global Change Ecology (theory)	3	75
BOT 614	Landscape and Global Change Ecology (practical)	1	25
	<b>Group B</b>		
BOT 615	Applied Systematics (theory)	3	75
BOT 616	Applied Systematics (practical)	1	25
BOT 617	Biodiversity and Biogeography (theory)	3	75
BOT 618	Biodiversity and Biogeography (practical)	1	25
	<b>Group C</b>		
BOT 619	Plant Biotechnology (theory)	3	75
BOT 620	Plant Biotechnology (practical)	1	25
BOT 621	Genetic Engineering (practical)	3	75
BOT 622	Genetic Engineering (theory)	1	25
	<b>Group D</b>		
BOT 623	Applied Mycology (theory)	3	75
BOT 624	Applied Mycology (practical)	1	25
BOT 625	Advanced Plant Pathology (theory)	3	75
BOT 626	Advanced Plant Pathology (practical)	1	25
<b>Total</b>		<b>6 + 2</b>	<b>200</b>

#### 3. Applied Paper [any one of the following]\*– 4 credits

Course No	Title	Credit	FM
BOT 631	Natural Resources Management (theory)	3	75
BOT 632	Natural Resources Management (practical)	1	25
BOT 633	Plant Conservation Biology (theory)	3	75
BOT 634	Plant Conservation Biology (practical)	1	25
BOT 635	Molecular Biology (theory)	3	75
BOT 636	Molecular Biology (practical)	1	25
BOT 637	Food Security and Food Safety (theory)	3	75
BOT 638	Food Security and Food Safety (practical)	1	25
<b>Total</b>		<b>3+1</b>	<b>100</b>

\* Department will run all or any of the given special and applied paper based on the availability of resources.

## COMPULSORY PAPERS (6 credits)

### Research Design and Biological Data Analysis

<b>Course title:</b> Research Design and Biological Data Analysis	<b>Full marks:</b> 75
<b>Course No.:</b> BOT 601	<b>Pass marks:</b> 37.5
<b>Nature of course:</b> Theory	<b>Credits:</b> 3
<b>Level:</b> MSc, III Semester	<b>Credit hours:</b> 48

#### Objectives

The overall aim is to develop basic skills in original research in plant science and provide basic training in methods of data analysis. The specific objectives are to provide/develop (i) understanding on research design, (ii) computational and analytical understanding necessary for processing and analyzing biological data, and (iii) basic understanding of the theory and practice of geographical information systems (GIS) and remote sensing techniques within the field of application in biodiversity conservation.

#### Course content

**Unit 1: Research design and hypothesis testing:** (i) Research design: introduction, types of research design. (ii) Populations, samples and observations; types of variables – scale and measurement. (iii) Designing experiments: types of experiments, replication, controls, randomization, independence. (iv) Hypothesis testing: biological and statistical hypotheses, deductive and inductive reasoning, the hypothetico-deductive method. (v) Research ethics, risk and safety measures. [9 h (1+1+2+3+2)].

**Unit 2. Biological data analysis – an introduction:** (i) Variations and statistical inference, managing and curating data; overview of the approaches in biological data analysis: descriptive and inferential statistical analysis, univariate and multivariate analysis. (ii) Descriptive analysis: introduction, measures of central tendency, frequency tables and histograms, stem and leaf plots, measures of dispersion, box-plots and outliers. (iii) Inferential statistical analysis: hypothesis testing and inferential statistics, sampling and inferential statistics, parametric and non-parametric statistics, testing basic assumptions of parametric tests, data transformation methods. [7 h (1+3+3)].

**Unit 3. Basic analysis:** (i) Tests for nominal variables: Chi square test. (ii) Tests for one measurement variable: parametric methods (t-tests and ANOVAs), non-parametric methods. (iii) Tests for multiple measurement variables: correlation and regression analyses. [10 h (1+5+4)].

**Unit 4. Multivariate analysis:** (i) Introduction, aims, nature of multivariate data, concept of similarity, distance measures, multivariate normality. (ii) Ordination and gradient analysis: introduction and concepts, data matrix, constrained and unconstrained analyses, main techniques (DCA, PCA, CA, CCA, RDA, NMDS). (iii) Classification: Hierarchical and K-means clustering, discriminant analysis. [10 h (2+6+2)].

**Unit 5. Geographical information systems (GIS) and remote sensing (RS):** (i) Fundamentals of GIS and remote sensing: introduction, aims and approaches, components and tools, computer system, applications for monitoring and conservation of biodiversity. (ii) Spatial data and database system. (iii) Map features and properties, coordinate system, map projection, coordinate transformation, digital terrain model, digital mapping and visualization of geospatial data. (iv) Introduction to spatial analysis. (v) Satellite imagery and digital image processing. [12 h (2+2+3+2+3)].

<b>Course title:</b> <u>Research Design and Biological Data Analysis</u>	<b>Full marks:</b> 50
<b>Course No.:</b> BOT 602	<b>Pass marks:</b> 25
<b>Nature of course:</b> Practical	<b>Credits:</b> 2
<b>Level:</b> MSc, III Semester	<b>Credit hours:</b> 32×4

## Objectives

The overall aim of this course is to strengthen practical knowledge on biological data analysis, GIS and remote sensing.

## Course content

### 1 Biological data analysis (20 practical)

#### 1.1 Basics

- 1.1.1 Application of spreadsheets in managing, manipulating and analyzing raw data, displaying results in graphs and tables (1 practical)
- 1.1.2 Checking data for outliers, errors and missing value (1 practical)
- 1.1.3 Computer software for univariate and multivariate data analysis (1 practical)

#### 1.2 Statistical methods and data analysis I

- 1.2.1 Descriptive statistics, testing basic assumptions of parametric tests, data transformation methods (1 practical)
- 1.2.2 Student's t-test, paired t-test and analysis of variance (3 practicals)
- 1.2.3 Non-parametric methods (1 practicals)
- 1.2.4 Correlation and regression analysis (3 practicals)
- 1.2.5 Categorical data: chi-squared test (1 practicals)

#### 1.3 Statistical methods and data analysis II: multivariate analysis

- 1.3.1 *Ordination*: obtaining eigenvalue and length of gradient, explorative analysis (DCA), unconstrained analyses (PCA, CA), constrained analyses (CCA, RDA), NMDS (5 practicals)
- 1.3.2 Defining groups with multivariate data: cluster analysis (2 practicals)
- 1.3.3 Comparing groups: discriminant analysis (1 practical)

### 2 GIS and remote sensing (12 practical)

- 2.1 Working knowledge of GIS Software
- 2.2 Maps and images and their characteristics
- 2.3 Data acquisition sources and database concepts
- 2.4 Map preparation and map upgradation
- 2.5 Interpretation of satellite images and aerial photographs
- 2.6 Handling of GPS, using GPS with map and compass, data collection and integration of GPS data
- 2.7 Load digital data
- 2.8 File management- raster layer and layer information
- 2.9 Spatial database building and editing
- 2.10 Attribute data automation
- 2.11 Geographic Analysis



- 2.12 Thematic Maps – road networks, drainage, land etc
- 2.13 Fundamental of Digital Terrain Modeling (DTM)
- 2.14 Land use and land cover change identification
- 2.15 Network analysis

### Text and reference books

- Burrough P.A. and McDonnell R.A. 2003 *Principles of Geographic Information Systems- Spatial Information Systems and Geostatistics*. Oxford University Press.
- Fowler J., Cohen L. and Jarvis P. 1998. *Practical Statistics for Field Biology*. John Wiley and Sons.
- Laake P., Benestad H.B. and Olsen B.R. 2007. *Research Methodology in the Medical and Biological Sciences*. Academic Press, CA, USA.
- Lepš J. and Šmilauer P. 1999. *Multivariate Analysis of Ecological Data*. Faculty of Biological Sciences, University of South Bohemia, České Budejovice
- Muaz J.M. 2013. *Practical Guidelines for Conducting Research. Summarizing Good Research Practice in Line with the DCED Standard*. <http://www.enterprise-development.org/page/download?id=2133>
- Sokal R.R. and Rohlf F.J. 1995. *Biometry* (3<sup>rd</sup> edition). W.H. Freeman & Company, NY, USA.
- Gorard S. 2013. *Research Design: Creating Robust Approaches for the Social Sciences*. SAGE Publications Ltd.
- Lilles R.M. and Kiefer R.W. 2002. *Remote Sensing and Image Interpretation*. 4<sup>th</sup> Edition. WSE Wiley.

### Suggested further readings

- Bailey N.T.J. 1994. *Statistical Methods in Biology*. Cambridge University Press, Cambridge.
- Crawley M.J. 2007. *The R Book*. John Wiley & Sons Ltd, England, UK.
- Crawley M.J. 2012. *Statistical Computing: An Introduction to Data Analysis Using R*.
- Gauch H.G. 1982. *Multivariate Analysis in Community Ecology*. Cambridge University Press, Cambridge, UK.
- Gotelli N.J. and Ellison A.M. 2004. *A Primer of Ecological Statistics*. Sinauer Associates, Inc. Publishers, Sunderland, MA, USA.
- Heywood I., Cornelius S. and Carver S. 2005. *An Introduction to Geographical Information System*. Pearson Education.
- ICIMOD 2010. *Basics of Geographic Information Systems and Remote Sensing*. Training course. ICIMOD, Kathmandu.
- Jenson J.R. 2003. *Remote Sensing of the Environment- An Earth resources Perspective*. Pearson Education.
- Jha P.K., Shakya D.D., Joshi S.D., Chaudhary R.P. and Sakya S.R. 2004. *Research Methods and Practice*. Buddha Academic Publishers and Distributors Pvt. Ltd., Kathmandu, Nepal.
- Legendre P. and Gallagher E.D. 2001. Ecologically meaningful transformations for ordination of species data. *Oecologia*, 129: 271–280.
- Legendre P. and Legendre L. 2012. *Numerical Ecology*. 3<sup>rd</sup> English edition. Elsevier Science BV, Amsterdam.
- Lo C.P. and Yeung A.KW. 2003. *Concepts and Techniques of Geographic Information System*. Prentice-Hall India.
- McCullagh P. and Nelder J.A. 1989: *Generalised Linear Models*. Second Edition. Chapman and Hall, London.
- McCune B. and Grace J.B. 2002. *Analysis of Ecological Communities*. MjM Software Design, Oregon, USA.
- Quinn P.G. and Keough J.M. 2002. *Experimental Design and Data Analysis for Biologists*. The press Syndicate of the University of Cambridge, Cambridge, UK.
- Silbershatz A., Korth H., Sudarshan S. 2005. *Database Systems Concepts*, 5th ed., McGraw-Hill.
- Venables W.N., Smith D.M. and the R Development Core Team. 1999–2006. *An Introduction to R*. R Development Core Team.

## Dissertation Proposal and Seminar

<b>Course title:</b> Dissertation Proposal and Seminar	<b>Full marks:</b> 25
<b>Course No.:</b> BOT 603	<b>Pass marks:</b> 12.5
<b>Nature of course:</b> Seminar	<b>Credits:</b> 1
<b>Level:</b> MSc, III Semester	<b>Credit hours:</b> 16×4

### Objectives

The general aim of this course is to provide training in essential scientific communication skills such as dissertation proposal writing and oral presentations.

### Course content

**Unit 1: Scientific writing and communication:** (i) Writing research proposal, report and article: general processes, steps and approaches, grant application. (ii) Literature review: sources and basic approaches. (iii) Poster preparation. (iv) Methods of effective oral presentation. [7 h (3+2+1+1)].

**Unit 2: Term paper and seminar:** Guided work and assignments in literature research in the area of interest and proposal writing for original research project (M.Sc. thesis to be conducted in 4<sup>th</sup> semester), seminar presentation. [9 h].

### Text and reference books

Kothari C.R. 1993. *Research Methodology*. Wiley Eastern Ltd., New Delhi, India.

Muaz J.M. 2013. *Practical Guidelines for Conducting Research. Summarizing Good Research Practice in Line with the DCED Standard*. <http://www.enterprise-development.org/page/download?id=2133>

Stuart C. 2005. *Speak for Yourself: How to Give Persuasive Presentations and Entertaining Talks - with Confidence*. Piatkus, London.

**SPECIAL PAPER [any one group] (8 credits)****Group A****BOT. 611, 612. Functional Plant Ecology****BOT. 613, 614. Landscape and Global Change Ecology**

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**Functional Plant Ecology**

<b>Course title:</b> <u>Functional Plant Ecology</u>	<b>Full marks:</b> 75
<b>Course No.:</b> BOT 611	<b>Pass marks:</b> 37.5
<b>Nature of course:</b> Theory	<b>Credits:</b> 3
<b>Level:</b> MSc, III Semester	<b>Credit hours:</b> 48

**Objectives**

The general objective of this paper is to discuss functional aspects from individual plants to ecosystems. The specific objectives are:

- To impart knowledge on nutrient cycles and productivity at various levels of ecological hierarchy
- To provide physiological bases for plant-environment interactions
- To understand plants' responses to varying levels of resources such as water and minerals
- To understand physiological mechanisms of adaptation/defense of plants to varying environmental conditions/stress.
- To discuss functional significance of plant-microbe interactions

**Course content**

**Unit 1. Nutrient cycles and productivity:** (i) Biogeochemical cycles: plant nutrients and nutrient use efficiency; quantitative study of biogeochemical cycles (C, N, P, S, hydrologic); cycling of non-essential elements; cycling of organic nutrients; nutrients cycling in different climatic regions; recycle pathways; litter removal and deforestation. (ii) Nutrient budget: nutrient dynamics in grassland, natural forest and converted ecosystems; hydrologic response to forest with particular reference to nutrients, nitrogen relations in population of certain tree species. (iii) Productivity: world distribution and comparison of primary production and biomass; environmental factors and productivity; productivity-diversity relation. [16 h (7+5+4)].

**Unit 2. Plant physiological ecology:** (i) The environment of plants: Atmosphere, hydrosphere, lithosphere, phytosphere, radiation and climate. (ii) Plant water relations: water relations parameters, water availability in soil, water relations of cell, water relations of whole plant (root, stem and leaf), water use efficiency, drought resistance. (iii) Mineral nutrition: mineral nutrients in soil, uptake of mineral nutrients, nutrient acquisition from extreme soil and habitats (acidic soil, calcareous soil, soil with high levels of heavy metals, saline soil, epiphytic habitat). (iv) Growth and allocation: physiological basis of variation of growth, allocation to storage, environmental influences (irradiance, temperature, water potential and salinity, nutrient supply, soil compaction, flooding, elevated CO<sub>2</sub>). (v) Physiological adaptation: functional adaptation of plants to extreme environments (alpine and tundra, metal contaminated soil, desert, epiphytic habitat, saline habitat, flooded lands). (vi) Phenology: concept and significance, methods of phenological studies, phenology and climate change. [18 h (2+5+3+3+3+2)].

**Unit 3. Ecological biochemistry and plant defense:** General introduction; cutin, suberin and waxes (introduction and their ecological role); secondary metabolites: principal groups (terpenes, phenolic compounds and nitrogen containing secondary products), site of synthesis and accumulation, role of secondary metabolites in plant defense (herbivory, microbial attack and others); essential oils and their ecological roles; plant defense against pathogens; allelopathy; optimal defense hypothesis. [8 h].

**Unit 4. Microbial ecology:** Scope and history; microbial diversity; interaction between micro-organisms and plants: rhizosphere; mycorrhizae; phyllosphere: microbial abundance, sources of microbes, leaf attributes and environmental factors controlling microbial populations, leaves as islands for colonization; ice nucleation activity and frost injury. [6 h].

**Course title:** Functional Plant Ecology

**Course No.:** BOT 612

**Nature of course:** Practical

**Level:** MSc, III Semester

**Full marks:** 25

**Pass marks:** 12.5

**Credits:** 1

**Credit hours:** 16×4

## Course content

### I. Experiment

1. To determine organic carbon and organic matter contents of different soil samples.
2. To estimate the available phosphorus content in grassland, cropland and forest soil samples.
3. To estimate the total nitrogen content in different soil samples.
4. To compare litter decomposition rate of different species.
5. To measure the relative growth rate (RGR) and net assimilation rate (NAR).
6. To compare specific leaf area (SLA) of evergreen and deciduous species.
7. To estimate the productivity of aquatic ecosystem by light and dark bottle method.
8. To determine water potential of tree species by pressure chamber.
9. To determine the relative water content (RWC) and bound water content (BWC) in the leaf of different species.
10. To estimate bacterial population of phyllosphere/rhizosphere.
11. To study allelopathic impact of invasive alien plants on seed germination of native plant species.
12. To estimate essential oil content in different plant species.

### II. Term paper/bibliographic review of the topics provided in the class/case study

#### Text books and references

- Atlas RM and R Bartha. 2005. *Microbial Ecology: Fundamentals and applications*. Pearson Education, Singapore.
- Bailey MJ, AK Lilley, TM Timms-Wilson, PTN Spencer-Philips. (Eds.) 2006. *Microbial Ecology of Aerial Plant Surfaces*. CAB International, UK.
- Barbour MG, JH Burk, WD Pitts, FS Gilliam and MW Schwartz. 1999. *Terrestrial Plant Ecology*. 3<sup>rd</sup> edition. California (USA): Benjamin/Cummings.

- Begon M, CR Townsend and JL Harper. 2006. *Ecology: from Individuals to Ecosystems*. Blackwell Publishing Ltd.
- Callaway RM. 2007. *Positive Interactions and Interdependence in Plant Communities*. Springer.
- Chapman JL and MJ Reiss. 1999. *Ecology: Principles and Applications*. Cambridge University Press.
- Crawley MJ (Ed). 1997. *Plant Ecology* (2<sup>nd</sup> ed.). Blackwell Science Ltd.
- Fokkema NJ and JE van den Heuvel (eds.). 1986. *Microbiology of the Phylloplane*. Cambridge: Cambridge University Press.
- Grime JP. 2001. *Plant Strategies, Vegetation Processes and Ecosystem Properties*. John Wiley & Sons, Chichester.
- Gurevitch J, SM Scheiner and GA Fox. 2006. *The Ecology of Plants*. The Sinauer Associates, Inc.
- Harborne JB. 1993. *Introduction to Ecological Biochemistry*. Academic Press, New York.
- Jonathan C. 2007. *Climate Change*. Cambridge University Press, Cambridge.
- Körner C. 2003. *Alpine Plant Life: Functional Plant Ecology of High Mountain Ecosystems* (2<sup>nd</sup> edition). Springer.
- Lambers H, FS Chapin III and TL Pons. 2008. *Plant Physiological Ecology*. 2<sup>nd</sup> edition. Springer.
- Larcher W. 1995. *Physiological Plant Ecology*. Springer
- Laszlo N and G Georg. 2009. *The Biology of Alpine Habitats*. Oxford University Press, USA.
- Odum EP and GW Barrett. 2005. *Fundamentals of Ecology*. Brooks/Cole, Thompson Asia Pte Ltd. Singapore.
- Singh JS, SP Singh and SR Gupta. 2006. *Ecology, Environment and Resource Conservation*. Anamaya Publishers, New Delhi
- Taiz L and E Zeiger. 1998. *Plant Physiology*. Sinauer Associates, Inc., Sunderland, Massachusetts.
- Wilson E.O. 1988. *Biodiversity*. National Academic Press, Washington, D.C.

### References for practical

- Cornelissen JHC, S Lavorel, E Garnier, S Diaz, et al. 2003. A hand book of protocols for standardized and easy measurement of plant functional traits worldwide. *Australian Journal of Botany* 51:335-380.
- Gupta, P.K. 2000. *Methods in Environmental Analysis: Water, Soil and Air*. Agrobios (India), Jodhpur, India.
- Pearcy RW, J Ehleinger, HA Mooney and PW Rundel (eds.). 1989. *Plant Physiological Ecology: Field Methods and Instrumentation*. Chapman and Hall, New York.
- Zobel DB, PK Jha, MJ Behan and UKR Yadav. 1987. *Practical Manual for Ecology*. Ratna Book Distributors, Kathmandu.

## Landscape and Global Change Ecology

<b>Course title:</b> <u>Landscape and Global Change Ecology</u>	<b>Full marks:</b> 75
<b>Course No.:</b> BOT 613	<b>Pass marks:</b> 37.5
<b>Nature of course:</b> Theory	<b>Credits:</b> 3
<b>Level:</b> MSc, III Semester	<b>Credit hours:</b> 48

### Objectives

The general objective of this paper is to impart knowledge of macroecology which includes landscape ecology and components of global changes. The specific objectives are:

- To introduce the concept of landscape approaches in ecological studies and conservation
- To understand structural and functional aspects of mountain ecosystem.
- To discuss various components of global changes such as land use change, biodiversity loss, climate change and biological invasion.

### Course content

**Unit 1. Landscape ecology:** (i) Principles and applications: concepts of landscape ecology, causes of landscape pattern, organisms and landscape patterns, metapopulation dynamics (concept and application), ecosystem process in the landscape, landscape approaches for conservation in Nepal. (ii) Land use and land cover change: types, spatial and temporal patterns (national and global), causes of land use and land cover change, impacts (on local climate, hydrology, carbon emission, biodiversity, agriculture productivity). [10 h (6 + 4)].

**Unit 2. Fire ecology:** Concept and principle, fire in the earth system, human dimension of fire, ecological impact (including impacts of fire suppression), fire for ecosystem-based management (practical implication of fire), fire and global environmental changes, wildfire prediction, prevention and preparedness, wildfire in Nepal. [8 h].

**Unit 3. Mountain ecology:** Delimitation, origin, type and global distribution of mountains; key environmental features; altitudinal pattern of biodiversity; treeline (species composition, structure, factors determining treeline); impact of climate change on mountains (treeline position, species range shift, endemic species, phenological changes, glacier retreat); human impact on mountain environments (pollution, developmental activities, grazing and deforestation); Himalayan environmental degradation: myth and evidences; mountain hazards; ecosystem services of mountains. [10 h].

**Unit 4. Climate change:** Introduction (climate vs. weather, climate change vs. climate variability, historical account of climate change research, climate change denialism); components and causes of climate change (natural and anthropogenic); patterns of climate change (global and regional patterns of changes in temperature, precipitation, extreme events); climate change impacts (on biodiversity and ecosystem, agriculture and food security, water resources, and human health); plant response to rising atmospheric CO<sub>2</sub>; tools to study climate change; mitigation and adaptation. [10 h].

**Unit 5. Invasion ecology:** Introduction and terminology; invasion process (dispersal, establishment, persistence and spread, and evolution); life history traits of IAS (Invasive Alien Species); theories related to biological invasion (enemy release hypothesis, Darwin's naturalization hypothesis, Evolution of increased competitive ability hypothesis, novel weapons hypothesis, fluctuating resources hypothesis,

biotic resistance hypothesis, invasional meltdown); impacts (ecological, evolutionary, economic/health); management of IAS; overview of IAS in Nepal (diversity, major invasive alien plant species, modes of introduction and spread, impacts, management efforts, policy review). [10 h].

**Course title:** Landscape and Global Change Ecology

**Course No.:** BOT 614

**Nature of course:** Practical

**Level:** MSc, III Semester

**Full marks:** 25

**Pass marks:** 12.5

**Credits:** 1

**Credit hours:** 16 × 4

## Course content

### I. Experiments

1. To record phenological patterns of plant species in a community
2. To study the relationship between biomass and species richness in grassland.
3. To analyze changes in community traits along elevation gradient
4. To analyze climate data of Nepal for climate change trends.
5. To estimate age of tree with the help of annual rings.
6. To estimate carbon stock of different forest stands.
7. To document invasive alien plant species of a locality.
8. To study the impact of invasive plant species on plant species diversity of a community.

### II. Term paper/bibliographic review of the topics provided in the class/case study

#### Text books and references

- Bowman DMJS, J Balch, P Artaxo, WJ Bond, et al. 2009. Fire on the earth system. *Science* 324: 481-484.
- Bowman DMJS, J Balch, P Artaxo, WJ Bond, et al. 2011. Human dimension of fire regime on earth. *Journal of Biogeography* 38:2223-2236.
- Burroughs WJ. 2001. *Climate Change: A Multidisciplinary Approach*. Cambridge University Press
- Chapin FS III, ES Zavaleta, VT Eviner, RL Naylor, et al. 2000. Consequences of changing biodiversity. *Nature* 405: 234-242.
- Clout MN and PA Williams. 2010. *Invasive Species Management*. Oxford University Press.
- Cochrane MA. 2009. *Tropical Fire Ecology: Climate Change, Landuse and Ecosystem Dynamics*. Springer + Paxis Publishing, Chichester, UK.
- Cowie J. 2013. *Climate Change: Biological and Human Aspects*. 2<sup>nd</sup> edition. Cambridge University Press, Cambridge.
- Davis MA. 2009. *Invasion Biology*. Oxford University Press, UK
- De Blois S, G Domon and A Bouchard. 2002. Landscape issues in plant ecology. *Ecography* 25: 244-256.
- Groombridge B and MD Jenkins. 2000. *Global Biodiversity: Status of the Earth's Living Resources in 21<sup>st</sup> Century*. World Conservation Press, Cambridge, UK.
- IPCC 2013. Summary for Policymakers. In: *Climate Change 2013: The Physical Science Basis*. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Stocker, T.F., D. Qin, G.-K. Plattner, M. Tignor, S. K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P.M. Midgley (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

- Ives JD. 2006. *Himalayan Perceptions*. Himalayan Association for Advancement of Sciences, Kathmandu, Nepal
- Körner C. 2003. *Alpine Plant Life: Functional Plant Ecology of High Mountain Ecosystems* (2<sup>nd</sup> edition). Springer.
- Körner C. 2012. *Alpine Treeline*. Springer
- Laszlo N and G Georg. 2009. *The Biology of Alpine Habitats*. Oxford University Press, USA.
- Manel S, MK Schwartz, G Luikart and P Taberlet. 2003. Landscape genetics: combining landscape ecology and population genetics. *Trends in Ecology and Evolution* 18 (4): 189-197.
- McKenzie D, C Miller and DA Falk. 2011. *The Landscape Ecology of Fire*. Springer
- Morison JIL and MD Morecroft. 2006. *Plant Growth and Climate Change*. Blackwell Publishing Ltd.
- Parmesan C. 2006. Ecological and evolutionary responses to recent climate changes. *Annual Review of Ecology, Evolution and Systematics* 37: 637-669.
- Simberloff D and von Holle B. 1999. Positive interaction of non-indigenous species: invasional meltdown? *Biological Invasion* 1: 21-32.
- Spehn EM, M Liberman and C Korner (eds.). 2006. *Land Use Change and Mountain Biodiversity*. Taylor and Francis, Boca Raton, FL, USA.
- Tiwari S, M Siwakoti, B Adhikari and K Subedi. 2005. *An Inventory and Assessment of Invasive Alien Plant Species of Nepal*. IUCN - The World Conservation Union, Nepal.
- Turner MG. 2001. *Landscape Ecology in Theory and Practice: Pattern and Process*. Springer.
- Turner MG. 2005. Landscape ecology: what is the state of the science. *Annual Review of Ecology, Evolution and Systematics* 36: 319-344.
- Valdia KS. 1998. *Dynamic Himalaya*. University Press, Hyderabad, India.
- Wiens JA, MR Moss (eds.). 2005. *Issues and Perspectives in Landscape Ecology*. Cambridge University Press, Cambridge.
- Williamson M. 1996. *Biological Invasion*. Chapman and Hall, London, UK.
- Wilson EO (Ed.). 1988. *Biodiversity*. National Academic Press, Washington, D.C.



**Group B****BOT. 615, 616. Applied Systematics****BOT. 617, 618. Biodiversity and Biogeography**

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**Applied Systematics****Course title:** Applied Systematics**Course No.:** BOT 615**Nature of course:** Theory**Level:** MSc, III Semester**Full marks:** 75**Pass marks:** 37.5**Credits:** 3**Credit hours:** 48**Objectives**

The overall aim of this course is to provide students critical understanding of the applied aspects of plant systematics. The specific objectives are:

- (i) to train students on the application of modern methods and tools for identification and analyzing taxonomic data and elucidating phylogenetic relationships;
- (ii) to train them with the knowledge on documentation, management and publication of taxonomic data.

**Course content**

**Unit 1. Contemporary methods in plant systematics:** (i) Biosystematics: definition, scope and significance, sources of information, biosystematic categories, principles and procedures, applications. (ii) Application of external and internal morphology, embryology, palynology, cytogenetics, phytochemistry and reproductive biology in plant systematics. [12 h (3+9)].

**Unit 2. Approaches of biological classification and phylogeny:** (i) Overview of biological classification. (ii) Molecular systematics: plant genomes, allozyme and isozyme, PCR techniques and DNA sequencing, DNA markers, acquisition and analysis of molecular data, concept of molecular clock. (iii) Phylogenetic systematics: introduction to phylogeny, approaches and methods of phylogenetic analysis, phylogenetic trees – types, construction and analysis. [14 h (2+7+5)].

**Unit 3. Flowering plant identification, description, and documentation of taxonomic data:** (i) Taxonomic literature, databases, herbaria and botanical gardens. (ii) Identification and naming of flowering plants: methods and approaches. (iii) Identification keys: types, key design principles, common problems in key usage. (iv) Methods and approaches of taxonomic revision and Flora writing. (v) Drawing and illustrations, basic photography techniques. (vi) Management and documentation of taxonomic data. [18 h (1+4+4+3+4+2)].

**Unit 4. Flora and taxonomic accounts:** (i) Floras and Monographs. (ii) Introduction to the major Flora of the world (Flora of India, Flora of Bhutan, Flora of China, Flora Malesiana, Pan-Himalayan Flora). [4 h].

<b>Course title:</b> <u>Applied Systematics</u>	<b>Full marks:</b> 25
<b>Course No.:</b> BOT 616	<b>Pass marks:</b> 12.5
<b>Nature of course:</b> Practical	<b>Credits:</b> 1
<b>Level:</b> MSc, III Semester	<b>Credit hours:</b> 15 × 4

## Objectives

The overall aim of this course is to improve necessary expertise to perform taxonomic revision for better understanding of the evolutionary relationship and phylogenetic classification. The specific objectives are (i) to make the students able to understand the concept of different taxa in the light of recent principles; (ii) to enable them to understand the applied aspects systematics, and (iii) to enable them to manage and document taxonomic data.

## Course content

### 1 Systematic revision

- 1.1 Systematic study: macro- and micro-morphology, anatomy, palynology
- 1.2 Preparation of identification keys
- 1.3 Drawing and illustrations
- 1.4 Photographic techniques (macro-photography)
- 1.5 Taxonomic database (in MS ACCESS): based on data obtained from systematic revision

### 2 Molecular systematics

- 2.1 DNA extraction
- 2.2 Gel electrophoresis
- 2.3 PCR techniques

### 3 Herbarium management: visit to herbaria (TUCH, KATH)

### 4 Term paper and seminar

### 5 Report/mini dissertation

## Text and reference books

- Erdtman G. 1986. *Pollen Morphology and Plant Taxonomy: Angiosperms*. E.J. Brill, Leiden, The Netherlands.
- Hillis D.M., Moritz C. and Mable B.K. 1996. *Molecular Systematics*. Second Edition. Sinaur Associates, Inc.
- Simpson M.G. 2010. *Plant Systematics*. Elsevier Academy Press, USA.
- Stace C.A. 1980 (reprint ed. 1984). *Plant Taxonomy and Biosystematics*. Edward Arnold, London
- Stuessy T.F. 1990. *Plant Taxonomy, the Systematic Evaluation of Comparative Data*. Columbia University Press, New York.

## Suggested further readings

- Fageri K. and Iversen J. 1989. *Text Book of Pollen Analysis*. John Wiley & Sons Ltd.
- Judd W.S., Campbell C.S., Kellogg E.A., Stevens P.F. and Donoghue M.J. 2010. *Plant Systematics: A Phylogenetic Approach*. Sinaur Associates Inc. Publishers, Sunderland, Massachusetts, USA

- Shivarajan V.V. 1991. *Introduction to the Principles of Plant Taxonomy*. Oxford & IBH Publishing Co. Pvt. Ltd., New Delhi, India.
- Siwakoti M. and Rajbhandary S., eds. 2015. *Taxonomic Tools and Flora Writing*. Department of Plant Resources (DPR), Ministry of Forest and Soil Conservation, Government of Nepal and Central Department of Botany, Tribhuvan University, Kathmandu, Nepal.
- Woodland D.W. 1997. *Contemporary Plant Systematics*. Barrien Springs, Michigan, USA.

## Biodiversity and Biogeography

<b>Course title:</b> Biodiversity and Biogeography	<b>Full marks:</b> 75
<b>Course No.:</b> BOT 617	<b>Pass marks:</b> 37.5
<b>Nature of course:</b> Theory	<b>Credits:</b> 3
<b>Level:</b> MSc, III Semester	<b>Credit hours:</b> 48

### Objectives

The overall aim of this course is to provide critical understanding of biodiversity and biogeography sciences. The specific objectives are to: (i) develop understanding of important biogeographical processes and patterns of biodiversity distribution; (ii) provide basic understanding of the status of biodiversity and of the methods in assessing species diversity; and (iii) develop understanding of the value of biodiversity and principles and approaches of biodiversity conservation.

### Course content

**Unit 1: The science of biogeography:** (i) Introduction and scope of biogeography, overview of historical and ecological biogeography. (ii) History of earth: geological time scale, continental drift/plate tectonics and earth's history, glaciations and biogeographic dynamics. (iii) Fundamental biogeographic processes and geographic patterns: dispersal and immigration, vicariance, speciation and extinction, endemism and provincialism, disjunction, maintenance of biotas. (iv) Evolutionary processes and history of biota: basic concepts, fossil records and origin of life, major evolutionary processes, history of flowering plant diversity, history of biota, phylogeography. [**11 h** (1+2+4+4)].

**Unit 2. Biodiversity – patterns and processes:** (i) Components and levels of biodiversity, theory of species diversity, mechanisms regulating diversity in space and time, island biogeography theory and patterns of species distribution. (ii) Assessment of species diversity: diversity indices, analytical methods and approaches. (iii) Biodiversity gradients and their determinants: spatial patterns, altitudinal and latitudinal gradients; diversity in time – succession, factors causing diversity gradients. [**13 h** (4+3+6)].

**Unit 3: Current biogeographic patterns and status of biodiversity:** (i) Concept and classification of biomes. (ii) Phytogeographical regions of the world: introduction, basic characteristics (species diversity and endemism) of six floristic kingdoms. (iii) Biogeography of Himalayan plants: introduction, major phytogeographic divisions (with reference to Nepal), major floristic and vegetation elements and their affinities, endemism and disjunction in Himalayan flora. (iv) Threat and status: geography of extinction, major drivers of biodiversity loss/extinction, current status of global biodiversity, status of plant diversity in the Nepalese Himalaya, biodiversity hotspots, important plant areas. [**14h** (1+6+4+3)].

**Unit 4. Value of biodiversity and conservation approaches:** (i) Values of biodiversity: direct and indirect values, option value, existence value; biodiversity and livelihood/food security; methods and approaches of valuing biodiversity. (ii) Biodiversity and traditional knowledge: introduction and definitions, theoretical advancement, principles and assumptions, major components, bioprospecting and traditional knowledge. (iii) Biodiversity conservation: principles and approaches at population, ecosystem and landscape levels; traditional knowledge and biodiversity conservation. [**10 h** (2+3+5)].

**Course title:** Biodiversity and Biogeography**Course No.:** BOT 618**Nature of course:** Practical**Level:** MSc, III Semester**Full marks:** 25**Pass marks:** 12.5**Credits:** 1**Credit hours:** 16 × 4

## Objectives

The overall aim of this course is to provide practical and analytical knowledge related to biodiversity distribution in space and time. The specific objectives are to enable the students with the ability: (i) to document, manage and analyse biodiversity data at different spatial scale; (ii) to analyze biogeographic patterns of Himalayan flora; (iii) to monitor the change in biodiversity patterns.

## Course content

### 1 Basics

- Qualitative and quantitative methods of biodiversity survey and analysis
- Applications of data analysis tools

### 2 Biogeography

- Biogeographic patterns of selected group of flowering plants of the Himalaya: chorology, endemism, disjunction
- Assessment of historic collection of plant specimens to compare changes in distribution patterns

### 3 Field Study: Biodiversity Survey

- Analysis of community structure and composition: classification, gradient analysis
- Assessment of species diversity and distribution pattern along environmental gradients
- Participatory survey to document resource utilization patterns and estimation of economic value of resource use
- Post field study: field data analysis and report writing

### 4 Term Paper and Seminar

### 5 Report/Mini Dissertation

## Text and reference books

Huston M.A. 1994. *Biological Diversity: The Coexistence of Species on Changing Landscapes*. Cambridge University Press, UK.

Lomolino M.V., Riddle B.R. and Brown J.H. 2006. *Biogeography*. Sinauer Associates, Inc., Sunderland, Massachusetts, USA (Third edition).

Primack R.B. 2006. *Essentials of Conservation Biology*. Fourth Edition. Sinauer Associates, Inc. Publishers, Sunderland, MA, USA.

Takhtajan A. 1986. *Floristic Regions of the World*. University of California Press.

## Suggested further readings

Banerji M.L. 1963. Outline of Nepal phytogeography. *Vegetatio* 11(5-6): 288-296. <https://doi.org/10.1007/BF00303794>.

- Campbell B.M. and M.K. Luckert. 2002. *Uncovering the Hidden Harvest: Valuation Methods for Woodland and Forest Resources*. Earthscan, London.
- Chaudhary R.P. 1998. *Biodiversity in Nepal - Status and Conservation*. S. Devi, Saharanpur, India and Tecpress Books, Bangkok, Thailand.
- Cox B.C. and Moore P.D. 2010. *Biogeography: An Ecological and Evolutionary Approach*. John Wiley & Sons, Inc., USA. (8<sup>th</sup> edition)
- Cunningham A.B., 2001. *Applied Ethnobotany: People, Wild Plant Use and Conservation*. Earthscan, London, UK.
- Futuyma D. 1997. *Evolutionary Biology*. Sinauer Associates, Sunderland, MA, USA.
- Ghimire S.K., Sapkota I.B., Oli B.R. and Parajuli R.R. 2008. *Non-Timber Forest Products of Nepal Himalaya: Database of Some Important Species Found in the Mountain Protected Areas and Surrounding Regions*. WWF Nepal, Kathmandu.
- GoN 2014. *Nepal National Biodiversity Strategy and Action Plan 2014-2020*. Government of Nepal Ministry of Forests and Soil Conservation, Kathmandu, Nepal.
- Good R. 1974. *The Geography of Flowering Plants*. Longman, London.
- Hill D., Fasham M., Tucker G., Shewry M. and Shaw P. (eds.) 2005. *Handbook of Biodiversity Methods: Survey, Evaluation and Monitoring*. Cambridge University Press, Cambridge, UK.
- Hubel S.P. 2001. *The Unified Neutral Theory of Biodiversity and Biogeography*. Princeton University Press, Princeton and Oxford.
- Kent M. and Coker P. 1994. *Vegetation Description and Analysis: a Practical Approach*. John Wiley, Chichester.
- Krebs C.J. 2001. *Ecology: the Experimental Analysis of Distribution and Abundance*. Fourth Edition. Addison-Wesley Educational Publishers, Inc., USA. (Fifth edition).
- Laird S. (ed.), 2002. *Biodiversity and Traditional Knowledge: Equitable Partnerships in Practice*. Earthscan, London, UK.
- Magurran, A.E. 1988. *Ecological diversity and its measurement*. Princeton university press, Princeton
- Mani M.S. 1978. *Ecology and Phytogeography of High Altitude Plants of the Northwest Himalaya: Introduction to High Altitude Botany*. Oxford and IBH Publishing Co., New Delhi, India.
- Mani M.S. 1974. Biogeography of the Himalaya. In: *Ecology and Biogeography in India* (M.S. Mani, ed.), pp. 664-681. Monographiae Biologicae, vol 23. Springer, Dordrecht.
- Martin G.J. 1995. *Ethnobotany: a Methods Manual*. Chapman & Hall, London, UK.
- Miehe, G., Pendry, C. and Chaudhary, R.P., eds. *Nepal: An Introduction to the Natural History, Ecology and Human Environment of the Himalayas. A companion to the Flora of Nepal*. Royal Botanic Garden, Edinburgh, UK.
- Myers A.A. and Giller P.S. (eds.). 1988. *Analytical Biogeography: an Integrated Approach to the Study of Animal and Plant Distributions*. Chapman & Hall, London, UK.
- Rau M.A. 1974. Vegetation and phytogeography of the Himalaya. In: *Ecology and Biogeography in India* (M.S. Mani, ed.), pp. 247-280. Monographiae Biologicae, vol 23. Springer, Dordrecht.
- Rao A.S. (1974) The vegetation and phytogeography of Assam-Burma. In: *Ecology and Biogeography in India* (M.S. Mani, ed.), pp 204-246. Monographiae Biologicae, vol 23. Springer, Dordrecht.
- Shrestha T.B. 1982. *Ecology and Vegetation of North-West Nepal (Karnali Region)*. Royal Nepal Academy, Kathmandu, Nepal.
- Shrestha T.B. and Joshi R.M. 1996. *Rare, Endemic and Endangered Plants of Nepal*. WWF Nepal Program, Kathmandu, Nepal.
- Stainton J.D.A. 1972. *Forests of Nepal*. John Murray, London.
- Takhtajan A. 1991. *Evolutionary Trends in Flowering Plants*. Colombia University Press.
- Whittaker R.J., Araújo M.B., Jepson P., Ladle R.J., Watson J.E.M and Willis K.J. 2005. *Conservation Biogeography: Assessment and Prospect. Diversity and Distributions* 11: 3-23.

Whittaker, R.J. and Fernández-Palacios, J.M. 2007. *Island Biogeography: Ecology, Evolution, and Conservation*, 2nd ed. Oxford University Press, Oxford.

Wilson E.O. 1988. *Biodiversity*. National Academic Press, Washington, D.C.

Wilson E.O. 1992. *The Diversity of Life*. Harvard Belknap, Cambridge.

### **Important journals (selected)**

- *American Journal of Botany*
- *Biodiversity and Conservation*
- *Biogeography and Macroecology*
- *Biological Conservation*
- *Conservation Biology*
- *Diversity and Distributions*
- *Ecography*
- *Global Ecology and Biogeography*
- *Journal of Applied Ecology*
- *Journal of Biodiversity*
- *Journal of Biogeography*
- *Nature Ecology & Evolution*

## **Group C**

**BOT. 619, 620. Plant Biotechnology**

**BOT. 621, 622. Genetic Engineering**

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### **Plant Biotechnology**

<b>Course title:</b> Plant Biotechnology	<b>Full marks:</b> 75
<b>Course No.:</b> BOT 619	<b>Pass marks:</b> 37.5
<b>Nature of course:</b> Theory	<b>Credits:</b> 3
<b>Level:</b> MSc, III Semester	<b>Credit hours:</b> 48

#### **Objectives**

The general aim of this course is to impart theoretical and practical knowledge on Plant Biotechnology. The specific objectives are to: (i) introduce tissue culture techniques and demonstrate the principles of tissue culture; (ii) provide knowledge on specialized cell culture techniques and their uses in plant science research and industry; (iii) understand how pharmaceuticals and phytochemicals can be produced in culture; (iv) make students be able to establish the commercial tissue culture industry in future as an entrepreneur; (v) describe various applications of plant biotechnology in environmental management; and (vi) understand the application of algal and fungal biotechnology.

#### **Course content**

**Unit 1. Tools and techniques of tissue culture:** (i) Overview of biotechnology, plant biotechnology achievements and current trends. (ii) Laboratory requirements for plant tissue culture, lab maintenance and fumigation, sterilization techniques. (iii) Media formulation and composition, plant growth regulators used in vitro, surface sterilization of explants, inoculation, sub-culturing and maintenance of culture. (iv) Indexing for plant pathogens: culture indexing for bacterial and fungal contaminant. [8 h (2+1+4+1)].

**Unit 2. Culture types and techniques:** (i) *In vitro* plant regeneration through explants culture. (ii) Callus formation, somatic embryogenesis, artificial seed production, suspension culture, types (batch, continuous and semi-continuous), techniques of single cell culture, embryo culture, anther and pollen culture, protoplast culture. (iii) Hardening of *in vitro*-raised plants. [8 h (3+4+1)].

**Unit 3. Applications of plant tissue culture:** (i) Micropropagation and its applications, production of virus free plants and micrografting. (ii) Somatic embryogenesis; artificial/synthetic seed: commercial production of artificial seed and its application. (iii) Callus and suspension culture and their application in production of secondary metabolites; factors affecting yield, immobilized cell systems, bioreactors, hairy root culture, methods of enhancement of secondary metabolite production in culture; biotransformation. (iv) Somaclonal variations and its application. (v) Haploid culture and its application. (vi) Protoplast culture and somatic hybridization: production of hybrid-cybrid. (vii) Embryo culture and its application in wide hybridization. [14 h (2+2+4+2+2+1+1)].

**Unit 4. Commercialization of tissue culture technology:** (i) Concept of commercialization and the need, design of commercial TC laboratory and management. (ii) Molecular farming: carbohydrate,



proteins, lipids, aromatic chemicals, enzymes, plant derived vaccines, pharmaceutical and biofuels. (iii) Germplasm storage and cryopreservation: significance of short, medium and long term (cryopreservation) preservation, achievements and current trends of cryopreservation. [7 h (1+5+1)].

**Unit 5. Algal/fungal/environmental biotechnology:** (i) Algal biotechnology: algae and cyanobacteria as source of nitrogen-rich fertilizer and important plant products. (ii) Fungal biotechnology: *in vitro* establishment of mycorrhiza, mushroom culture. (iii) Environmental biotechnology: waste management, composting, bioremediation. (iv) Biofertilizer: isolation and identification of symbiotic and non-symbiotic nitrogen fixing bacteria, concept of cross inoculation, inoculation to leguminous seeds. [11 h (2+3+3+3)].

**Course title:** Plant Biotechnology

**Course No.:** BOT 620

**Nature of course:** Practical

**Level:** MSc, III Semester

**Full marks:** 25

**Pass marks:** 12.5

**Credits:** 1

**Credit hours:** 16 × 4

### Course content

1. Preparation of media by direct method (MS medium).
2. Preparation of stock solutions for medium.
3. Preparation of medium supplemented with plant growth hormones.
4. Technique of isolation, surface sterilization and inoculation of different explants.
5. Surface sterilization and plant propagation by seed culture (orchids and other).
6. Callus culture and growth of callus.
7. Somatic embryogenesis from callus and preparation of synthetic seeds.
8. Micropropagation of plants by axillary bud/ single node culture proliferation.
9. Cytological and histological analysis of *in vitro* cells.
10. Production of virus free plants by meristem/shoot tip culture.
11. Anther/microspore culture of rice, wheat.
12. Protoplast culture and protoplast fusion of Pea or tobacco.
13. Technique of *in vivo* rooting from stem cuttings in some woody plants.
14. Technique of acclimatization of *in vitro* propagated plants.
15. Biological waste management/Vermicomposting.
16. Mushroom culture.

### Text and reference books

- Bhojwani S. S. 1990. *Plant Tissue Culture: Applications and Limitations*, Elsevier Science Publishers.
- Bhojwani S.S. and M. K. Razdan. 1996. *Plant Tissue Culture: Theory and Practice*. Elsevier Science Publishers.
- Chawala H.S. 2009. *Introduction to Plant Tissue Culture*. Third Edition. Oxford and IBH Publishing Co. Pvt. Ltd.
- Cheremisinoff N.P. 1996. *Biotechnology for Waste and Waste Water Treatment*. Noyes Publications, USA.
- Debergh P.C. and Zimmerman R.H. 1990. *Micropropagation*. Kluwer Academic Publ. Dordrecht.

- Evans G.M. and Furlong J.C. 2003. *Environmental Biotechnology: Theory and Application*. John Wiley and Sons Ltd.
- Gamborg O.L. and Phillips G.C. 1995. *Plant Cell, Tissue and Organ Culture – Fundamental Methods* (Lab. Manual). Springer-Verlag.
- Greene J.J. and Rao V.B. 1998. *Recombinant DNA Principles and Methodologies*. Marcel Dekker.
- John H. Dodds, Roberts L.W. 1995. *Experiments in Plant Tissue Culture* (3rd Edition). Cambridge University Press. Cambridge, UK.
- Lal R. and Lal S. 1995. *Genetic Engineering of Plants for Crop Improvement*. CRC Press.
- Pierik R.L.M. *In vitro Culture of Higher Plants*. Kluwer Academic Publisher, Netherlands.
- Punia M.S. 1999. *Plant Biotechnology and Molecular Biology: A Laboratory Manual*. Scientific Publishers, India.
- Ramawat K.G. and Goyal S. 2014. *Comprehensive Biotechnology*. S. Chand Publishing, New Delhi.
- Ramawat K.G. and Goyal S. 2014. *Molecular Biology and Biotechnology*. S. Chand Publishing, New Delhi.
- Razdan M. K. 2003. *Introduction to Plant Tissue Culture*. Agritech Publications.
- Satyanarayan U. 2005. *Biotechnology*. 1<sup>st</sup> ed. Arunabha Sen Books and Allied Pvt. Ltd.
- Slater A, Scott N and Fowler M. 2003. *Plant Biotechnology: the Genetic Manipulation of Plants*. Oxford University Press.
- Smith R. 2000. *Plant Tissue Culture: Techniques and Experiments*. Academic Press.
- William G. H. 2006. *Plant Biotechnology (The Green World)*. Chelsea House Publications.

### **Text and reference books for practical**

- Bhattarai T. 2000. *Experimental Plant Biochemistry and Plant Biotechnology (Tissue culture)*. Bhudipuram Prakashan, Kathmandu.
- Bregman A. 1990. *Laboratory Investigations in Cell and Molecular Biology*. John Wiley and Sons, New York.

## Genetic Engineering

<b>Course title:</b> Genetic Engineering	<b>Full marks:</b> 75
<b>Course No.:</b> BOT 621	<b>Pass marks:</b> 37.5
<b>Nature of course:</b> Theory	<b>Credits:</b> 3
<b>Level:</b> MSc, III Semester	<b>Credit hours:</b> 48

### Objectives

The general aim of this course is to impart theoretical and practical knowledge about various aspects of molecular biology and Genetic Engineering of plants. After the successful completion of the course, the students are expected to be able to: (i) know and make use of various tools and techniques used in genetic engineering; (ii) genetically manipulate microbes and plants; (iii) artificially induce mutations in plants; and (iv) explain the methods of screening of DNA libraries and sequencing techniques.

### Course content

**Unit 1. Introduction:** History and importance of genetic engineering. [1 h].

**Unit 2. Basic tools and techniques of genetic engineering:** Restriction enzymes and other DNA modifying enzymes (nucleases, ligases and polymerases), PCR (basics, various components of PCR and their role), application of PCR in genetic engineering; types of PCR; gel electrophoresis, blotting. [7 h].

**Unit 3. Cloning vectors:** Plasmid, polylinker, lambda phage, cosmid, Artificial chromosomes (YAC, BAC), shuttle vectors, virus based vectors. [5 h].

**Unit 4. cDNA and genomic library:** Genomic library, cDNA library, expression library, subtraction library. [3 h].

**Unit 5. Cloning strategies in prokaryotes and eukaryotes:** Cloning in bacteria other than *E. coli*, cloning in yeast and other fungi, gene cloning in higher organisms (animals and plants), expression analysis of transgenes. [4 h].

**Unit 6. Expression systems:** Recombinant DNA technology, Synthesis of protein through expression vector, fusion protein; expression system in viruses (baculovirus), prokaryotes (*E. coli*, *Bacillus*) and eukaryotes (*Pichia*, insects and mammalian cells). [5 h].

**Unit 7. Analysis and expression of cloned DNA:** Restriction digestion, nucleic acid hybridization, Library screening by membrane hybridization, Western Blotting and immunoscreening for expression library, DNA sequencing, Microarray. [7 h].

**Unit 8. Gene transfer methods:** Marker and reporter genes, methods of gene transfer (direct, indirect), genetic transformation and selection of transformants in prokaryotes (*E. coli*, *Agrobacterium tumefaciens*); transformation and selection of transformants in eukaryotes (yeasts, higher plants). [6 h].

**Unit 9. Engineering of plants for crop improvement:** Application of plant genetic engineering for developing insect-resistance, disease-resistance and herbicide resistance in plants; developing stress and senescence-tolerance in plants; application of plant genetic engineering for quality: fruit ripening, flower pigmentation, shape and size, longer flowering, improved storage, terminator seed and terminator technology; molecular markers and marker assisted selection in plant breeding – RFLP, RAPD, AFLP. [7 h].

**Unit 10. Biosafety and ethical issues in genetic engineering:** Introduction, regulatory framework for release and marketing of genetically modified organisms (GMOs), biosafety protocol, handling of biotechnology (including terminator technology), sanitary and phytosanitary measures, impact of GMOs in biodiversity conservation in developing countries; ethics of genetic engineering. [3 h].

**Course title:** Genetic Engineering

**Course No.:** BOT 622

**Nature of course:** Practical

**Level:** MSc, III Semester

**Full marks:** 25

**Pass marks:** 12.5

**Credits:** 1

**Credit hours:** 16 × 4

### Course content

1. Extraction of Plasmid DNA and measurement of concentration and purity
2. Restriction digestion of Plasmid DNA and agarose gel electrophoresis of DNA
3. Construction of restriction map
4. Ligation reaction and construction of chimaeric plasmid
5. Production of competent *E. coli* cell and transformation
6. Selection of transformant
7. Labeling of nucleic acids and southern hybridisation
8. Amplification of particular DNA sequence by normal PCR
9. Extraction of Genomic DNA
10. Extraction of RNA and cDNA preparation by RT-PCR

### Text and reference books

Ausubel F, Bent R. 2005. *Short Protocols in Molecular Biology*. Wiley

Brown, TA. 2006. *Gene Cloning and DNA analysis. An introduction*. Blackwell Publishing

Campbell, N.A. and Reece, J.B. 2002. *Biology*. Pearson Education/Benjamin Cummings

Carson, S and Robertson, D. 2006. *Manipulation and Expression of Recombinant DNA*. Academic Press.

Glick, B.R. and Pasternak, J.J (recent edition). *Molecular Biotechnology*. American Society of Microbiology Press

- Griffiths A J F., Gelbart, W. M., Miller, J.H., Leontin, R.C. 2002. *Modern Genetic Analysis*. Freeman
- Griffiths A J F., Gelbart, W. M., Leontin, R.C, Suzuki, W.M. Miller, J.H. 2004. *An Introduction to Genetic Analysis*. Freeman
- Krenzer, H and Massey, Y. 2000. *A Recombinant DNA and Biotechnology*. American Society of Microbiology Press.
- Kumar Anil and GARG; Neha. 2005. *Genetic Engineering*. Nova Science Publication
- Lehninger, A.L., Nelson, D.L. and Cox, M.M. (recent edition). *Principles of Biochemistry*. Worth Publishers, USA or CBS, India
- Lodish, H., Berk, A., Zipursky, S.L., Matsudaira, P., Baltimore, D., Darnell, J. 2004. *Molecular Cell Biology*. Freeman and Co.
- Meesfeld. 1999. *Applied Molecular Genetics*. Wiley-Liss
- Primrose S B, Twyman RM, Old RW. 2007. *Principle of Gene Manipulation and Genomics*. Blackwell science
- Robertson D, Shore S., and Miller DM. 1997. *Manipulation & Expression of Recombinant DNA*. Academic Press.
- Sambrook, J. and Russel, D. 2003. *Molecular Cloning. A laboratory Manual*. Vol. I to III CHSL Press
- Stryer, L. (recent edition). *Biochemistry*. Freeman and Co.
- Trun N&Trempey J. 2004. *Fundamentals of Bacterial Genetics*. Blackwell
- Turner P, McLennan A, Bates A and White M. 2007. *Instant note on Molecular Biology*. Taylor and Francis.
- Watson JD, Gilman, M, Witkoski, J, Zoller, M (1993). *Recombinant DNA*. Freeman
- Watson JD, Baker, TA, Bell, SP, Gann, A, Levine, M. Losick, R (2004) *Molecular biology of gene*. Pearson

### **Text and reference books for practical**

- Sambrook, J. et al. 2001. *Molecular Cloning: A Laboratory Manual*. Third Edition. Cold Spring Harbour Laboratory, USA
- Szeberenyi, J. 2006. *Experiments in Molecular Cell Biology*. Schenk Verlag, Germany.

## **Group C**

**BOT. 623, 624. Applied Mycology**

**BOT. 625, 626. Advanced Plant Pathology**

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### **Applied Mycology**

<b>Course title:</b> <u>Applied Mycology</u>	<b>Full marks:</b> 75
<b>Course No.:</b> BOT 623	<b>Pass marks:</b> 37.5
<b>Nature of course:</b> Theory	<b>Credits:</b> 3
<b>Level:</b> MSc, III Semester	<b>Credit hours:</b> 48

### **Objectives**

The general aim of this course is to provide theoretical and practical knowledge on significance and application of fungi and microbes. The specific objectives are to: (i) develop understanding on general aspects of mycology; (ii) elaborate knowledge on soil fungi and their importance in forest, soil and agriculture; and (iii) impart knowledge on fungal utilization through industrial and modern technology.

### **Course content**

**Unit 1. General aspects of mycology:** (i) General introduction, historical development and advances in mycology, importance and significance of fungi and microbes, characteristics of pathogenic and non-pathogenic fungi, concept of modern techniques (serological and molecular) in mycology (ii) Fungi as saprophytes: decomposition of organic matter, coprophilous fungi, cellulolytic fungi, lignolytic fungi (iii) Fungi as parasites: parasitism; mycoparasites, fungal parasites on plants, humans, insects and nematodes (iv) Fungi as symbionts: mycorrhizae, types of mycorrhizae, fungi-algae and fungi-insect mutualism, significance of mycorrhizal and mutualistic interaction. [**9 h** (4+1+2+2)].

**Unit 2. Soil and microbes:** (i) Concept of soil and microbes, microbial population and diversity in soil, classification of microorganisms in different types of soil (ii) structure and development of microbial community in soil, factors affecting microbial community (influence of C and N, inhibitors and stimulators, influence of physical factors) (iii) techniques for studying fungi and bacteria (methods for culturing, isolation and identification) (iv) microbial role in biogeochemical cycling (carbon, nitrogen and sulphur cycles), effective microbes on soil nutrient dynamics (v) plant-soil microbe interaction, pathogenic and beneficial fungi/microbes associated in governing forest and agriculture ecosystems, biodegradation of soil organic matter and crop residue (vi) Plant growth promoting fungi/microbes and their application, microbial toxins in soil (vii) significance of microbes in wood decaying and litter decomposition, (viii) microbial/fungal allelopathy and its significance, impact of invasive plants and weeds on soil fungi/microbes in forest and agriculture ecosystems (ix) climate change impacts on microbial activities. [**18 h** (2+3+2+1+2+3+1+2+2)].

**Unit 3. Industrial mycology:** (i) Fermentation and microbial products: types, techniques and processes of fermentation; production of food, alcohol, organic acids, vitamins, antibiotics, toxins and enzymes, single cell protein, biofuels; secondary metabolites (fungal enzymes) and their industrial significance; (ii) Composting and bio-fertilizers: process and techniques of compost preparation and green manuring; process and techniques of biofertilizers, biopesticides and plantonics. [**9 h** (5+4)].

**Unit 4. Mushrooms cultivation:** (i) Overview of tools and techniques of mushroom cultivation: spawn preparation and extraction method of bio-active components of mushrooms (*Ganoderma*, *Lentinus*, *Grifolia*, *Termitomyces*, *Cordyceps* and *Morchella*). (ii) Mushroom disease management: mushroom disease symptoms and management: viral (La France disease), bacterial (wet spot, bacterial blotch and fungal diseases (green mold, blue green molds, black molds, dry bubbles, wet bubbles, cow-web molds, red bread molds), insect pests (slug, sciarid fly, cecid fly, mites), nematodes; (iii) Post harvest technology: short-term preservation (washing, packaging, conventional packing, storage of fresh mushrooms, transportation, steeping preservation), long-term preservation (canning, drying and pickle preparation). [12 h (5+5+2)].

**Course title:** Applied Mycology

**Course No.:** BOT 624

**Nature of course:** Practical

**Level:** MSc, III Semester

**Full marks:** 25

**Pass marks:** 12.5

**Credits:** 1

**Credit hours:** 16 × 4

### List of practical

1. Isolation of soil microbes from rhizosphere and phyllosphere by serial dilution method
2. Isolation of economically important microbes (root nodule bacteria, *Trichoderma*)
3. Alcohol fermentation (preparation of wine)
4. Isolation, culture, staining and estimation of mycorrhizae
5. Determination of soil microbial biomass.
6. Estimation of sugars, proteins and amino acids in fungal mycelium and culture filtrate.
7. Cultivation of different mushrooms as prescribed in the theory.
8. Preparation of compost, biofertilizer (root nodule bacteria) and biopesticide
9. Isolation and pure culture of mushroom strains.
10. Preparation of mushroom spawn.
11. Study of mushrooms pathogens.

### Text and reference books

Agrios, G.N. 1999. *Plant Pathology*. Academic Press

*Annual Review of Phytopathology*, 1999. Vol. 37, APS Press

Cairney, J.W.G. & Chambers, S.M. 1999. *Ectomycorrhizal Fungi*. Springer Publishers

Chandanwala, K. 1986. *Introduction to Plant Pathology*. Ammol Publishers and Distributors

Cheet, I. 1993. *Biotechnology in Plant Disease Control*. Wilen-Liss, Inc.

Dennis Allsopp and Seal, K.J. 1986. *Introduction to Biodeterioration*. E Edward Arnold Ltd.

Dix, N. J. (ed.). 2012. *Fungal Ecology*. Springer Science & Business Media.

Dix, N. J., & Webster, J. 1995. Colonization and decay of wood. In *Fungal Ecology* (pp. 145-171). Springer Netherlands.

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Ignacimuthu, S.J. 1996. *Applied Plant Biotechnology*. Tata McGraw–Hill Publ. Company Ltd.

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- Miles, P.G. and Chang, S.T. 1997. *Mushroom Biology*. World Scientific Publ. Company
- Natish, S. Chopra, V.L. & Ramachandra, S. 1994. *Biotechnology in Agriculture*. Oxford and IBH
- Rajak, R. 2000. *Microbial Biotechnology for Sustainable Development and Productivity*. Scientific pub
- Roberts, S. Fritz & Eilen. I. Simms. 1992. *Plant Resistance to Herbivores and Pathogens* (Ecology, Evolution and Genetics). University of Chicago Press.
- Rudra P. Singh, Uma S. Singh & Keisuke Kohmoto (eds.) 1995. *Pathogenesis and Host Specificity in Plant Diseases*. Vol. III. Pergamon Press.
- Scheffer, R.P. 199. *The Nature of Disease in Plants*. Cambridge University Press.
- Tarr, S.A.J. . 1987. *Principles of Plant Pathology*. Academic Press
- Verma, A & Hock, B. 1999. *Mycorrhizae*. Springer Publishers



## Advanced Plant Pathology

**Course title:** Advanced Plant Pathology

**Course No.:** BOT 625

**Nature of course:** Theory

**Level:** MSc, III Semester

**Full marks:** 75

**Pass marks:** 37.5

**Credits:** 3

**Credit hours:** 48

### Objectives

The general aim of this course is to provide theoretical and practical knowledge on plant pathology. The specific objectives are to: (i) develop understanding on general aspects of plant pathology and factors affecting plant diseases; (ii) elaborate knowledge on agriculture and forest pathology; and (iii) impart knowledge on integrated pest management.

### Course content

**Unit 1. General aspect of plant pathology:** (i) History of plant pathology; concept of pest, pathogen and weeds; nature and concept of plant diseases, classification of plant disease (ii) factors affecting plant diseases (temperature, light, moisture, wind, host plant nutrition, soil pH and soil structure) (iii) disease dissemination (through air, water, pollen, seed, animals, transplants and other vectors) (iv) plant disease clinic, climate change relation to crop disease development and weed and pest infestation. [**6 h** (3+1+1+1)].

**Unit 2. Pathogenesis, physiology of diseased plant and defense mechanism:** (i) Koch's postulate; process of disease development: specificity, recognition, pre-penetration; direct penetration and entry by pathogens through other routes (natural openings, wounds, root hairs, buds), pathogen development inside host tissue; plant disease forecasting. (ii) Molecular basis of host pathogen interaction, enzymes and toxin in plant disease (classification of enzymes and toxins). (iii) Physiology of diseased plants. (iv) Biotic stress and defense mechanism in plants (morphological and structural defense, biochemical defense, synthesis of proteins and enzymes, toxin detoxification, altered respiration and hypersensitive reaction); abiotic stresses (heat and chilling stress, water and salt stress) in plants, resistance and ways to overcome stress effects. [**10 h** (3+1+2+4)].

**Unit 3. Agriculture pathology – symptoms, etiology and control of crop diseases:** (i) Cereal crops: rice (brown spot; foot rot; false smut and viral diseases); wheat (brown and yellow rust; flag smut; burnt; foot rot; powdery mildew; tundra and yellow); maize (head smut and rust). (ii) Cash crops: tea (blister blight, die back and brown blight); coffee (red blister, red root rot, rust disease); cardamom (chirkey diseases, foorkey disease and leaf blight). (iii) Vegetable crops: potato (early and late blight, brown rot, ring rot, potato leaf roll of virus, mild mosaic of potato); tomato (early and late blight); crucifers (club root of crucifers). (iv) Fruit plants: banana (leaf spot, bunchy top); mango (powdery mildew, die back, anthracnose, blotch); apple (*Alternaria* rot; Bull's eyes rot; apple scab); citrus (greening and gummosis). (v) Weed and pest infestation in agriculture, impacts and control measures. [**11 h** (3+2+3+2+1)].

**Unit 4. Forest pathology:** (i) Introduction and significance. (ii) Host, causal agents, symptoms and control measures of forest diseases: damping off; pine blister rust; *Atropellis* cankers of pine; die back and wilt disease, *Fomes* root rot and butt rot; leaf spot; tar spot; powdery mildew; concept of rot disease (white rot, brown rot, soft rot and bacterial rot). (iii) Pest infestation in forests: alien invasive pests in Nepalese forests, their impacts and control measures (application of biopesticides). [**8 h** (1+4+2+1)].

**Unit V. Applied tools for disease management:** (i) Tools for plant disease diagnosis: substrate metabolism, FAME analysis, protein analysis, ELISA, and PCR techniques. (ii) Control and management of plant diseases: cultural methods (pathogen avoidance, exclusion of inoculums and eradication of pathogens); physical methods (heat treatment, refrigeration and radiation); chemical methods (protectants, eradicans, therapeutants, inorganic and organic fungicides, antibiotics, fumigants and oils, and biocides (nomenclature and formulations, methodology of pesticide/fungicide/weedicide application, safeners; spreaders and stickers, pesticide resistance management, pesticide act in Nepal); Biological methods (suppressive soils, fungal and bacterial antagonists, biopesticides (essential oils, microorganisms and plant extract), improvement of biological control agents. (iii) Breeding for disease resistance: introduction, selection, hybridization, back cross, reversal dominance, modifier genes, extrachromosomal inheritance and other gene interaction; application of biotechnology for development of target specific pesticides; integrated pest management (IPM: principles, strategies and method). [13 h (3+5+5)].

<b>Course title:</b> <u>Advanced Plant Pathology</u>	<b>Full marks:</b> 25
<b>Course No.:</b> BOT 626	<b>Pass marks:</b> 12.5
<b>Nature of course:</b> Practical	<b>Credits:</b> 1
<b>Level:</b> MSc, III Semester	<b>Credit hours:</b> 16 × 4

### List of practical

1. Symptomatology of crop and forest diseases (herbarium and field study).
2. Microscopic study of plant diseases (slide preparation and study of pathogens).
3. Demonstrate Kitchin's postulate.
4. Isolation, culture, subculture and identification of available plant diseases (crop and forest).
5. Study of viability of fungal spores.
6. Fungal characteristics in pure colonies (physico-chemical approach).
7. Measurement of fungal spores by the use of ocular micrometer.
8. Photography of fungal vegetative and reproductive parts through digital microscope.
9. Demonstration of induction of wilting by *Fusarium* toxins
10. Abiotic stress effect on plant growth and development.
11. Extraction of essential oil from selected aromatic plants.
12. A mini field project to study crop diseases from field and market specimens.

### Text and reference books

- Agrios, G.N. 2005. *Plant Pathology*, 5th ed. Elsevier Academic Press, London.
- Aneja, K.R. 2003. *Experiments in Microbiology, Plant Pathology and Biotechnology*, 4th ed. New Age International Publishers, New Delhi.
- Barnett, H.L. 1972. *Illustrated Genera of Imperfect Fungi*, 4th ed. Burgess Publishing Co. Ltd., Minneapolis.
- Bilgrami, K.S. & R.S. Verma. 1948. *Physiology of Fungi*. Vikas Publishing House Pvt. Ltd., New Delhi.
- Booth, C. 1971. *Methods in Microbiology*, vol IV. Academic Press Inc. (London) Ltd., London.
- Dickinson, M. 2003. *Molecular Plant Pathology*. BIOS Scientific Publishers, Oxford.
- Fry, W.E. 1982. *Principles of Plant Disease Management*. Academic Press, New York

- Gilman, J.C. 1957. *A Manual of Soil Fungi*, 2nd ed. Iowa State College Press, Iowa.
- Gupta, G.P. 2004. *Plant Pathology*. Discovery Publishing House, New Delhi.
- Horsfall, J. G. & A. E. Diamond. 1959. *Plant Pathology: An Advanced Treatise*, Vol. I-III. Academic Press, New York.
- Lucas, G.B., C.L. Campbell and L.T. Lucas. 2001. *Introduction to Plant Diseases: Identification and Management*, 2nd ed. Kluwer Academic Publishers, Massachusetts.
- Lucas, J.N. 2002. *Plant Pathology and Plant Pathogens*, 3rd ed. Blackwell Science Ltd., Malden.
- Manners, J.G. 1993. *Principles of Plant Pathology*. University Press, Cambridge.
- Mehrotra, R.S. 2003. *Plant Pathology*. Tata McGraw-Hill Publishing Co. Ltd., New Delhi.
- Miles, P.G. & S.T. Chang. 2004. *Mushroom: Cultivation, Nutritional Value, Medicinal Effects and Environmental Impacts*. CRC Press, Florida.
- Negi, S. S. 1996. *An Introduction to Forest Pathology*. International Books Distributors, Dehradun.
- Parry, D.W. 1990. *Plant Pathology in Agriculture*. University Press, Cambridge.
- Rangaswami, R.S. 2005. *Diseases of Crop Plants of India*. Prentice Hall of India Pvt. Ltd., New Delhi.
- Sambamurty, A.V.S.S. 2006. *Text Book of Plant Pathology*. I.K. International Pvt. Ltd., New Delhi.
- Sharma, P. D. 1997. *Plant Pathology*. Rastogy Publications, New Delhi.
- Singh, R.S. 1978. *Introduction to Principles of Plant Pathology*. Oxford & IBH Pub. Co. Ltd., New Delhi.
- Strange, R.N. 2003. *Introduction to Plant Pathology*. John Wiley & Sons, New York.
- Tar, S. A. J. 1972. *The Principle of Plant Pathology*. McMillan Press, London.
- Trigiano, R.N., M.T. Windham and A.S. Windham. 2008. *Plant pathology: Concepts and Laboratory Exercises*. CRC Press, Florida.

## APPLIED PAPER [any one of the following] (4 credits)

### Natural Resources Management

<b>Course title:</b> <u>Natural Resources Management</u>	<b>Full marks:</b> 75
<b>Course No.:</b> BOT 631	<b>Pass marks:</b> 37.5
<b>Nature of course:</b> Theory	<b>Credits:</b> 3
<b>Level:</b> MSc, III Semester	<b>Credit hours:</b> 48

#### Objectives

The general objective is to provide an understanding of the multiple uses of natural resources and their management. The specific objectives are to (i) make the students familiar with comprehensive resource planning, resource management and conservation and environmental and socio-economic impacts of natural resources, and (ii) develop among the students an ability to evaluate the environmental effects of resource exploitation

#### Course content

##### Unit 1. Natural resources (30 h)

- Soil and water resources:* (i) Soil: the base of life, soil formation, soil structure and classification, soil nutrients and their management; soil types of Nepal, soil fertility; soil degradation; soil erosion; soil conservation; Mineral resources of Nepal. (ii) Water resource: source (surface and ground water); global supply and demand; methods of water conservation; watershed management approaches; water resources of Nepal. [**10 h** (5+5)].
- Energy resources:* Types and use; fossil fuels (oil, natural gas, coal); alternative energy (nuclear, hydro-energy, solar, biomass, geothermal); energy efficiency and conservation; energy use pattern in Nepal; energy use pattern and climate change. [**5 h**].
- Food resources:* Plant based food resources (global and national); world food situation and food security; factors affecting food production; industrialized food production; organic agriculture and sustainability. [**5 h**].
- Biodiversity resources:* (i) Status and distribution of biodiversity (national and global); (ii) Ecosystem function of biodiversity (including diversity-stability debate); (iii) Loss of biodiversity (trends, causes, and consequences); biodiversity hotspots; IUCN threat categories; rare and endangered plants and animals of Nepal; (iv) Strategy for biodiversity conservation (detail account of *in situ* and *ex situ* conservation); (v) Economics of biodiversity conservation. [**10 h** (1+1+4+3+1)].

##### Unit 2. Conservation and management of Natural Resources (18 h)

- Conservation policies:* (i) Social and cultural perspectives on Natural Resource Management (NRM), natural resources and knowledge systems for management: indigenous, traditional, and scientific; (ii) Environmental policies: environmental conventions; environmental legislation; environmental organizations; environmental education. [**8 h** (3+5)].
- Environmental impact assessment (EIA):* (i) Concept and principles; EIA requirements and administrative procedures (baseline information, screening, scoping and TOR); (ii) EIA process: identification, prediction and evaluation of impacts; evaluation and comparison of alternatives;

mitigation measures; monitoring; auditing; compliance and enforcements; role of civil society; EIA guidelines for Nepal; drafting EIA reports. [10 h (4+6)].

**Course title:** Natural Resources Management

**Course No.:** BOT 632

**Nature of course:** Practical

**Level:** MSc, III Semester

**Full marks:** 25

**Pass marks:** 12.5

**Credits:** 1

**Credit hours:** 16 × 4

### Course content

1. To determine bulk density of soil samples from different land uses.
2. To determine humus content of soils from different land uses.  
by De-Sigmoid's method.
3. To determine soil carbonates and bicarbonates of soil samples from different land uses.
4. To determine CO<sub>2</sub> released from soil microbial activity.
5. To determine free CO<sub>2</sub> present in different water samples.
6. To determine acidity of different water samples.
7. To determine alkalinity of different water samples.
8. To determine potability of drinking water.
9. To perform phytochemical screening of medicinal plants.
10. To prepare and submit Environmental Impact Assessment (EIA) report of developmental project.
11. Term Paper and Seminar
12. Report/Mini Dissertation

### Text and references

- Baland J.-M. and Platteau J.-P. 1996. *Halting Degradation of Natural Resources: Is there a Role for Rural Communities?*. Food and Agriculture Organization of the United Nations and Clarendon Press, Oxford.
- Brady N.C. and Weil R.C. 2002. *The Nature and Properties of Soil*. Pearson Education Inc. and Dorling Kindersley Publishing, Inc. India.
- Chaudhary R.P. 1998. *Biodiversity in Nepal - Status and Conservation*. S. Devi, Saharanpur, India & Tecpress Books, Bangkok, Thailand.
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- Huston M.A. 1994. *Biological Diversity: The Coexistence of Species on Changing Landscapes*. Cambridge University Press.
- Jha P.K., Karmacharya S.B., Balla M.K., Chettri M.K. and Shrestha B.B., eds. 2010. *Sustainable Use of Biological Resources*. Ecological Society (ECOS), Kathmandu, Nepal.
- Jha P.K., Karmacharya S.B., Chettri M.K., Thapa C.B. and Shrestha B.B., eds. 2008. *Medicinal Plants in Nepal: The Anthology of Contemporary Research*. Ecological Society (ECOS), Kathmandu, Nepal.
- Jha S. 1990. *Conservation for Development in Nepal*. National Book Organization, Dew Delhi,
- Jonathan C. 2007. *Climate Change*. Cambridge University Press, Cambridge.

- Lekhak H.D. and Lekhak B. 2009. *Natural Resource Conservation and Sustainable Development in Nepal*. Kshitiz Publication, Kathmandu, Nepal.
- McCann K.S. 2000. The diversity stability debate. *Nature* 405: 228-233
- Miller G.T. 1997. *Environmental Sciences*. Wardsworth Publishing Company, USA.
- Miller G.T. 2002. *Living in the Environment*. Wardsworth Publishing Company, Inc. USA.
- Pickett S.T.A., Ostfeld R.S., Shachak M. and Likens G.E., eds. *The Ecological Basis of Conservation: Heterogeneity, Ecosystems, and Biodiversity*. Chapman and Hall.
- Ramakrishnan P.S. 2001. *Ecology and Sustainable Development*. National Book Trust, India.
- Savory A. 1988. *Holistic Resource Management*. Island Press, California, USA.
- Sharma B.K. 2014. *Bioresources of Nepal*. Subidhya Sharma, Kathmandu, Nepal.
- Singh J.S., Singh S.P. and Gupta S.R. 2006. *Ecology, Environment and Resource Conservation*. Anamaya Publishers, New Delhi.
- Waltner-Toews D. 2004. *Ecosystem Sustainability and Health*. Cambridge University Press, Cambridge.
- WCMC (World Conservation Monitoring Centre). 1992. *Global Biodiversity: Status of the Earth's Living Resources*. Chapman & Hall, London.
- Wilson E.O. 1988. *Biodiversity*. National Academic Press, Washington, D.C.

## Plant Conservation Biology

<b>Course title:</b> Plant Conservation Biology	<b>Full marks:</b> 75
<b>Course No.:</b> BOT 633	<b>Pass marks:</b> 37.5
<b>Nature of course:</b> Theory	<b>Credits:</b> 3
<b>Level:</b> MSc, III Semester	<b>Credit hours:</b> 48

### Objectives

The overall aim of this course is to provide critical understanding of conservation biology science, and the processes and approaches of biodiversity conservation and management.

### Course content

**Unit 1. Science of conservation biology:** Introduction and definitions, goals, history, philosophical roots, ethical and guiding principles, tools and approaches. [2 h].

**Unit 2. Biodiversity:** (i) components and levels, overview of patterns and processes of biodiversity distribution and their determinants. (ii) Current status of biodiversity, biodiversity hotspots, valuing biodiversity. [5 h (2+3)].

**Unit 3. Threats and extinctions:** (i) Overview of the drivers of biodiversity loss/extinction. (ii) Extinction: types, processes and rates of extinction, prediction of extinction rates, vulnerability to extinction (factors responsible for high extinction risk). (iii) Endemism: introduction, types of endemism, global pattern of endemism, endemism in the Himalaya. (iv) Rarity: concept and models of rarity, causes of rarity. (v) Threat assessments and priority setting: methods and approaches (IUCN threat categories, CAMP method, RVA method). [11 h (2+3+2+1+3)].

**Unit 4. Conservation biology of small populations:** (i) Population concept, causes and problems of small populations. (ii) Extinction forces and consequences: deterministic and stochastic forces; extinction vortices, minimum viable population and effective population size. (iii) Conservation approaches at population level: overview of *In-situ* and *ex-situ* conservation, solutions to small population problems. (iv) Demographic and genetic approaches: population modeling and predictions, population viability analysis (PVA), metapopulation approach, conservation genetics. [11 h (1+2+2+6)].

**Unit 5. Conservation approaches at ecosystem and landscape levels:** (i) Ecosystem-level approaches: ecosystem resilience and stability, protected area (PA) systems (introduction, history, categories, importance, management planning), ecosystem approach as a conceptual framework. (ii) Shifting in the conservation paradigm (SLOSS debate), conservation outside PAs, ecological restoration. (iii) Landscape-level approaches: landscape ecology and spatial heterogeneity, corridors, landscape-based conservation (with reference to Nepal), trans-boundary conservation. (iv) Conservation instruments: laws, strategies, action plans, international conservation agreements. [12 h (4+2+4+2)].

**Unit 6. Local society, TEK and biodiversity conservation:** (i) Introduction and definitions, theoretical advancement, principles and assumptions, major components. (ii) TEK and biodiversity conservation: traditional resource management (TRM) system (with reference to Nepal), community institutions and conservation practices, application of integrating TEK in biodiversity assessment and conservation planning. (iii) Sustainable production and harvest of biological resources: concept, approaches and practices with reference to medicinal and aromatic plants and other NTFPs. [7 h (3+2+2)].

**Course title:** Plant Conservation Biology**Course No.:** BOT 634**Nature of course:** Practical**Level:** MSc, III Semester**Full marks:** 25**Pass marks:** 12.5**Credits:** 1**Credit hours:** 16 × 4

## Objectives

The overall aim of this course is to provide practical and analytical knowledge related to the principles and approaches of biodiversity conservation.

## Course content

### 1. Biodiversity conservation: setting priority for action

1.1 Threat value and vulnerability indices

### 2. Population-level study

2.1 Population size and structure

2.2 Population modelling and analysis of population dynamics and viability/extinction risks through population models using secondary data

### 3. Project work (field-based study)

#### a. Ecosystem- and landscape-level studies

3.1 Assessment of habitat/landscape heterogeneity and status of biodiversity

3.2 Identification of important plant areas

3.3 Observe conservation action and review operation/management plan of a protected area or a community forest.

#### b. Participatory research for TEK and TRM

3.4 Documentation of TEK (structural, relational and utilitarian aspect) in relation to plant diversity

3.5 Traditional traditional resource management system (institutions and management practices)

3.6 Post field study: field data analysis and writing report/mini dissertation

### 4. Term paper and seminar

## Text and reference books

Akçakaya H.R., Burgman M.A. and Ginzburg L.R. 1999. *Applied Population Ecology*. Sinauer Associates, Inc. Sunderland, MA, USA.

Primack R.B. 2014. *Essentials of Conservation Biology*. Sixth Edition. Sinauer Associates, Inc. Publishers, Sunderland, MA, USA.

## Suggested Further Readings

Baland J.-M. and Platteau J.-P. 1996. *Halting Degradation of Natural Resources: Is there a Role for Rural Communities?*. Food and Agriculture Organization of the United Nations and Clarendon Press, Oxford.

Burroughs W.J. 2001. *Climate Change: A Multidisciplinary Approach*. Cambridge University Press.



- Cunningham A.B. 2001. *Applied Ethnobotany: People, Wild Plant Use and Conservation*. Earthscan, London, UK.
- Eiedler L.P. and Jain S.K., eds. 1992. *Conservation Biology: The Theory and Practice of Nature Conservation, Preservation and Management*. Chapman and Hall, NY, USA.
- Frankham R., Ballou J.D., Briscoe D.A. and McInnes K.H. 2002. *Introduction to Conservation Genetics*. Cambridge University Press
- Ghimire S.K. 2008. Medicinal plants in the Nepal Himalaya: Current issues, sustainable harvesting, knowledge gaps and research priorities. In: *Medicinal Plants in Nepal: The Anthology of Contemporary Research*. (P.K. Jha, S.B. Karmacharya, M.K. Chettri, C.B. Thapa and B.B. Shrestha, eds.), pp. 25-42. Ecological Society (ECOS), Kathmandu, Nepal.
- Ghimire S.K., Sapkota I.B., Oli B.R. and Parajuli R.R. 2008. *Non-Timber Forest Products of Nepal Himalaya: Database of Some Important Species Found in the Mountain Protected Areas and Surrounding Regions*. WWF Nepal, Kathmandu.
- GoN 2014. *Nepal National Biodiversity Strategy and Action Plan 2014-2020*. Government of Nepal Ministry of Forests and Soil Conservation, Kathmandu, Nepal.
- Groom M.J., Meffe G.K., and Carroll C.R. 2005. *Principles of Conservation Biology*, 3<sup>rd</sup> edition. Sinauer Associates Inc., USA.
- Halladay P. and Gilmour D.A., eds. 1995. *Conserving Biodiversity Outside Protected Areas*. IUCN.
- Hamilton A. and Hamilton P. 2006. *Plant Conservation: An Ecosystem Approach*. Earthscan, London, UK.
- Hubel S.P. 2001. *The Unified Neutral Theory of Biodiversity and Biogeography*. Princeton University Press, Princeton and Oxford.
- Hunter M.L. and Gibbs J.P. 2007. *Fundamentals of Conservation Biology*. Blackwell Publishing Ltd.
- Krebs C.J. 2001. *Ecology: the Experimental Analysis of Distribution and Abundance*. Fourth Edition. Addison-Wesley Educational Publishers, Inc., USA. (Fifth edition).
- Laird S., ed. 2002. *Biodiversity and Traditional Knowledge: Equitable Partnerships in Practice*. Earthscan, London, UK.
- Lomolino, M.V., Riddle, B.R. and Brown, J.H. 2006. *Biogeography*. Sinauer Associates, Inc. Massachusetts, USA (Third edition).
- Martin G.J. 1995. *Ethnobotany: A Methods Manual*. Chapman & Hall, London, UK.
- Pickett S.T.A., Ostfeld R.S., Shachak M. and Likens G.E., eds. *The Ecological Basis of Conservation: Heterogeneity, Ecosystems, and Biodiversity*. Chapman and Hall.
- Primark R.B., Paudel P.K. and Bhattarai B.P. 2013. *Conservation Biology: A Primer for Nepal*. Dreamland Publication Pvt. Ltd., Kathmandu, Nepal.
- Ramakrishnan P.S., Chandrashekhara U.M., Elouard C., Guilamoto C.Z., Maikhuri R.K., Rao K.S., Sankar S. and Saxena K.G. 2000. Mountain Biodiversity, Land Use Dynamics, and Traditional Ecological Knowledge. UNESCO.
- Savory A. 1988. *Holistic Resource Management*. Island Press, California, USA.
- Silvertown J. 1987. *Introduction to Plant Population Ecology*. Second Edition. Longman Scientific & Technical, UK.
- Soulé M.E. and Wilcox B.A., eds. 1980. *Conservation Biology: An Evolutionary-Ecological Perspectives*. Sinauer Associates, USA.
- Soulé M.E., ed. 1986. *Conservation Biology: The Science of Scarcity and Diversity*. Sinauer Associates, USA.
- Tandon V., Bhattarai N.K. and Karki M., eds. 2001. *Conservation Assessment and Management Prioritization (CAMP) Report*. IDRC Canada/HMG Ministry of Forest and Soil Conservation, Kathmandu, Nepal.
- Turner M.G., Gardner R.H. and O'Neill R.V. 2001. *Landscape Ecology: In Theory and Practice*. Springer-Verlag New York, USA.
- Whittaker, R.J. and Fernández-Palacios, J.M. 2007. *Island Biogeography: Ecology, Evolution, and Conservation*, 2nd edn. Oxford University Press, Oxford.

Zimmerer K.S. and Young K.R. 1998. *Nature's Geography: New Lessons for Conservation in Developing Countries*. The University of Wisconsin Press, Wisconsin, USA.

### **Important journals (selected)**

- *Biodiversity and Conservation*
- *Biological Conservation*
- *Biotropica*
- *Conservation and Society*
- *Conservation Biology*
- *Ecology and Society*
- *Global Change Biology*
- *Journal of Applied Ecology*
- *The Journal of Wildlife Management*

## Molecular Biology

**Course title:** Molecular Biology

**Course No.:** BOT 635

**Nature of course:** Theory

**Level:** MSc, III Semester

**Full marks:** 75

**Pass marks:** 37.5

**Credits:** 3

**Credit hours:** 48

### Objectives

The main objectives of this course is to enable students to (i) describe the structure and organization of nucleic acids and their roles in living systems, (ii) explain the transfer of information within the cell and between the cell generations, (iii) explain the mechanism of regulation of gene expression inside a cell, and (iv) explain the synthesis, transport and roles of proteins within the cell.

### Course content

**Unit 1. Structure of genetic material at the molecular level:** Nucleic acids: chemical and physical properties, molecular structure of eukaryotic chromosome; heterochromatin and euchromatin, satellite DNAs, nucleolar gene, repeated DNA sequence, mobile DNA. [7 h (2+1+1+1+2)].

**Unit 2. Gene expression:** Overview of gene expression in prokaryotes and eukaryotes; transcription and synthesis of different RNAs, processing of RNA transcript. Catalytic RNA, RNA splicing and Spliceosome. Transport of RNA through nuclear pore, translation and polypeptide synthesis, post-translational modification. Protein trafficking and degradation. Antibiotics and inhibition of protein synthesis. [10 h (3+2+3+1+1)].

**Unit 3. Regulation of gene expression:** Control of protein synthesis in prokaryotes and eukaryotes- an overview. Role of promoter; TBP (TATA-binding proteins) structure/functions, TAFs (TBP-associated factors) structure and functions. Control in transcription level: structure and function of transcriptional activators and repressors. Signal transduction and the control of transcriptional regulators, RNA processing, RNA degradation; antisense RNA. Gene silencing, Gene regulation during development. [12 h (1+3+2+4+2)].

**Unit 4. Molecular cytogenetics:** Nuclear DNA content, C-value paradox, Cot curve and its significance. Restriction mapping: concept and techniques. Multigene families and their evolution. In situ hybridization and techniques. Chromosomes micro-dissection and micro-cloning, Flow cytometry, confocal microscopy and karyotype analysis. [10 h (2+1+2+1+4)].

**Unit 5. Evolution of genome:** Biological diversity, Genome evolution and genomes of higher organisms, Genome projects: Human genome project and other genome projects, Sequencing of Genome, application of genome sequencing; comparative genome analysis and its application. [9 h].

<b>Course title:</b> <u>Molecular Biology</u>	<b>Full marks:</b> 25
<b>Course No.:</b> BOT 636	<b>Pass marks:</b> 12.5
<b>Nature of course:</b> Practical	<b>Credits:</b> 1
<b>Level:</b> MSc, III Semester	<b>Credit hours:</b> 16 × 4

### Course content

1. Laboratory safety
2. Isolation and purification of plasmid DNA from bacteria
3. Quantitative estimation of nucleic acid concentration and purity by spectrophotometer
4. Isolation of genomic DNA from bacteria
5. Restriction digestion and agarose gel-electrophoresis, and construction of restriction maps
6. Isolation of eukaryotic DNA from plants
7. Extraction of DNA fragment from gel
8. Isolation of RNA
9. Separation of RNA by formaldehyde agarose gel-electrophoresis.
10. Isolation of mRNA
11. *In vitro* amplification of DNA by polymerase chain reaction and agarose gel-electrophoresis of the amplified product.
12. Isolation of protein from plant tissues
13. Separation of protein by polyacrylamide gel-electrophoresis
14. Protein band recognition by coomassie blue or silver staining.

### Text and reference books

- Alberts B., Lewis J., Raff M., Johnson A. and Roberts K. 2004. *Molecular Biology of Cell*. Garland Publishing Inc.
- Ausubel F.M., Brent R., Kingston R.E., Moore D.D., Seidman J.G., Smith J.A. and Struhl K. 2002. *Short Protocols in Molecular Biology*. Wiley.
- Campbell N.A. and Reece J.B. 2002. *Biology*. Pearson Education/Benjamin Cummings.
- Dale J.W. and Park S.F. 2010. *Molecular Genetics of Bacteria*. 5th edition. Wiley -Blackwell.
- Glick B.R. and Pasternak J.J. (recent edition). *Molecular Biotechnology*. American Society of Microbiology press.
- Grierson D. and Covey S.N. 1988. *Plant Molecular Biology*. Springer Science Business Media, New York.
- Griffiths A.J.F., Gelbart W.M., Miller J.H. and Lewontin R.C. 2002. *Modern Genetic Analysis*. Freeman.
- Griffiths A.J.F., Gelbart W.M., Lewontin R.C., Wessler S.R., Suzuki D.T. and Miller J.H. 2004. *An Introduction to Genetic Analysis*. Freeman.
- Lehninger A.L., Nelson D.L. and Cox M.M. 2000. *Principles of Biochemistry*. Worth Publishers, USA or CBS, India.
- Lodish H., Berk A., Zipursky S.L., Matsudaira P., Baltimore D. and Darnell J. 2004. *Molecular Cell Biology*. Freeman.
- Sambrook J. and Russel D. 2001. *Molecular Cloning: A laboratory Manual*. CHSL Press.
- Stryer L. (recent edition). *Biochemistry*. Freeman and Co.
- Trun N. and Trempy J. 2004. *Fundamentals of Bacterial Genetics*. Blackwell.
- Turner P.C., McLennan A.G., Bates A.D. and White M.R.H. 2007. *Instant Notes Molecular Biology*. Taylor and Francis
- Watson J.D., Baker T.A., Bell S.P., Gann A., Levine M. and Losick R. 2004. *Molecular Biology of the Gene*. Pearson Education, Inc.

## Food Security and Safety

<b>Course title:</b> Food Security and Safety	<b>Full marks:</b> 75
<b>Course No.:</b> BOT 637	<b>Pass marks:</b> 37.5
<b>Nature of course:</b> Theory	<b>Credits:</b> 3
<b>Level:</b> MSc, III Semester	<b>Credit hours:</b> 48

### Objectives

The general aim of this course is to provide theoretical and practical knowledge on food security and safety. The specific objectives are to (i) develop understanding on food security concept, policy and programs; (ii) elaborate knowledge on food safety issue and strategies; and (iii) impart knowledge on food storage, post harvest management and plant quarantine.

### Course content

**Unit 1. Food security:** (i) *Introduction:* concept and definition, conceptual framework of food security, key factors of food security, global; national; household and individual food and nutritional security, micro-economic analysis of food security, threats to food security; (ii) *Food aid policy and program:* concept and history, domestic and international food assistance policy and programs; mechanism to promote food security (economic and livelihood aspects); (iii) *Agriculture and forest for food security:* farming system, modern agriculture, green revolution and GM crops, sustainable agriculture and wild edible plants, undervalued and marginalized crops; food sovereignty, food governance, sustainable development and food security; food security scenario in the different agro-ecological zones in Nepal. [12 h (4+4+4)].

**Unit 2. Food safety:** (i) *Food illness:* concept and history of food safety, unsafe sources, inadequate cooking, improper holding temperature, contaminated processing equipments, hygiene; (ii) *Food hazards:* food borne infectious and microbiological agents, pesticide residues, misuse of food additives, chemical contaminants including biological and food adulteration; environmental and health implication of food hazards, GM crops and food safety concern, (iii) *Food protection:* principles of food processing and preservation, concept of food protection, hygiene, reduce microbial contamination and control growth (physical, chemical and biological methods), control chemical agents and toxins, food education and trainings. [12 h (3+4+5)].

**Unit 3. Seed protection for food security and safety:** (i) concept and history of seed protection, seed pathogens (bacterial, fungal and viral); (ii) method of detection of seed pathogens (examination without incubation: dry seeds, after softening, seed washing; incubation methods: blotter method, rolled paper towel method, 2,4-D method, deep-freezing method, agar plate method) (iii) seedling symptom test (Hiltner's brick stone method, sand method, standard soil method, test tube agar method); (iv) control of seed-borne pathogen; role of micro-organisms in seed quality and storage; seed certification; seed Act and regulation in Nepal. [12 h (1+5+3+3)].

**Unit 4. Plant quarantines:** (i) History, definition, certification, intra and inter-state movement of disease materials (ii) plant quarantine station and their function in Nepal, plant quarantine Act and Regulation of Nepal. [3 h (1+2)].

**Unit 5. Post harvest management and safety:** (i) concept of post harvest loss, post-harvest management technology and strategies, post harvest changes in seed and tubers biochemical

constituent's quality, effect of environmental factors on post harvest changes in seed and tubers. (ii) Biotechnological approaches to manipulate ethylene biosynthesis and action, alternate post-harvest methodology and quality attributes, scope for genetic modification of post-harvest life of flowers and fruits (iii) losses caused by plant diseases: reduction in quantity and quality of plant produce (iv) toxicity to humans and animals (v) bioterrorism, agro-terrorism, biological warfare (vi) traditional agricultural practices and agro-biodiversity in the management of plant diseases. [9 h (2+2+2+1+1+1)].

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**Course title:** Food Security and Safety

**Full marks:** 25

**Course No.:** BOT 638

**Pass marks:** 12.5

**Nature of course:** Practical

**Credits:** 1

**Level:** MSc, III Semester

**Credit hours:** 16 × 4

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### Course content

1. Study of food security (field based) in nearby community.
2. Analysis of food security data (data obtained from different sources in Nepal).
3. Isolation and identification of microbes in different food stuffs.
4. Experiment on seed viability test of selected crops.
5. Study of seed-borne fungi by standard method.
6. Control of seed-borne pathogens by fungicide.
7. Isolation and identification of microbes in different food stuffs.
8. Survey on post harvest management practices
9. Survey on people's perception on impacts of climate change on food safety and security

### Books and references

Agrios, G.N. 2005. *Plant Pathology*. 5th ed. Elsevier Academic Press, London.

Aneja, K.R. 2003. *Experiments in Microbiology, Plant Pathology and Biotechnology*. 4th ed. New Age International Publishers, New Delhi.

Asian Development Bank. 2012. *Agriculture, Food security and Rural Development*. Oxford University Press.

Dickinson, M. 2003. *Molecular Plant Pathology*. BIOS Scientific Publishers, Oxford.

Nyle C Brady and Ray R. Well. 2004. *The Nature and Property of Soil*. Pearson Education (Singapore) Pvt. Ltd.

Rangaswami, R.S. 2005. *Diseases of Crop Plants of India*. Prentice Hall of India Pvt. Ltd., New Delhi.

Sambamurty, A.V.S.S. 2006. *Text Book of Plant Pathology*. I.K. International Pvt. Ltd., New Delhi.