

**CURRICULUM**  
**OF**  
**CROP PHYSIOLOGY**

(Revised 2005)



**HIGHER EDUCATION COMMISSION**  
**ISLAMABAD**

## **CURRICULUM DIVISION, HEC**

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## **PREFACE**

Curriculum of a subject is said to be the throbbing pulse of a nation. By looking at the curriculum one can judge the state of intellectual development and the state of progress of the nation. The world has turned into a global village; new ideas and information are pouring in like a stream. It is, therefore, imperative to update our curricula regularly by introducing the recent developments in the relevant fields of knowledge.

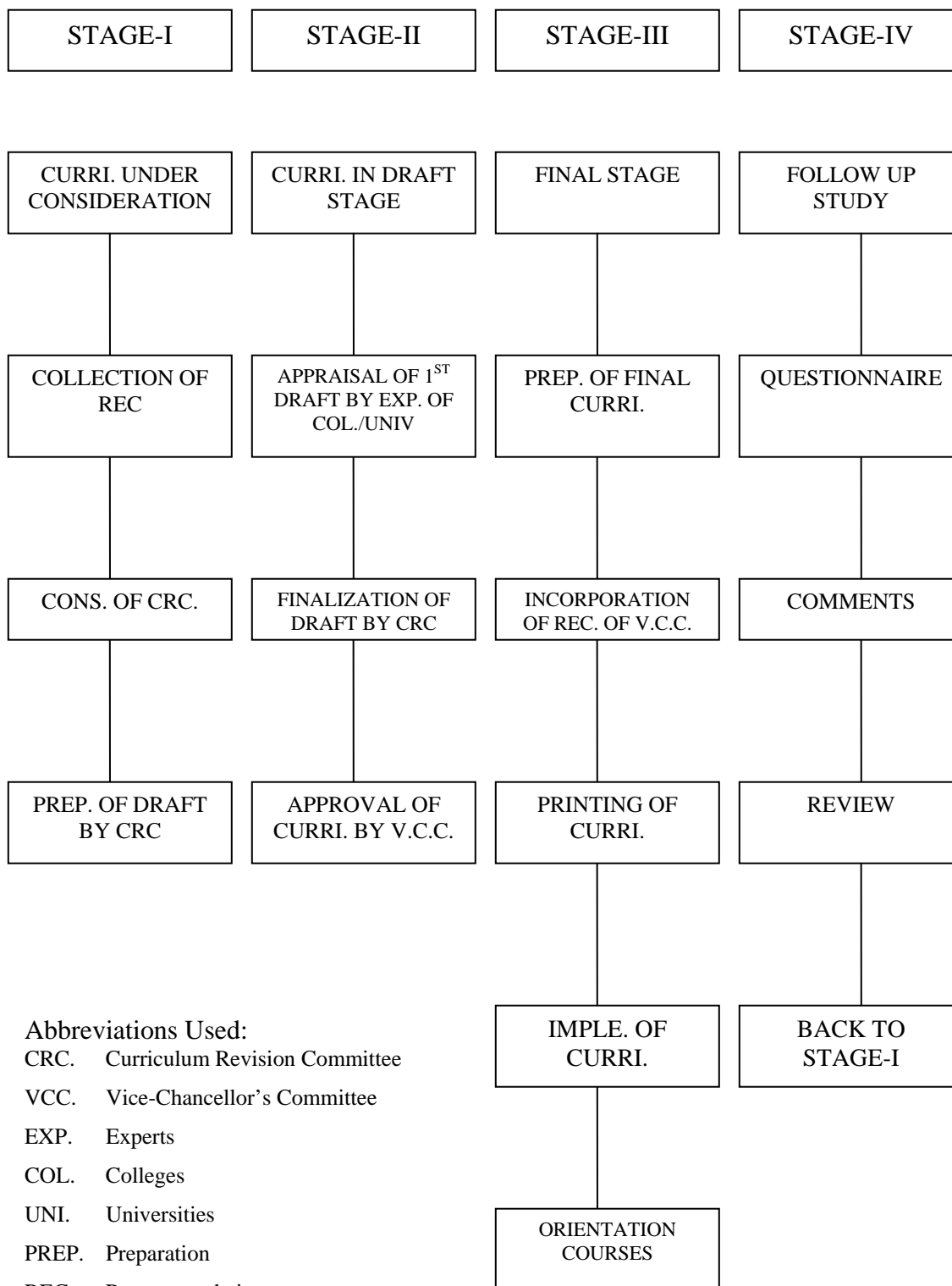
In exercise of the powers conferred by sub-section (1) of section 3 of the Federal Supervision of Curricula Textbooks and Maintenance of Standards of Education Act 1976, the Federal Government vide notification no. D773/76-JEA (Cur.), dated December 4, 1976, appointed University Grants Commission as the competent authority to look after the curriculum revision work beyond class XII at bachelor level and onwards to all degrees, certificates and diplomas awarded by degree colleges, universities and other institutions of higher education.

In pursuance of the above decisions and directives, the Higher Education Commission (HEC) is continually performing curriculum revision in collaboration with universities. According to the decision of the special meeting of Vice-Chancellors' Committee, curriculum of a subject must be reviewed after every 3 years. For the purpose, various committees are constituted at the national level comprising senior teachers nominated by universities. Teachers from local degree colleges and experts from user organizations, where required, are also included in these committees. The National Curriculum Revision Committee for Crops Physiology in its meeting held in July 18-20, 2005 at the HEC Regional Centre, Lahore revised the curriculum after due consideration of the comments and suggestions received from universities and colleges where the subject under consideration is taught. The final draft prepared by the National Curriculum Revision Committee duly approved by the Competent Authority is being circulated for implementation by architectural institutions.

**(PROF. DR. ALTAF ALI G. SHAIKH)**  
**Adviser (Acad/R&D)**

August 2005

# CURRICULUM DEVELOPMENT





# INTRODUCTION

A final meeting of the National Curriculum Revision Committee to revise the curriculum for undergraduate and postgraduate studies in Crop Physiology was held from July 18-20<sup>th</sup>, 2005 at HEC, Regional Centre, Lahore.

Following attended the meeting

- |    |  |          |
|----|--|----------|
| 1  | Prof. Dr. Ihsan Ilahi<br>Adviser Academics,<br>Kohat University of Science and Technology,<br>Banu Road, Off Jarma, Kohat.                         | Convener |
| 2. | Prof. Dr. Rahim Bux Mirbahar<br>Meritorious Professor,<br>Faculty of Crop Production,<br>Sindh Agriculture University,<br>Tandojam                 | Member   |
| 3. | Prof. Dr. Abdul Razak Mahar.<br>Professor,<br>Department of Botany,<br>Shah Abdul Latif University,<br>Khairpur, Sindh                             | Member   |
| 4. | Prof. Dr. Yusuf Ali Chaudhary.,<br>Dean,<br>Faculty of Agriculture,<br>AJK University<br>Rawalakot, AK.  | Member   |
| 5. | Prof. Dr. Ali Nawaz Channa<br>Professor<br>Faculty of Crop Production<br>Sindh Agricultural University, Tando Jam                                  | Member   |
| 6. | Prof. Dr. Mushtaq Hussain Kazmi,<br>Faculty of Agriculture,<br>AJK University<br>Rawalakot, AK.  | Member   |
| 7. | Dr. Fauzia Yusuf Hafeez,<br>Deputy Chief Scientist/Head Bio-fertilizers<br>Division,<br>National Institute of Biotechnology (NIBGE),<br>Faisalabad | Member   |

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|-----|---|--------|
| 8.  | Dr. Rana Muhammad Iqbal,<br>Principal,<br>College of Agricultural and Environmental<br>Sciences,<br>Islamia University, Bahawalpur.     | Member |
| 9.  | Dr. Himayat Ullah<br>Associate Professor,<br>Faculty of Agriculture<br>Gomal University, D.I. Khan                                      | Member |
| 10  | Mrs. Shahnaz Sarfraz<br>Associate Professor,<br>Department of Botany,<br>Lahore College for Women University,<br>Jail Road, Lahore      | Member |
| 11. | Dr. Rahim Din Khan<br>Associate Professor,<br>Faculty of Agriculture<br>Gomal University, D.I. Khan                                     | Member |
| 12. | Dr. Shahzad Maqsood Ahmad Basra,<br>Associate Professor,<br>Department of Crop Physiology,<br>University of Agriculture,<br>Faisalabad. | Member |
| 13. | Dr. Ghazala Nasim,<br>Assistant Professor,<br>Deptt. of Mycology and Plant Pathology<br>University of the Punjab, Lahore                | Member |
| 14. | Dr. Muhammad Aslam Khan<br>Assistant Professor,<br>University College of Agriculture,<br>B.Z., University, Multan                       | Member |
| 15  | Dr. Faheem Aftab<br>Assistant Professor<br>Department of Botany<br>Punjab University, Lahore  | Member |
| 16  | Dr. Inamullah,<br>Research Officer,<br>Cereal Crops Research Institute,<br>Pirsabak, Nowshera, NWFP.                                    | Member |

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|-----|--|------------------|
| 17  | Mr. Sohail Qadir<br>Lecturer,<br>Department of Agronomy,<br>Balochistan Agricultur College, Quetta           | Member           |
| 18. | Dr. Jehan Bakht,<br>Associate Professor,<br>Department of Agronomy,<br>NWFP Agriculture University, Peshawar | Member/Secretary |

The meeting started with recitation from the Holy Quran.

Mr. Bashir Ahmad, Dy Director, HEC, Regional Centre welcomed the participants on behalf of Chairman Higher Education Commission, Islamabad.

Mr. Muhammad Tahir Ali Shah briefed them of the obligations of the commission for revision and development of curriculum as per provisions of the Act of parliament 1976. He informed the participants regarding the concerted efforts of HEC for raising standards of education to international levels. He mentioned that HEC is providing training facilities, within country and abroad and requested all the members to visit HEC website for details. He further mentioned that HEC is providing funds to strengthen library and laboratory facilities.

Prof. Dr. Ihsan Illahi continued as convener and Dr. Jehan Bakht as secretary of the committee. Three day thresh-hold discussions on every course, made necessary corrections, amendments and updated the book list where ever new additions are available. The Committee finalized the curriculum for B.Sc (Hons) and M.Sc (Hons) in Crop Physiology and recommendations.

Prof. Dr. Altaf Ali G. Shaikh chaired the concluding session and introduced the members of the committee to various Academic Programms of the commission aimed at facilitating the universities in execution of their programmes including repair and maintenance of laboratories, provision of books for libraries, institution of indigenous Ph.D. scholarships, provision of computer and other modern tools like internet and e.mail etc.

## Scheme of Study for 4-Year B.Sc (Hons) Agriculture

Mathematics / Biology	6 Credits
Statistics 1 & 2	6
Computers / IT	3
Pak Studies	2
Islamiat	2
Communications Skills	3
English	3
Basic Agriculture	3
<b>Sub-Total</b>	<b>28</b>

One subject from each of the following disciplines

Agronomy	3
Plant Breeding & Genetics	3
Entomology	3
Plant Pathology	3
Food Technology	3
Horticulture	3
Soil Sciences	3
Agriculture Economics	3
<b>Sub-Total</b>	<b>24</b>

Additional Courses from disciplines mentioned below and above

Agriculture Extension	
Forestry & Range Management	
Animal Science	
Marketing & Agri Business	
Rural Development	
Human Nutrition	
Agriculture Chemistry	
Agriculture Engineering	
Water Management	
<b>Sub-Total</b>	<b>21-25</b>

**Sub-Total during the first four semesters** **73 – 77**

Semester 5, 6, 7	<b>19 Credit Hours</b> each	<b>57</b>
<b>Final Semester</b>		<b>15</b>
<b>Grand Total</b>		<b>145 – 149</b>

**SCHEME OF STUDIES**  
**FOR UNDER-GRADUATE COURSES IN CROP PHYSIOLOGY**

<b>Subject/Title</b>	<b>Credit Hours.</b>
Introduction to Physiology of Crop Plants	3(2-1)
Plant Cell Structure and Function	3(2-1)
Crop Physiology-I	3(2-1)
Crop Physiology-II	3(2-1)
Physiology of Growth and Development	3(2-1)
Physiology of Crop Nutrition	3(2-1)
Environmental Physiology	3(2-1)
Crop Ecology	3(3-0)
Fundamentals of Biological Nitrogen Fixation	3(2-1)
Physiology of Crop Yield-I (Cereals Crops)	3(2-1)
Physiology of Crop Yield-II (Non-Cereal Crops)	3(2-1)
Physiological Aspects of Tissue Culture	3(2-1)
Physiology and Biochemistry of Plant Growth Substances	3(2-1)
<u>Internship</u>	<u>20(0-20)</u>
<u>Total Major Courses</u>	<u>60</u>

**Note:**        **Universities and Colleges may adopt their own system for course numbers for different Degrees.**

**OUTLINE OF COURSES**  
**FOR UNDER-GRADUATE STUDIES IN CROP PHYSIOLOGY**

**INTRODUCTION TO PHYSIOLOGY OF CROP PLANTS**

**3(2-1)**

**Vision:** To develop skills of the undergraduate students in the subject of crop physiology at an introductory level.

**Theory**

Concept and significance of crop physiology. Basic terminology used in crop physiology. Cell structures and their functions. Physico-chemical properties of water, solutions, suspensions and colloidal system of plant cells. Buffers. Absorption, role and transport of water in crop plants. Mineral nutrition of plants. Carbon metabolism; photosynthesis and respiration. Seed germination and dormancy. Plant growth and development. Role of growth substances in crop plants. Biological nitrogen fixation,. Crop Plants and environment. Introduction to Tissue culture and biotechnology.

**Practical**

Introduction to equipments used in crop physiology. Preparation of various solutions. Measurement of soil and plant water contents. Seed germination and seedling growth. Nutrient diagnosis in crop plants.

**Books Recommended**

1. Salisbury, F.B. and C.W. Ross. 1992. Plant Physiology. 4<sup>th</sup> ed., Wordsworth Publishing Co. Inc. Belmont, Calif. U.S.A.
2. Meidner, H. 1984. Class Experiments in Plant Physiology, George Allen and Unwin, London, U.K.
3. Moore, T.C. 1981. Research Experiences in Plant Physiology. A Laboratory manual. 2<sup>nd</sup> ed. Springer-Verlag Heidelberg, Germany.
4. Hopkins, W.G. 2004. Introduction to Plant Physiology. 3<sup>rd</sup> ed. John Wiley and Sons, New York, USA.
5. Bajracharya, D. 1999. Experiments in plant physiology. A laboratory manual. Narosa Pub. N. Delhi India.
6. Taiz, L. and E. Zeiger. 2002. Plant physiology, 3<sup>rd</sup> ed. Sinauer Associates, Sunderland, USA.

**Vision:** To create awareness of basic physiological processes going on within a plant community and to acquaint the students with the prerequisite knowledge and skills to become a competent researcher

### **Theory**

Properties and role of water in plants. Imbibition and seed germination. Mechanisms of absorption and translocation of water. Transpiration. Physiology and regulation of stomatal movement. Mineral nutrition of crop plants. Source-sink relationships and their manipulation. Partitioning and re-mobilization of assimilates. Plant growth regulators, role and uses in agriculture, Photoperiodism,. vernalization and dormancy.

### **Practical**

Measurement of water potential in plants. Water imbibition by seed and germination, Demonstration of hydroponics. Measurement of transpiration rate, Demonstration of effects of various growth regulators on crop plants.

### **Books Recommended**

1. Ilahi, I. 1995, Plant Growth. UGC Press, Islamabad.
2. Taiz, L. and E. Zeiger. 2002. Plant physiology, 3<sup>rd</sup> ed. Sinauer Associates, Sunderland, USA
3. Meidner, H. 1984, Class Experiments in Plant Physiology, George Allen and Unwin, London, U.K.
4. Moore, T.C. 1981. Research Experiences in Plant Physiology. A Laboratory Manual. 2<sup>nd</sup> ed. Springer Verlag. Heidelberg, Germany.
5. Hopkins, W.G. 2004. Introduction to Plant Physiology, 3<sup>rd</sup> ed. John Wiley and Sons, New York, USA.
6. Hans, M. and P. Schopfer. 1995. Plant Physiology. Springer Verlag, Heidelberg, Germany.
7. Fageria, N.K., V.C. Baligar and R.B. Clark. 2005. Physiology of Crop Production. Academic Press, New York

**Vision:** To create awareness of basic physiological processes going on within a plant community and to acquaint the students with the prerequisite knowledge and skills to become a competent researcher. This course will further enhance the capabilities of the students to undertake problem oriented research.

### **Theory**

Photosynthesis: Photophosphorylation, mechanism and biochemistry of CO<sub>2</sub> fixation in C<sub>3</sub>, C<sub>4</sub> and CAM plants. Factors affecting photosynthesis. Photorespiration, Respiration; types and bioenergetics. Nitrogen metabolism; transformation of inorganic nitrogen into amino acids and proteins. Carbohydrate metabolism. Physiology and Biochemistry of seed germination.

### **Practical**

Determination of rate of photosynthesis and respiration. Seed germination test. Identification of C<sub>3</sub>, C<sub>4</sub> and CAM plants.

### **Books Recommended**

1. Ilahi, I. 2001. Biophysical and biochemical processes in plants. UGC Press, Islamabad.
2. Gardener, F.P., R.B. Pearce, and R.L. Mitchell. 1988. Physiology of Crop Plants. Iowa state University Press, Ames, Iowa, USA.
3. Meldner, H. 1984, Class Experiments in Plant Physiology, George Allen and Unwin, London, U.K.
4. Moore, T.C. 1981. Research Experiences in Plant Physiology. A Laboratory Manual. 2<sup>nd</sup> ed. Springer Verlag. Hiedelberg Germany.
5. Hopkins, W.G. 2004. Introduction to Plant Physiology, 3<sup>rd</sup> ed. John Wiley and Sons, New York, USA.
6. Hans, M. and P. Schopfer 1995. Plant Physiology. Springer Verlag, Heidelberg, Germany.
7. Bewley, J.D. and M. Black. 1994. Physiology and Biochemistry of Seed in relation to germination. I. Development, Germination and Growth. Springer Verlag. Heidelberg, Germany.
8. Hall, D.O. and K. Rao. 1999. Photosynthesis, 6<sup>th</sup> ed. Cambridge University Press, UK.

## **ENVIRONMENTAL PHYSIOLOGY**

**3(2-1)**

**Vision:** To correlate the environment and physiological processes in crop plants.

### **Theory**

Plant and Environment,. Effect of light, temperature, precipitation, relative humidity, CO<sub>2</sub> and pollutants on physiology of crop growth and development. Physiological strategies for increasing crop productivity. Crop productivity in relation to green house effects, global warming and climate changes.

### **Practical**

Demonstration of effects of light, temperature, water and nutrients on crop plants.

### **Books Recommended**

1. Gupta, U.S. 1984. Environmental Physiology of Crop Plants. Academic Press, New York.
2. Anonymous.1990. Impact of Carbondioxide, Trace Gases and Climate Changes on Global Agriculture, ASA, Madison, WI, USA .
3. Loomis, R.S., and D.J. Conner. 1993. Crop Ecology. Productivity and Management in Agricultural Systems. Cambridge University Press, Cambridge, UK.
4. Moore, T.C. 1981. Research Experiences in Plant Physiology. A Laboratory Manual. 2<sup>nd</sup> ed. Springer-Verlag Heidelberg, Germany.
5. Alastair, H.F. and R.K.M. Hay. 2001. Environmental physiology of plants, 3<sup>rd</sup> ed. Academic Press, New York.
6. Hall, A.E. 2000. Crop response to environment. Culinary and Hospitality Indus. Pub. Services.
7. Pritchard, S.G. and J.S. Amthor. 2005. Crops and environmental change. Haworth Press Incor.

## **PHYSIOLOGY OF GROWTH AND DEVELOPMENT**

**3(2-1)**

**Vision:** To understand the basic events of growth and development in major crops and to determine the crop growth.

### **Theory**

Concept of growth and development. Growth curve and growth regions. Factors affecting plant growth and development. Environmental control of growth and development; genetic, atmospheric, edaphic, biological and

cultural factors. Photoperiodism, thermoperiodism, vernalization and tropisms. Role of phytohormones in crop growth and development. Fruit set, seed development, ripening and techniques for production of seedless fruits. Maturation, abscission and senescence.

### **Practical**

Demonstration of various tropic responses. Growth analysis of crop plants.

### **Books Recommended**

1. Ilahi, I. 1995. Plant Growth. UGC Press, Islamabad.
2. Tesar, J.B. 1984. Physiological Aspects of Growth and Development. CSSA and ASA., Madison, WI, USA
3. Willkins, M.B. 1981. Physiology of Growth and Development. McGraw Hill Book Co. New York.
4. Gardner, F.P., R.B. Pearce and R.L. Mitchell. 1988. The Physiology of Crop Plants. Iowa State University Press. Ames, Iowa. USA.
5. Taiz, L. and E. Zeiger. 2002. Plant Physiology, 3<sup>rd</sup> ed. Sinauer Associates, Sunderland, USA
6. Thomas, B. and D. Vince-Prue. 1997. Photoperiodism in Plants. 2nd ed. Academic Press NewYork.
7. Otline, L and S. Day. 2002. Mechanism in plant development. Blackwell, UK.

## **PLANT CELL STRUCTURE AND FUNCTION**

**3(2-1)**

**Vision:** This course aims to develop basic understanding of the cell organelles and their functions.

### **Theory**

Prokaryotic, eukaryotic and mesokryotic plant cells. The plant cell apoplast and symplast. Apoplast: cell wall and vacuole, Symplast: cytoplasm, plasmodesmata, plasma membrane, cytosomes, endoplasmic reticulum, Golgi complex, microbodies, ribosomes, mitochondria, plastids, nucleus, nuclear membrane, microtubules, microfilaments and tonoplast. Cell metabolism and its regulation.

### **Practical**

Slide preparation of various types of cells. Identification of cell organelles.

## **Books Recommended**

1. Albert, B., Bray, D., Lewis, J., Raft, M., Roberts, K. and Watson, J.D., 1995. Molecular Biology of the Cell, 2<sup>nd</sup> edition. Garland Science, New York.
2. Campbell and Mitchel, R., 1999. Biology, 5<sup>th</sup> edition. Addison Wesley Longman Inc.
3. De-Roberties, E.D.P. and E.M.F.Jr. DeRoberties. 1992. Cell and Molecular Biology, 8<sup>th</sup> editon. John Willey and Sons, USA.
4. Taiz, L. and E. Zeiger. 2002. Plant Physiology, 3<sup>rd</sup> ed. Sinauer Associates, Sunderland, USA

## **PHYSIOLOGY OF CROP NUTRITION**

**3(2-1)**

**Vision :** To give an insight to the physiological basis of nutrient importance, deficiencies, biological functions and uptake mechanisms in plants.

### **Theory:**

Introduction and scope of crop nutrition. Essential elements, their physiological roles, deficiency symptoms, Mechanisms of absorption, translocation, and metabolism of nutrients. Effects of deficiencies and toxicities of nutrients on physiological functions/processes. Nutrient requirements and management for efficient plant growth and yield. Mycorrhizae and their role in nutrient absorption.

### **Practical**

Techniques of growing plants for nutritional studies. Identification of deficiency and toxicity symptoms of different nutrients.

## **Books Recommended**

1. Marschener, H. 1995. Mineral Nutrition of Higher Plants. Academic Press, London, U.K.
2. Mengel, K. and E.A. Kirkby 1999. Principles of Plant Nutrition, 3rd ed. International Potash Instt., Berne, The Netherlands.
3. Fageria, N.K., V.C. Baliger, and C.A. Jones. 1991. Growth and Mineral Nutrition of Field Crops. Morcel Dekker, New York, U.S.A.
4. Pessarakli, M. 1999. Handbook of Plant and Crop Stress. Marcell Decher, New York, USA.

5. Emanuel, E. and A.J. Baloom. 2004. Mineral nutrition of plants, 2<sup>nd</sup> ed. Sinauer Associates, Sunderland, USA.
6. Bajracharya, D. 1999. Experiments in plant physiology. A laboratory manual. Narosa Pub. N. Delhi India.

## **FUNDAMENTALS OF BIOLOGICAL NITROGEN FIXATION 3(2-1)**

**Vision:** To create awareness about the physiological basis of nitrogen fixation in plants with relations to microorganisms

### **Theory**

Nitrogen and plant growth. Nitrogen cycle in nature. Symbiotic and asymbiotic nitrogen fixation. Associative symbiosis. Nitrogen fixing microorganisms. Mechanism of BNF. Process of nodulation. Factors affecting the process of nodulation and biological nitrogen fixation. Introduction to biofertilizers.

### **Practical**

Demonstration of inoculation methods. Study of nodule formation under different environmental conditions. Identification of effective and non-effective nodules. Methods used to measure biologically fixed nitrogen.

### **Books Recommended**

1. Stacy, G., R.H. Burris and H.J. Evans. 1992. Biological Nitrogen Fixation. Chapman and Hall. London, UK.
2. Werner, D. and W.E. Newton. 2005. Nitrogen fixation in agriculture, forestry, ecology, and the environment. Springer-Verlag Heidelberg, Germany.
3. James, E.K., J.I. Sprent, M.J. Dilworth and W.E. Newton. 2005. Nitrogen-fixing leguminous symbiosis. Springer-Verlag Heidelberg, Germany.
4. Elmerich, C. and W.E. Newton. 2005. Associative and endophytic nitrogen-fixing bacteria and cyanobacterial associations. Springer-Verlag Heidelberg, Germany.
5. Pawlowsai, K. and W.E. Newton. 2005. Nitrogen-fixing actinorhizal symbioses. Springer-Verlag Heidelberg, Germany.
6. Cappuccino, J.G. and N.Sherman. 2001. Microbiology (A lab manual), 6<sup>th</sup> ed. Benjamin Cumming,. New York, USA.
7. Stacy, G. 1997. Biological Nitrogen Fixation. Chapman and Hall. Inc., New York, USA.

## **CROP ECOLOGY**

**3(2-1)**

**Vision:** To understand the characteristics of agro-ecosystems and its dynamics.

### **Theory**

Introduction: the eco-system concept; species and population dynamics. Crop Eco-system; plant environment, aerial and soil environments. Environmental factors and crop productivity; responses of crop plants to atmospheric, edaphic, biotic, pyric and anthropic factors. Crop yield variability in relation to ecological optima; interaction between organism, competition, predation, parasitism, symbiosis and allelopathy. Ecological strategies for improved crop productivity; allocation and management of resources. Agro-ecological zones of Pakistan.

### **Practical**

Visits to major agroecological zones of Pakistan and analysis of soil samples.

### **Books Recommended**

1. Fitter, A.H. and R.K.M.Hay. 1991. Environmental Physiology of Plants. Academic Press. London, U.K.
2. Smith, R.L. 1986. Elements of Ecology. Harper and Row, Publishers, New York.
3. Tivy, J. 1990. Agricultural Ecology. Longman Group. Essex Ltd. UK.
4. Loomis, R.S. and D.J. Connor. 1993. Crop Ecology, Productivity and Management in Agricultural Systems. Cambridge University Press, New York.
5. Hussain. F. 1995. Manual of Plant Ecology. National Book foundation, Islamabad, Pakistan.
6. Larcher, W. 1995. Physiological Plant Ecology. 3<sup>rd</sup> Ed. Springer Verlag. Hiedelberg, Germany.

## **PHYSIOLOGY OF CROP YIELD-I (Cereal Crops)**

**3(2-1)**

**Vision:** To understand the physiological processes involved in the improvement and increase of yield of cereal crops.

## **Theory**

Developmental physiology of cereal crops. Physiology of leaf growth and tillering. Leaf number, size, orientation, leaf area index and space distribution in relation to light interception, photosynthetic efficiency. Source-sink relationships; partitioning coefficient. Grain growth and development. Physiological basis of economic yield. Senescence and maturity indices.

## **Practicals**

Identification of developmental stages in cereals. Leaf area measurements and calculations of leaf area index. Measurements of plant biomass and photosynthetic efficiency.

## **Books Recommended**

1. Hay, R.K.M. and A.J. Walker. 1989. An Introduction to the Physiology of Crop Yield. Longman, Scientific and Technical, New York, USA.
2. Coombs, J., D.O. Hall, S.P. Long. and J.M.O. Scurlock. 1987. Techniques in Bioproductivity and Photosynthesis, 2<sup>nd</sup> ed. Pergamon Press, Oxford, U.K.
3. Edwards, D.A.C. 1982. Physiological Determinants of Crop Growth. Academic Press, New York, USA.
4. Evans, L.T. 1980. Crop Physiology. Cambridge University Press, Cambridge. U.K.
5. Goldsworthy, R.P. and N.M. Fisher. 1984. The Physiology of Tropical Field Crops. John Wiley and Sons, New York, USA.
6. Stockopf, N.C. 1981. Understanding Crop Production. Reston Publishing Company, Reston, Virginia, USA.
7. Acquach, G. 2001. Principles of crop production: Theory, techniques and technology, 1st ed. Prentice Hall.

## **PHYSIOLOGY OF CROP YIELD-II (Non Cereal Crops)**

**3(2-1)**

**Vision:** To understand the physiological processes involved in the improvement and increase of yield of non cereal crops

## **Theory**

Sugar, fiber, oil seed, legume and tuber crops; introduction and growth patterns. Physiology of germination, propagation, seedling growth, branching and leaf expansion. Carbon dioxide assimilation and photosynthetic efficiency. Source-sink relationships. Physiological basis of crop yield. Lint morphology

and physiology. Senescence, maturity and maturity indices. Partitioning coefficient and economic yield.

## **Practical**

Leaf area measurements and calculations of leaf area index. Measurements of plant biomass and photosynthetic efficiency. Identification of developmental stages in non-cereal crops.

## **Books Recommended**

1. Coombs, J., D.O. Hall, S.P. Long. and J.M.O. Scurlock. 1987. Techniques in Bioproductivity and Photosynthesis, 2<sup>nd</sup> ed. Pergamon Press, Oxford, U.K.
2. Edwards, D.A.C. 1982. Physiological Determinants of Crop Growth. Academic Press, New York, USA.
3. Evans, L.T. 1980. Crop Physiology. Cambridge University Press, Cambridge. U.K.
4. Goldsworthy, R.P. and N.M. Fisher. 1984. The Physiology of Tropical Field Crops. John Wiley and Sons, New York, USA.

## **PHYSIOLOGICAL ASPECTS OF TISSUE CULTURE      3(2-1)**

**Vision:** To enable the students develop an understanding of plant tissue culture and its importance to crop physiology.

### **Theory**

Historical background. Composition of different culture media. Sterilization techniques (glassware and media). Culture conditions and environment. Physiology of donor plant and explant. Physiology of callus formation, differentiation and dedifferentiation. Morphogenesis and factors affecting morphogenesis. Organogenesis (root and shoot formation). Protoplasts: isolation, culture and fusion. Haploid plants and their use in agriculture. Embryogenesis and factors affecting embryogenesis. Micropropagation; application in agriculture. *In vitro* stress induction with special reference to salt, drought and temperature. Problems and limitations of tissue culture techniques.

## Practical

Glassware selection, cleaning and sterilization. Study and preparation of various media. *In Vitro* seed germination. Explant: selection, preparation and inoculation techniques. Callus induction and culture.

## Books Recommended

1. Dodds, J.H. and L.W. Roberts. 1999. Experiments in Plant Tissue Culture. 3<sup>rd</sup> ed. Cambridge University Press, Cambridge, U.K.
2. Skelsey, F.A. 1984. Biotechnology in Agriculture-New Tool for the Oldest Science. Joint Council on Food and Agricultural Sciences, U.S. Department of Agriculture, USA.
3. Smith. J. E. 1996. Biotechnology, 3<sup>rd</sup> ed. Cambridge University Press, Cambridge, U.K.
4. Bhojwani, S.S. and M.K. Razdan. 1983. **Plant** Tissue Culture: Theory and Practice. Elsevier Publishers, Amsterdam. The Netherlands.
5. Withers, L.A. and P.G. Alderson. 1986. Plant Tissue Culture and its Agricultural Applications. Butterworths Publishers, Cambridge, UK.

## **PHYSIOLOGY AND BIOCHEMISTRY OF PLANT GROWTH**

### **SUBSTANCES**

**3(2-1)**

**Vision:** To understand the mechanism of the action of growth substances and their role in plant growth and development.

## Theory

Growth substances; their nature, classification, occurrence, biosynthesis, translocation, mode of action and degradation. Physiological role of growth substances. Use of growth substances in agriculture. Role of growth substances in tissue culture. Growth substances and plant adaptation to stress conditions.

## Practical

Preparation of stock and working solutions of various plant growth substances. Demonstration of the effects of different growth substances on seed germination and seedling growth. Bioassay of selected growth substances.

## **Books Recommended**

1. Davies P.J. 1987. Plant Hormones and Their Role in Plant Growth and Development, Martinus Nijhoff Publishers, Dordrecht, The Netherlands.
2. Davies P.J. 2005. Plant Hormones: Biosynthesis, signal transduction and action. Kluwer Academic Publishers, Dordrecht, The Netherlands
3. Frankenberger, W.T. Jr. and M. Arshad, 1995. Phytohormones in Soils. Marcel Dekker Inc., New York, U.S.A.
4. Srivastava, L.M. 2002. Plant Growth and Development, Hormones and Environment. Academic Press, USA.
5. Taiz, L. and E. Zeiger. 2002. Plant Physiology, 3<sup>rd</sup> ed. Sinauer Associates, Sunderland, USA.
6. Ranjan, R., S.S. Purohit and V. Prasad. 2004. Plant hormones. Agrobios, Jodhpur, India.
7. Lalit, M.S. 2004. Plant growth and development, hormones and environment. Academic Press, New York USA.
8. Hooykass, P.J.J., M.A. Hall and K.R. Libbenga. 1999. Biochemistry and molecular biology of plant hormones. Elsevier Publishers, Amsterdam, The Netherlands.
9. Arteca, R.N. 1997. Plant growth substances: Principles and applications. Chapman & Hall Inc., New York, USA.

## **INTERNSHIP**

**20(0-20)**

**Vision:** The aim of this exercise is to gain practical experience of field/laboratories/research establishments/industries etc.

Report writing and presentation

**SCHEME OF STUDIES  
FOR POSTGRADUATE COURSES IN CROP PHYSIOLOGY**

<u>Subject/Title</u>	<u>Credit Hours.</u>
Seed Physiology	4(3-2)
Developmental Physiology of Crop Plants	4(3-2)
Physiological Aspects of Crop Yield	4(3-2)
Physiology and Biochemistry of Herbicides	4(3-2)
Stress Physiology	3(3-0)
Physiology of Drought	3(3-0)
Biological Nitrogen Fixation and Crop Productivity	3(3-0)
Advanced Crop Physiology	4(3-2)
Recent Advances in Crop Physiology	3(3-0)
Analytical Techniques in Crop Physiology	4(2-4)
Plant Molecular Biology	4(3-2)
Biophysics of Growth	3(3-0)
Plant Metabolism and Bioenergetics	3(3-0)
Modeling Crop Growth and Development	4(3-2)
Plant Water Relations	3(2-2)
Special Problem	2(0-4)
Seminar	1(1-0)
Thesis M.Sc. (Hons)	
Thesis Ph. D.	

**Note: Universities and Colleges may adopt their own system for course numbers for different Degrees.**

**OUTLINE OF COURSES**  
**FOR POST-GRADUATE STUDIES IN CROP PHYSIOLOGY**

**SEED PHYSIOLOGY**

**4(3-2)**

**Vision:** To focus on the latest developments in the area of seed physiology and its practical applications.

**Theory**

Definition of seed. Seed structure. Physiology of seed formation and development. Composition of seed. Physiology and biochemistry of seed germination. Factors affecting seed germination and emergence. Seed viability and seed vigor. Seed dormancy and methods of breaking dormancy. Seed longevity and storage. Seed enhancement.

**Practical**

Seed testing for moisture, viability and vigor. Demonstration of methods of breaking seed dormancy. Germination under different moisture, temperature and salt regimes. Seed vigor enhancement techniques.

**Books Recommended**

1. Joshi, A. K. and B.D. Singh. 2004. Seed Science and Technology. 1st ed. Kalyani Publishers. New Dehli, India.
2. Benech-Arnold, R.L. and R.A. Sanchez. 2004. Handbook of Seed Physiology. Application to agriculture, Haworth Press, New York.
3. Bewley, J.D., and M.Black. 1994. Seed: Physiology of Development and Germination. 2<sup>nd</sup> ed. Plenum Press. New York.
4. Copeland, L.O. and M.B. McDonalad. 2002. Principles of Seed Science and Technology. 2<sup>nd</sup> ed. Burgess Publishing Company. Minneapolis, Minnesota, USA.
5. Fala, F. 1987. Handbook of Vigour Test Methods. 2<sup>nd</sup> ed. ISTA Secretariat, Waginengin, The Netherland.
6. ISTA. 1985. International Rules for Seed Testing. Waginengin, The Netherlands.
7. McDonald, M.B. and L.O. Copland. 1989. Seed Science and Technology. Laboratory Manual. Iowa State University Press, Ames, USA.

## **DEVELOPMENTAL PHYSIOLOGY OF CROP PLANTS 4(3-2)**

**Vision:** To understand the pattern of growth and development in major crops and use this knowledge for enhancement of crop productivity.

### **Theory**

Structural organization of plants at subcellular, cellular, tissue and organ level. Basic events of growth; cell growth, cell division; cell enlargement and cell differentiation. Growth Patterns. Meristems. Physiology of root and shoot initiation and development. Leaf growth and stomatal development. Physiology of flowering, fruit set, ripening, maturity and senescence.

### **Practical**

Identification of developmental stages in various field crops. Root and shoot growth patterns. Assessment of number, size and position of stomata.

### **Books Recommended**

1. Garner, B. L. 1995. Plant Stem Physiology and Functional Morphology, Academic Press, U.S.A.
2. Gregory, P.J., J.V. Lake, and D.A. Rose. 1990. Root Development and Function, Cambridge University Press, UK.
3. Salisbury, F.B. and C.W. Ross. 1992. Plant Physiology. 4<sup>th</sup> ed., Wordsworth Publishing Co. Inc. Belmont, Calif. U.S.A.
4. Hopkins, W.G. 2004. Introduction to Plant Physiology. 3<sup>rd</sup> ed. John Wiley and Sons, New York, USA.
5. Taiz, L. and E. Zeiger. 2002. Plant physiology, 3<sup>rd</sup> ed. Sinauer Associates, Sunderland, USA.

## **PHYSIOLOGICAL ASPECTS OF CROP YIELD 4(3-2)**

**Vision:** To understand the role of physiological processes involved in crop yield

### **Theory**

Physiological basis of crop yield. Leaf area development in relation to plant population. Concept of critical and optimum Leaf Area Index (LAI). Leaf number, size, orientation and space distribution in relation to light interception. Photosynthetic efficiency, effect of canopy architecture on crop yield. Factors affecting pollination and fertilization. Sink capacity, sink strength and source-

sink relationships. Grain growth and development. Senescence and degradative processes affecting grain development.

## **Practical**

Leaf area measurement. Calculation of LAI. Calculation of seed growth rate. Calculation of effective seed filling duration from linear regression. Calculation of economic and biological yields. Partitioning coefficient.

## **Books Recommended**

1. Boote, K.J., J.M. Bennett, T.R.S. Sinclair and G.M. Paulsen. 1994. Physiology and Determination of Crop Yield, ASA, CSSA, Madison, Wisconsin, U.S.A.
2. Coombs J., D.O. Hall, S.P. Long, and J.M.O. Scutock 1987, The Techniques in Bioproductivity and Photosynthesis, 2nd ed. Pergamon Press Oxford, New York.
3. Edwards, D.A.C. 1982. Physiological Determinants of Crop Growth.. Academic Press, New York.
4. Hay, R.K.M., and A.J. Walker. 1989. An Introduction to the Physiology of Crop Yield. Longman, Scientific and Technical, New York.
5. Stoskopf, N.C. 1981. Understanding Crop Production. Reston Publishing Co., Virginia, USA.
6. Taiz, L. and E. Zeiger. 2002. Plant physiology, 3<sup>rd</sup> ed. Sinauer Associates, Sunderland, USA.
7. Chetti, M.B., S.M. Hiremath and M. Kalpana. 2004. Physiological Approaches for Enhancing Productivity Potential under Drought Condition. Studium Press.

## **PHYSIOLOGY AND BIOCHEMISTRY OF HERBICIDES**

**4(3-2)**

**Vision:** To understand the role and mode of action of herbicides in crop management.

### **Theory**

Classification of herbicides. Chemical and physical properties of herbicides. Surfactants and their significance. Mode of entry and action of herbicides. Factors affecting uptake and translocation. Metabolism of herbicides. Morphological responses of plants to herbicides. Herbicide effects on physiological processes; cell division, elongation, germination, early growth, solute transport, cell membrane structure and function, water and CO<sub>2</sub>

exchange, photosynthesis and respiration. Herbicides: plant selectivity, resistance and tolerance.

## **Practicals**

Calculation of herbicide doses. Preparation of solutions with different concentrations. Demonstration of different methods of herbicide application. Demonstration of herbicide effects on weeds and crop plants.

## **Books Recommended**

1. Anderson, W.P. 1993. Weed Science Principles. 2<sup>nd</sup> Ed. West Pub. Co. USA.
2. Ashton, F.M. and A.S. Crafts. 1981. Mode of Action of Herbicides. 2<sup>nd</sup> ed. John Wiley and Sons. New York.
3. Rao, V.S. 1988. Principles of Weed Science. 3<sup>rd</sup> ed. Oxford and IBH Pub. Co. (Pvt). Ltd., New Delhi, India.
4. Sundus, L.J. 1976. Herbicides Physiology, Biochemistry and Ecology. 2<sup>nd</sup> ed. Academic Press, New York. USA.

## **STRESS PHYSIOLOGY**

**4(3-2)**

**Vision:** To understand and classify the various stresses and manipulate the knowledge acquired to manage the stressed environments in a profitable way.

### **Theory**

Introduction to biotic and abiotic stresses. Responses of plants to various stresses. Physiological effects of edaphic, moisture, temperature, radiation, pollutants, chemicals, mineral and salt stresses. Mechanisms of plant injury; physiological and biochemical basis. Plant resistance mechanisms at the whole plant, organ, cellular and molecular levels. Plant adjustments to stress conditions. Measures of minimizing the stress effects.

### **Practical**

Introduction to hydroponics, Demonstration of moisture, salinity and nutrient stresses to the plants in hydroponics.

## **Books Recommended**

1. Levitt, J. 1980. Responses of Plants to Environmental Stresses. 2<sup>nd</sup> ed. Vol-I and II. Academic Press, London.

2. Moone, H.A., W.E. Winner, and E.J. Pell. 1991. Responses of Plants to Multiple Stresses. Academic Press, San Diego, U.S.A.
3. Turner, N.C., and J.B. Passioura. 1986. Plant Growth, Drought and Salinity. CSIRO, Australia.
4. Fowden, L., T. Mansfield, J. Stoddart. 1993. Plant Adaptations to Environmental Stresses. Springer Verlag, Berlin, Germany.
5. Fitter, A.H., and R.K.M. Hay. 1991. Environmental Physiology of Plants. Academic Press London.
6. Pessarakli, M (ed). 2002. Handbook of Plant and Crop Stress. Marcel Dekker, New York
7. Orcutt, D.M. and E.T. Nelson. 2000. Physiology of Plants under Stress. John Wiley and Sons, USA.
8. Taiz, L. and E. Zeiger. 2002. Plant physiology, 3<sup>rd</sup> ed. Sinauer Associates, Sunderland, USA.

## **PHYSIOLOGY OF DROUGHT**

**4(3-2)**

**Vision:** To understand the mechanisms of drought resistance in crop plants and its measurements.

### **Theory**

Global perspectives of drought. The development of water deficit in plants. Responses of plants to drought stress. Mechanisms of drought tolerance in crop plants. Morpho-anatomical consequences of drought. Water relations during drought. Natural and artificial strategies for improving water use efficiency. Water stress and photosynthetic apparatus. Photosynthetic adjustments to water stress. Relationships of drought with phytohormones, nitrogen fixation, nitrate reductase activity and protein synthesis. Induction of drought tolerance in crop plants. Crop research strategies for drought prone areas.

### **Practical**

Techniques in water potential measurements, Measurement of water potential in water-stressed plants, Crop growth analysis under drought

### **Books Recommended**

1. Close, T.J., and E.A. Bray. 1993. Plant Responses to Cellular Dehydration during Environmental Stress. Current Topics in Plant Physiology. Vol. 10. American Society of Plant Physiology, Rockville, MD, U.S.A.

2. Paleg, L.G., and D. Aspinall, 1981, The Physiology and Biochemistry of Drought Resistance in Plants, Academic Press, Sydney.
3. Smith, J.A.C., and H. Griffiths. 1993. Water deficits: Plant Responses from cell to community. Bios Scientific Publishers.
5. Jones, H.G., T.J. Flowers and M.B. Jones. 1989. Plant under stress. Biochemistry, Physiology and Ecology and their applications to plant improvement. Cambridge University Press. Cambridge, UK
6. Pessarakli, M (ed). 2002. Handbook of Plant and Crop Stress. Marcel Dekker, New York

## **BIOLOGICAL NITROGEN FIXATION AND CROP PRODUCTIVITY**

**4(3-2)**

**Vision:** To understand the symbiotic and asymbiotic relationships among plants and microorganisms and evaluate methods used to measure BNF.

### **Theory**

Introduction to biological nitrogen fixation (BNF). BNF in asymbiotic and symbiotic associations in legumes and non-legumes. Nitrogenase; structure and function. Mechanism and biochemistry of BNF. Genetics and regulation of BNF, molecular characterization of nif gene. Cross inoculation groups. Estimation of BNF. Physiological and ecological limitations of BNF. Biological Nitrogen Fixation and plant productivity. Role of BNF in Agroforestry. Production and maintenance of legume inoculants.

### **Practical**

Morphology and anatomy of nodules. Isolation of Rhizobium from nodules. Gram's staining, re-inoculation test. Measurement of BNF. Nitrogen estimation by Kjeldahl's method/acetylene reduction assay.

### **Books Recommended:**

1. Stacy, G., R.H. Burris and H.J. Evans. 1992. Biological Nitrogen Fixation. Chapman and Hall Inc., New York, USA.
2. Hardarson, G. 2003. Maximizing the Use of Biological Nitrogen Fixation in Agriculture. Kluwer Academic Publishers, Amsterdam, The Netherlands.

3. Klipp, W., B. Masepohl, J.R. Gallon and W.E. Newton. 2005. Genetics and Regulation of Nitrogen Fixation in Free Living Bacteria. Springer-Verlag, Berlin, Germany.
4. Elmerich, C. and W. E. Newton. 2005. Associative and Endophytic Nitrogen Fixing Bacteria and Cyanobacterial Associations. Springer-Verlag, Berlin, Germany.
5. James, E.K., J.I. Sprent, M.J. Dilworth and W.E. Newton. 2005. Nitrogen Fixing Leguminous Symbiosis. Springer-Verlag, Berlin, Germany.
6. Stacy, G. 1997. Biological Nitrogen Fixation. Chapman & Hall Inc., New York, USA.

## **ADVANCED CROP PHYSIOLOGY**

**4(3-2)**

**Vision:** To equip the students with the advancements in the field of crop physiology

### **Theory**

Physiological aspects of crop productivity. Production potentials of crop plants; morphological and physiological basis. Crop responses to light variation. Plant architecture in relation to yield. Development in relation to yield in cereals and legumes. Physiology of yield of underground storage organs. Carbon dioxide fertilization of crop plants under controlled conditions.

### **Practical**

Visits to different laboratories/centers of advance research in the field of Crop Physiology and report writing.

### **Books Recommended**

1. Gupta, U.S. 1988, Progress in Crop Physiology, Oxford and IBH Publishing Co., PVT. Ltd., New Dehli, India.
2. Johnson, C.B. 1981. Physiological Process Limiting Plant Productivity, Productivity, Butter-worths, London.
3. Marten, J. and D.E. Sadave, 1994, Plants, Genes and Agriculture. Jones and Bartlett Publishers International, U.S.A.
4. Wilkins, M.B. (ed). 1992. Advanced Plant Physiology. Longmans Singapore Publishers (pvt) Ltd, Singapore.

## **RECENT ADVANCES IN CROP PHYSIOLOGY**

**3(3-0)**

**Vision:** To update the knowledge of the students with the current developments in the field of crop physiology.

### **Theory**

Lectures on selected topics of recent advances in crop physiology. Evaluation of the research in the field of crop physiology. Lectures and class discussion by the subject specialists. Project development in crop physiology.

### **Suggested Readings**

1. Agronomy Journal. American Society of Agronomy, U.S.A.
2. Crop Science. Crop Science Society of America.
3. Physiologia Plantarum
4. Plant Physiology. American Association of Plant Physiologists, U.S.A.
5. Annual Review of Plant Physiology, USA.
6. Recent Advances in Agronomy.
7. Current Science

## **ANALYTICAL TECHNIQUES IN CROP PHYSIOLOGY**

**4(2-4)**

**Vision:** To equip the students with current analytical techniques applied in the field of crop physiology.

### **Theory**

Principles of various analytical techniques used in qualitative and quantitative analysis of seeds, seedlings and plants; chromatography, electrophoresis, spectroscopy, centrifugation and use of tracers. Plant growth analysis, measurements of components of plant microclimate and measurements of nitrogen fixation.

### **Practical**

Different techniques used in the modern research will be taught with special emphasis on practical work. Techniques included in this course will depend upon the availability of instruments and expertise.

## **Books Recommended**

1. Coombs, J., D.O. Hall., S.P. Long. J.M.O. Scurlock. 1985. Techniques in Bioproductivity and Photosynthesis. Pergamon Press, Oxford, U.K.
2. Meidner, H. 1984. Class Experiments in Plant Physiology. George Allen and UNWIN, London, U.K.
3. Moore, T.C. 1981. Research Experience in Plant Physiology. A Laboratory Manual. 2<sup>nd</sup> ed. Springer Verlag. New York.
4. Hall, D.O., J.M.O. Scurlock, H.R. Balhar-Norden Kampf, R.C. Leegood and S.P. Long. 1993. Photosynthesis and Productivities in a Changing Environment: A field and laboratory manual. Chapman and Hall. London.
5. Percy, R.W., J.R. Ehleringer, H.A. Mooney and P.W. Rundel. 1991. Plant Physiological Ecology: Field Methods and Instrumentation. Chapman and Hall.
6. Wood, P. 1996. Scientific Illustrations. 2<sup>nd</sup> ed., Amazon Publishers, USA.
7. Rodney, F. B. 2000. Modern Experimental Biochemistry. 3<sup>rd</sup> ed. Benjamin Cummins.
8. Robert, S. and Liam, G. 2003. Experimental Biochemistry: Theory and Exercises in Fundamental Methods.
9. Dietmar, T. 1998. Nucleic Acid Electrophoresis: Lab Manual. Springer-Verlag, Berlin.

## **PLANT MOLECULAR BIOLOGY**

**4(3-2)**

**Vision:** To provide a vision of molecular biology to crop physiologists.

### **Theory**

Introduction to molecular biology; Macro molecules in plant physiology, Proteins, Carbohydrates, Lipids, Nucleotides, Nucleosides and their role; Structure of DNA, RNA; Genes and Gene expression, Protein synthesis, Chromosomes, Mitotic and meiotic behavior of genes, DNA replication & repair mechanism. Plant genome organization and fluidity. Gene regulation, signal transduction, chloroplast and mitochondrial genome. Plant genetic engineering and its application in agriculture.

### **Practicals**

DNA isolation and amplification. Isolation of Protein; Visits to research labs with related facilities.

## **Books Recommended**

1. Devi, P. 2005. Principles and Methods of Plant Molecular Biology, Biochemistry and Genetics. Student Edition, India
2. Bruening, G., G.J. Harada, T. Kosuge, and A. Hollaender. 1987. Tailoring Genes for Crop Improvement. Plenum Press, New York, USA.
3. Keen, N.T. T.Kosuge and L.L. Walling. 1988. Physiology and Biochemistry of Plant Microbial Interaction. Am. Soc. of Plant Physiologists. Maryland, USA.
4. Mantell, S.H., J.A. Mathhews and R.A. Mckee. 1985. Principles of Plant Biotechnology. Blackwell Scientific Publications, Oxford, U.K.
5. Old, R.W. and S.B. Primrose. 1985. Principles of Gene Manipulation 3<sup>rd</sup> ed. Blackwell Scientific Publications, Oxford, U.K.
6. Buchanan, B.B., W. Gruissem and R.L. Jones. 2002. Biochemistry and molecular biology of plants. John Wiley and Sons, USA
7. Pena, L. 2005. Transgenic Plants. Methods and Protocol. HUMANA, JN, USA
8. Hafeez, F, Y, Zafar, Y and Khalid, A. M. 2005. Modern techniques in Biotechnology. A theoretical Manual, NIBGE, Faisalabad.

## **BIOPHYSICS OF GROWTH**

**4(3-2)**

**Vision:** To provide knowledge of biophysical aspects of plant growth.

### **Theory**

Long and short distance translocation. Principles of cell wall growth. Mechanisms of cell wall loosening and extension. Changes in cellulose microfibril orientation during differential growth. Relationship of cell wall extension with water and solute uptake. Regulation of leaf growth, internodal growth and root growth. Energy transduction and carbon relations during growth. Radiation biology; UV, IR and laser. Biomagnetism.

### **Practical**

Measurement of cell turgor pressure, osmotic pressure. Seedling growth analysis

## **Books Recommended**

1. Baker, N.R., W.J. Davies, C.K. Ong. 1985. Control of Leaf Growth, Cambridge University Press, Cambridge, U.K.
2. Cosgrove, D.J. and D.P. Knievel. 1987. Physiology of Cell Expansion During Plant Growth. American Society of Plant Physiologists, Rockville, MD, USA.

3. Dale, J.E. 1982. The Growth of Leaves. Edward Arnold, London, UK.
4. Tazawa, M., M. Katsumi, Y. Masuda and H. Okamoto. 1989. Plant Water Relations and Growth under Stress. My K.K., Tokyo, Japan.

## **PLANT METABOLISM AND BIOENERGETICS**

**3(3-0)**

**Vision:** To understand the processes of plant metabolism and energy relationships.

### **Theory**

Biological architecture; mitochondria and chloroplast. Oxidation-reduction reactions. Oxidizing reducing agents. Energy flow in plant systems. Bio-synthesis of protein, carbohydrates, fats and other compounds. Respiration, its regulation and energetics.

### **Books Recommended**

1. Goodwin T.W. and E.I. Mercer. 1988. Introduction to Plant Biochemistry. Pergamon Process Ltd.
2. Lehniger, A.L. 1981. The Molecular Basis of Biological Energy Transformation. II.Ed. Hopkins University Press, USA.
3. Taiz, L. and E. Zeiger. 2002. Plant Physiology. 3<sup>rd</sup> ed. Sinauer Publishers, Sunderland, USA.
4. Hopkins, W.G. 2004. Introduction to Plant Physiology. 3<sup>rd</sup> ed. John Wiley and sons, New York, USA.

## **MODELING CROP GROWTH AND DEVELOPMENT**

**4(3-2)**

**Vision:** To understand and take advantage of different crop models for the prediction of growth and development of crop plants.

### **Theory**

Concept of crop modeling and agri-informatics. Introduction to growth models for various crops. Types of crop models. Purpose and objectives of crop simulation models. Limitations of crop models. Development of crop growth models. Requirments for simulating crop growth; basic informations and daily meteorodogical informations. Components of a model: Recent sub-models; phenological development, tiller and leaf development, PAR interception and photosynthesis and dry matter partitioning. Verification of crop models.

## **Practicals**

Data collection for model development and verification. Computer exercises for hand on experience on models for different crops.

### **Books Recommended:**

1. Hay, R.K.M and A.J. Walker. 1989. An Introduction to Physiology of Crop Yield. Longman Group, UK Ltd.
2. Charles-Edwards, D.A., D.Doley and G.M. Rimmington. 1986. Modelling Plant Growth and Development. Sydney, Australia.
3. Charles-Edwards, D.A. 1982. Physiological Determinants of Crop Growth. Academic Press, London.
4. Milthrope, F.L. and J.Moorby. 1979. An Introduction to Crop Physiology. Cambridge University Press, London.

## **PLANT WATER RELATIONS**

**3(2-2)**

**Vision:** To understand the role of water within the plants and its importance.

### **Theory**

Importance of water for plants. Physical properties of water. The ascent of sap, the cohesion mechanism, anatomy of pathway. Capillary rise in xylem, tensile strength and electrical properties. Free energy and chemical potential, analysis of chemical potential. Water potential standard state, hydrostatic pressure, water activity and osmotic potential, Van't Hoff relations and matric potential. Water potential and plant cells. Plasmolysis, chemical and water potential of water vapors, plant air interface, water flux and kinetics of volume change.

### **Practical**

Techniques and experimental approaches for measurement of plant water status. Measurement of water content, water potential, pressure chamber technique and psychrometric techniques. Methods of inducing water stress in plants.

### **Books Recommended**

1. Kramer, P.J. 1983. Water relations in plant. Academic Press. New York.
2. Nobel, P.S. 1992. Physio-chemical and Environmental Plant Physiology. 4th Ed. Academic Press, New York.

3. Turner, N.C. 1981. Techniques and experimental approaches for measurement of plant water status. Plant and soil. Volume 58. Dr. W. Junk Publishers. Hague, Netherland.
4. Taiz, L. and E. Zeiger. 2002. Plant physiology, 3<sup>rd</sup> ed. Sinauer Associates, Sunderland, USA.
5. Ehlers, W. and M.J. Goss. 2004. Water Dynamics in Plant Production. CABI Publishing,

### **SPECIAL PROBLEM**

**2(0-4)**

**Vision:** To inculcate the potential for project development and execution.

Project development, survey, field, laboratory, pot or green house experiments. Compilation, presentation of data and report writing.

### **SEMINAR**

**1(1-0)**

**Vision:** To develop communication skills of the students.

Selection of seminar topic. Preparation of material for presentation. Class presentation.

**THESIS M.Sc. (HONS) CROP PHYSIOLOGY**

**10(0-20)**

**THESIS Ph. D. CROP PHYSIOLOGY**

**20(0-40)**

## **RECOMMENDATIONS**

The committee recommended the following:

1. The committee recommended that departments of Crop Physiology be established in those agricultural universities/institutions where it does not exist.
2. The committee further recommended that Crop Physiology be given an equivalent status as other major disciplines of agriculture by the Federal and Provincial Public Service Commissions.
3. Adequate number of posts of Crop Physiologists be created in agricultural departments/organizations of the country to strengthen the agricultural system by giving due recognition to this important field.
4. National Book Foundation of Pakistan may be requested to reproduce some of the basic text books in Crop Physiology in consultation with the experts.
5. Internship:
  - a) Last six-months/final semester of the academic program should preferably be reserved for internship. However, where internship opportunities are not available, optional courses should be offered as an alternative.
  - b) The committee recommends that HEC should provide remuneration @ Rs.5000/month for the internship.
6.
  - a) Laboratory and library facilities may be further strengthened to make academic programs more effective.
  - b) Faculty should be trained to impart effective teaching in Crop-physiology.