COURSE SYLLABUS: Molecular Marker Assisted Plant Breeding
HOS 6236
Fall Semester 2015

Familiarity with molecular marker systems – identification, utilization, and integration in plant breeding programs – is a prerequisite for employment in both public and private settings. This course provides an overview of terminology, methodology, and applied examples of utilizing molecular markers in a plant breeding program.

At the conclusion of this course, students will be able to:

- List and explain differences between molecular marker systems available for use
- Describe current use of molecular markers in plant breeding programs
- Diagram the steps necessary to effectively implement molecular markers in a plant breeding program
- Determine the most effective and efficient molecular marker method to use for common plant breeding strategies
- Perform genetic linkage mapping using molecular markers with one common software program
- Perform QTL analysis using a molecular marker based genetic linkage map
- Describe available software to aid in marker assisted breeding

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Office hours: Wednesdays Period 3 (9:35-10:25am)

Prerequisites: It is expected that you will have basic knowledge (undergraduate level) of plant breeding science and theory, statistics, and molecular biology. If you have not had classes in these areas previously, you will find many of the course topics difficult to follow.

Credit hours: 3

Class Meeting Days: MWF Period 4 (10:40-11:30am)

Location: 2316 Fifield

COURSE OUTLINE & SCHEDULE (Fall 2015)

DATE	TOPIC	ASSIGNMENTS /EXAMS
Aug 24(M)	Introductions, review of class syllabus and projects	Knowledge quiz
Aug 26(W)	Marker Assisted Plant Breeding	Bring summary of your research project
Aug 28(F)	Review of genetics and molecular biology	
Aug 31(M)	Review of genetics and molecular biology	
Sept 2(W)	History of molecular markers	
Sept 4(F)	Genetics/plant breeding discussion	Read and be prepared to discuss Mendel paper
Sept 7(M)	**Labor Day Holiday – No Class**	
Sept 9(W)	Assignment work day	Decide on lecture topic area, begin lecture outline
Sept 11(F)	Survey of molecular markers	Explore the tutorial on genetic markers at http://www.extension.org/pages/60385/genetic-markers:-conifer-genomics-module-6#.VdYc7JerHgo
Sept 14(M)	Survey of molecular markers	Explore the tutorial on converting markers at http://www.extension.org/pages/66750/marker-conversion#.VdYcMJerHgo
Sept 16(W)	Genotyping by sequencing (GBS)	Watch GBS method overview workshop (Dr. Rob Elshire) at https://www.youtube.com/watch?v=NGqKJ0TnL9o
Sept 18(F)	Markers/Next-Gen sequencing discussion	Read and be prepared to discuss Next-generation sequencing paper
Sept 21(M)	Rubric development	Just an example to look through – there are many ways to develop a rubric http://www.assessment.uconn.edu/docs/How_to_Create_Rubrics.pdf
Sept 23(W)	Successful examples – fingerprinting and diversity	
Sept 25(F)	Exam 1	Genetics review, marker types, GBS, marker usage
Sept 28(M)	Linkage mapping	Explore tutorial on scoring a molecular marker at http://www.extension.org/pages/32365/genotyping-with-molecular-markers:-scoring-a-molecular-marker-on-an-agarose-gel
Sept 30(W)	Linkage mapping	Explore linkage mapping video at http://www.extension.org/pages/60392/genetic-mapping:-conifer-genomics-module-8#.VdYeN5erHgo
Oct 2(F)	Linkage mapping discussion	Read and be prepared to discuss Linkage mapping paper
Oct 5(M)	Linkage mapping	
Oct 7(W)	Linkage mapping	
Oct 9(F)	Linkage mapping	
Oct 12(M)	Quantitative trait loci (QTL) analysis	Watch QTL mapping video at http://www.extension.org/pages/60395/conifer-translational-genomics-network-online-module-9:-mapping-quantitative-trait-loci-qtl
Oct 14(W)	QTL analysis	
Oct 16(F)	QTL analysis discussion	Read and be prepared to discuss QTL analysis paper

Oct 19(M)	QTL analysis	
Oct 21(W)	QTL analysis	
Oct 23(F)	QTL analysis	Read and be prepared to discuss QTL mapping paper
Oct 26(M)	QTL validation	First draft of assignment due for peer review
Oct 28(W)	Successful examples – putting QTL studies to use	
Oct 30(F)	Exam 2	Linkage and QTL mapping, marker-assisted breeding. Costumes optional.
Nov 2(M)	Polyploidy	
Nov 4(W)	Linkage disequilibrium (LD)	Watch LD and Association genetics videos at http://www.extension.org/pages/63011/association-analysis
Nov 6(F)	**Homecoming Holiday – No Class**	
Nov 9(M)	Linkage disequilibrium (LD)	
Nov 11(W)	**Veteran's Day Holiday – No Class**	
Nov 13(F)	Association genetics discussion	Read and be prepared to discuss association genetics paper
Nov 16(M)	Association genetics	
Nov 18(W)	Genomic selection	
Nov 20(F)	Genomic selection	Watch Breeding in a Genomics Era Webinar at https://www.youtube.com/watch?feature=player_embedded&v=MXU-Oy5oQeE
Nov 23(M)	MAB examples	
Nov 25(W)	**Thanksgiving Holiday – No Class**	
Nov 27(F)	**Thanksgiving Holiday – No Class**	
Nov 30(M)	Student lectures	
Dec 2(W)	Student lectures	
Dec 4(F)	Student lectures	
Dec 7(M)	Make-up day	
Dec 9(W)	Course wrap-up	
Dec 18(F)	Final Exam 10:00am-12:00pm Group 18B	LD, association genetics, genomic selection, MAB examples

TEXT AND SUGGESTED READING

Text:

There is no required text for this course. A suggested reading list for major course topic areas is provided below. The instructor will make every effort to ensure students receive the most current information; thus additional readings may be assigned based

on current literature. The citations for assigned readings will be posted on the class website or via email one week prior to use.

Suggested Reading List:

Molecular Plant Breeding

- Bernardo, R. 2008. Molecular markers and selection for complex traits in plants: Learning from the last 20 years. *Crop Science* 48:1649-1664.
- Collard, B.C.Y., and D.J. Mackill. 2008. Marker-assisted selection: an approach for precision plant breeding in the twenty-first century. *Philosophical Transactions of the Royal Society B* 363:557-572.
- Collard, B.C.Y., M.Z.Z. Jahufer, J.B. Brouwer, and E.C.K. Pang. 2005. An introduction to markers, quantitative trait loci (QTL) mapping and marker-assisted selection for crop improvement: The basic concepts. *Euphytica* 142:169-196.
- Moose, S.P., and R.H. Mumm. 2008. Molecular plant breeding as the foundation for 21st century crop improvement. *Plant Physiology* 147:969-977.
- Privalle, L.S., J. Chen, G. Clapper, P. Hunst, R. Spiegenhalter, and C.X. Zhong. 2012. Development of an agricultural biotechnology crop product: Testing from discovery to commercialization. *Journal of Agricultural and Food Chemistry* 60:10179-10187.
- Tester, M., and P. Langridge. 2010. Breeding technologies to increase crop production in a changing world. *Science* 327:818-822.
- Xu, Y. 2010. Molecular plant breeding. CAB International, Oxfordshire, UK.
- Xu, Y., and J.H. Crouch. 2008. Marker-assisted selection in plant breeding: from publication to practice. *Crop Science* 48:391-407.
- Young, N.D. 1999. A cautiously optimistic vision for marker-assisted breeding. *Molecular Breeding* 5:505-510.

Molecular Marker Types

- Agarwal, M., N. Shrivastava, and H. Padh. 2008. Advances in molecular marker techniques and their applications in plant sciences. *Plant Cell Reports* 27:617-631.
- Ellegren, H. 2004. Microsatellites: simple sequences with complex evolution. *Nature Reviews Genetics* 5:435-445.
- Elshire, R.J., J.C. Glaubitz, Q. Sun, J.A. Poland, K. Kawamoto, E.S. Buckler, S.E. Mitchell. 2011. A robust, simple genotyping-by-sequencing (GBS) approach for high diversity species. *PLoS ONE* 6(5): e19379. doi:10.1371/journal.pone.0019379
- Kalia, R.K., M.K. Rai, S. Kalia, R. Singh, and A.K. Dhawan. 2011. Microsatellite markers: an overview of the recent progress in plants. *Euphytica* 177:309-334.
- Rafalski, A. 2002. Applications of single nucleotide polymorphisms in crop genetics. *Current Opinion in Plant Biology* 5:94-100.
- Roberts, R.J. 2005. How restriction enzymes became the workhorses of molecular biology. *Proceedings of the National Academy of Sciences* 102:5905-5908.
- Schlotterer, C. 2004. The evolution of molecular markers – just a matter of fashion? *Nature Reviews Genetics* 5:63-69.
- Varshney, R.K., S.N. Nayak, G.D. May, and S.A. Jackson. 2009. Next-generation sequencing technologies and their implications for crop genetics and breeding. *Trends in Biotechnology* 27:522-530.

Linkage and QTL Mapping

- Cregan, P.B., J. Mudge, E.W. Fickus, D. Danesh, R. Denny, and N.D. Young. 1999. Two simple sequence repeat markers to select for soybean cyst nematode resistance conditioned by the *rhg1* locus. *Theoretical and Applied Genetics* 99:811-818.
- De Franceschi, P., T. Stegmeir, A. Cabrera, E. van der Knaap, U.R. Rosyara, A.M. Sebolt, L. Dondini, E. Dirlewanger, J. Quero-Garcia, J.A. Campoy, and A.F. Iezzoni. 2013. Cell number regulator genes in *Prunus* provide candidate genes for the control of fruit size in sweet and sour cherry. *Molecular Breeding* DOI 10.1007/s11032-013-9872-6.
- Frary, A., T.C. Nesbitt, S. Grandillo, E. van der Knaap, B. Cong, J. Liu, J. Meller, R. Elber, K.B. Alpert, and S.D. Tanksley. 2000. *fw2.2:* A quantitative trait locus key to the evolution of tomato fruit size. *Science* 289:85-88.
- Paterson, A.H., E.S. Lander, J.D. Hewitt, S. Peterson, S.E. Lincoln, and S.D. Tanksley. 1988. Resolution of quantitative traits into Mendelian factors by using a complete linkage map of restriction fragment length polymorphisms. *Nature* 335:721-726.
- Salvi, S. and R. Tuberosa. 2015. The crop QTLome comes of age. *Current Opinion in Biotechnology* 32:179-185.
- Tanksley, S.D. 1993. Mapping polygenes. *Annual Review of Genetics* 27:205-233.
- Tanksley, S.D., and S.R. McCouch. 1997. Seed banks and molecular maps: unlocking genetic potential from the wild. *Science* 277:1063-1066.
- Voorrips, R.E., and C.A. Maliepaard. 2012. The simulation of meiosis in diploid and tetraploid organisms using various genetic models. *BMC Bioinformatics* 13:248.

Linkage Disequilibrium and Association Mapping

- Brachi, B., N. Faure, M. Horton, E. Flahauw, A. Vazquez, M. Nordborg, J. Bergelson, J. Cuguen, and F. Roux. 2010. Linkage and association mapping of *Arabidopsis thaliana* flowering time in nature. *PLoS Genet* 6(5):e1000940.
- Hou, J., C. Wang, X. Hong, J. Zhao, C. Xue, N. Guo, J. Gai, and H. Xing. 2011. Association analysis of vegetable soybean quality traits with SSR markers. *Plant Breeding* 130:444-449.
- Myles, S., J. Peiffer, P.J. Brown, E.S. Ersoz, Z. Zhang, D.E. Costich, and E.S. Buckler. 2009. Association mapping: critical considerations shift from genotyping to experimental design. *The Plant Cell* 21:2194-2202.
- Oraguzie, N.C., E.H.A. Rikkerink, S.E. Gardiner, and H.N. de Silva (eds.) 2007. Association mapping in plants. Springer-Verlag, New York, NY.
- Yan, J., T. Shah, M.L. Warburton, E.S. Buckler, M.D. McMullen, and J. Crouch. 2009. Genetic characterization and linkage disequilibrium estimation of a global maize collection using SNP markers. *PLoS ONE* 4(12):e8451.

Pedigree Based Analysis and Genomic Selection

- Heffner, E.L., A.J. Lorenz, J-L. Jannink, and M.E. Sorrells. 2010. Plant breeding with genomic selection: gain per unit time and cost. *Crop Science* 50:1681-1690.
- Heffner, E.L., M.E. Sorrells, and J-L. Jannink. 2009. Genomic selection for crop improvement. *Crop Science* 49:1-12.
- Jannink, J-L., A.J. Lorenz, and H. Iwata. 2010. Genomic selection in plant breeding: from theory to practice. *Briefings in Functional Genomics* 9:166-177.
- Jonas, E. and D-J. de Koning. 2013. Does genomic selection have a future in plant breeding? *Trends in Biotechnology* 31:497-504
- Rosyara, U.R., M.C.A.M. Bink, E. van de Weg, G. Zhang, D. Wang, A. Sebolt, E. Dirlewanger, J. Quero-Garcia, M. Schuster, and A.F. Iezzoni. 2013. Fruit size QTL

identification and the prediction of parental QTL genotypes and breeding values in multiple pedigreed populations of sweet cherry. *Molecular Breeding* 32:875-887.
- Van de Weg, W.E., R.E. Voorrips, R. Finkers, L.P. Kodde, and E.J. Meulenbroek. 2006. Pedigree genotyping: a new pedigree-based approach of QTL identification and allele mining by exploiting breeding material. *Acta Horticulturae* 708:483-488.

ATTENDANCE AND MAKE-UP POLICY, EXAMS, CLASS ASSIGNMENT & GRADING

Attendance and Make-up policy:

Attendance to class is expected. Assignments are due on the dates announced. One point will be deducted for each day following the due date, and no credit will be given for assignments one week after the due date. Exam make-ups will be arranged only for university-approved excused absences (illness, religious holidays, military obligation, official university activities, special curricular requirements, or severe weather conditions). Excused absences during exam periods must be scheduled within a week of the original test and at the convenience of the instructor.

Additional information regarding this policy can be found at:
https://catalog.ufl.edu/ugrad/current/regulations/info/attendance.aspx

Exams:

Three exams including the course final (see schedule) cover topics presented during lecture.

Class Assignment:

Each student will be responsible for developing a 20-25 minute lecture describing the use of one software package important for genetic analysis. Many options are available: Linkage and QTL mapping, graphical genotyping, diversity analysis, primer design, gene annotation, etc.

Successful lectures should cover the historical background of the software, its uses and limitations, examples of use, and importance for marker assisted breeding activities. Collectively, students will develop an evaluation rubric that will be used to evaluate each lecture.

Detailed assignment instructions will be provided in class.

Grading:

There are 400 total points available for the course (3 exams and 1 assignment, each 100 points). Course grades will be assigned according to the following scale.

Letter	Grade Point	Percentage	Total Course Points
A	4.00	94-100	376+
A-	3.67	90-93.9	360-375.9
B+	3.33	87-89.9	348-359.9
B	3.00	84-86.9	336-347.9
B-	2.67	80-83.9	320-335.9
C+	2.33	77-79.9	308-334.9
C	2.00	74-76.9	296-307.9
C-	1.67	70-73.9	280-295.9
D+	1.33	67-69.9	268-279.9
D	1.00	64-66.9	256-267.9
D-	0.67	60-63.9	240-255.9
E	0.00	59.9 below	239.9 and below

For additional information on UF grading policies, see
https://catalog.ufl.edu/ugrad/current/regulations/info/grades.aspx

STUDENTS REQUIRING ACCOMODATIONS

Students with disabilities requesting accommodations should first register with the Disability Resource Center (352-392-8565, www.dso.ufl.edu/drc/) by providing appropriate documentation. Once registered, students will receive an accommodation letter which must be presented to the instructor when requesting accommodation. Students with disabilities should follow this procedure as early as possible in the semester.

COURSE EVALUATION

Students are expected to provide feedback on the quality of instruction in this course by completing online evaluations at https://evaluations.ufl.edu. Evaluations are typically open during the last two or three weeks of the semester, but students will be given specific times when they are open. Summary results of these assessments are available to students at https://evaluations.ufl.edu/results/.

UNIVERSITY HONESTY POLICY

UF students are bound by The Honor Pledge which states, “We, the members of the University of Florida community, pledge to hold ourselves and our peers to the highest standards of honor and integrity by abiding by the Honor Code. On all work submitted for credit by students at the University of Florida, the following pledge is either required or implied: “On my honor, I have neither given nor received unauthorized aid in doing this assignment.” The Honor Code (http://www.dso.ufl.edu/sccr/process/student-conduct-honor-code/) specifies a number of behaviors that are in violation of this code and the possible sanctions. Furthermore, you are obligated to report any condition that

facilitates academic misconduct to appropriate personnel. If you have any questions or concerns, please consult with the instructor or TAs in this class."

COUNSELING AND WELLNESS CENTER

Contact information for the Counseling and Wellness Center: http://www.counseling.ufl.edu/cwc/Default.aspx, 392-1575; and the University Police Department: 392-1111 or 9-1-1 for emergencies.