Inheritance of Final Leaf Number in Dicktoo × Oregon Wolfe Barley Dominant and Dicktoo × Calicuchima barley F_2 populations

Introduction

For plants to live through harsh winter weather, they must be able to withstand periods of low temperature. The capacity to survive through the winter is called winterhardiness. Winterhardiness is important for native plants in natural environments and for cultivated plants in agriculture. Particularly in an era of climate change, it is important to understand the traits that determine the winterhardiness of plants. In the case of crops exposed to greater oscillations of temperature with more extreme highs and lows, such knowledge will be essential for maintaining productive agricultural and horticultural production.

Winterhardiness is deceptively simple to measure: the difference in the number of plants per unit area at the beginning of winter minus the number remaining in the same area at the end of winter. However, many component traits determine this simple difference. A principal component of winterhardiness is low temperature tolerance. However, low temperature tolerance is difficult to measure under field conditions, as it is affected by such factors as acclimation period, moisture availability, timing of the low temperature stress during the plant growth cycle, duration of the stress, snow cover, etc. Therefore, low temperature tolerance is most often measured under controlled environment conditions, and these data are then validated by extensive field testing (Mahfoozi et al. 2005). Even the most cold tolerant plants require a period of acclimation, and they will achieve their maximum low temperature tolerance at the vegetative rather than reproductive stage (Fowler et

al. 2001). Environmental signals are cues for acclimation and maintenance of the vegetative state.

Two principal environmental signals are photoperiod duration and temperature. Plants that are sensitive to short photoperiod will remain in a vegetative state as long as the daylength remains below a critical threshold (Roberts et al. 1988). Many plants have an additional growth retardation system that is called vernalization. Plants that require vernalization must receive a low temperature treatment (~4-10°C for 6 – 8 weeks) in order to transition from the vegetative to the reproductive stage. Plants that are vernalization sensitive respond to the extended period of low temperature exposure by accelerating the time to reproductive transition (Szűcs et al. 2007). Low temperature and short photoperiod signaling are hypothesized to both be involved in regulating the expression of genes involved low temperature tolerance (Skinner et al. 2005).

Therefore, one approach to understanding the genetics of winterhardiness is to engage in a genetic dissection of the component traits. The Oregon State University Barley Project has taken this approach in an effort to develop barley varieties that can capitalize on winter rainfall patterns, survive the winter, and provide farmers with stable and high returns of quality grain. This has involved genetic dissection of low temperature tolerance (Francia et al. 2004), photoperiod sensitivity (Fowler et al. 2001) and vernalization requirement/sensitivity (Cooper et al. 2006).

The three growth habit types of barley (and of other members of the Triticeae) are determined by vernalization genes. The winter, facultative, and spring growth habit types can be rigorously defined based on their allele composition at two of the vernalization loci (Table 1) (von Zitzewitz et al. 2005). Spring types are planted in the spring and grow in the summer. Facultative types can be planted in the spring but they

also have sufficient winterhardiness that they can be planted in the fall. Winter types must be planted in the fall because they require vernalization. Facultative types are the most agronomically desirable, provided that they have sufficient winterhardiness. They are desirable because the same variety could be planted in fall or winter, and many grain markets demand specific varieties.

The genetic basis of vernalization sensitivity in barley can be described in terms of a three-locus model (Takahashi and Yasuda 1971), but the two loci involved in the genetics of vernalization in most cultivated germplasm are *VRN-H1* and *VRN-H2* (von Zitzewitz et al. 2005). *VRN-H1* is on chromosome 5H and *VRN-H2* is on chromosome 4H. *VRN-H1* is a gene that is involved in plant growth and development. When this gene is expressed, the plant undergoes a vegetative to reproductive transition. The meristem differentiates, and the plant goes through its growth cycle. This meristem identity gene is likely involved in many other aspects of plant growth and development (Yan et al. 2005). *VRN-H2* is a gene than encodes a repressor, which influences *VRN-H1* to prevent its expression. In winter types, this repressor prevents the expression of *VRN-H1* until a certain period of low temperature is achieved (Dubcovsky et al. 2005). As long as the repressor is present in long-day, *VRN-H1* is not expressed and the plant remains vegetative. The mechanism by which exposure to low temperature reduces, or prevents expression of *VRN-H2* is not known.

The repression of the meristem identity gene could enhance cold tolerance by preventing the vegetative to reproductive transition when there is a high risk of low temperature injury (Yan et al. 2005). There is also evidence that plants in the vegetative stage achieve and maintain low temperature tolerance longer than plants undergoing transition (Fowler et al. 2001). This is important for crops that grow in environments with cold, harsh winters, because it stops the plant from growing during

winter. Once a sufficient period of cold is experienced, the *VRN-H2* genes ceases expression and *VRN-H1* is allowed to be expressed leading to growth and differentiation. In spring growth habit types, the interaction between the *VRN-H1* gene and the VRN-H2 repressor is not present. In some spring types the *VRN-H2* repressor gene is physically deleted and therefore there is no repressor to prevent meristem growth. In others, the repressor is produced, but it has no binding site in *VRN-H1*, due the deletion of a critical region in the first intron of this gene (Fu et al. 2005). Facultative genotypes are low temperature tolerant but do not require vernalization – the mechanism(s) by which they achieve and maintain low temperature tolerance are not understood – but all facultative types identified to date are homozygous recessive at *VRN-H1* and have a deletion of *VRN-H2* (Karsai et al. 2005).

Table 1 Genotypes (in the homozygous condition) of winter, spring, and facultative barley types

Phenotype	**Genotype**
Winter	*vrn-H1vrn-H1Vrn-H2Vrn-H2*
Facultative	*vrn-H1vrn-H1vrn-H2vrn-H2*
Spring	*Vrn-H1Vrn-H1Vrn-H2Vrn-H2* *Vrn-H1Vrn-H1vrn-H2vrn-H2*

When conducting research on vernalization requirement/sensitivity the measure of the phenotype is crucial. The three most commonly used phenotypes are the double ridge stage of meristem development (Kirby and Appleyard 1987), heading date (Wehrhahn and Allard 1965), and final leaf number (FLN) (Wang et al. 1995). Heading date is the simplest to measure. However, there are maturity genes that influence development rate and therefore could bias estimates of vernalization requirement/sensitivity (Hayes et al. 1993). The double ridge stem of meristem

development is an unequivocal assay of the vegetative to reproductive transition, but it requires dissection and microscopy and is therefore time-consuming (Danyluk et al. 2003; von Zitzewitz et al. 2005). FLN is the method of assessment of vernalization requirement/sensitivity used by some research groups (e.g. Fowler et al. 2006). It is less time-consuming to measure than meristem dissection, but is more time consuming to measure than heading date.

The OSU Barley Project and the collaborating group at the Agricultural Research Institute in Martonvasar, Hungary have used heading date as the measure of vernalization requirement/sensitivity in many studies (e.g. Kóti et al. 2006, Karsai et al. 2006, Szűcs et al. 2007). However, in view of the use of FLN by other research groups and the need to make comparisons between results obtained in different labs, it is necessary to determine if the two measures of the phenotype lead to the same conclusions regarding the genetic basis of vernalization requirement/sensitivity. The objective of this research was to measure FLN on the same genetic materials (F_2 populations derived from matings between parents differing for *VRN-H* alleles) that had been genotyped for *VRN-H1* and *VRN-H2* allele type and scored for heading date (Szűcs et al. 2007). Three parameters were used to compare the interpretation of the data on the inheritance of vernalization using the two methods of phenotype assessment: phenotypic frequency distributions; analyses of variance, and correlations.

Materials and Methods

Full details on the materials and methods used in this study are presented in (Szűcs et al. 2007). Briefly, three barley germplasm accessions (Dicktoo, Calicuchima, and the Oregon Wolfe Barley Dominant genetic stock) were used as parents in three cross combinations. The crosses were: Dicktoo × Oregon Wolfe Barley Dominant (OWB-D); Dicktoo × Calicuchima; and Calicuchima × OWB-D. Each of the parental lines is completely homozygous. The three accessions differ in origin, growth habit, and other attributes. Dicktoo is variety that was released in Nebraska in the 1950's. It has facultative growth habit and has been used extensively to study the inheritance of the components of winterhardiness (Hayes et al. 1997). Calicuchima is a spring growth habit variety developed by the International Maize and Wheat Improvement Center (CIMMYT) Barley Program located at El Batan, Mexico. It was first used by OSU as a source of resistance to barley stripe rust (incited by *Puccinia striiformis* f.sp. *hordei*) (Hayes et al. 1996). The Oregon Wolfe Barley Dominant (OWB-D) genetic stock has spring growth habit and is a parent of the Oregon Wolfe Barley doubled haploid mapping population, an international resource for genetics research and instruction (Costa et al. 2001; www.barleyworld.org). The three accessions were chosen for this study based on their contrasting *VRN-H* alleles, as shown in Table 2.

F_1 progeny from all three crosses were selfed to create three F_2 populations of 93 plants each. The F_2 populations were grown under greenhouse conditions with supplemental light on a 16 h light/24 h photoperiod and a constant 18 ± 1.5°C day and night temperature without any vernalization treatment (Szűcs et al. 2007). Therefore,

spring types were expected to grow and transition to a reproductive state from a vegetative state whereas winter types would remain in a vegetative condition.

Table 2. Vernalization alleles and phenotypes of three barley germplasm accessions and expected F_2 segregating patterns in their F_2 progeny

Parent 1		**Parent 2**		**F2**
Dicktoo		**OWB –D**		**Expect segregation** for Vrn requirement
Genotype	Phenotype	Genotype	Phenotype	
v1v1/v2v2	No Vrn requirement	*V1V1/V2V2*	No Vrn requirement	
Parent 1		**Parent 2**		**F2**
Dicktoo		Calicuchima		Expect segregation for Vrn requirement
Genotype	Phenotype	Genotype	Phenotype	
v1v1/v2v2	No Vrn requirement	*V1V1/V2V2*	No Vrn requirement	

Each F_2 plant was genotyped for allele type at the *VRN-H1* and *VRN-H2* loci using allele-specific primers. This aspect of the research was not part of this thesis project; the genotyping is described in detail by Szűcs et al. (2007). For the purposes of this thesis project, the key points are that the presence/absence of *VRN-H2* was confirmed by assay of co-dominant alleles at the tightly linked *SNF2* locus. Primers for *VRN-H1* were designed to differentiate the winter (wild type) allele from the spring alleles due to deletions of the putative *VRN-H2* binding region in the *VRN-H1* first intron.

Both the heading date and the final leaf number (FLN) were measured on the parents, F_1, and all F_2 plants of the Dicktoo × OWB-D and Dicktoo × Calicuchima populations. Each F_2 plant is genetically distinct and therefore cannot be replicated. Parents and F_1s were replicated to a total of 24 plants. FLN was not measured on the F_2 progeny of the Calicuchima × OWB-D cross. Heading date was measured as the number of days elapsed between planting and the appearance of the inflorescence (Szűcs et al. 2007). Plants that did not flower after 170 days were assigned a heading date of the same value. The FLN was measured on the putative main stem (tallest

tiller with most physiologically advanced inflorescence) of each F_2 plant after all spring habit plants in each of the two F_2 populations had reached physiological maturity. At the same time, the number of leaves was counted on a representative stem of each of the plants that had remained in a vegetative state. This value was considered the FLN although if plants had been allowed to continue growth more leaves would likely have been produced.

Results

As shown in Table 3, Calicuchima had the highest average FLN, followed by Dicktoo and then the OWB-D. Values for the F_1s were intermediate between the two parents.

Table 3 FLN, growth habit and *VRN-H* allele combinations for parent and F_1 genotypes.

Genotype	FLN	Growth Habit	*VRN-H1VRN-H2*	Germplasm
Dicktoo	6.63 ± 0.9	Facultative	*v1v1v2v2*	Parent
OWB-D	3.25 ± 0.4	Spring	*V1V1V2V2*	Parent
Calicuchima	7.50 ± 0.5	Spring	*V1V1V2V2*	Parent
Dicktoo × OWB-D	5.50 ± 0.5	Spring	*V1v1V2v2*	F_1
Dicktoo × Calicuchima	6.50 ± 0.5	Spring	*V1v1V2v2*	F_1

The frequency distribution of FLN for the Dicktoo × OWB-D F_2 population shows two distinct subpopulations (Figure 1). There were a large number of phenotypic transgressive segregants that had FLN values greater than Dicktoo. The frequency distribution for the Dicktoo × Calicuchima (Figure 2) was continuous. There were F_2 plants with smaller and larger FLN values than either parent.

The results of the ANOVA of FLN for the Dicktoo × OWB-D and Dicktoo × Calicuchima populations are shown in Tables 4 and 5. There were highly significant effects for alleles at *VRN-H1* and *VRN-H2*, and for the interaction of alleles at the two loci.

The chi square tests for the observed vs. expected number of plants in each of the nine *VRN-H* genotype classes showed an excellent fit with values of P = 0.54 in the Dicktoo × OWB-D and P = 0.60 in the Dicktoo × Calicuchima populations, respectively (Szűcs et al. 2007). As shown in Figures 3 and 4, in both the Dicktoo ×

Figure 1 Frequency distribution for FLN in the Dicktoo × OWB-D F_2 population

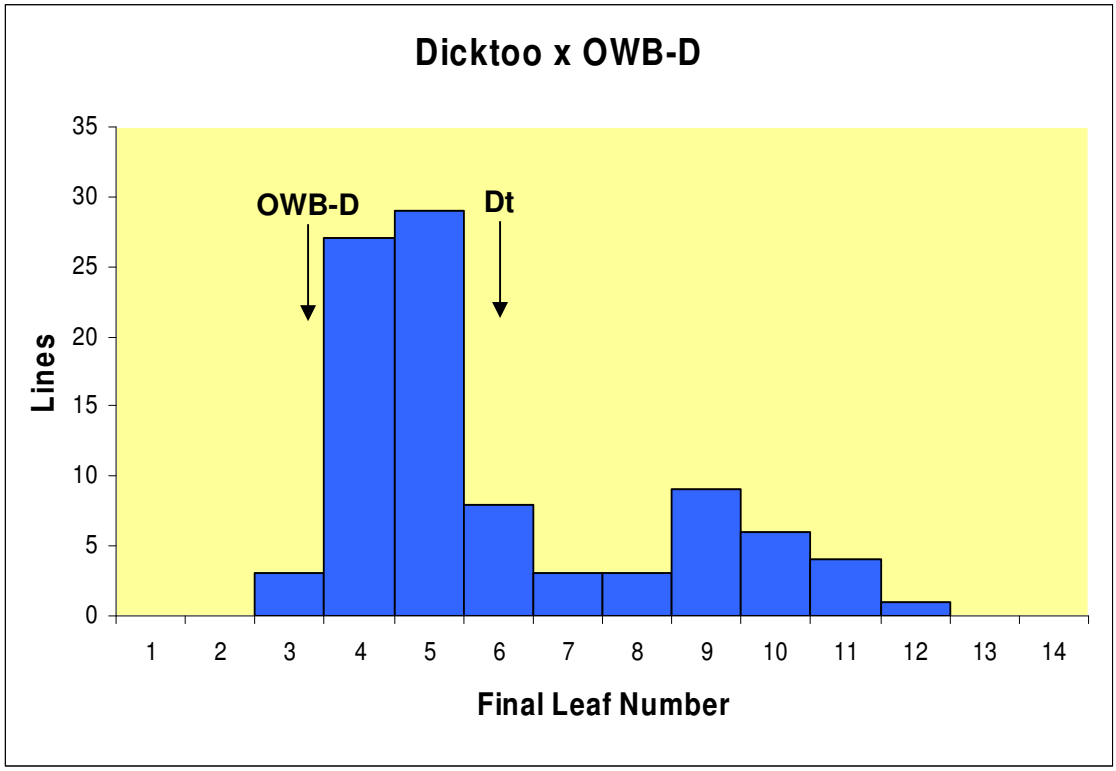


Figure 2 Frequency distribution for FLN in the Dicktoo × Calicuchima F_2 population

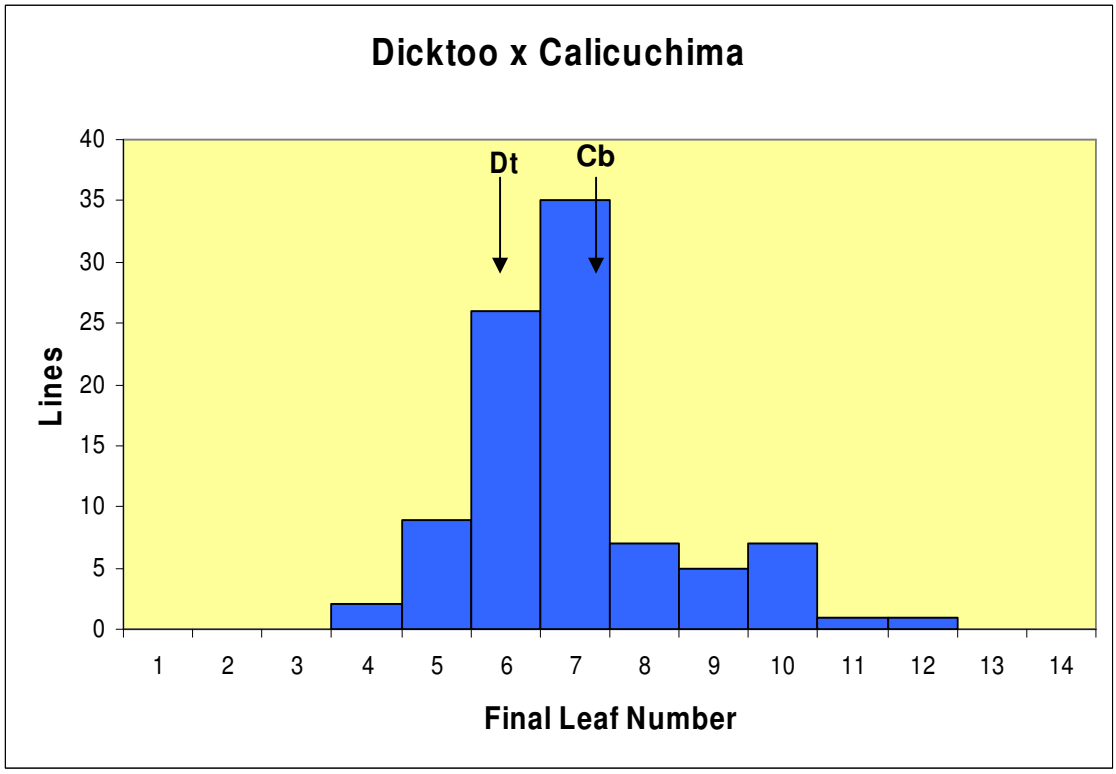


Table 4 Effects of *VRN-H1* and *VRN-H2* and their interactions on final leaf number in Dicktoo × OWB-D F_2 populations

Source of variation	Degrees of freedom	Type III mean square	F value	P Value
VRN-H1	2	183.48	105.13	<0.001
VRN-H2	2	57.67	33.04	<0.001
VRN-H1 × *VRN-H2*	4	47.67	13.66	<0.001

Table 5 Effects of *VRN-H1* and *VRN-H2* and their interactions on final leaf number in Dicktoo × Calicuchima F_2 populations

Source of variation	Degrees of freedom	Type III mean square	F value	P Value
VRN-H1	2	38.05	58.43	<0.001
VRN-H2	2	27.96	42.93	<0.001
VRN-H1 × *VRN-H2*	4	5.48	8.42	<0.001

OWB-D and Dicktoo × Calicuchima populations the two winter genotype classes (*v1v1V2V2* and *v1v1V2v2*) had significantly higher FLN values than the spring genotype classes.

The correlations between heading date and FLN for the Dicktoo × OWB-D and Dicktoo × Calicuchima populations were r = .94 and r = 0.8, respectively. Both correlations were highly significant (P < 0.0001).

Figure 3 Mean FLN in the nine *VRN-H* genotype classes of the Dicktoo × OWB-D F_2 population

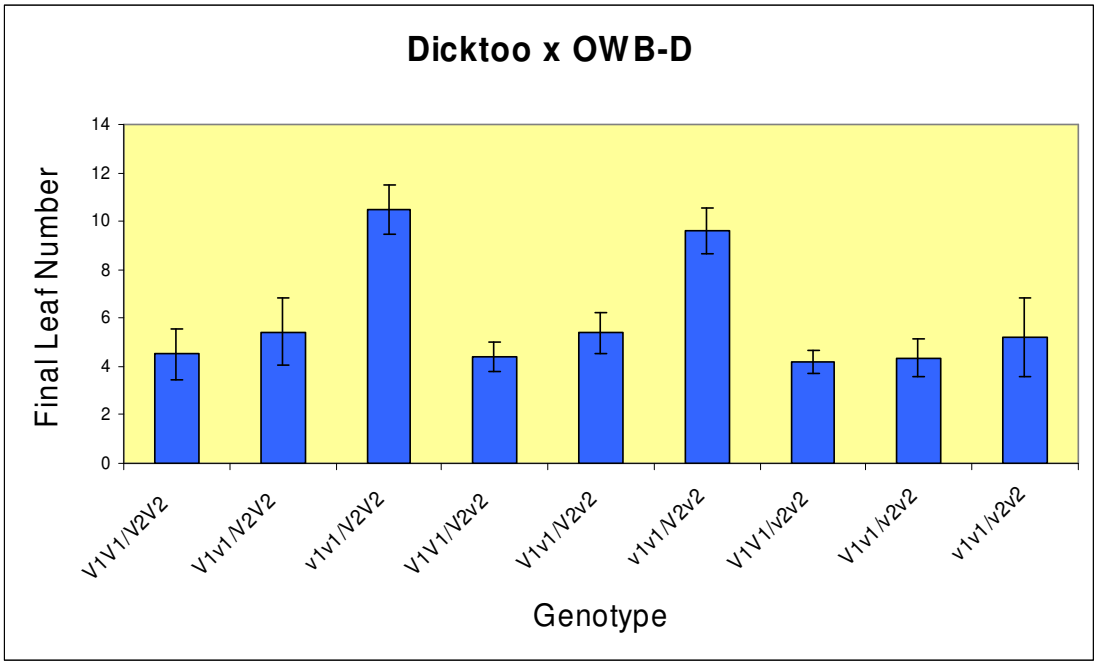
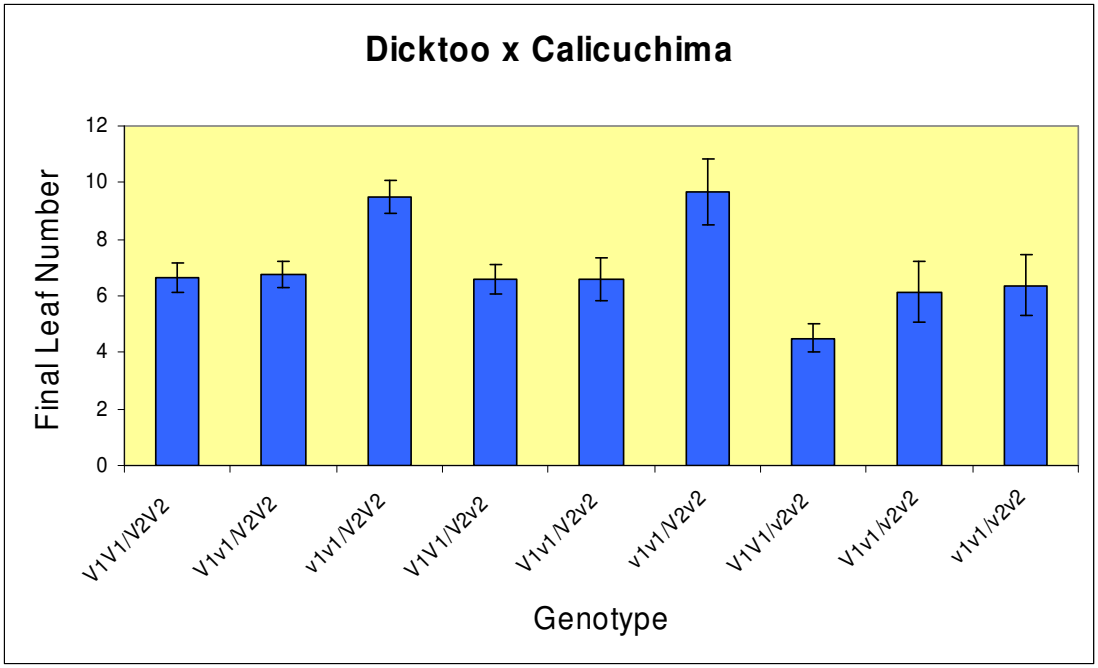


Figure 4 Mean FLN in the nine *VRN-H* genotype classes of the Dicktoo × Calicuchima F_2 population



Discussion

The FLN data and the heading date data are very similar, as measured by correlations and comparison of the phenotypic frequency distributions and ANOVAs reported herein with those of Szűcs et al. (2007). The phenotypic frequency distributions for heading date were more discrete than those for FLN, particularly in the case of the Dicktoo × Calicuchima population. This is probably due to the assignment of high heading date values (170 days) for winter habit F_2 plants that did not flower vs. the actual leaf counts on these lines at the same time that spring habit lines reached physiological maturity. FLN values would probably have been much higher had these actually been obtained at 170 days. Nonetheless, the results of the ANOVAs were identical for the two measures of the vernalization sensitivity phenotype. Finally, the correlations between the two measures of the vernalization sensitivity phenotype were very high for both F_2 populations. Given that FLN is more time-consuming to measure than heading date, the latter is an acceptable measure of the vernalization sensitivity phenotype for this sample of barley germplasm assayed under greenhouse conditions. Therefore, the results and conclusions of Szűcs et al. (2007) regarding the inheritance of vernalization can be used with confidence as the foundation for further research on the role of vernalization sensitivity and winter hardiness.

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International and Local Research Experience

Introduction

When doing research, there is always a way that the research can impact the world. That is why it is important to stay up to date with new research, especially when doing research yourself. When studying barley genetics, it is important to know about other research going on around the world. There are numerous researchers all around the world that study barley. These researchers may be developing new cultivars to improve barley agriculture, they may be trying to understand the genetics of barley, or they may be trying to improve health through use of barley grains in food.

Last fall I traveled to Lleida, Spain to work on a barley research project. Lleida Spain is located about 100 miles west of Barcelona. The area is an arid agricultural region where there is an abundance of grains grown as well as goat herding and citrus fruits. By traveling abroad I was able to learn more about what kind of research is being done on barley in other parts of the world and participate in the research myself while being able to experience a different culture. During my time in Spain I had the opportunity to be involved with a much different research and school experience than I had at Oregon State University. Oregon State University is located in Corvallis, Oregon. Corvallis is situated in the Willamette Valley where there is an abundance of grass seed grown as well as a multitude of other agricultural and food products. They key differences between the University of Lleida and Oregon State University include school history, current university academics and atmospheres, as well as my research

experiences at both institutions. In the following pages I will compare and contrast my experiences at both universities.

University of Lleida

History

The University of Lleida has a long history dating back to the middle ages. In 1300 the University of Lleida was established by a charter from the King of Aragon, James II. The creation of the charter for the university was issued by papal bull in Rome on the 1st of April 1297, by Pope Boniface VIII (History, 2006). The university was named the Estudi General de Lleida. The school continued with vitality for a few centuries as a place where students from all over Aragon and other territories came to study. However, in the later 16th century, the university began to have competition from other universities in the area. This decreased the universities exclusivity, but the schools of the Estudio of Lleida managed to maintain their old prestige acquired through time (History, 2006).

In the 17th century, with the reign of Philip V, a new university was created 70 kilometers from the University of Lleida. During this time there was a continued political repression of the Catalonian region by the monarch. With the construction of the new school, the University of Lleida was shut down along with all other universities in Catalunya as result of a royal law. During the time banning the university, the building continued as a seminary.

It was not until 1968 that the first true reopening of the university began. During this time academic studies were re-implemented through the help of the University of Barcelona and other institutions in Barcelona. New buildings were added to the university, with a focus on the agricultural department on the outskirts of town. The original building for the University of Lleida was located in the center of

town. In December 1991, the Parliament of Catalonia passed an act to officially create the University of Lleida. This established the university as a permanent school with a constitution and a rector of the university through election. Since then, the University of Lleida has been committed to innovation and the permanent improvement of the quality of teaching, research and management in the service of society (History,2006).

University of Lleida Currently

Today, the University has about 10,000 students total, with about 3,000 of those students in the agricultural department. The university has about eight colleges that contain many other departments within. The different colleges are located all over the city; they are not all on one campus. Students in the university system in Spain, as well as other countries in Europe, study only their selected major. The classes required are only those in their major; most students conduct their studies and take classes in just one building. Being that the different buildings are located on different campuses it is convenient that they do not have to travel to different buildings during the day to take different classes.

I was mostly involved with the Agricultural College where there are ten areas of study. Agriculture is an important department because there is much agriculture that surrounds the city, as well as extends all over the province of Lleida and other parts of Spain. Many of the students and faculty work with local farmers and ranchers to learn more about resource management, challenges that agriculture faces in the region and look for solutions to those problems. The agricultural college participates in research to help discover new methods for agriculture as well as help the local farming community.

Research Experience

While at the University of Lleida, I worked in the lab of Dr. Ignacio Romagosa. I worked alongside a graduate student on a project involving barley root growth and structure. During my time in the Romagosa lab, there were not many research projects going on being that Dr. Romagosa was frequently traveling to Madrid. There was one staff member working in the lab at the time and she was involved with a small research project involving barley genetics.

The lab was equipped with growth chambers, basic PCR equipment and an autoclave. Much other of the equipment and technology needed for genetic research was shared by many labs. There was also a computer lab located close to the Romagosa lab which was shared with one other faculty lab. The computer lab was used for statistical analysis, research and computing data.

The limited amount of equipment and technology available for genetic research seemed to be due to a lack of funding. Currently Spain has a difficult system to navigate when funding research groups and the money allocated to research has very strict rules. The Spanish Ministry of Science and Technology only allows for one grant at a time within a research group no matter what the amount of need (Pain, 2004). The application for this financial support is very cumbersome and takes an extreme amount of time to process. Many times PhD students have to start their program before they even receive any money. This leads to many months of unpaid work. Even after a grant is received, most of them only last about two years. After the two year period, there is a need to re-apply without certainty of receiving any support. The small budgets of research groups, the impossibility of appointing personnel by means of contracts, and delays in payments are common topics in Spanish science; in

fact, this lack of funding is one of the major problems that hamper the productivity of the Spanish research groups (Pain, 2004).

There have been new laws and regulations to help organize and overcome current restrictions. However, it will take a while for the new laws to be integrated into the research system. Also, these new regulations are just a few changes to many restrictions that need to be changed. The increase in funding allowed to research institutions in Spain and the flexibility in those funds are slowly becoming more apparent. Although the revisions are small, they are a step in helping Spain improve the working conditions of the Spanish researchers as well as Spanish science and technology overall.

The atmosphere in the lab in Spain was very laid back and friendly. The staff and students were very helpful and accommodating to making me feel comfortable and knowledgeable in the lab. The working hours of the staff seemed to be consistent with that of typical Spanish culture. The staff would take regular coffee breaks and a two to three hour lunch before returning to work. However, while at work though, the staff was on task and productively working to accomplish the tasks needed.

In the lab, I studied the root growth and structure of different barley cultivars. The project was based off a previous project conducted by the Scottish Crop Research Institute (Bengough et al. 2004). While the graduate student I worked with studied about twenty or more barley cultivars, I specifically worked on both the dominant and recessive Oregon Wolfe Barley types. We conducted the experiment following the procedure explained in the literature and adapting it for our purposes. We treated the seeds in order for germination to occur and then used growth chambers, acrylamide gels, and plastic plates to grow the seeds. After the gel plates with the seeds were prepared, they remained in the growth chamber for 4 days. Pictures of the individual

plates were taken showing the root growth and structure of the individual seeds. Later, statistical analyses of the pictures were done in order to verify the data.

While this project was meant to be another chapter in my research experience, it unfortunately was unable to be completed. After finishing my study abroad term in Spain, I was unable to retrieve the results from the statistical analyses on the Oregon Wolfe Barley seedlings. This was due to technical difficulties with the statistical computer program and being unable to communicate effectively with the graduate student involved in the project.

Oregon State University

History

The history of Oregon State University (OSU) is not as old as the University of Lleida; however, the university has come a long way from its start in the mid 1800s. The settlers from the Oregon Trail established themselves in Corvallis. Corvallis means “the heart of the valley”. The city was named for the fertile ground that allowed for many crops to be grown. In 1856, the Corvallis Academy was founded. John Wesley Johnson, a graduate of Yale College, was the first teacher and principal. Johnson later became the University of Oregon's first president (Beach, 2004). In 1858 Corvallis Academy was renamed to Corvallis College and the construction of the first building was started. In the year 1859 Oregon became the 33rd State in the Union and the first building was completed.

The First Morrill Act was signed by President Abraham Lincoln on July 2, 1862. This act offered state grants of public land to help support colleges of agriculture and mechanic arts (Beach, 2004). After a few years of financial instability, the Corvallis College offered its first class of collegiate standing in 1867 with an enrollment of four students. In 1868 the Oregon State Legislature adopted Corvallis College as the Agricultural College of the State of Oregon. However permanent funding of the college was not established until two years later. In 1868 the State of Oregon allowed for Corvallis College to offer three degrees: Bachelor of Arts, Bachelor of Science, and Master of Arts. The first graduating class consisting of three students (two men and one woman) was in 1870. That year the tuition per term was ten dollars and the overall enrollment in the college level was 28 students.

The first Department of Agriculture was established in 1883 and was also the first Agricultural Department to be created in Oregon. In the same year, the first college newspaper was printed named “The Gem” and the first intercollegiate athletic event was held in the form of a baseball game. By 1885 the Oregon State Senate passed a bill to purchase the college and the state assumed complete control of the school.

In the following years, the college had a considerable amount of growth with the permanent funding from the state. The school was renamed the Oregon Agricultural College in 1890 and by 1893 an athletic program, which included football, was established. School colors were selected as orange and black and the “Orangemen” and “Aggies” were used as nicknames (Beach et al. 2004). Expansion continued in all areas including new departments, new buildings, sororities, fraternities and even a bookstore. Many acres of farmland and experimental farms were established under the land grant for agricultural research and study. By 1900 the Oregon Agricultural College was the largest in Oregon.

In 1910 the first reference to a “Beaver” as the mascot for the college was used. In continuing years more athletic programs such as basketball, wrestling, tennis and swimming as well as other sports would be established. More schools, departments and programs were added as well. Some departments included: the Department of Forestry, the School of Pharmacy, the School of Veterinary Medicine, and the Department of Education.

By 1961 the college had expanded and the Oregon State Legislature established the school’s current name as Oregon State University (OSU). In 1962 Linus Pauling, a graduate of OSU, was awarded the Nobel Peace Prize for peace-building. He was previously awarded in 1954 with the Nobel Prize in chemistry for

describing chemical bonds. Linus Pauling became the only person in history to receive two unshared Nobel prizes.

Oregon State University continued to grow and develop in its size and academic programs as well as extra-curricular programs. Residence halls were built for students and research in agriculture, science and other areas continued to grow. New buildings were continuously being constructed to accommodate for the growing number of students and programs. Even today Oregon State University continues to grow with the recently built Kelly Engineering Center and Weatherford Hall.

Oregon State University Currently

Oregon State University currently has over 19,000 students (81% of those students are Oregon residents). The university has thirteen colleges which all together offer over 200 academic degree programs. OSU is one of only two universities in the nation, along with Cornell University, that are now designated as land, sea, space and sun grant institutions (Duncan, 2005).

OSU has strong roots in agriculture from its long history as an agricultural college. Research areas have historically been in science and agriculture but today research is being conducted in eleven of Oregon State University's colleges and continues on into the many departments. OSU is Oregon's largest research university in the state and acquires more than 60% of the federal and state allocations for funding in Oregon (OSU Research Office, 2006). The College of Forestry ranks number one as the leading forestry program in North America, according to a survey of 53 university forestry programs in the United States and Canada according to a study done by the Journal of Forestry (Stauth, 2006). Oregon State also has the largest

tsunami research facility in the world and conducts research with state-of-the-art equipment and technology.

Research Experience

I had the opportunity to be a part of some of the research going on campus. I participated in the lab of Dr. Patrick Hayes in the Crop and Soil Science Department working with barley. I was able to work on a few projects with the research group which included working in the field, in the greenhouse and in the lab. I helped collect data on the barley stripe rust project (Richardson et al. 2006) as well as other on going projects in the lab and field.

There was a significant amount of equipment and technology available in the lab for use with genetic research and study. Often times there were several research projects being conducted at the same time whether in the field, lab or greenhouse. A significant amount of funding for these projects helps to maintain the current technology and tools to allow continued research as well as providing the use of the greenhouse and field facilities.

The team involved in the barley project at OSU has a very excellent work ethic. Everyone was continually working on current projects to complete the tasks in a timely and efficient manner. However, new projects of research were being continually added as new students or staff would join the barley team. Everyone in the lab was very friendly and helpful to me during my time in the lab. If ever I had any questions or concerns, someone would be there to help as well as teach what needed to be done.

Comparison

Overall both of my experiences in research at Oregon State University and abroad at the University of Lleida, gave me incite into research. In a comparison though, it is important to be able to compare the impact of the work being done at both research facilities. This can be measured by the number of publication produced by the research group and how many times those papers are cited.

A comparison between Dr. Patrick M. Hayes at Oregon State University and Dr. Ignacio Romagosa at the University of Lleida will be sufficient to see the impact of the research being conducted at both labs. The ISI Web of Knowledge is a source to collect information about published papers and works cited as well as many other details. The table shows the results when comparing the scientific activity of research groups lead by Dr. Patrick M. Hayes and Dr. Ignacio Romagosa (Table 1) (ISI Web of Knowledge, 2007).

Table 1 Comparisons of publication statistics 1996 – 2007. (source: the Web of Knowledge)

Name	Total Published Papers	Total citations	Average citations per paper
Dr. Patrick M. Hayes	70	1,013	14
Dr. Ignacio Romagoza	41	431	11

The lab at Oregon State University seems to have a greater impact on issues regarding barley research both internationally and nationally. This may be due to the funding available to researchers in the United States. More funding, allows for a large amount of people to be involved and more tools to aid in research. In the last five years (2001-2006) the OSU Barley Project has received over $3,176,000 in funding for continued research. These grants have been awarded for a length of one to six years. The funding comes from many public and private entities. Some include state

and federal funding while others are private corporations. From just these few examples, it is easy to see that funding research in the United States is supported on many levels.

In the case of Dr. Romagosa, funding for research in Spain is not as accessible as funding in the United States due to restrictions and rules of the Spanish government. Dr. Ignacio Romagosa is involved in helping combat these difficulties as he is on a grant review panel in Spain that gives grants to agricultural research in Spain. Even though funding may prevent access to supplies for research. Dr. Romagosa has been actively involved in research as a corresponding editor of the Journal of Theoretical and Applied Genetics in the areas of breeding methodology, genotype by environment and cereals (Theor. Appl. Genet. 2007). Spain's membership in the EU has provided a greater access to funding. This access should lead to new opportunities for Spanish research.

The research conducted at Oregon State University continually works to help discover more about barley genetics, develop new cultivars to help farmers and continually influences the research community. The lab in Spain also works towards these goals even though they may lack the funding needed some for research. However, that lack can also lead to a more resourceful way of solving problems. For example, the University of Lleida works closely with local farmers and ranchers to create more innovative ways to solve problems. This is also useful in research as new ideas can stem from resourceful and innovative techniques.

I thoroughly enjoyed working with the barley group at Oregon State University as well as the researchers in the lab at the University of Lleida. Although each experience was different, I have learned an incredible amount about genetics, technology, and the challenges that are presented in the United States as well as

abroad when conducting research. Both opportunities aided me in my college career and helped me better understand myself and the world around me. I look forward to taking these experiences with my in the future in order to continue to pursue my goals.

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