Motel 6? Airbnb? A practical to futuristic look at lodging for oats and other small grains

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Oat (*Avena sativa* L.) is a small grain with 210,000 acres planted in Minnesota (USDA, 2016). Oats are popular for human consumption in oatmeal and other baked goods; they are considered healthy because of high protein content and contain beta glucans, a soluble fiber that lowers cholesterol (Braaten et al, 1994). Since the middle of the 20th century, oat cultivation has dropped precipitously in the Midwest. This is due to profitability of other crop species such as maize and soybean, but also due to unfavorable agronomic tendencies. One tendency is lodging, which broadly encompasses stem breakage (Stem Lodging) or the falling over of stems (Root Lodging). Lodging is a substantial barrier to the successful cultivation of oats and other small grains in the upper Midwest. Both types of lodging reduce harvestable yields in oats and adversely affect grain quality (Pendleton, 1954; Fehr, 1987). While the mechanics of lodging resistance in oats are described (Grafius and Brown, 1954), little research exists for understanding the genetic or physiological basis for lodging resistance in oats.

Genetic markers offer breeders a chance to select on lodging tolerance based on genotypic values independently of natural lodging events. Genetic markers linked to genes controlling root and stem lodging in other small grains have been identified (Keller et al, 1999; Kashawagi et al, 2004; Liu et al, 2015). Genomic prediction of lodging severity in sorghum has been 67 percent accurate, potentially allowing selection for lodging resistance to be integrated into breeding pipelines (Yu et al, 2016). Though genetic markers associated with basic phenotypes of lodging resistance have been described in European oat populations (Tumino et al, 2017), no loci have been mapped for oat germplasm in the upper Midwest. The utility of having markers linked to lodging resistance in local germplasm could result in new, lodging resistant oat varieties for Minnesota growers.

While genetic markers linked to genes underlying the basic phenotypes of lodging resistance have the possibility of improving genetic gains in oats, they do not explain the physiological reasons for lodging resistance. Lodging resistance in oats is likely comprised of many complex phenotypes related to stem composition, panicle and stem morphology, and plant phenology. A better understanding of the physiology of lodging resistance could result in new phenotypes for targeted breeding improvement. Before this can occur, quantification of how different physiological parameters affect a plants response to lodging under wind stress is necessary. This will necessitate the development of novel phenotyping platforms and image analysis protocols.

This research will identify genetic and physiological components of lodging in oats and other small grains through the objectives below:

1) Map genetic effects for lodging in oats.

Mapping for lodging resistance will be performed using an association panel of 280 diverse oat lines from breeding programs across the upper Midwest. Phenotypes used in mapping will include lodging severity, root lodging angle, presence and absence of stem lodging, stem

strength, and plant height. Additionally, two biparental mapping populations will be created that segregate separately for root and stem lodging to enable more accurate mapping of loci governing lodging resistance in oats. This will enable validation of alleles from the association panel to assess their effect on lodging resistance in oats.

2) **Measure new phenotypes using novel technology**

Field based phenotyping systems will be designed and built for collecting image data on lodging and plant movement. Phenotyping will occur in a separate field design encompassing 16 small grain varieties (Oat, Wheat, 2- and 6-Row Barley) initiated at four different planting dates. Phenotyping systems will entail a semi-automatic, hemispherical camera system mounted on a fixed steel track. The camera system will be constructed in a manner to facilitate image analysis of lodging and other plant behaviors. MATLAB scripts will be written to analyze the video and image data obtained from the camera systems to detect lodging and plant movement in the field.

3) Quantify field behavior in oats and other cereals

Using the MATLAB analysis of video and image data, small grain varieties will be scored for lodging. Additionally, plant movement will be quantified in the field via analysis of color change within a segment of each variety row to estimate wave patterns. Waves will be further quantified from the color data using a Fast Fourier Transform implemented in MATLAB to analyze the dominant frequencies and relative amplitude contributions for wave movement within each variety. The resulting data will then be tested for correlation between physiological parameters and increased movement under direct wind stress, and patterns in lodging outcomes.

Ultimately this research will provide practical insights into the genetic basis of lodging resistance in oats for improving gains from selection. Additionally, it will create novel phenotyping technologies and apply them to decipher the relationship between plant physiology, plant movement, and plant lodging outcomes in oats and other small grains.

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