Physiological Maturation of Jointed Goatgrass (*Aegilops cylindrica*) Caryopses

Michael P. Quinn[1], Don W. Morishita[1], William Price[2]

[1]Department of Plant, Soil, and Entomological Sciences, University of Idaho, Twin Falls, ID, and [2]Statistical Programs, University of Idaho, Moscow, ID

Introduction

- Jointed goatgrass (*Aegilops cylindrica*) is an invasive annual grass weed that infests winter wheat fields and is capable of reducing wheat yield and quality (Anderson 1993; Donald and Ogg 1991).
- Selective jointed goatgrass control can be achieved utilizing new varieties of herbicide-resistant winter wheat (Ball et al. 1999). More recently, locally adapted varieties have been developed with the herbicide resistance gene (Souza 2003).
- Research has demonstrated that use of a herbicide resistant crop system will lead to the development of resistant jointed goatgrass biotypes (Rainbolt et al. 2004; Zemetra et al. 1998). Therefore, it is critical to view this new technology not as cure all, but as another management tool. In order to be effective, integrated weed management strategies must be utilized and this includes understanding jointed goatgrass biology (Mallory-Smith and Hylsop 1999).
- A better understanding of seed biology may suggest ways to improve management techniques (Donald and Zimdahl 1987).

Objectives

- Determine the point, in the maturation process of jointed goatgrass, at which the seed first becomes germinable.
- Model germination response to varying maturity.
- Examine seed germination differences within the spike.

Materials and Methods

Experimental Design

- Greenhouse experiments were initiated at the University of Idaho, Moscow, ID. in December 2002 and near Filer, ID in August 2003. Both experiments were completed their respective following springs.
- The Moscow experiment was arranged in a randomized complete block design with three reps, blocked according to phenological development. For the purpose of model construction, it was considerably larger than the Filer experiment.
- The Filer experiment was a completely random design.
- Treatments consisted of 33 harvest dates and each harvest date was determined by the number of days after anthesis (DAA) a spike was allowed to remain on the plant. Harvest dates ranged from 2 to 34 DAA in one day increments. Anthesis was defined as one third of the spikelet having anthers extruded.
- At harvest, individual spikes were disarticulated from the rachis and divided into three sections: top, middle, and bottom and placed into labeled coin envelopes and stored at 22 C for 72 d to after-ripen.
- Spikelets were then surface sterilized, hydrated, and placed into a 16 C dark germinator for 20 d. Germination was noted for each section daily.

Statistical Analysis

Model Construction

- Both maximum germination, and time to germinate were modeled using nonlinear mixed model regression.
- Time to germinate was modeled using a quadratic form.

Materials and Methods (continued)

Model Validation

- The Filer experiment was conducted to validate the models constructed from the previous experiment. Since the purpose of validation is merely to examine model performance on an independent data set, less data is required than in the estimation process. Thus, only one block of 48 plants were used in this experiment. Treatments consisted of 19 harvest dates, and ranged from 2 to 34 DAA in one-day increments through 6 DAA, then reduced to two-day increments. Treatment assignment, spikelet harvesting, after-ripening, and germination were conducted according to the protocol established for the first experiment.
- Model validation was accomplished by using the models estimated from the original data to calculate new predicted values based on the data from the second experiment.

Results

- Comparisons of blocks with the GLM procedure revealed no significant differences. Therefore, the data were pooled and fit to linear plateau (Figure 1: a,b,c) and quadratic models (Figure 2:a,b,c).
- Linear plateau models constructed for jointed goatgrass germination in relation to DAA revealed significant differences between the top and the other two spike sections in the first year (Figure 1:a,b,c).
- The DAA at which there was no change in average percent germination (plateau) were 25, 21, and 23 d for the top, middle, and bottom spike sections (Figure 1:a,b,c).
- Spikelets harvested before 7 DAA had less than 3% germination regardless of their position on the spike.
- Spikelets harvested only two days after anthesis had seed that were able to germinate.
- All of the quadratic models displayed an inverse parabolic curve. This indicates that time to germination initially decreased as DAA increased ($DAA_{MAX} = - ß_{1i} /[2*ß_{2i}]$) at which point germination time began increasing as DAA increased (Figure 2:a,b,c).
- Contrasts conducted on the curves generated by the quadratic model for time to germinate showed a coincidence of lines (Table 1).

Model Validation

- Examination of the skewness of the data and associated standard deviations of the validation models revealed no shifts in the data or excessive values (Tables 2 & 3).
- Data from the second experiment indicated that the linear plateau models constructed from the first year underestimated the germination response observed in the second year (Figure 3:A,B,C).
- Initial germination was 24, 20, and 7% greater in the top, middle, and bottom sections of the spike in this experiment versus the first year (Figure 3).
- Spikelets harvested < 7 DAA in the second experiment responded similarly to the first year with 0 to 3% germination regardless of their position on the spike.
- In the second year, limited germination was observed in samples harvested only three days after anthesis.
- Whole joint weights of spikes collected from the top section of the spike were less than those of spikelets collected from the other two sections (Figure 5).
- Validation of the quadratic models constructed for time to germination indicated that the models from the first year overestimated the response observed in the second year (Figure 4:a,b,c).

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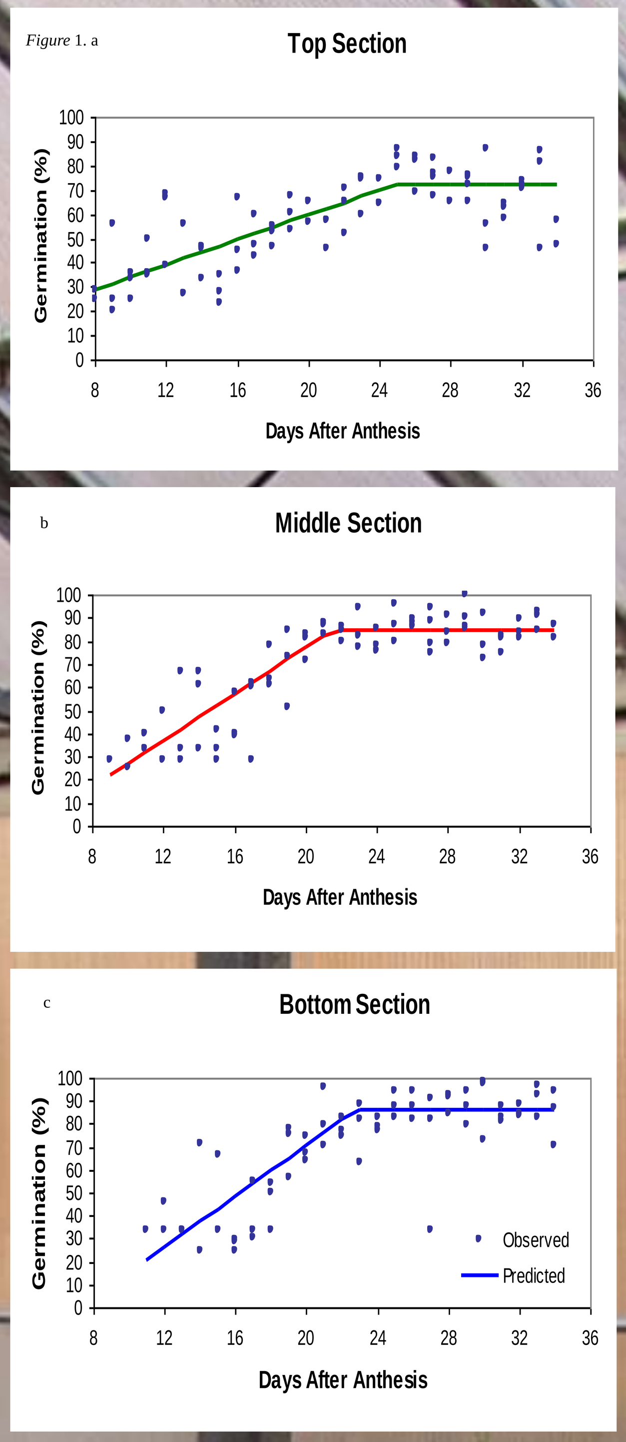
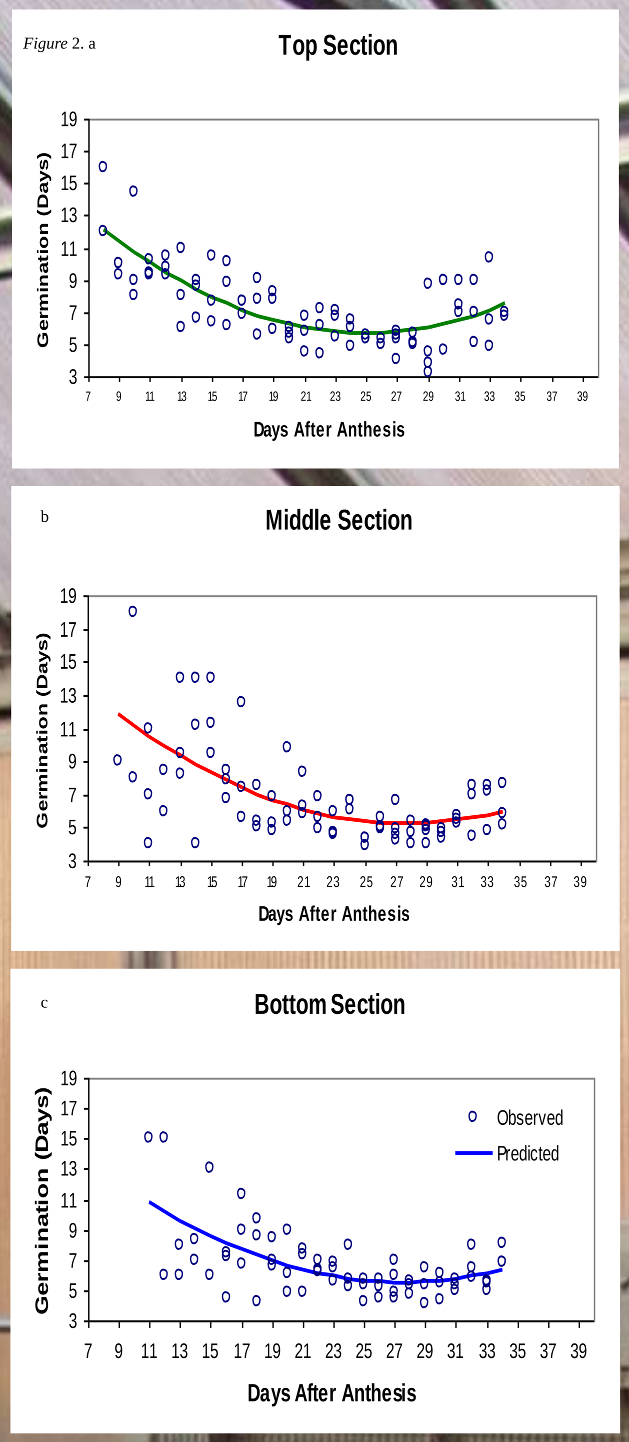
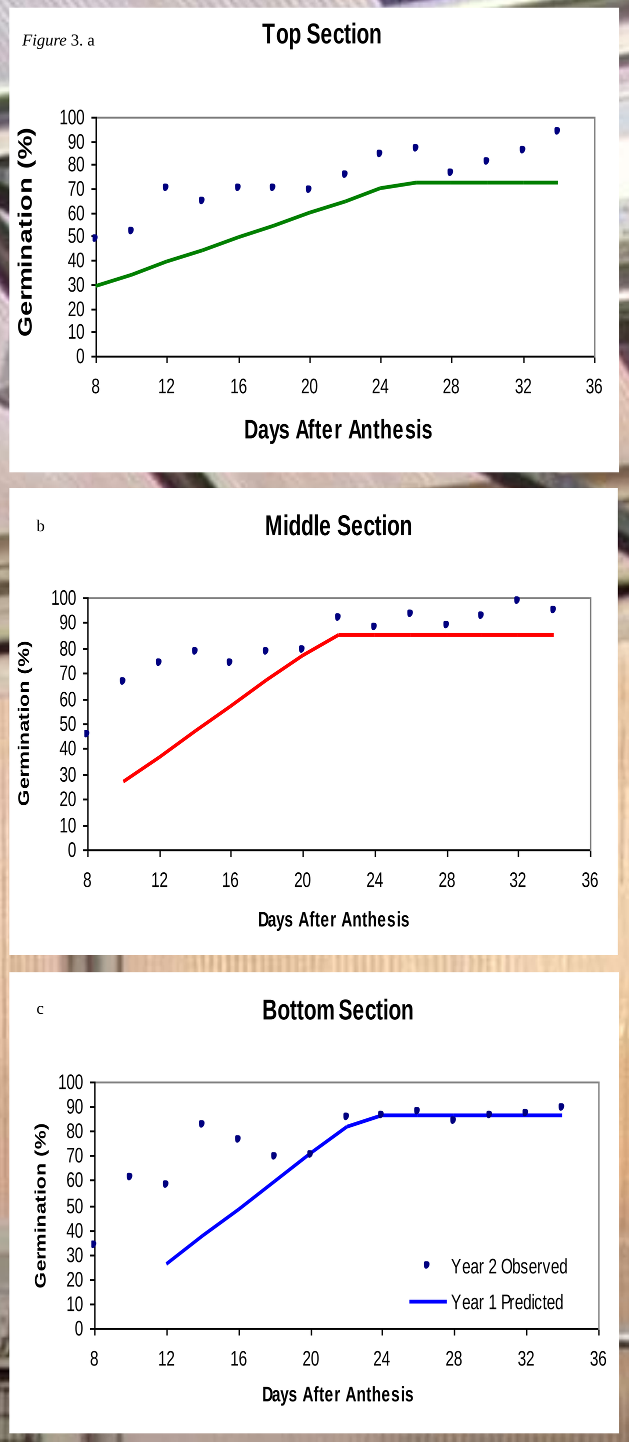






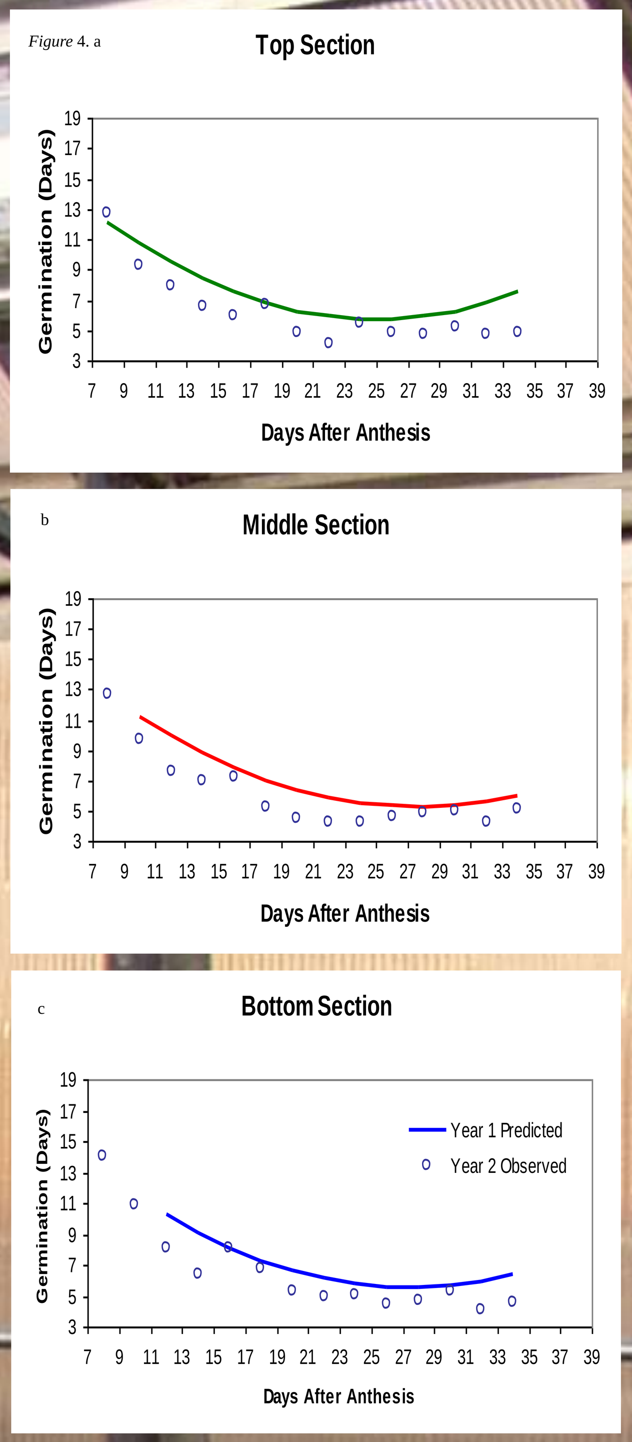


Table 1. Paired contrasts of quadratic models lines.

Contrast	F Value	P > F
Top vs Bottom - Line[1]	1.09	0.3537
Top vs Middle - Line	1.32	0.2684
Middle vs Bottom - Line	0.33	0.8067
Top vs Middle - Min[2]	2.16	0.1429
Top vs Bottom - Min	1.66	0.1984
Middle vs Bottom - Min	0.14	0.7079

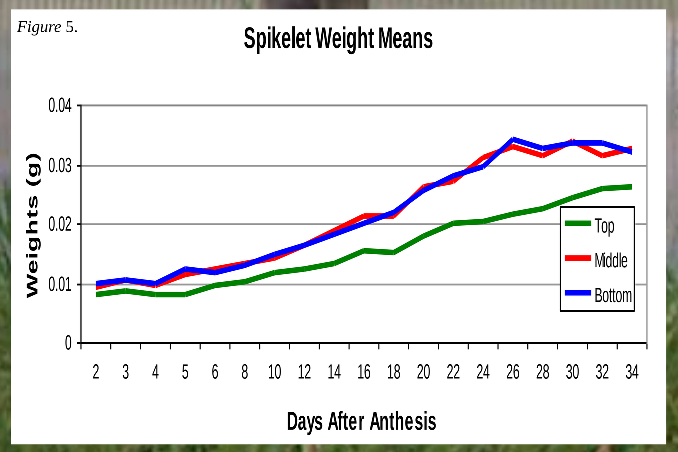
[1]Line represents the values predicted by the quadratic model.
[2]Min represents the point at which jointed goatgrass spikelets germinated in the least number of days.

Table 2. Univariate statistics for validation procedure by spike section for linear plateau models of germination by days after anthesis.

Spike Section	Skewness	Standard deviation	P > t
Top	0.441	0.068	0.0001
Middle	0.86	0.129	0.0005
Bottom	0.863	0.179	0.0112

Table 3. Univariate statistics for validation procedure by spike section for quadratic models of days till germination by days after anthesis.

Spike Section	Skewness	Standard deviation	P > t
Top	0.524	0.845	0.0001
Middle	0.267	0.709	0.0001
Bottom	0.313	0.941	0.0017



Conclusions

- Although limited, jointed goatgrass spikelets are capable of germination at 2 days after anthesis.
- Spikelets from the middle and bottom sections required fewer DAA to reach their maximum germination levels as well as have a greater maximum germination. This suggests that grain fill, and possibly development, occur more rapidly in basipetal spikelets.
- Quadratic models constructed for time to germination in both years suggest that dormancy mechanisms exist in all sections of the spike and develop after 20 DAA.
- Fluctuations in response of both germination percentage and time to germination were attributed to minor environmental differences between study locations.
- Top spike section weights starting at 6 DAA were less than middle and bottom spike sections (p< 0.0001), based on analysis of variance conducted on individual days.

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