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Wild Oat (Avena Fatua L.) Time of Emergence and Density Influence Tame Oat (Avena Sativa L.) Yield and Quality

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Introduction

Wild oat (*Avena fatua* L.) remains one of the most abundant and problematic weeds on the Canadian prairies (Kirkland, 1993; O'Donovan et al., 2000). Because of the inherent genetic similarity between wild and tame oat, no herbicides exist to selectively remove the weed from the crop. Oat producers are thus forced to manage wild oat using cultural control methods, but the degree of control with these methods is frequently inadequate. Although it is well established that time of emergence of weeds relative to the crop affects yield (O'Donovan et al., 1985; Dieleman et al., 1995; Bosnic and Swanton, 1997), the relationship between relative time of emergence and density in affecting tame oat-wild oat competition is not well understood. A quantification of tame oat yield losses in relation to these two variables is critical on several fronts: 1) It will provide an assessment of the importance of selecting for earlier emerging tame oats in breeding programs; 2) It will help to provide estimations of wild thresholds in tame oat; 3) Decision rules in bioeconomic models are based on threshold densities generated from yield loss-weed density relationships. To this end, we conducted an experiment to quantify losses in tame oat yield and quality caused by varying densities of wild oats emerging at different times.

Materials and Methods

The experiment was conducted at two locations in Saskatchewan in 2002 and 2003. The study sites were located at the Agriculture Canada Research Station and at the Kernen Crop Research near Indian Head and Saskatoon, respectively. The experiment was designed as a 2-way factorial randomized complete block with four replicates. Wild oats were planted every 50 growing degree days (GDD)) (base temperature = 0 C) at target densities of 0, 20, 80, and 320 plants m^{-2}. Wild oat planting occurred relative to the crop, providing two emergence times before crop emergence (-100 and -50 GDD) and two following crop emergence (50 and 100 GDD). Planting on a GDD basis standardized planting dates by accounting for differences in biological activity based on air temperature, as well as providing a highly accurate estimate of emergence time effects on crop yield loss. Emergence time studies have been traditionally conducted based on planting at specific Julian dates (O'Donovan et al., 1985) or crop stages (Dieleman et al., 1995; Bosnic and Swanton, 1997) rather than thermal time and have thus provided poor estimations of the actual relationship between emergence time and yield loss. Tame oat (AC Assiniboia) was seeded perpendicular to the wild oat treatments at a target density of 250 plants m^{-2}. This occurred over the front 6 m of the plot, allowing for a 2 m check at the back of the plot that allowed wild oat emergence to be monitored without having to differentiate between the two species. Fertilizer was applied at tame oat seeding based on soil test recommendations.

Statistical Analysis

The relationship of tame oat yield loss to varying wild oat densities and relative time of emergence was analyzed by fitting the data separately for each location and year to the hyperbolic crop yield model (Cousens et al., 1987):

$$Y_L = \frac{I\mathrm{D}}{e^{CT} + I\mathrm{D}/A}$$

Equation [1]

where Y_L is percent yield loss, D is wild oat density (plants m^{-2}), T is the actual median time of emergence of the weed relative to the crop in growing degree days (GDD) (base temperature = 0 C), and I, A, and C are model parameters. Parameter I is the percent yield loss per unit weed as $\mathrm{D} \to 0$ at $\mathrm{T} = 0$, A is the asymptotic yield loss as $\mathrm{D} \to \infty$, and C is the rate at which I declines exponentially as T becomes larger.

The relationship between wild oat seed production and wild oat density and relative time of emergence was described with the following equation (Bosnic and Swanton, 1997):

$$S_d = \frac{a\mathrm{D}}{e^{CT} + a\mathrm{D}/B}$$

Equation [2]

where S_d is wild oat seed production (number of seeds m^{-2}), D is wild oat density (plants m^{-2}), T is the actual median time of emergence of the weed relative to the crop (GDD), and a, B, and C are model parameters. Parameter a is the number of wild oat seeds produced per wild oat plant as $\mathrm{D} \to 0$ at $\mathrm{T} = 0$, B is the maximum wild oat seed production m^{-2} as $\mathrm{D} \to \infty$, and C is the rate at which a declines exponentially as T becomes larger.

The relationship of percent wild oat contamination to wild oat density and relative time of emergence was described with the following equation:

$$P_{wo} = \frac{p\mathrm{D}}{e^{CT} + p\mathrm{D}/B}$$

Equation [3]

where P_{wo} is wild oat contamination or the percentage of wild oat in the harvested tame oat grain sample as a function of wild oat density (D) and time of emergence relative to the crop (T), p is the percentage wild oat contamination per wild oat plant as $\mathrm{D} \to 0$ at $\mathrm{T} = 0$, B is the maximum percentage wild oat contamination as $\mathrm{D} \to \infty$, and C is the rate at which p declines exponentially as T becomes larger. Regressions were performed on all data using the nonlinear regression procedure in SAS (SAS Institute, 1996) and regression lines for the predicted values were plotted against all observed values. The extra sum of squares principle for nonlinear regression was used to estimate the stability of parameter estimates among data sets.

Results and Discussion

Tame oat grain yield and yield loss varied with site-year, time of wild oat seedling emergence, and wild oat density. The hyperbolic regression model, Equation 1, provided a satisfactory fit for all tame oat yield loss data sets as indicated by significant approximate F-tests, as well as *Psuedo* R^2 values ranging between 0.80 - 0.83. Wild oat seedlings that emerged before the crop caused greater yield loss than seedlings that emerged after the crop at similar densities in all site-years (Figure 1). For example, at Indian Head in 2003, a wild oat density of 100 plants m^{-2} emerging 92 GDD before the crop resulted in 45% yield loss compared to 20% for wild oat emerging 56 GDD after the crop at the same density (Figure 1A). Furthermore, oat yield losses from wild oat the emerged 92 GDD before the crop ranged from 0 to 71%, while losses when wild oat emerged 56 GDD after the crop only ranged from 0 to 46%. Therefore, wild oat emergence time relative to tame oat is more critical than weed density when describing the affect of wild oat on tame oat yield. Time of emergence of the weed relative to the crop was more important than weed density when describing the relationship between barnyardgrass (*Echinochloa crus-galli* L.) and corn (*Zea mays* L.) yield (Bosnic and Swanton, 1997) and redroot pigweed (*Amaranthus retroflexus* L.) and soybean (*Glycine max* L. Merr) yield (Dieleman et al., 1995).

Maximum estimated yield losses (*A* parameter) were highest at Indian Head in 2002 (96%) and lowest at Indian Head in 2003 (41%) (Figure 1). Extra sum of squares tests indicated that parameter *A* varied significantly among site-years, suggesting that yield losses at high wild oat densities are variable. The low yield loss at Indian Head in 2003 was likely due to drastically reduced wild oat emergence as a result of drought, in which case average final wild oat emergence was only 24% (Figure 1B). Estimates of yield loss at low wild oat densities, parameter *I*, ranged from 0.40 to 0.49% and did not vary significantly among site-years, indicating that yield loss caused per wild oat plant remained was constant among years (Figure 1). Parameter *C*, which has previously been defined as an index of crop competitiveness (Dieleman et al., 1995), also varied significantly among site-years, suggesting different abilities of the crop to compete against late emerging weeds in different years.

Estimated wild oat seed production varied with time of seedling emergence relative to tame oat, wild oat density, and site-year. The hyperbolic regression model, Equation 2, provided a satisfactory fit for all tame oat yield loss data sets as indicated by significant approximate F-tests, as well as *Psuedo* R^2 values ranging between 0.72 - 0.82. Wild oat that emerged before tame oat produced significantly higher amounts of seed than wild oat that emerged after the crop (Figure 2). For example, at Kernen in 2003, 100 wild oat plants m^{-2} emerging 30 GDD before the crop produced an estimated 8251 seeds m^{-2} compared to only 2089 seeds m^{-2} from wild oat emerging 112 GDD after the crop (Figure 2C). Wild oat seed production decreased with increasing density in all site-years. Time of emergence of barnyardgrass seedling emergence relative to corn influenced barnyardgrass reproductive output (Bosnic and Swanton, 1997).

Maximum estimated seed production m^{-2} (*B* parameter) was highest at Kernen in 2003 (28 015 seeds m^{-2}) and lowest at Indian Head in 2003 (7823 seed m^{-2}) (Figure 2). Extra sum of squares tests indicated that parameter *B* varied significantly among site-years, suggesting that reproductive output at high wild oat densities is variable among site-years. Estimates of wild oat seed production at low wild oat densities, parameter *a*, ranged from 56.55 to 82.66 seeds m^{-2} and

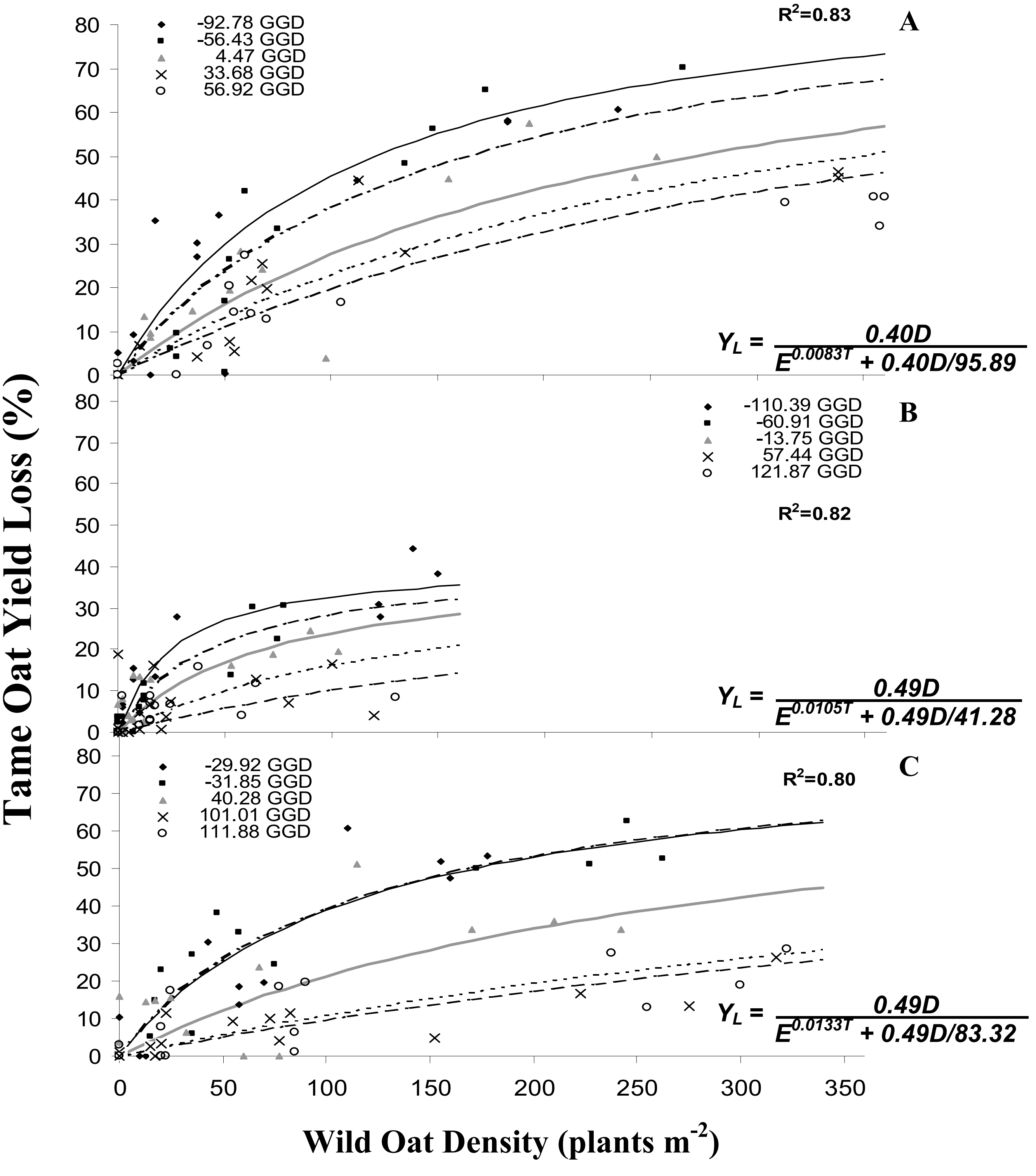

Figure 1. Observed and predicted tame oat yield losses due to different densities of wild oat emerging at different times relative to the crop at (A) Indian head 2002, (B) Indian Head 2003, and (C) Kernen 2003. Symbols represent observed values at each target wild oat planting (5) and lines are the result of fitting the data to Equation 1: -100 GDD (♦———♦); -50 GDD (■– – –■); 0 GDD (▲———▲); 50 GDD (x-----x); 100 GDD (○———○). Legend indicates actual median emergence time of wild oat relative to tame oat.

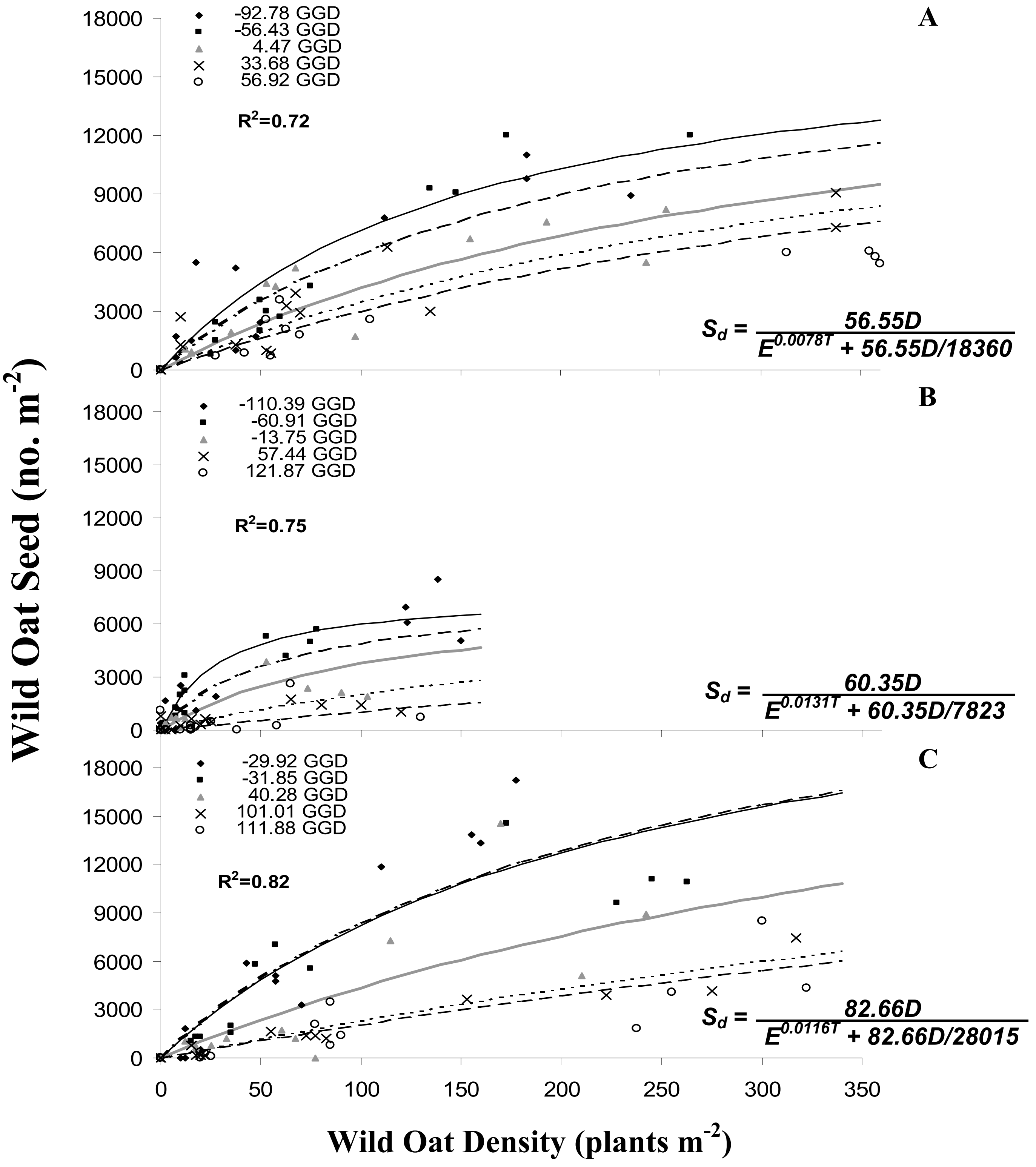

Figure 2. Observed and predicted wild oat seed production at different densities of wild oat emerging at different times relative to the crop at (A) Indian head 2002, (B) Indian Head 2003, and (C) Kernen 2003. Symbols represent observed values at each target wild oat planting (5) and lines are the result of fitting the data to Equation 1: -100 GDD (♦———♦); -50 GDD (■– – –■); 0 GDD (▲———▲); 50 GDD (x-----x); 100 GDD (○— — —○). Legend indicates actual median emergence time of wild oat relative to tame oat.

did not vary significantly among site-years, indicating that the number of wild oat seed produced per wild oat plant was constant among years (Figure 2). These differences in reproductive output of wild oat may be due to a number of factors, including differential plasticity among wild oat biotypes, differences in environmental conditions, or differences in the competitive ability of the tame oat crop among site-years (Maun and Barrett, 1986). Parameter *C* also varied significantly among site-years, indicating different abilities of the crop to reduce seed production on late emerging wild oat plants in different years (Figure 2).

Wild oat contamination, or the percentage of wild oat in the harvested grain sample, varied considerably among site-years, time of wild oat seedling emergence, and wild oat densities (Figure 3). The hyperbolic regression model, Equation 3, provided a satisfactory fit for all tame oat yield loss data sets as indicated by significant approximate F-tests, as well as *Psuedo* R^2 values ranging between 0.78 - 0.79. In all three site-years, wild oat contamination was higher when wild oat emergence preceded crop emergence compared with when wild oat emergence followed crop emergence (Figure 3). Although wild oat competition was intense and reproductive output high at Indian Head in 2002, the relationship between percent wild oat in the harvested grain sample and wild oat time of emergence and density was less asymptotic than expected, particularly where wild oat emergence preceded that of the crop (Figure 3A). This was likely due to unavoidable seed shattering of the wild oat at the first two emergence dates. Nonetheless, time of emergence was critical in determining the percentage of wild oat in the harvested tame oat grain sample, even at low densities (Figure 3B) and where seed shattering had occurred (Figure 3A).

The amount of wild oat contamination caused by each individual wild oat plant (*p* parameter) varied among site-years, as did the time of emergence effect on wild oat contamination (*C* parameter) (Figure 3). Maximum estimated wild oat contamination (*B* parameter) also varied significantly among site-years, and was highest at Kernen in 2003 (26%). Because only 1% wild oat contamination is tolerable in the grain sample, the implications of wild oat time of emergence and density on tame oat quality are of considerable importance. For example, at Kernen in 2003, 10 wild oat plants emerging 29 GDD before the crop would result in a 1% contamination level in the tame oat grain sample. However, it would take 60 wild oat seedlings m^{-2} emerging 111 GDD after the crop to cause the same 1% contamination. Therefore, it becomes essential for oat producers to ensure that the crop emerges prior to wild oats.

Conclusions

Time of wild oat seedling emergence relative to tame oat is important in determining tame oat yield and quality. Early emerging wild oats at high densities have the potential to severely reduce tame oat yield and quality. Our results demonstrate the importance of applying control measures to reduce the competitive effects of early emerging wild oat, thereby minimizing tame oat yield and quality losses, as well as reducing weed seed production to minimize long-term seedbank changes. By ensuring that wild oat emergence occurs subsequent to crop emergence, it may be possible to reduce the negative effects of wild oat competition on tame oat yield, and quality. The results of this study can be incorporated into calculations of economic thresholds, bioeconomic models, and used in the development of economic decision rules for managing wild oat in tame oat crops.

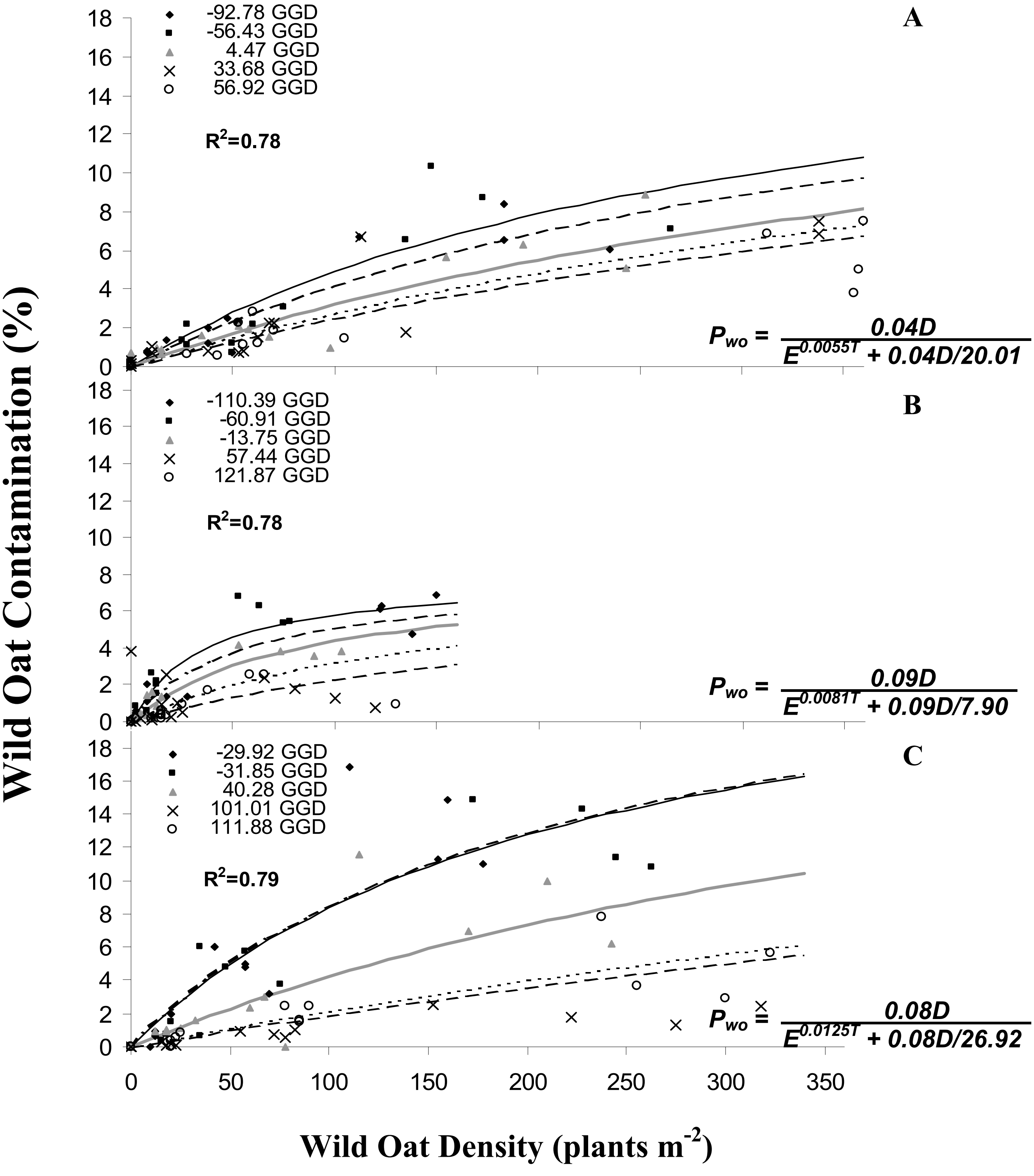

Figure 3. Observed and predicted wild oat seed contamination of the tame oat grain sample at different densities of wild oat emerging at different times relative to the crop at (A) Indian head 2002, (B) Indian Head 2003, and (C) Kernen 2003. Symbols represent observed values at each target wild oat planting (5) and lines are the result of fitting the data to Equation 1: -100 GDD (♦——♦); -50 GDD (■– – –■); 0 GDD (▲——▲); 50 GDD (x-------x); 100 GDD (○— — —○). Legend indicates actual median emergence time of wild oat relative to tame oat.

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