Notes

Comparison of Agricultural Seed Loss in Flooded and Unflooded Fields on the Tennessee National Wildlife Refuge

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Abstract

Waterfowl exploit seed resources in agricultural fields to help meet the energy demands associated with migration, thermoregulation, and various life-history activities. Biologists commonly flood agricultural fields to increase the availability of seed for waterfowl and to provide hunting opportunities. Previous studies suggest that flooding may accelerate seed loss; however, simultaneous comparison of seed loss with unflooded fields has not been made. We compared rates of loss between seed contained in wire mesh bags placed in an unflooded agricultural field vs. seed submersed in a flooded field on the Tennessee National Wildlife Refuge from October 2007 to January 2008. Agricultural seed mass declined 40–300% more rapidly in the flooded than in the unflooded field. Corn, soybean, and grain sorghum seed mass declined 42%, 87%, and 46%, respectively, after 12 wk of continuous submersion, which was similar to previous studies that measured seed loss in flooded mesh bags. However, the rate of seed mass loss in unsubmersed mesh bags was 1.3–6.9 times lower than scattered seed lying on the ground under granivore exclosures in a separate experiment. We hypothesize lower rates of seed loss in mesh bags compared to scattered seed may be an artifact of the bags, which are commonly used in seed fate studies. Our results suggest biologists should delay flooding agricultural fields until immediately prior to the arrival of waterfowl and be aware that absolute estimates of seed loss from studies that use mesh bags may be biased negatively.

Keywords: waterfowl management; agriculture; food resources; flooding; corn; soybean; grain sorghum

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Introduction

Waterfowl must acquire substantial energy in nonbreeding areas to rebuild lipid reserves metabolized during southward migration, meet energy needs associated with thermoregulation and winter life-history activities (e.g., courtship), and accumulate sufficient resources for return flight to northern breeding areas (Neely and Davison 1971; Williams et al. 1999). The amount of cropland on the landscape has increased over the past 100 y, which has increased the abundance of agricultural seed available for wildlife. Agricultural seed is a primary food resource for waterfowl in migrating and wintering areas (Baldassarre and Bolen 1984; Delnicki and Reinecke 1986; Combs and Fredrickson 1996; Heitmeyer 2006). Agricultural grains have more true metabolizable energy than moist-soil seeds or acorns (Petrie et al. 1998; Checkett et al. 2002; Kaminski et al. 2003), and yield per unit area for unharvested agricultural crops is considerably greater than natural wetland plants (Kross et al. 2008; NASS 2008; Foster et al. 2010). For these reasons, agricultural plants are grown and flooded to increase available energy for waterfowl.

Waterfowl managers usually flood agricultural fields to increase the availability of seed to waterfowl and to enhance hunting opportunities (Reinecke et al. 1989). Previous studies suggest agricultural seed loss in flooded fields is rapid. Rates of corn and grain sorghum seed loss underwater in South Carolina and Mississippi were approximately 50% for corn and 42% for grain sorghum after 90 d (Neely 1956; Nelms and Twedt 1996). However, these rates of loss are lower than those reported by Foster et al. (2009) for scattered seed in unflooded fields, which were 84% for corn and 95% for grain sorghum over similar duration. For soybean, loss of scattered seed in unflooded fields (78%, Foster et al. [2009]) was lower than submersed seed (>86%, Neely [1956]; Nelms and Twedt [1996]). These differences raise the question whether seed loss is greater underwater or in an unflooded harvested field. Our objective was to compare simultaneous rates of seed mass loss between unflooded and flooded fields for corn, grain sorghum, and soybean, which are commonly planted and flooded for waterfowl (Reinecke et al. 1989).

Methods

We conducted our study on the Tennessee National Wildlife Refuge (NWR) Duck River Unit (35°58′23″N, 87°57′46″W) from October 2007 to January 2008. We quantified rates of seed mass loss for corn, soybean and grain sorghum seed inundated in an agricultural field flooded for waterfowl and in an adjacent unflooded zone. Our sampling methods followed the general procedures of Shearer et al. (1969). Specifically, we prepared 40 wire mesh bags (12.7 × 20.3 cm) each for corn, soybean and grain sorghum, and placed 100 randomly selected seeds acquired from agricultural fields on the Tennessee NWR in each bag. Wire mesh bags prevented depredation by granivores and facilitated relocation of seed. For each species, 10 seed bags were taken to the lab and used to generate estimates of initial dry weight. We did not dry and weigh seeds that were placed in the field at the beginning of the study because drying could have confounded natural seed loss. We placed 15 bags per species in flooded and unflooded treatment zones of the field on 16 October 2007. Submersed bags were placed at common depth (ca. 45 cm), and remained flooded for the duration of the experiment. Unflooded bags were placed on the ground approximately 100 m upslope of the flooded bags. Although seeds in the unflooded bags became wet from precipitation, they never were submersed in standing water. Bags were strung 10–15 cm apart along 12-gauge wire and attached to metal posts so they could be relocated. We removed five submersed and five unflooded bags per species every 4 wk thereafter and ended the study at 12 wk. Thus, the total number of seed bags for each crop species was 40 (10 bags to generate initial mass estimates + 5 bags × 2 treatments × 3 durations). Within 24 h of removal from the field, we dried seed to constant mass in a drying oven (72 h at 90°C for soybeans and grain sorghum, and 48 h at 103°C for corn; Foster [2009]) and weighed seed to the nearest 0.01 g. The response variable for analysis was dry seed mass per bag for each crop type after 0, 4, 8, and 12 wk exposure in an unflooded or flooded agricultural field.

We designated bags as experimental units for analyses. Given that bags were placed in one field, they may be considered pseudoreplicates of flooding treatments (Hurlbert 1984). Unfortunately, only one flooded field was available on Tennessee NWR for use during this study. Pseudoreplication in studies that involve large-scale flooding is common in ecological experiments (e.g., Gray and Kaminski 2005). Given that various environmental factors that affect seed deterioration (e.g., water chemistry, temperature, microbes) can differ among geographic regions or watersheds (Foth 1984; Horne and Goldman 1994), it may not be reasonable to assume that rates of seed mass loss on Tennessee NWR are similar elsewhere. Thus, we caution readers that our results may be limited to agricultural fields on the Tennessee NWR.

We used 2-way analysis of variance (ANOVA) to test for differences in seed mass between treatments (submersed and unflooded) and among four postplacement durations (0, 4, 8, and 12 wk) for each crop type (Zar 2009). When ANOVAs were significant, we used Tukey's Honestly Significant Difference (HSD) multiple comparison test to determine whether pair-wise differences existed for effects with more than two levels (Zar 2009). We performed all analyses using the SAS® system (SAS Institute, Cary, NC) at $\alpha = 0.05$ (SAS Institute 1999).

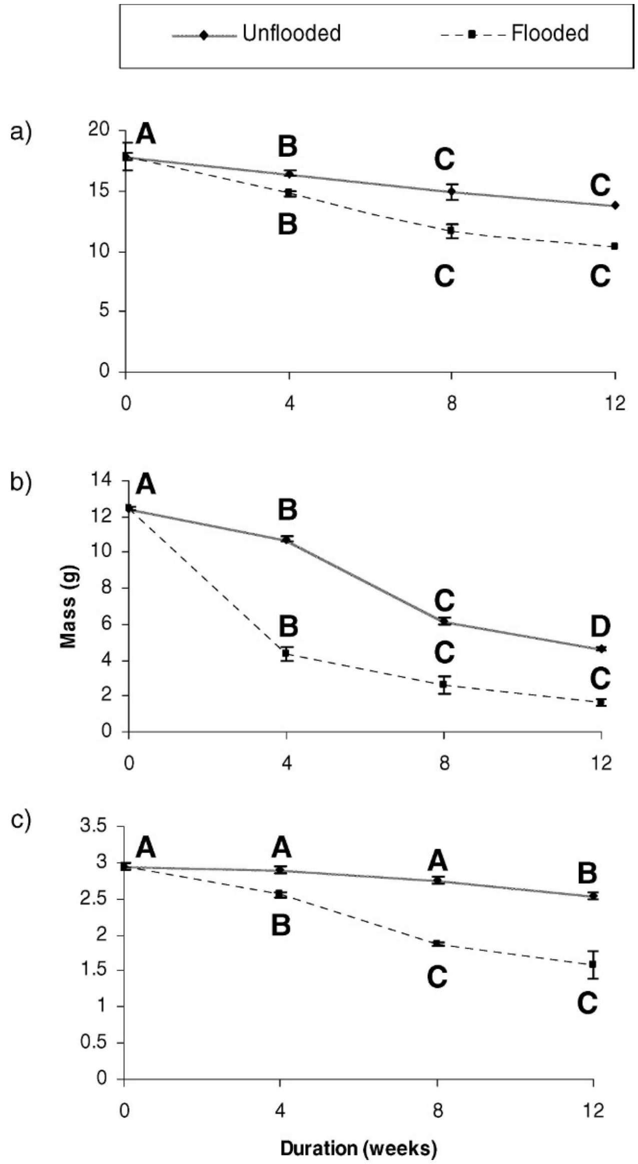

Figure. Mean corn (**a**), soybean (**b**), and grain sorghum (**c**) mass per seed bag between flooding treatments and among weeks postplacement of seed bags, Tennessee National Wildlife Refuge, October 2007–January 2008. Means within treatments with different letters are statistically different by analysis of variance and Tukey's Honestly Significant Difference test. Except for duration = 0, flooding treatments were always different ($P < 0.001$).

Results

Mass of corn seed remaining in unflooded bags ($\bar{x} = 84\%$, SE = 2.5%) was 22% greater than in submersed bags ($\bar{x} = 68.5\%$, SE = 5.4%) across time periods ($F_{1,39} = 32.9$, $P < 0.001$), and decreased with postplacement duration ($F_{2,39} = 17.3$, $P < 0.001$; Figure a). Treatment and duration effects interacted for soybean and grain sorghum ($F_{2,39} \geq 8.8$, $P < 0.001$). Except for initial mass, soybean and grain sorghum seed mass remaining in submersed bags was 10–150% lower than in unflooded bags for each duration ($F_{1,9} \geq 24.7$, $P \leq 0.001$; Figure b,c). Mass in bags decreased with increasing duration postplacement for submersed and unflooded soybean and grain sorghum seed ($F_{2,14} \geq 13.5$, $P < 0.001$), but the pattern of decline differed between treatments (Figure b,c).

Discussion

Mass of corn, soybean, and grain sorghum seed declined 42, 87, and 46%, respectively, after 12 wk of submersion. These rates of decline were similar to rates reported from the 1950s in South Carolina and 1990s in Mississippi for similar duration (i.e., 39–50% for corn, 86–91% for soybean, and 42% for grain sorghum; Neely [1956]; Nelms and Twedt [1996]). Therefore, rates of underwater seed decline may be fairly consistent across flooded agricultural fields in the southeastern United States, despite low replication in our study.

Decline in seed mass underwater was 1.4–3.3 times greater than unsubmersed seed. Dry seed generally has high water-absorbing potential, which enables rapid water uptake to facilitate germination (Leubner 2000). Thus, when seeds are submersed in water, they often swell and soften, which compromises the seed coat and can promote colonization by microbes. Further, aquatic environments are excellent reservoirs of microbes that contribute to decomposition (Mitsch and Gosselink 2000). Thus, we hypothesize the differences in rates of loss between submersed and unflooded seed was a combination of greater rates of imbibition, seed coat deterioration, and microbe colonization in the aquatic environment.

Interestingly, seed mass loss in unsubmersed mesh bags was 1.3–6.9 times lower than loss of seed that was scattered on the ground under granivore exclosures in corn, grain sorghum, and soybean fields (Foster et al. 2009). We hypothesize the lower decline of seed mass in mesh bags compared to seed lying on the ground is an artifact of the bags, which reduce surface area contact between the seed, substrate, and microbes. Given that it is common procedure to estimate seed loss using mesh bags (Neely 1956; Shearer et al. 1969; Nelms and Twedt 1996), researchers should recognize absolute estimates of mass from such studies may be biased negatively. The bags we used were identical between flooding treatments; thus, they should not have confounded relative seed loss results.

Management Implications

Agricultural seed mass declined 40–300% more rapidly in a flooded than in an unflooded field. Thus, we recommend biologists delay flooding agricultural fields until immediately prior to waterfowl arriving. Because this may be difficult to schedule, we recommend wetland managers provide moist-soil wetlands in addition to unharvested agricultural fields. Natural seeds found in moist-soil wetlands decompose more slowly than most agricultural seeds (Neely 1956; Shearer et al. 1969; Nelms and Twedt 1996). Thus, moist-soil wetlands can be flooded early to provide habitat for waterfowl before flooding agricultural sites, or a limited number of agricultural fields may be flooded to meet the energy needs of early migrants. For unharvested agricultural fields, seed loss may be minimal if flooding occurs such that seed heads remain above the waterline. Finally, biologists should be aware the absolute values of seed loss from studies that use mesh bags for estimates may be biased negatively. Thus, we recommend research should be conducted to determine absolute rates of loss for seed submersed and in direct contact with the substrate, which could be accomplished via a mesocosm study. Until these studies are performed, we recommend absolute rates of seed loss from mesh-bag studies not be used to model temporal decreases in available seed resources for waterfowl.

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