Ratoon Grain Sorghum and Other Seeds for Waterfowl in Sorghum Croplands

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Abstract: Grain sorghum provides energy-rich seeds for waterfowl and may provide important alternative foraging habitat considering a noted decrease of waste agricultural seeds for wintering waterfowl in the Mississippi Alluvial Valley. We conducted experiments in 22 sorghum fields in Arkansas, Mississippi, and Louisiana during falls 2006–2007 to evaluate abundance of ratoon grain (i.e., post-harvest, second crop), waste grain from the harvested first crop, and natural seeds. Nitrogen fertilized plots in 2007 produced >4 times more ratoon grain ($\bar{x} = 219.57 \pm 39.65$ [SE] kg (dry)/ha) than other treatments. Nitrogen fertilized plots in the southern sub-region of our study produced ~5 times more ratoon grain ($\bar{x} = 262.93 \pm 50.28$ kg/ha) than other plots. We recommend not manipulating sorghum stubble after harvest, applying nitrogen fertilizer under certain conditions, flooding fields after ratoon grain is produced, and integrating moist-soil wetland management into agricultural lands to increase abundance of foods for wintering waterfowl.

Key words: grain sorghum, milo, Mississippi Alluvial Valley, moist-soil, ratoon, waterfowl

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The Mississippi Alluvial Valley (MAV) provides critical migration and wintering habitats for North American waterfowl (Reinecke et al. 1989). Originally, the MAV was a vast bottomland hardwood ecosystem extending over 10 million ha, predominantly in Arkansas, Mississippi, and Louisiana (Reinecke et al. 1989, Fredrickson 2005). Since the mid-1800s and especially during the 1960s and 1970s, extensive timber harvest for forest products and clearing for agriculture have caused significant deforestation (Sternitzke 1976). Only 2.6 million ha of forested land remained by the late 1990s (Twedt and Loesch 1999).

Flooded cropland and waste agricultural seeds (i.e., seeds lost before or during harvest; Stafford et al. 2006) have partially replaced historical foraging habitat for waterfowl in the MAV (Delnicki and Reinecke 1986, Reinecke et al. 1989). However, abundance of waste agricultural seeds in the MAV and elsewhere in the southeastern United States has decreased due to increased harvest efficiency and longer periods of seed exposure between increasingly earlier fall harvest and arrival of wintering waterfowl (Manley et al. 2004, Stafford et al. 2006, Foster et al. 2010). Waterfowl researchers have suggested increased development and management of alternative foraging habitats to diminish effects of decreased availability of waste grain (Fredrickson 1983, Stafford et al. 2006, Foster et al. 2010). Additionally, increasing abundance of lesser snow geese (*Chen caerulescens*) wintering in the MAV may influence availability of waste agricultural seeds. These populations may decrease food resources for other wintering waterfowl (Abraham and Jefferies 1997, Havens et al. 2009).

Although rice, corn, and soybean are dominant row crops producing waste seeds for waterfowl in the MAV, grain sorghum (hereafter sorghum) also provides potential waterfowl forage (Reinecke et al. 1989). Sorghum typically is grown in areas of the United States too dry for corn production. From 2006–2009, approximately 468,000 ha of sorghum were harvested in Arkansas (172,000 ha), Mississippi (90,650 ha), and Louisiana (205,000 ha) compared to approximately 2,580,000 ha of corn and 9,230,000 ha of soybean (National Agricultural Statistics Service 2010).

After harvest, sorghum can regrow shoots from live roots or stalks and produce a second inflorescence (i.e., ratoon). Harvested ratoon sorghum increased total grain production by 3000–4000 kg/ha in some areas of Texas (Gerik et al. 2003). Ratoon sorghum production is possible in the MAV, but generally, yields are not sufficient to justify commercial harvest by most producers (E. J. Larson, Mississippi State University [MSU], personal communication).

Though harvesting ratoon sorghum may not be economically profitable in the MAV, this grain production may provide food for wintering ducks. Further, waste sorghum from the first harvest and seeds from natural plants in sorghum fields can provide food for waterfowl. Availability of selective chemical herbicides and herbicide-resistant technology (e.g., glyphosate resistance) are limited for sorghum compared to corn and soybean; thus, natural plants may be more prevalent in sorghum croplands (MSU Extension 2006). Moreover, sorghum grain has a metabolizable energy value (ME) of approximately 3.5 kcal/g (dry mass) for ducks, comparable to corn and rice (Kaminski et al. 2003). Common natural seeds have an average ME of approximately 2.5 kcal/g (Kaminski et al. 2003).

Decreased abundance of waste agricultural seeds for wintering waterfowl, loss of natural habitat, and possible foraging competition for these seeds with snow geese suggests that habitat management providing supplemental food for wintering ducks may be warranted in the MAV (Stafford et al. 2006, Kross et al. 2008, Foster et al. 2010). Accordingly, our objectives were to compare abundance of ratoon sorghum seed, waste sorghum grain, and natural seeds among post-harvest treatments of mowing, crushing, or no manipulation of sorghum stubble, and nitrogen fertilization or not in fields in the MAV.

Study Area

We collected data from six sorghum fields in 2006 and 16 fields in 2007 in Arkansas ($n=8$), Mississippi ($n=2$), and Louisiana ($n=12$). Fields were on public (National Wildlife Refuges [NWRs]) and private lands and were categorized as either in northern (>34° N) or southern sub-regions of the MAV based on latitude (Wiseman 2009). Farmers on NWRs and private lands used standard agricultural production and harvest practices for initial sorghum crop production in the MAV. No farmer used a defoliant before harvest.

Methods

Experimental Design and Treatment Application

We used a split-plot randomized block design with one block in each of 22 sorghum fields (Gomez and Gomez 1984). Each block contained three 0.81-ha plots separated by a 30-m buffer between adjacent plots. We randomly assigned one of three post-harvest treatments to each plot within a block (i.e., mow, crush, and no treatment [control] of sorghum stubble). Additionally, we assigned randomly a nitrogen fertilization treatment (~168 kg/ha prilled ammonium nitrate [~57 kg N/ha] or none) to half (0.41 ha) of each plot.

Farmers or NWR staff applied treatments 1–10 days after harvest (8–9 September 2006, 8 August–25 September 2007). Cooperators used a tractor-drawn rotary mower to cut sorghum stubble approximately 13 cm above ground for the mowed treatment and pulled a heavy pipe or roller over stubble for the crushed treatment. Cooperators used a spin spreader to apply nitrogen fertilizer immediately after stubble treatments were applied. Ammonium nitrate is not subject to volatilization when broadcast on the soil surface like urea-based nitrogen fertilizers and remains stable until rain incorporates it into the soil.

Field Methods

We began data collection after ratoon crop maturation or first killing frost (3–11 November 2006, 2 November–12 December 2007). We used a 1-m^2 sampling frame and randomly selected 10 sampling sites within each split-plot. We clipped all ratoon sorghum seed heads within the sampling frame and placed them in a labeled bag. We considered any seed head a ratoon if it was attached to a previously cut stalk or a sprout rooted within the sampling frame.

We sampled natural seed and waste grain abundances using a blower-vac and circular plastic sampling frame (12.7-cm diameter × 4 cm tall; Penny et al. 2006). We randomly located the blower-vac within each 1-m^2 sampling frame, vacuumed for 10 seconds (Penny et al. 2006), and placed collected material in a labeled bag. If any portion of a harvested sorghum head was within the circular sampling area, we collected and combined it with the vacuumed material.

Penny et al. (2006) recommended the blower-vac for use on dry soils. If we encountered wet soil conditions, we sampled natural seeds and waste grain using a modified core sampling technique (Ripley and Perkins 1965). We randomly placed the circular frame used with the blower-vac within the 1-m^2 sampling frame and pressed it 1 cm into the soil. Then, we extracted litter, soil, and seeds from within the circular frame by sliding a metal spatula under the circular frame and lifting it vertically before placing contents in a labeled bag. We collected any portion of a sorghum head within the circular frame as described above.

To compare masses of seeds collected using the blower-vac and modified core methods, we collected 40 blower-vac and 40 modified core samples from 4 randomly selected dry-soil sampling locations at 4 study sites. We randomly placed the blower-vac within a 1-m^2 sampling area and collected samples as described above. Then, not moving the circular frame, we collected samples as described above using the modified coring technique, considering these as paired samples. We stored material collected using each device in separate labeled bags.

Laboratory Methods

We stored all samples at −10 C until processed. After thawing samples, we placed ratoon sorghum from samples in individual paper bags and dried samples for 24 hours at 80 C. After drying, we separated sorghum seeds from other plant material using forceps, dried seeds to a constant mass, and weighed samples (± 0.001 g; Gray et al. 1999). To process vacuumed samples, we separated natural seeds and waste sorghum grain from soil and litter using forceps, dried each separately to a constant mass, and weighed samples (± 0.001 g; Gray et al. 1999).

We processed waste grain and natural seed samples collected from wet sites with the modified core sampler using procedures recommended for processing soil cores by Kross et al. (2008). Then, we separated sorghum and natural seeds and processed these components and those of paired blower-vac and modified core samples as described above.

Statistical Methods

Ratoon Sorghum Seeds We deleted three plots (each from a different block) from analyses because 1) weather prohibited treatment application to one plot, 2) feral hog damage prevented random selection of sample sites within one plot, and 3) data were recorded incorrectly in the laboratory for one plot. Financial constraints required us to process 5 instead of 10 subsamples from 36 (38%) of 96 split-plots. We calculated mean kg (dry)/ha of ratoon sorghum grain from 5 or 10 subsamples processed from each stubble treatment-fertilizer combination in all 22 blocks and performed statistical analyses on split-plot means. We used PROC MIXED in SAS 9.2 for all analyses and designated an a priori $\alpha = 0.05$. We used outcomes of ANOVA tests for effects of experimental treatments and interactions to evaluate effect of computing split-plot means from either 5 or 10 subsamples. The *F*- and *P*-statistics were similar and inferences were the same using either 5 or 10 subsamples. Therefore, we calculated final means using the maximum number of subsamples (i.e., $n = 5$ or 10) available for all analyses. We designated post-harvest stubble treatment, fertilization, sub-region (i.e., north or south), and year as fixed effects and site and block (nested within site) as random effects. We tested all main effects and interactions but removed non-significant interactions for final inference.

Waste Sorghum and Natural Seeds We compared masses of waste grain and natural seeds collected with the modified core sampler and blower-vac using a paired *t*-test (Freund and Wilson 2003). The modified core sampler collected more waste grain and natural seed than the blower-vac ($t_{38} > 2.0$, $P < 0.009$); thus, we plotted mass of waste grain and natural seed collected using the modified coring technique against each of these collected via the blower-vac, validated linearity, and used simple linear regression to estimate mass of each seed type collected by the modified core.

Masses of waste grain and natural seed collected using the modified core were correlated with seed masses collected using the blower-vac (i.e., waste grain: slope = 0.8426, y-intercept = –0.0011, $r^2 = 0.96$, $n = 37$; natural seeds: slope = 0.6702, y-intercept = – 0.0026, $r^2 = 0.63$, $n = 37$). We used the regression equations to generate estimates of grain and seeds comparable to those collected by the blower-vac and then used these estimates to calculate split-plot means for those plots in which subsamples were collected using the modified core.

We performed statistical analyses on split-plot means (kg/ha of grain or seeds). We designated stubble treatment, sub-region, and year as fixed effects and site and block (nested in site) as random effects. We did not consider nitrogen fertilization in analyses of waste grain because its abundance is related to initial combine harvest operations and not fertilization. We tested main effects and interactions but removed non-significant interactions for final inference. We used an a priori $\alpha = 0.05$ for all statistical tests.

Results

Ratoon Sorghum Seeds

We detected a fertilization by year interaction on mean abundance of ratoon grain ($F_{1,\ 108} = 11.30$, $P = 0.011$). Fertilized plots produced over 4 times more ratoon grain ($\bar{x} = 219.57$ kg/ha ± 39.65 [SE]) than non-fertilized plots in 2007 ($\bar{x} = 53.23$ kg/ha ± 11.43; $t_{108} = 5.76$, $P < 0.001$) and fertilized ($\bar{x} = 15.27$ kg/ha ± 6.20; $t_{108} = –3.69$, $P = 0.004$) and non-fertilized plots in 2006 ($\bar{x} = 29.06$ kg/ha ± 12.71; $t_{108} = 3.34$, $P = 0.001$). We also detected an interaction between fertilizer and sub-region ($F_{1,\ 108} = 18.12$, $P < 0.001$). Fertilized plots at southern sites produced nearly 5 times more ratoon grain than non-fertilized plots at southern sites ($\bar{x} = 262.93$ kg/ha ± 50.28 vs. 55.07 kg/ha ± 14.63; $t_{108} = 5.07$, $P < 0.001$) and fertilized plots and non-fertilized plots at northern sites ($\bar{x} = 41.87$ kg/ha ± 8.50, $t_{108} = –2.81$, $P = 0.006$; $\bar{x} = 36.07$ kg/ha ± 9.2; $t_{108} = 2.50$, $P = 0.014$). We did not detect a difference in mean ratoon grain abundance among post-harvest stubble treatments ($F_{2,\ 108} = 0.38$, $P = 0.687$).

Waste Sorghum and Natural Seeds

Mean abundance of waste grain was 109.84 ± 36.50 kg/ha. We did not detect any effects of mechanical treatment ($F_{2,\ 47} = 0.05$, $P = 0.950$), year, or sub-region on abundance of waste grain ($F_{1,\ 47} \leq 2.04$, $P > 0.160$).

Southern sites ($\bar{x} = 16.36$ kg/ha ± 2.70; $F_{1,\ 109} = 4.07$, $P = 0.046$) produced more natural seed than northern sites ($\bar{x} = 15.05$ kg/ha ± 3.53). We did not detect effects of post-harvest stubble treatment ($F_{2,\ 109} = 0.04$, $P = 0.954$) or fertilizer ($F_{1,\ 109} = 2.18$, $P = 0.143$) on abundance of natural seeds.

Discussion

Differences in rainfall between 2006 and 2007 may have influenced potential production of ratoon grain and explain the observed fertilizer by year interaction. Our study sites were in counties classified as severely to moderately dry in July 2006, an important month in grain development (Vanderlip 1993, NCDC 2007). During August–November 2006, these counties had normal amounts of precipitation. In 2007, northern counties were classified as normal to moderately dry and southern counties were normal during the initial growing season, and during the ratoon growing season all counties were normal to wet (NCDC 2008).

Though sorghum is drought resistant, moisture stress during certain growth stages can negatively impact initial grain production (Vanderlip 1993), and vigorous ratoon production rarely follows a poor initial crop (Livingston and Coffman 1997). Water stress and delayed rainfall also can negatively affect ratoon grain production (Touchton and Martin 1981). Rainfall also influences effectiveness of supplemental nitrogen fertilization (i.e. ammonium nitrate) because it must be incorporated into the soil by rain or it will not be available to growing plants (MSU Extension 2009a).

We did not test effects of dates of harvest and application of treatments because these varied and could not be controlled among sites. However, dates of harvest and subsequent treatment application may have influenced ratoon production and partially explain the sub-region by year interaction. In 2006, we applied treatments at all sites in 2 days (8–9 September). In 2007, we applied treatments over 42 days because crops were harvested between 15 August and 25 September. In 2007, we applied treatments at all southern sites within 3 days (15–17 August) but over 34 days at northern sites (22 August – 25 September) because harvest dates varied throughout the northern sub-region. Ratoon grain yield may have been negatively impacted at sites that did not produce mature ratoon crops before frost occurred (Touchton and Martin 1981), particularly when the ratoon crop was initiated late due to late harvest and/or drought stress inhibiting regenerative plant development.

Growing degree days (GDD60; Reddy et. al 1996) also varied between years and sub-regions and could explain interactions involving both sub-region and year. First crops of sorghum require approximately 2,000 GDD60 after plant emergence to produce a mature crop, approximately 800–850 after bloom (Espinoza and Kelley 2004). To produce a mature ratoon crop, sorghum requires approximately 800 GDD60 after harvest (Espinoza and Kelley 2004).

In 2006, northern sub-region sites accumulated approximately 86 GDD60 between harvest and data collection (MSU Extension 2009b). In 2007, these sites accumulated ~407 GDD60 in the same time frame (MSU Extension 2009b). Northern sites apparently did not accumulate enough GDD60 either year to produce a mature ratoon crop; however, the additional GDD60 in 2007 may have been adequate to improve ratoon production. Sites in the southern sub-region accumulated ~634 GDD60 in 2006 between harvest and data collection and ~1,210 GDD60 in 2007 during the same time frame (MSU Extension 2009b). In both years, ratoon crops were produced but ratoon grain may not have reached full yield potential in 2006. The ability of southern sub-region sites to accumulate more GDD60 after harvest of the first crop may increase ratoon yield at sites in the southern sub-region.

Waste grain from initial harvest and natural seeds provided little potential food for waterfowl (i.e., combined <130 kg/ha). Sorghum producers that manage fields for production agriculture strive to minimize waste grain and natural seed production (MSU Extension 2006). Abundance of waste grain was approximately two times greater than a current forging threshold estimate (i.e., 50 kg/ha; Greer et al. 2009); however, waste sorghum may decompose or be consumed by granivores before waterfowl arrive on wintering grounds (Foster et al. 2010). Abundances of natural seed in both sub-regions were well below the current foraging threshold estimate (Greer et al. 2009) and would contribute little available food for wintering waterfowl.

Management Implications

Ratoon production in harvested sorghum fields is beneficial because little food resources are present otherwise. We did not detect a treatment effect of stubble manipulation and therefore recommend leaving stubble standing after harvest to minimize costs to land managers. Nitrogen fertilization increased ratoon yield in some cases and should be considered. Recently volatile prices of nitrogen fertilizer may be cost prohibitive (e.g., US $1.43/kg N in 2009; MSU Extension 2010) but are continuing to decline from a recent high of $1.56/kg N in 2007 (USDA 2009). Producers and managers should consider current cost of fertilizer and amount of fertilizer needed to increase ratoon yield based on soil fertility and favorable environmental conditions during both initial grain production and beginning of ratoon production.

Leaving a portion of the initial grain crop unharvested may be desirable to conserve grain for wintering waterfowl (Foster et al. 2010), because ratoon yields can vary depending upon environmental conditions and fields with little or no ratoon sorghum provide little food for waterfowl. Leaving a portion of the initial grain crop may also provide more food for waterfowl at lower cost than a ratoon crop (i.e., foregone income vs. cost of fertilizer; Foster et al. 2010). Though decomposition and granivory reduce waste sorghum available to waterfowl, unharvested sorghum left standing decomposes at a much lesser rate (Foster et al. 2010). Managers also may consider seeding harvested sorghum fields with commercially available millets after sorghum harvest (e.g., *Panicum ramosum*;

Atkeson and Givens 1952, Strickland et al. 2009). Millets mature in approximately 60 days and thus would produce a fall crop in most years before frost and provide additional food to waterfowl.

Wildlife managers should consider planting sorghum hybrids that mature early, require fewer GDD60, and can tolerate early spring planting to increase time between harvest and frost (Touchton and Martin 1981). Increased time would allow increased GDD60 accumulation and thereby increase ratoon yields. They also should consult local crop agronomists to determine proper hybrid selection.

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