Determining Avian Herbivory Patterns at Sowing Using Loblolly and Longleaf Pine Seed

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Abstract

Avian herbivory of pine seeds is a leading cause of seedling loss in container nurseries. Practices currently used to prevent herbivory are not fully effective and have not changed much in the last 60 years. Because no clear avian herbivory patterns of seeds have been documented, two trials were conducted to determine effects of: (1) container cell color and growing medium depth using longleaf pine (*Pinus palustris* Mill.) seeds at two sites, and (2) genetic quality of longleaf pine and loblolly pine (*P. taeda* L.) seeds at two sites. In the first trial, fewer seeds were consumed after 5 days from cavities filled to two-thirds of operational capacity compared with those filled to operational capacity, but by day 10, birds foraged in all cavities regardless of medium depth. In the second trial, birds showed no preference for pine species or genetic quality of seeds. Birds tended to avoid an open field area. Birds also recognized where containers had been placed for a previous trial, which led to earlier and faster seed consumption in the subsequent trial.

Introduction

Tree seedling production using containers has increased almost 5,000 percent over the last 40 years across the Southern United States (Starkey et al. 2015). Currently, more than 230 million conifer seedlings are grown in containers each year in the South (figure 1) (Haase et al. 2021). Increasing seed efficiency is a primary objective of nursery managers to ensure each container cavity produces a seedling from each pure live seed sown. When a container cavity does not produce a seedling, seed efficiency is reduced, and the nursery incurs economic losses. The cost of seeds, wasted growing medium left in the container cavity, and fewer seedlings available to sell at the end of the growing season all contribute to lost revenue by the nursery.

In a 2012 survey, 80 percent of container seedling nursery managers reported birds as the largest factor contributing to reductions in seed efficiency with a 1.33-percent seedling loss (Starkey et al. 2015). Avian herbivory leads to more seedling loss than pre- and post-emergence damping-off or insects (Starkey et al. 2015). To put that into economic perspective, if a container nursery with a capacity to grow 40 million seedlings endures a 1.33 percent loss, and seedlings are priced at 20 cents each, production loss will be 532,000 seedlings or $106,400 in revenue.

Avian herbivory of seeds is not a new problem in tree seedling nurseries. Reines and Greene (1957) described a single bird consuming 67 seeds in less than 1 minute at a Georgia nursery. Nursery managers have implemented preventive measures to curb damage from birds for more than 60 years. Kingsley (1958) tested thiram and anthraquinone on loblolly (*Pinus taeda* L.) and slash pine (*P. elliotti* Englm.) seed and had good protection from birds while also reducing labor costs associated with patrolling the nursery. Thiram and anthraquinone are still recommended as seed treatments against birds in container nurseries (Landis et al. 1998). Suspending shade cloth over container sets during the germination phase is another practice currently used to prevent birds from reaching seeds. Issues with this method include birds getting trapped under the shade cloth leading to increased feeding (Starkey et al. 2015) and the cost of the shade cloth necessary to cover large areas (up to 40 ac [16 ha]). In addition, removing the shade cloth must coincide with a certain stage of germination, which can vary depending on the conifer species and genetic sources within species (Clouse

Figure 1. Many conifer seedlings are grown in container production systems in the South. (Photo by Paul Jackson, 2021)

2021). Noise-making devices such as propane-fueled exploders have been used to prevent herbivory, but they require frequent maintenance, can be dangerous to handle, and birds become accustomed to their presence (Jackson 1991). The use of cover crops such as soybeans (*Glycine max* L.) and sorghum (*Sorghum bicolor* L.) have been successful luring birds away from seeded areas when grown in close proximity to the nursery (Dorward 1965).

In 2018, avian herbivory of seeds was a problem in a longleaf pine (*Pinus palustris* Mill.) trial conducted to detect Sonderegger pine (*Pinus x sondereggeri* H.H. Chapm.) seedlings during the germination phase (Bolner at al. 2019). Birds were observed foraging only on seeds sown in container cavities that were filled with medium to operational levels (within 0.4 in [1 cm] of the top) compared with those filled to two-thirds capacity (within 3.6 in [4.8 cm] of the top) (figure 2). After these observations, the authors contacted Mike Coyle, Container Operations Manager at International Forest Company (IFCO, Moultrie, GA) to learn if he had observed any seed foraging patterns during daily operations. His observations were: (1) birds tend to forage more heavily on longleaf pine seeds compared with other pine species, (2) birds seem to forage on seed lots bred for improved genetic quality compared with open-pollinated or wild-collected seed lots, (3) different avian species often forage on fall-sown seeds compared with those that forage on spring-sown seeds, and (4) birds tend to forage in containers located along the edges near tree lines compared with more open areas of the nursery.

Using the information gathered from the 2018 trial and from Mike Coyle at IFCO, and knowing that current preventive methods against avian herbivory still result in significant seed loss (Starkey et al. 2015), two trials were designed. The objectives for Trial One were to determine if container medium depth, container color, and site surroundings such as an open field or tree-lined edge affected avian herbivory of seeds. The objective of Trial Two was to determine if sowing loblolly pine and longleaf pine seeds from different genetic sources affected avian herbivory.

Figure 2. In a 2018 longleaf pine trial, seed castings were left behind as a result of avian herbivory. (Photo by Paul Jackson, 2018)

Materials and Methods

Trial One

Non-treated longleaf pine seeds were sown singly into Ray Leach Cone-Tainer™ cells (RL98 Stubby, 6.5 in^3 [107 cm^3], Stuewe and Sons, Inc., Tangent, OR) on October 23, 2020 at Louisiana Tech University (Ruston, LA). Containers were filled with a peat moss-based growing medium (Pro-Mix®, Premier Tech Horticulture, Quakertown, PA). Two container colors (white or black) and two medium fill levels (operational level within 0.4 in [1 cm] of the top or two-thirds of operational level within 3.6 in [4.75 cm] of the top) (figure 3) were evaluated in the trial for a total of four treatments. Two geographic locations were selected to set out containers: an open field site (32°31'02" N, 92°39'05" W) and an area adjacent to a wooded fencerow (32°30'58" N, 92°39'13" W). Each tray of 49 cells served as a replication with 3 trays per treatment at each location for a total of 24 trays and 1,176 cells. Trays were placed in a completely randomized block design on three nursery tables at each

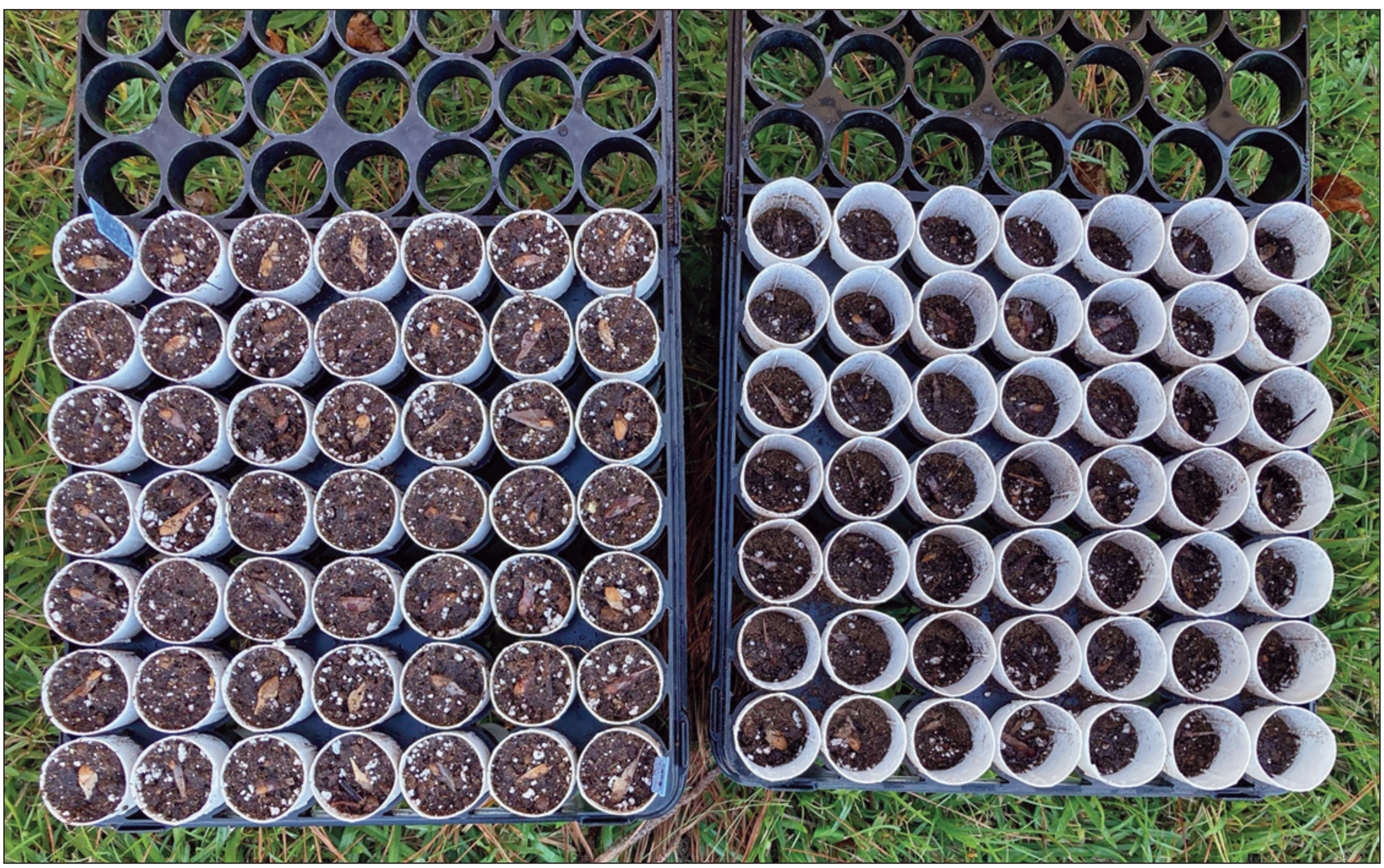

Figure 3. For Trial One, container cells were filled with medium to operational levels (left) or to two-thirds capacity (right). (Photo by Paul Jackson, 2020)

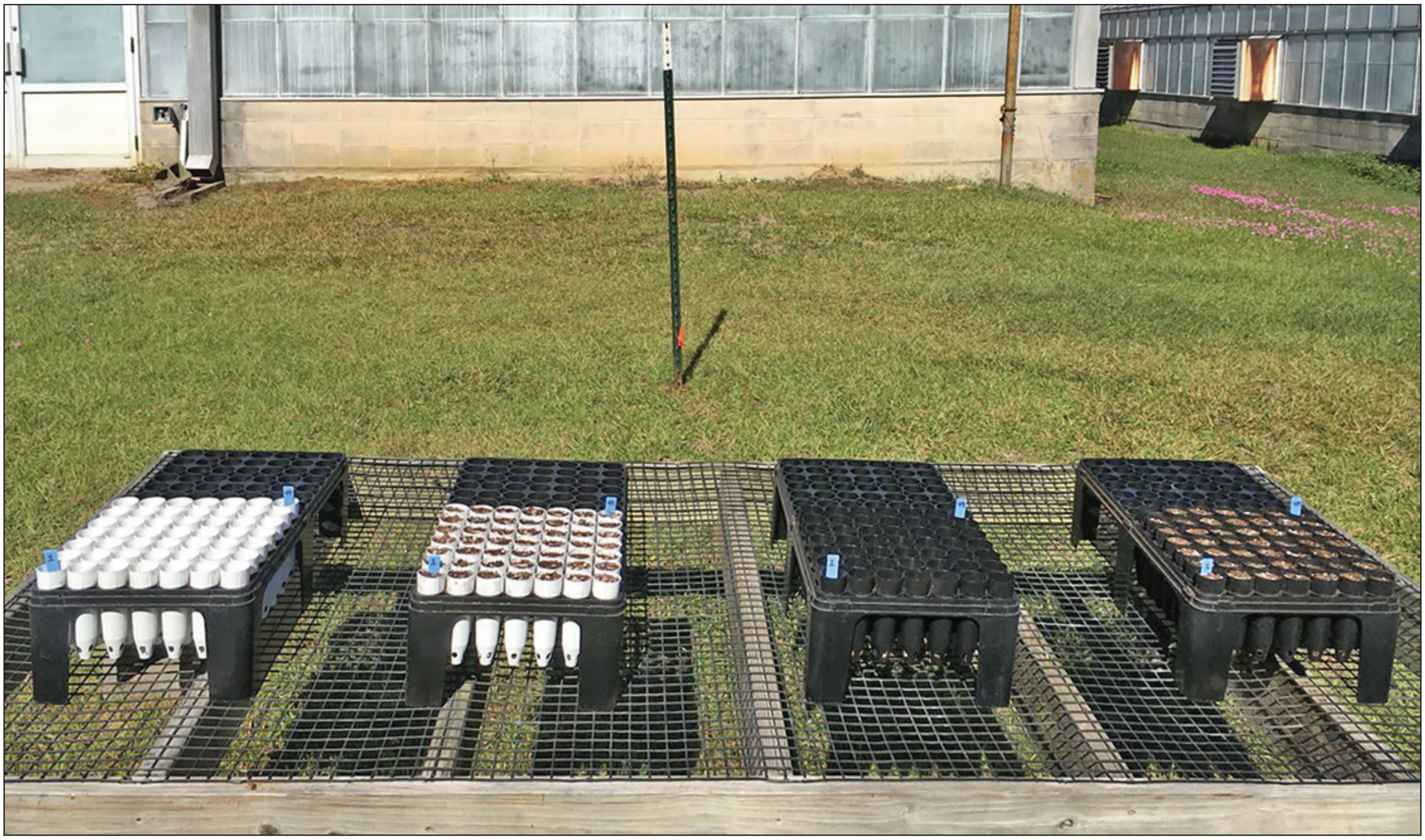

Figure 4. Trial One was set up in a randomized complete block of trays set out on a nursery table. (Photo by Kelsey Shoemaker, 2020)

location (figure 4). Beginning on October 24, 2020, container cells were checked daily for 10 days to determine if seeds were present or consumed (figure 5). A seed was considered consumed if completely missing or if feeding was evident, such as seed castings remaining in the container (figure 6).

Figure 5. To assess avian herbivory, containers were checked daily for the presence or absence of seeds. (Photo by Paul Jackson, 2020)

Trial Two

Black IPL Rigi-Pots™ (IPL-110, 6.7 in^3 [110 cm^3] cells, Stuewe and Sons, Inc., Tangent, OR) were filled to operational levels with a Pro-Mix® growing medium on April 6, 2021 at Louisiana Tech University. Containers were sown singly with two seed lots of longleaf pine and three seed lots of loblolly pine for a total of five treatments in the trial. Longleaf pine seed lots were either collected from

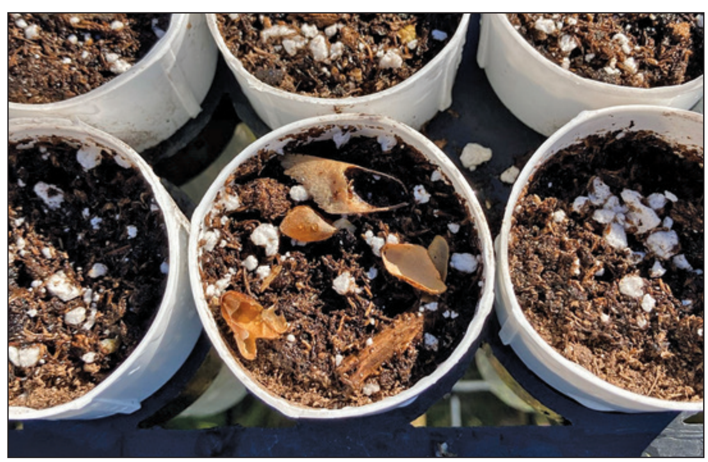

Figure 6. Seed castings left in the container cell are an indicator that seeds were foraged. (Photo by Paul Jackson, 2020)

a wild source and not genetically improved (low quality) or collected from a genetically improved family (high quality). Loblolly pine seed lots were either a C-grade, second-generation selection (low quality); an A-grade, second-generation selection (medium quality); or a controlled, mass-pollinated seed lot (high quality). Grades for the low- and medium-quality loblolly pine seed lots were assessed based on selection factors associated with tree volume, straightness, and forking potential.

Two geographic locations were selected: the area adjacent to a wooded fencerow (same as in Trial One) and a tree line near the edge of a pasture (32° 30' 49" N, 92° 39' 08" W). Each IPL Rigi-Pot™ container (45 cells) served as a replication, and there were 4 containers per treatment at each location for a total of 40 containers, 720 longleaf pine seeds, and 1,080 loblolly pine seeds used in the trial. Trays were set out in a completely randomized block design on four nursery tables at each location (figure 7). Similar to Trial One, container cells were checked to determine if seeds were present or consumed during a 15-day period.

Avian herbivory was observed at each site using passive, infrared, motion-activated trail cameras throughout the trial. Afterwards, photographs were reviewed for avian herbivorous events. Documented data from these events included avian species, sex (if identifiable), the seed lot at which the bird was observed, site, date, and time. To compare avian species photographed consuming seeds to all species in the area, SM4 Song Meters (Wildlife Acoustics, Inc., Maynard, MA) were placed at each site (figure 8). These devices were set to record during the peak of daily avian activity—approximately 10 minutes before and 10 minutes after sunrise each morning (Robbins 1981) during data collection. Avian species heard singing or calling during each 20-minute recording period were documented.

Data Analyses

For both trials, an analysis of variance was conducted using a General Linear Model, and multiple comparisons of means were conducted using Duncan's Multiple Range Test using SAS statistical software (9th ed., SAS Institute, Cary, NC). Analyses were conducted on data collected every 5 days during each trial.

Figure 7. For Trial Two, tables and containers were arranged in a randomized complete block as shown at the pasture edge site. (Photo by Kelsey Shoemaker, 2021)

Figure 8. The SM4 song meter (left) and a motion-activated trail camera (right) were used to document avian herbivory in Trial Two. (Photo by Heidi Adams, 2021).

Results

Trial One

At the open field site, a total of 24 of the 588 longleaf pine seeds were completely missing from cells regardless of medium level or container color, and another 19 seeds were located in nearby cells or between cells in the tray. We speculate that these seeds were displaced by wind or rain because seed castings or evidence of feeding was not apparent.

After 5 days of observation at the wooded fencerow site, cells filled with medium to operational levels endured more herbivory than those filled to two-thirds capacity. By day 10, herbivory of seeds was similar between medium levels. Container color had no significant effect on seed herbivory (figure 9).

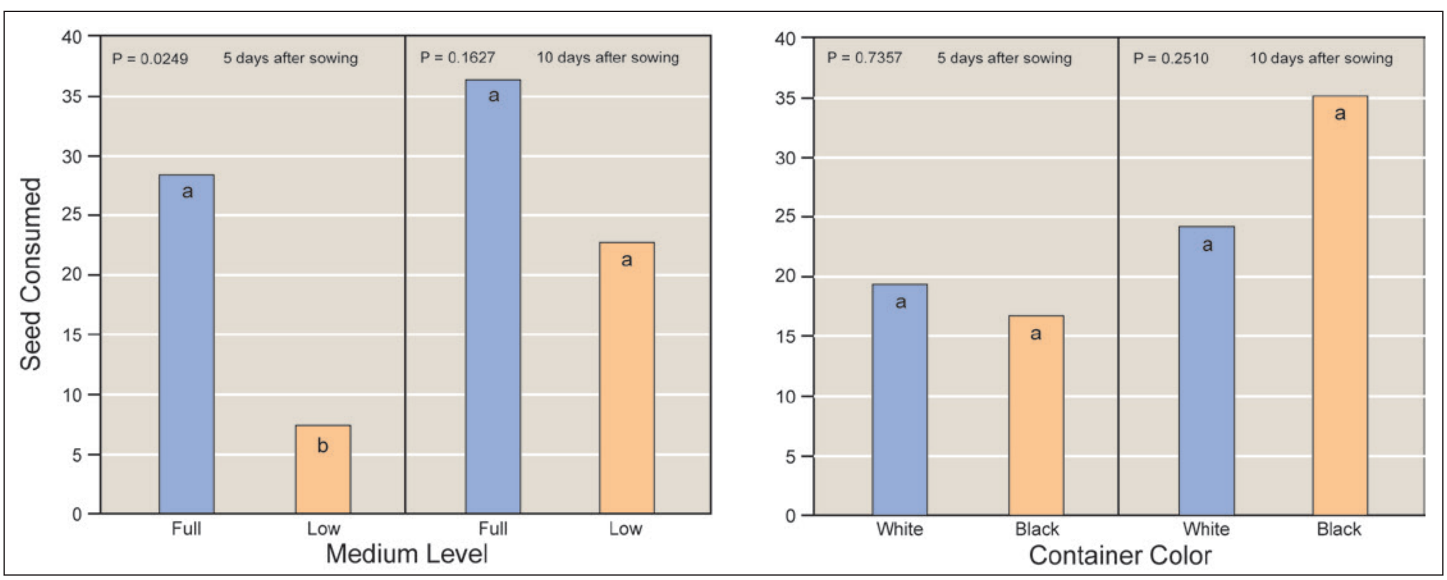

Figure 9. The average number of longleaf pine seeds consumed at the wooded fencerow site were compared 5 and 10 days after sowing (a) between containers filled to operational levels or to two-thirds capacity and (b) between black or white container cells. After 10 days, avian herbivory did not differ by either treatment. Means within each treatment and evaluate date with the same letter are not significantly different based on Duncan's Multiple Range Test.

Trial Two

At the wooded fencerow site, seed herbivory began immediately. Two days after sowing (DAS), there seemed to be a preference for high- and medium-grade loblolly pine seed compared with other seed lots (table 1). By day 4, almost all seeds were consumed regardless of pine species or seed grade.

At the pasture edge site, less than 5 seeds were consumed after 5 days regardless of species or seed grade (table 2). By day 10, herbivory of loblolly pine seeds was more than double that of longleaf pine but not statistically different. Herbivory appeared to be indiscriminate tray to tray. For instance, seeds in one high-grade longleaf pine tray and one high-grade loblolly pine tray were completely consumed by day 10, while no seeds were consumed in other trays of the same seed grade and pine species. By day 15, almost all seeds were consumed regardless of pine species or seed grade.

Table 1. Average number of loblolly pine and longleaf pine seeds of various genetic quality consumed in Trial Two at the wooded fencerow site 2 and 4 days after sowing (DAS).

Pine Species	Seed Grade	Average # seeds consumed	
		2 DAS	4 DAS
loblolly	high	31.0	44.0
	medium	33.5	41.5
	low	18.8	44.5
longleaf	high	10.8	43.8
	low	18.5	44.8
P-value		0.5632	0.8449

Table 2. Average number of loblolly pine and longleaf pine seeds of various genetic quality consumed in Trial Two at the pasture edge site 5, 10, and 15 days after sowing (DAS).

Pine Species	Seed Grade	Average # seeds consumed		
		5 DAS	10 DAS	15 DAS
loblolly	high	1.5	33.8	44.5
	medium	3.0	44.0	45.0
	low	0.5	32.5	44.5
longleaf	high	1.0	16.5	43.5
	low	1.0	16.8	43.8
P-value		0.2095	0.3658	0.2883

During the trial, there were 13 audio recordings from the wooded fencerow site and 19 audio recordings from the pasture edge site. Based on a review of these recordings, 30 total avian species were in the vicinity of the trial locations: 22 at the wooded fencerow site, 25 at the pasture edge site, and 17 at both sites (table 3). Northern cardinals (*Cardinalis cardinalis*) accounted for 95 percent of the photographed herbivory events at the wooded fencerow site and 100 percent at the pasture edge site (figure 10). The remaining 5 percent of photographed herbivory events at the wooded fencerow site were blue jays (*Cyanocitta cristata*).

Nine mammalian species were also photographed in the vicinity of the trial sites: eastern cottontail (*Sylvilagus floridanus*), feral cat (*Felis catus*), gray fox (*Urocyon cinereoargenteus*), nine-banded armadillo (*Dasypus novemcinctus*), North American raccoon (*Procyon lotor*), red fox (*Vulpes vulpes*), striped skunk (*Mephitis mephitis*), Virginia opossum (*Didelphis virginiana*), and white-tailed deer (*Odocoileus virginianus*). None of these mammals, however, disturbed the seeds.

Discussion

In Trial One, fewer longleaf pine seeds were consumed from container cells filled to two-thirds capacity. However, herbivory remained an issue as seeds sown at lower medium depths were eventually consumed. Even if this treatment had shown more promise in preventing herbivory, the root plugs that would develop in the container cavities with a smaller volume of medium may not have met nursery quality standards for good outplanting performance. Container color was not a significant factor in deterring herbivory even though more

Figure 10. A pair of northern cardinals were captured by a trail camera foraging on seeds at the wooded fencerow site in Trial Two. (Photo courtesy of Heidi Adams 2021)

Table 3. Number of avian herbivory events and audio detections at both Trial Two locations by species.

Avian species	Wooded fencerow		Pasture edge	
	Herbivory events	Audio detections	Herbivory events	Audio detections
Northern cardinal (*Cardinalis cardinalis*)	93	13	89	19
Blue jay (*Cyanocitta cristata*)	5	9	0	12
American crow (*Corvus brachyrhynchos*)	0	12	0	17
Carolina chickadee (*Poecile carolinensis*)	0	11	0	17
Carolina wren (*Thryothorus ludovicianus*)	0	10	0	13
Red-bellied woodpecker (*Melanerpes carolinus*)	0	9	0	10
Brown thrasher (*Toxostoma rufum*)	0	10	0	5
Tufted titmouse (*Baeolophus bicolor*)	0	8	0	7
White-eyed vireo (*Vireo griseus*)	0	2	0	13
Ruby-throated hummingbird (*Archilochus colubris*)	0	7	0	6
White-throated sparrow (*Zonotrichia albicollis*)	0	9	0	4
Common grackle (*Quiscalus quiscula*)	0	10	0	1
Northern mockingbird (*Mimus polyglottos*)	0	10	0	1
Brown-headed cowbird (*Molothrus ater*)	0	0	0	8
Blue-gray gnatcatcher (*Polioptila caerulea*)	0	0	0	7
American robin (*Turdus migratorius*)	0	5	0	1
Red-winged blackbird (*Agelaius phoeniceus*)	0	4	0	2
Pine warbler (*Setophaga pinus*)	0	5	0	0
Wood thrush (*Hylocichla mustelina*)	0	2	0	3
Eastern phoebe (*Sayornis phoebe*)	0	0	0	4
Fish crow (*Corvus ossifragus*)	0	1	0	3
Red-tailed hawk (*Buteo jamaicensis*)	0	0	0	4
Cedar waxwing (*Bombycilla cedrorum*)	0	2	0	0
Indigo bunting *(Passerina cyanea*)	0	2	0	0
Killdeer (*Charadrius vociferus*)	0	0	0	2
Red-eyed vireo (*Vireo olivaceus*)	0	0	0	2
Eastern bluebird (*Sialia sialis*)	0	1	0	0
Eastern meadowlark (*Sturnella magna*)	0	0	0	1
Eastern wood-pewee (*Contopus virens*)	0	0	0	1
Mourning dove (*Zenaida macroura*)	0	1	0	0

seeds remained in white cells. Because seedlings are typically grown in black containers across the South, changing to white containers would not be economical unless seed herbivory had been dramatically different between black and white containers.

The idea of testing the potential for herbivory among seed lots of various genetic levels came from previous observations in an operational nursery. In Trial Two, almost all seeds were consumed regardless of seed grade or pine species. This herbivory occurred during what would be a normal 2-week germination window in the nursery. This trial differed, however, from operational procedure because multiple seed grades were sown in close proximity on the same tables. Seed lots of various genetic qualities are typically sown together in large compartments throughout the nursery. Therefore, if birds prefer seeds based on genetic quality, this behavior may be better observed in areas of the nursery where seeds of the same genetic grade are sown together in high quantities.

During Trial One, only 43 of 588 seeds were missing or found outside of the containers at the open field site compared with 356 of 588 seeds consumed at the wooded fencerow site. This disparity is likely due to edge effects at the wooded fencerow site. Northern cardinals were photographed during Trial Two at the wooded fencerow site and observed on containers from afar during Trial One. These birds and other passerines are known to be prey to a variety of predators and likely avoided the open field area. Several potential predators photographed or recorded during the trial included feral cats, gray and red fox, and red-tailed hawks (*Buteo jamaicensis*). Foraging in an exposed area like the open field site exposes small birds to greater predation risks. For example, Horn et al. (2003) determined the proximity to cover was inversely related to the number of birds visiting a bird feeder. Similarly, Kross et al. (2020) discovered avian damage to sunflower (*Helianthus annuus* L.) was higher at a field's edge compared with 160 ft (49 m) or more from the edge.

Northern cardinals are opportunistic granivores, feeding on seeds and other vegetative matter for most of the year (Halkin and Linville 1999, Hamel 1992). The pattern observed in Trial One fits an opportunistic approach as foraging increased in cavities with less medium after the more accessible seeds sown in operationally filled cavities were no longer available. In the fall, these birds will feed on fruit and insects during their pre-basic molt, acquiring carotenoids that will turn their developing plumage red (Halkin and Linville 1999). Northern cardinals tend to be solitary most of the year, but will form a monogamous pair bond during the reproductive season. At this time, the pair will be very territorial (Halkin and Linville 1999). This territory can range between 0.5 to 6.5 ac (0.2 to 2.6 ha) depending on food resource availability (Halkin and Linville 1999).

Northern cardinals have a good memory for food acquisition. Just as in mammals, the avian hippocampus functions in learning and memory. In a study evaluating the volume of the avian hippocampus, for instance, northern cardinals had a greater hippocampal volume-to-body mass ratio than 18 of the 22 other avian species examined (Sherry et al. 1989). This anatomical feature allows northern cardinals to better remember food resources, such as the seedling containers used in this study. Herbivory events at the wooded fencerow site during Trial Two began much sooner than at the pasture edge site. The likely reason for this is the wooded fencerow site was used previously during Trial One, and the northern cardinals recognized the available food source shortly after seeds were placed at the site. Foraging began there almost immediately, and there was no preference for a certain pine species or seed grade.

Several tactics may be used to deter northern cardinals from feeding on pine seeds in the nursery, though it is important to note that one single method may not be entirely effective. One tactic is to establish decoy food plots or feeding stations around the perimeter of container sets, particularly in areas in close proximity to habitat edges (e.g., wooded fencerows). This technique is not used to sustain the northern cardinal population but provides a food source more appealing than pine seeds, such as bird feeders filled with black-oil sunflower seeds. This tactic has been effective in other scenarios, including the reduction of blackbird (Icteridae) damage to sunflower crops (Linz et al. 2011, 2015).

The use of avicides is also a common technique to reduce avian damage to crops. Anthraquinone has been used to reduce dickcissel (*Spiza americana*) damage to rice (*Oryza sativa* L.; Avery et al. 2001) and sandhill crane (*Antigone canadensis*) damage to corn (*Zea mays* L.; Barzen and Ballinger 2018). Methyl anthranilate was effective in reducing avian damage to Colorado corn crops, North Dakota sunflower crops, and Washington State cherry (*Prunus avium* L.) crops (Askham 2000). Caffeine has also been used as a deterrent, contributing to a reduction in rice consumption by red-winged blackbirds (*Agelaius phoeniceus*) in Louisiana (Avery et al. 2005). Before using avicides to treat pine seeds, a trial test should be conducted to evaluate product efficacy and environmental safety.

Other methods to manage avian herbivory include auditory (e.g., propane cannons) and visual (e.g., reflective ribbons or mirrors, drones) deterrents (Dolbeer 1990, Rivadeneira et al. 2018). Lethal measures to address avian herbivory of pine seeds should be avoided as northern cardinals—along with many other avian species—are protected under the Federal Migratory Bird Treaty Act of 1918 (16 U.S.C. 703–712, MBTA). The list of all species protected under the MBTA can be found in the Code of Federal Regulations under Title 50 Part 10.13. Additionally, this tactic has several drawbacks, including low acceptance among the general public, low cost-effectiveness, and the risk of species misidentification, putting non-target species at risk (Linz et al. 2015).

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