Anthraquinone Repellent Research: Literature Review

1. Abbott, H. G. 1958. Application of avian repellents to Eastern white pine seed. Journal of Wildlife Management 22: 304-306. Abbott 1958.pdf

Four materials, anthraquinone, Morkit, quinizarine, and Arasan Seed Disinfectant and Protectant (50% tetramethyl thiuram disulphide) were all found to be effective as bird repellents when applied to E. White Pine (*Pinus strobus*) seed planted in nursery seedbeds. No statistical difference in relative effectiveness of repellents was determined. Repellency of materials was best demonstrated against Grackles (*Quiscalus quiscala*). Feeder tests of unplanted white pine seed treated with the same materials gave less positive results. Chipping Sparrows (*Spizella passerina*) and House Sparrows (*Passer domesticus*) eventually fed as freely on treated as on untreated seed.

2. Ateyyat, M. A., and M. S. Abu-Darwish. 2009. Short communication. Insecticidal activity of different extracts of Rhamnus dispermus (Rhamnaceae) against peach trunk aphid, Pterochloroides persicae (Homoptera: Lachnidae). Spanish Journal of Agricultural Research 7: 160-164. Ateyyat and Abu-Darwish 2009.pdf

Bark of *Rhamnus dispermus* Ehrenb (Rhamnaceae**)** was collected from Ash-Shoubak, Jordan, and extracted with hexane, chloroform, acetone and ethanol, respectively. The aim of this study was to test the insecticidal activity of these extracts against the peach trunk aphid (PTA), *Pterochloroides persicae* (Homoptera: Lachnidae), since it has been shown that *Rhamnus* spp. may contain compounds that can act as botanical pesticides. Three concentrations (100, 1000, and 10,000 ppm) of each dry extract were obtained by dissolving the dry extract in 0.01% solution of dimethyl sulfoxide (DMSO). Results showed that, at the highest concentration (10,000 ppm), all the extracts caused mortality in the PTA adults after 24 h of exposure. Both the acetone and ethanol extracts showed higher mortality (69 and 71%, respectively) than the hexane and chloroform extracts (40 and 56%, respectively) after 72 h of exposure at the highest concentration. In comparison, the synthetic control, Imidacloprid, killed 93% of the PTA adults. Nevertheless, extracts from *R. dispermus* provided valuable mortality rates for the PTA and can be used as botanical insecticides as part of the integrated pest management programs of this insect pest.

3. Avery, M. L., J. S. Humphrey, and D. G. Decker. 1997. Feeding deterrence of anthraquinone, anthracene, and anthrone to rice-eating birds. Journal of Wildlife Management 61: 1359-1365. Avery et al. 1997.pdf

Safe, effective bird repellents are needed as seed treatments and for many other agricultural uses. Quinones are distributed widely in nature and many have predator defense and antiherbivory functions. One compound, 9,10-anthraquinone, was identified as a bird repellent in the 1940s, but is not registered for use in the United States. We evaluated it and 2 structurally related compounds, anthrone and anthracene, for repellency to rice-eating birds. In choice tests with individually caged red-winged blackbirds (*Agelaius phoeniceus*) anthraquinone and anthrone produced comparable reductions in consumption of treated rice at rates of 0.05, 0.10, and 0.25% (g/g). At 0.50%, however, only anthraquinone suppressed consumption of untreated rice as well as treated rice. Anthracene was least effective of the 3 compounds and was tested only at 0.50%.

In 1- cup tests, consumption of anthraquinone-treated rice by individual blackbirds was suppressed at 0.10, 0.25, and 0.50%. Rice consumption by individually caged female boat-tailed grackles (*Quiscalus major*) exposed to the 0.50% treatment was similar to that of redwings at the 0.10% treatment. In choice tests of 3-bird groups in large flight enclosures, red-winged blackbirds discriminated strongly against 0.25% anthraqunione-treated rice. Observations of videotaped birds revealed no evidence of contact irritation or unpleasant taste; rather post-ingestive illness, as evidenced by one vomiting bird, suggests that anthraquinone repellency is due to learned behavior.

4. Avery, M. L., D Decker, and J. S. Humphrey. 1998. Development of seed treatments to control blackbirds. Proceedings of the Vertebrate Pest Conference 18: 354-358. Avery et al. 1998a.pdf

Bird repellents to protect seeds are a potentially important aspect of integrated vertebrate pest management strategies. Yet, there currently are no repellents registered for seed treatment uses. This is due not to lack of effective candidate compounds, but to monetary and regulatory constraints that inhibit commercialization of promising compounds. Two examples of this dilemma are methiocarb and anthraquinone, each of which has considerable potential for bird repellent uses and each of which faces considerable registration hurdles as prospective seed treatment compounds. A concerted, coordinated effort among private industry, producer groups, and state and federal agencies may be the best strategy to bring potentially useful repellents to commercial reality.

5. Avery, M L., J. S. Humphrey, T. M. Primus, D. G. Decker, and A. P. McGrane. 1998b. Anthraquinone protects rice seed from birds. Crop Protection 18: 225-230. Avery et al. 1998b.pdf

Application of bird-repellent chemicals to seed prior to planting is one possible approach to reducing bird damage to rice. Anthraquinone is a promising seed treatment compound, and in this paper we describe a sequence of tests evaluating a formulated commercial anthraquinone product. In l-cup cage tests, rice consumption by individual male red-winged blackbirds (*Agelaius phoeniceus*) and female boat-tailed grackles (*Quiscalus major*) was reduced 64-93% by 0.5 and 1.0% (g/g) anthraquinone treatments. Daily rice consumption by single male boat-tailed grackles tested in large enclosures was reduced from > 14 g in pretreatment to < 1 g by a 1.0% treatment. One of five test birds ate nothing during a 1 day post-treatment session. In a 7 day trial within a 0.2 ha flight pen, a group of four male grackles consumed 1.3% of anthraquinone-treated rice seed compared to 84.1% of sorghum, a nonpreferred alternate food. At two study sites in southwestern Louisiana, loss of rice sprouts in 2 ha plots sown with anthraquinone-treated seed was 0 and 12% compared to losses of 33% and 98% in nearby untreated plots. The formulation performed well at every stage of testing, and further development of anthraquinone products for bird-damage management is warranted.

6. Avery, M. L., D. A. Whisson, and D. B. Marcum. 2000. Responses of blackbirds to mature wild rice treated with flight control bird repellent. Proceedings of the Vertebrate Pest Conference 19: 26-30. Avery et al. 2000a.pdf

Red-winged blackbirds (*Agelaius phoeniceus*) and other granivorous species cause substantial economic damage to wild rice in California. Currently available damage control techniques have only limited effectiveness and there is considerable need for new effective techniques. We conducted a field trial in northern California to determine the effectiveness of the bird repellent Flight Control™ (50% Anthraquinone),a pplied at rates of 18.6 and 55.8 L/ha, in reducing blackbird depredations to wild rice. We detected no effect of the treatments on blackbird behavior in the field, even though captive red-winged blackbirds were deterred in feeding trials with wild rice seeds collected from our study plot. We suggest several possible reasons for this: 1) blackbirds used wild rice for cover as well as a food source; 2) birds perhaps received insufficient exposure to the repellent owing to either the birds' ability to hull the seeds rapidly, low anthraquinone residues on the seeds, and/or non-uniform coverage of seed heads; 3) although Flight Control™ is a feeding deterrent, an aversive response might require repeated exposure to treated rice; and 4) frequent turnover in the depredating population would result in birds not being present long enough to acquire an avoidance response. Clearly, a better understanding of blackbird movements and behavior in wild rice is needed to develop an effective management strategy.

7. Avery, M. L., E. A. Tillman, J. S. Humphrey, J. L. Cummings, D. L. York, and J. E. Davis, Jr. 2000. Evaluation of overspraying as an alternative to seed treatment for application of Flight Control bird repellent to newly planted rice. Crop Protection 19: 225-230. Avery et al. 2000b.pdf

Anthraquinone is a promising candidate as a repellent to protect newly planted rice from blackbird depredation. Current technology for applying chemicals to rice seed prior to planting might be incompatible with the relatively large volume of bird repellent material needed on rice seeds. Therefore, an alternate method of application, overspraying the field after the seed is planted, could prove more efficient and practical. We examined this approach in pen and field trials. In group pen tests, red-winged blackbirds (*Agelaius phoeniceus*) consistently avoided Flight Control (50% anthraquinone) applications equivalent to 23.3 and 37.2 l/ha, but were not deterred by 9.3 l/ha. Several test birds vomited after they fed on treated seeds. In a 0.2 ha flight pen, blackbird flocks removed 58% of rice seed from untreated plots compared to 6% taken from plots sprayed with Flight Control at a rate of 18.6 l/ha. In southwestern Louisiana, plots of newly planted rice were sprayed with Flight Control at either 9.3 or 18.6 l/ha. We did not observe blackbird repellency at any of the treated sites. Anthraquinone residues on rice from the test plots indicated that there was insufficient repellent on the seeds in the fields to deter depredating blackbirds. For overspraying to be practical and effective, methods must be devised to deliver the chemical more efficiently to the planted seeds.

8. Avery, M L., E. A. Tillman, and C. C. Laukert. 2001. Evaluation of chemical repellents for reducing crop damage by Dickcissels in Venezuela. International Journal of Pest Management 47: 311-314. Avery et al. 2001.pdf

In Venezuela, lethal control of wintering Dickcissels (*Spiza americana*) is considered a threat to the species survival. To help farmers protect their rice and sorghum crops from depredations by Dickcissels and to minimize the killing of large numbers of these birds, alternative non-lethal crop protection measures are needed. To that end, the responses of captive Dickcissels to three bird-repellent chemicals applied to rice seed were evaluated. In one-cup feeding trials, treatments of methiocarb (0.05%g g, applied as Mesurol® 75% wettable powder) and anthraquinone (0.5%, applied as Flight Control®) reduced consumption of rice by 70% relative to pretreatment consumption. Other anthraquinone treatments (0.05, 0.1%) and methyl anthranilate (0.05%) were ineffective. In two-cup trials, with untreated millet as the alternative food, consumption of rice treated with 0.05 and 0.1% anthraquinone was reduced by 90% relative to pretreatment levels. Overall, Dickcissels responded to the repellents similarly to the red-winged blackbird (*Agelaius phoeniceus*). Because Flight Control® has been used successfully to reduce blackbird use of rice fields in the USA, the prospect is good for successful reduction of damage to ripening rice by Dickcissels in Venezuela, particularly if repellent use is coupled with the establishment of alternative feeding sites.

9. Avery, M L. Behavioural and ecological considerations for managing bird damage to cultivated fruit. Pages 467-477 in D. J. Levey, W. R. Silva and M. Galetti editors. Seed dispersal and frugivory: ecology, evolution and conservation. CAB International, Oxon, United Kingdom. Avery 2002.pdf

10. Avery, M. L., J. S. Humphrey, and E. A. Tillman. 2002. Responses of blackbirds to aerial application of Flight Control bird repellent to ratoon rice in Cameron Parish, Louisiana. Pages 321-326 *in* J. E. Hill and B. Hardy, editors. Proceedings of the Second Temperate Rice Conference. International Rice Research Insititute, Los Banos, Philippines. Avery et al. 2002.pdf

Blackbird damage to ripening rice is an economically important problem for many producers in Louisiana and elsewhere. Currently, management options for dealing with this problem are limited and generally ineffective. One possible option is the application of a chemical feeding deterrent. In October 1998, we tested the commercial bird repellent Flight Control, which has anthraquinone as its active repellent ingredient. Blackbird use of a 4-ha plot of ratoon rice treated with Flight Control at a rate of 18.7 L ha^{-1} declined dramatically and birds stayed off the plot for 7 d postspray. These results corroborate those obtained in a similar trial in 1997 and suggest that Flight Control can be an effective component of blackbird damage reduction strategies in ripening rice.

11. Avery, M. L. and J. L. Cummings. 2003. Chemical Repellents for reducing crop damage by blackbirds. In G. M. Linz, editor. Proceedings of a special symposium of the Wildlife Society 9th Annual Conference, Bismarck, North Dakota, pp 41-48. Avery and Cummings 2003.pdf

Chemical repellents are intended to prevent birds from feeding on a particular food (the crop) at a given location. To be considered effective, a chemical repellent must produce 1 of 2 responses: (1) depredating birds remain but feed on an alternative, noncrop food item; or (2) depredating birds leave and go elsewhere to feed. The search for a safe, cost-effective chemical repellent has spanned decades. During the 1950s, 1960s, and 1990s, repellent screening programs, using captive red-winged blackbirds (*Agelaius phoeniceus*), brown-headed cowbirds (*Molothrus ater*), and European starlings (*Sturnus vulgaris*), identified numerous potentially useful compounds.

Despite promising results from trials with captive birds and verification in subsequent field trials, formal registration of bird repellent chemicals for crop protection has remained elusive. In this paper, we present recent results from cage and field trials of various candidate compounds and discuss the potential utility of chemical repellents within integrated blackbird management strategies.

12. Ayers, C. R. 2009. Effects of mowing on anthraquinone for deterrence of Canada geese and survey of Canada goose fecal contaminants. Master's Thesis North Carolina State University, Raleigh, North Carolina, USA. Ayers 2009.pdf

Resident Canada goose (*Branta canadensis*) populations have increased in urbanizing regions of the eastern United States, where man-made ponds and lakes surrounded by managed turfgrass offer ideal habitats. High concentrations of geese in urbanizing areas may cause feces accumulation, outbreaks of zoonotic diseases, eutrophication of adjacent waterways, and spread of turfgrass weeds. Although repellents effectively deter geese from turfgrass areas, frequent mowing (e.g., 2 – 3 times/week) may impact their long-term efficacy. My objective was to evaluate the effect of 2 different mowing schedules on the longevity of Flight Control® PLUS (FCP), an anthraquinone based avian digestive irritant. From June 2007 to October 2008, I conducted 4, 30-day experiments of repellent efficacy on free-ranging geese at 8 sites.
Flight Control® PLUS effectively repelled Canada geese, but longevity of the chemical may depend on keeping treated blades alive and under mowing height. I recommend identifying areas of high goose concentration and using FCP when geese are most prevalent. Transmission of *G. lamblia* by Canada geese does not appear to be a high risk. If geese test positive for *Giardia* sp., trophozoites should be collected to identify species. Resident Canada goose droppings at our study sites contribute 17 – 31% of recommended TKN and 17 – 38% of recommended P in lawn fertilization rates. Resident Canada goose fecal nitrogen and phosphorus deposition could degrade water quality in areas adjacent to goose concentrations. Although *Kyllinga* spp. and annual bluegrass are turfgrass weeds, the low percentage of germinations indicates little risk of their dispersal by resident Canada geese.

13. Ayers, C. R., C. E. Moorman, C. S. Deperno, F. H. Yelverton, and H. J. Wang. 2010. Effects of mowing on anthraquinone for deterrence of Canada Geese. Journal of Wildlife Management 74: 1863-1868. Ayers et al. 2010.pdf

Anthraquinone (AQ)-based repellents have been shown to reduce Canada goose (*Branta canadensis)* use of turfgrass; however, impacts of frequent mowing on efficacy of AQ have not been studied. Our objective was to determine efficacy and longevity of a rainfast AQ-based avian repellent, FlightControl® PLUS (FCP), as a deterrent of free-ranging resident Canada geese under 2 mowing frequencies. We conducted the study at 8 sites in the Triangle region (Raleigh, Durham, and Chapel Hill) of North Carolina, USA. We arranged our experiment in a randomized complete block design, with each of 8 sites containing 4 0.1-ha treatment combinations: 1) treated with FCP and mowed every 4 days (T4), 2) treated with FCP and mowed every 8 days (T8), 3) untreated and mowed every 4 days, and 4) untreated and mowed every 8 days. We conducted 4 37-day field sessions (Jun–Jul 2007, Sep–Oct 2007, Jun–Jul 2008, and Sep–Oct 2008), representing the summer molting phase and the full-plumage phase. Resident goose use (measured by daily no. of droppings) was 41–70% lower on treated plots than on untreated plots, but use was similar between T4 and T8. Average FCP coverage on grass blades decreased in coverage from approximately 95% to 10% over the 30-day posttreatment phase. Results indicate that resident Canada goose use of FCP-treated turfgrass areas was lower than untreated areas even when chemical coverage on grass was 10%. Further, mowing frequency did not have a clear impact on the efficacy of FCP as a Canada goose repellent.

14. Ba, N. M., F. Sawadogo, C.L. Dabire-Binso, I. Drabo, and A. Sanon. 2009. Insecticidal activity of three plants extracts on the cowpea pod sucking bug, *Clavigralla tomentosicollis*, STAL (Hemiptera: Coreidae). Pakistan Journal of Biological Sciences 12: 1320-1324. Ba et al. 2009.pdf

In Burkina Faso, farmers commonly use insecticidal plants for crop protection. To understand how insecticidal plant works (their mode of action), we carried out a bioassay on *Clavigralla tomentosicollis*, the cowpea pod sucking bugs with three insecticidal plants, *Cassia nigricans* V., *Cymbopogon schoenanthus* S. and *Cleome viscose* L. Three modes of exposures (1) direct contact application, (2) stomach poisoning activity (3) and inhalation toxicity activity, were tested. The results showed a potent contact and stomach toxicity on 1^{st} instars larvae regardless of the three crude extracts. But the plant extracts was less effective with older stages of the insects. A highest effectiveness was recorded with inhalation of vapours of crude extracts regardless of insect stages and type of plants. Implications of these findings are discussed regarding the use of plant extract for controlling pod sucking bugs in cowpea fields.

15. Ballinger, K. E. Jr., M. K. Gilmore, and R. W. Price. 1999. Recent developments in the use of flight control to repel birds from airports. Proceedings of the Bird Strike Committee Ballinger et al. 1999.pdf

Birds found at or near airport flight operations pose a threat to aircraft. There were 2843 reported bird strikes in the United States in 1997 and 837 reported bird strikes in Canada for the year 1998. Potential for loss of life and economic losses due to aircraft damage have driven the need for research into effective techniques in lowering the risk of bird strike in the immediate area of flight operations. Flight Control® is a documented bird repellent. Flight Control® was released commercially in January 1999 in the United States for use on turf, ornamental trees and bushes, building surfaces and roof structures. Full scale testing was performed with the cooperation of Reagan National Reagan Airport in Washington, D.C., from September 1998 through the end of December 1998. Ground maintenance personnel from the airport applied Flight Control® and USDA Wildlife Services employees made bird surveys. A reduction in certain birds was observed where Flight Control® was applied. During the three months of the trial, a total reduction of 82% was recorded for five abundant bird species on the grassy surfaces that were treated. Total bird count at the airport remained unchanged during the period. Shifting of bird populations away from treated areas was observed.

16. Barbee, G. C., M. M. Santer, and W. R. McClain. 2010. Lack of acute toxicity of an anthraquinone bird repellent to non-target crayfish (*Procambarus clakii*) associated with rice-crayfish crop rotations. Crop Protection 29: 506-508. Barbee et al. 2010.pdf

Aeroz™ (9,10-anthraquinone (AQ)), a chemical rice seed treatment that effectively deters birds from depredating newly planted fields, could be an important management tool that enables rice producers to plant earlier in the season and increase yields. This bird repellent, while non-lethal to birds, has unknown toxicity to crayfish that often are closely integrated with rice production in southern regions of the USA. This study was conducted to assess if AQ, the active ingredient in Aeroz™, could be acutely toxic to the red swamp crayfish *Procambarus clarkii* (Girard), the crayfish species most often associated with rice cultivation, via seed ingestion and/or through their contact with chemical in pond water. Mortality data from a 96 h feeding study indicate that AQ-treated (1.76% by wt) rice seed was not acutely toxic to juvenile (3 mo.) crayfish through the ingestion exposure route. In addition, a 96 h aquatic acute toxicity test showed that the LC50 of AQ in juvenile crayfish is >85 μg L−1 and above the water solubility limit of AQ. These results indicate that very minimal, if any, acute toxicity would be observed in juvenile crayfish if exposed to AQ via ingestion or dissolved or suspended in the water column.

17. Blackwell, B. F., T. W. Seamans, and R. A. Dolbeer. 1999. Plant growth regulator (Stronghold) enhances repellency of anthraquinone formulation (Flight Control) to Canada geese. Journal of Wildlife Management 63: 1336-1343. Blackwell et al. 1999.pdf

There is a need for nonlethal methods of reducing conflicts between burgeoning populations of resident giant Canada geese (*Branta canadensis*) and humans at airports and other settings. An anthraquinone based formulation (Flight Control® [FC]; 50% anthraquinone [AQ], active ingredient) has shown promise in deterring grazing by Canada geese. We hypothesized that the addition of a plant growth regulator (Stronghold® [SH]) might enhance the effectiveness of FC by minimizing the exposure of new, untreated grass. To isolate the effects of grass height, plant growth regulator, and the combination of a repellent with a plant growth regulator on grazing by geese, we conducted 3 experiments, each using 24 geese in 6 18.3- × 30.5-m pens in northern Ohio during 1998. We evaluated the response of geese to short (4-11 cm) and tall grass (16-21 cm) in a 9-day test (15-23 Jul). Next, SH (applied at 1.2 L/ha) was evaluated as a grazing repellent in a 14-day test 30 Jul-12 Aug). Finally, we evaluated the effectiveness of FC (2.3 L/ha) combined with SH (0.9 L/ha SH) as a grazing repellent in a 22-day test (11 Sep-2 Oct). We found no difference ($P = 0.529$) in the number of geese per observation in tall- (1.7 ± 1.5; $\bar{x}$ ± SE) versus short-grass plots (11.1 ± 7.9). In the SH test, 14 days postapplication, mean observation on untreated (1.8 ± 1.3) and treated plots (2.2 ± 1.3) did not differ ($P = 0.567$). Also, there was no difference ($P = 0.706$) in the number of bill contacts per minute in untreated (15.3 ± 9.9) versus treated plots (18.1 ± 14.2). In contrast, over a 22-day FC/SH test, the mean number of geese per observation was 2.6 times greater ($P < 0.001$) on untreated (2.9 ± 0.5) versus treated plots (1.1 ± 0.5). Further, the mean number of bill contacts per minute was 8.2 times greater ($P < 0.001$) on untreated (54.4 ± 11.2) than treated plots (6.6 ± 2.3). We observed no abatement in repellency 22 days posttreatment. Thus, we conclude that SH greatly enhanced the repellency of FC to grazing Canada geese, and we contend that the use of a plant growth regulator with FC will prove effective in reducing goose foraging at airports and other sites.

18. Blackwell, B. F., D. A. Helon, and R. A. Dolbeer. 2001. Repelling sandhill cranes from corn: whole-kernel experiments with captive birds. Crop Protection 20: 65-68. Blackwell et al. 2001.pdf

Sandhill cranes (*Grus canadensis*) are opportunistic omnivores that incorporate both waste and unharvested cereal grains (Gramineae) in their diets. Limited hunting of cranes to reduce crop damage has had questionable results, and lethal control of depredating species is increasingly contentious. Our objectives were to evaluate anthraquinone-based Flight Control™ and methyl anthranilate-based ReJeX-iT™ AG-36 as nontoxic avian foraging repellents in separate 2-choice pen tests with captive greater sandhill cranes (*G. c. tabida*) fed with whole-kernel corn (*Zea mays*). In both tests, crane pairs consumed, respectively, 8.6 and 9.8 times more untreated than treated corn. Total corn consumption did not differ among the treatment and control groups during the 8-day experiment. Though both repellents were effective at deterring cranes from treated corn, neither has been tested on corn under field conditions.

19. Bollin, F. S. 1966. Direct seeding of red and white oaks in southeastern Louisiana. Master's Thesis Louisiana State University, Baton Rouge, Louisiana. Bollin 1966.pdf

A split-split-split-split plot, factorial experiment with four replications was used to test the effects of site, species, planting methods, and seed treatment on the seedling establishment of direct seeded oak acorns. Idlewild Experiment Station, near Clinton, Louisiana, was the site of the study. The effect of the seed treatments on germination of the acorns was also tested in an indoor laboratory.
Acorns were planted on April 24-25, 1965, on two sites differing in rodent populations. White oak, cow oak, and cherrybark oak were the species that were tested. The acorns were planted 1 to 2 inches deep by dibble and in a furrow-like hole. Seed treatments consisted of untreated acorns, untreated acorns protected by wire screens, arasan-endrin-coated acorns, anthraquinone-endrin-coated acorns, and endrin-coated acorns.
Weekly observations of the field study were made to assess any rodent, bird, or insect damage and to record germination and survival. Trappings were carried out to determine relative rodent populations on the two areas. Daily germination was recorded in the laboratory germination study and an examination of the ungerminated acorns was conducted after the study was completed.

20. Campbell, T. E. 1976. Bird and mammal problems in southeastern pine forests. Proceedings of the Vertebrate Pest Conference 7: 229-234. Campbell 1976.pdf

Birds and rodents eat pine seeds needed for regeneration, and the larger mammals destroy established seedlings by browsing or trampling. Some of the problems they cause have been solved or solutions are near; some still defy solution.

21. Copping, L. G., and S. O. Duke. 2007. Natural products that have been used commercially as crop protection agents. Pest Management Science 63: 524-554. Copping and Duke 2007.pdf

Many compounds derived from living organisms have found a use in crop protection. These compounds have formed the basis of chemical synthesis programmes to derive new chemical products; they have been used to identify new biochemical modes of action that can be exploited by industry-led discovery programmes; some have been used as starting materials for semi-synthetic derivatives; and many have been used or continue to be used directly as crop protection agents. This review examines only those compounds derived from living organisms that are currently used as pesticides. Plant growth regulators and semiochemicals have been excluded from the review, as have living organisms that exert their effects by the production of biologically active secondary metabolites.

22. Croker, T. C. Jr. 1968. Longleaf pine: an annotated bibliography, 1946 through 1967. Southern Forest Experiment Station, New Orleans, Louisiana. 52 pp. (USDA FS Research Paper SO-35). Croker 1968.pdf

Lists 665 publications appearing since W. G. Wahlenberg compiled the bibliography for his book, *Longleaf Pine*.

23. Cummings, J. L. 1999. Bye bye blackbird? Rice Journal 102: 18-19. Cummings 1999.pdf

24. Cummings, J. L., M. L. Avery, O. Mathre, E. A. Wilson, D. L. York, R. M. Engeman, P. A. Pochop, and J. E. Davis, Jr. 2002a. Field evaluation of Flight Control to reduce blackbird damage to newly planted rice. Wildlife Society Bulletin 30: 816-820. Cummings et al. 2002a.pdf

An effective, economic, and environmentally safe bird repellent is needed to reduce blackbird (Icterinae) depredations to newly planted rice. We evaluated Flight Control™, a 50% anthraquinone product, as a seed treatment for newly planted rice. We treated rice seed with Flight Control at a 2% (g/g) concentration (1% active anthraquinone) the day of planting. This concentration reduced the number of blackbirds (P=0.0003) using treated fields and blackbird damage to rice seed (P=0.0124). The chemical concentration of anthraquinone on rice seed averaged 0.79% (SE-0.06%) at planting; 0.39% (SE= 0.04%) at day 1, 0.34% (SE=0.05%) at day 3, and 0.41% (SE=0.06%) at day 5 post-planting. Rice seedling counts were similar between treated and untreated exclosures, suggesting that Flight Control had no phytotoxic effects to rice seed. Our results showed Flight Control to be an effective blackbird repellent that warrants further development as a management tool to reduce blackbird damage to newly planted rice and other agricultural commodities.

25. Cummings, J. L., P. A. Pochop, R. M. Engeman, J. E. Davis, Jr., and T. M. Primus. 2002b. Evaluation of Flight Control to reduce blackbird damage to newly planted rice in Louisiana. International Biodeterioration and Biodegradation 49: 169-173. Cummings et al. 2002b.pdf

Blackbirds cause extensive damage to newly planted and ripening rice. To date there is not a registered bird repellent for reducing this damage. We evaluated Flight Control®, a 50% anthraquinone product, as a potential repellent to blackbirds in cage and field tests in Louisiana. In one- and no-choice cage tests, brown-headed cowbird and red-winged blackbird consumption of 2% Flight Control® treated to newly planted rice seed. Chemical residues at 7 days post-planting averaged 0.66% anthraquinone. Further field testing is warranted.

26. Cummings, J. L., D. L. York, T. M. Primus, R. M. Engeman, and R. E. Mauldin. 2006. Effectiveness of Flight Control to reduce damage to lettuce seedlings from horned larks. Proceedings of the Vertebrate Pest Conference 22: 225-227. Cummings et al. 2006.pdf

Lettuce is an important economic crop in California, with approximately 101,000 ha in production and a value of $1.3 billion in 2002. Bird damage to lettuce in the San Joaquin Valley, the central coast, and southern California is believed to amount to millions of dollars annually. We evaluated the effectiveness of Flight Control™ (50% anthraquinone applied at 10 L/ha) as a foliar spray for protecting emerging lettuce seedlings from depredation by horned larks. In field enclosure trials conducted near Huron, in the San Joaquin Valley of California, damage to treated lettuce seedlings was 8.5%, compared to 68% damage to untreated seedlings. In a field test, anthraquinone residues on the day of treatment averaged 570 ppm and at Day 50 after treatment were lower than the method of detection (0.063 ppm). However, homed lark numbers using test sites were too low to detect any differences in damage among treated and untreated sites. Anthraquinone offers promise for reducing bird depredations to sprouting lettuce, but additional testing should be conducted to evaluate this repellent in a large-scale field setting.

27. Cummings, J. L., R. W. Byrd, W. R. Eddleman, R. M . Engeman, and S. K. Tupper. 2011. Effectiveness of AV-1011 to reduce damage to drill-planted rice from blackbirds. Journal of Wildlife Management 75:353-356. Cummings et al. 2011.pdf

We determined efficacy of AV-1011® (a 50% anthraquinone product; Arkion® Life Sciences, New Castle, Delaware) on drill-planted rice seed to reduce blackbird damage and determine residue levels of anthraquinone in rice seeds and seedlings and in the mature rice crop under field enclosures at the University of Missouri-Delta Center farm near Portageville, Missouri. Red-winged blackbirds (*Agelaius phoeniceus*) damage was higher for untreated than AV-1011® treated rice seedlings at assessment period 3, 15 days postplanting ($F_{1,141} = 15.81$, $P < 0.001$), and at assessment period 4, 19 days postplanting ($F_{1,136} = 11.54$, $P = 0.001$). Blackbird damage to AV-1011-treated seedling for assessment periods 3 and 4 was 8% and 7%, respectively, while blackbird damage to untreated seedlings during the same assessment periods was 52% and 44%. More blackbird used untreated plots than AV-1011- treated plots during assessment periods 2, 3, and 4 ($F_{1,17.8} = 20.02$, $P < 0.001$). Overall concentrations of anthraquinone on seeds averaged 5,993 ug/g or 0.59% during the test period. Concentrations of anthraquinone in mature rice seed and plant collected at harvest averaged 1.22 ug/g and 0.10 ug/g, respectively. AV-1011 offers promise for reducing bird depredations to newly planted rice, but additional testing should be conducted to evaluate this repellent in a large-scale field setting.

28. Dambach, C. A., and D. L. Leedy. 1948. Ohio studies with repellent materials with notes on damage to corn by pheasants and other wildlife. Journal of Wildlife Management 12:392-398. Dambach and Leedy 1948.pdf

Wild animals, particularly crows and the introduced ring-necked pheasant have long been blamed for digging out or pulling planted corn soon after it germinates. State conservation departments in the pheasant belt have, at least in some recent years, been the target of criticism by farmers for dam-age allegedly done by pheasants. On the other hand, many sportsmen and some personnel of conservation organizations have disputed this claim. Some states have conducted investigations to determine the validity and extent of pheasant damage claims and to seek corrective measures if needed. Judging from recent correspondence, a number of additional states have similar investigations under way or are planning to conduct them. The following report on Ohio studies of this problem may be of some help to these investigators.

29. Damron, B. L., and J. P. Jacob. 2001. Toxicity to poultry of common weed seeds. University of Florida Extension Fact Sheet PS-55. Damron and Jacob 2001.pdf

All plants are in some way useful and beneficial, so what makes a plant a "weed?" Modern agriculture involves the large-scale production of a single type of plant. Under these conditions any other type of plant is called a "weed" and is defined as "a plant out of place." Seeds from these "out of place" plants often get harvested along with grain crops, and can find their way into poultry feeds. Unfortunately, some of these weed seeds are toxic to poultry.
Questions about weed seeds arise sporadically as contaminated grain samples are discovered. This review will not cover every weed seed found to cause adverse symptoms in poultry but rather will focus on the seeds most prevalent in grains grown or used in the Southeastern United States.

30. Day, T., and L. R. Matthews. US Patent Application Publication No. US 2005/0186237 A1. Day and Matthews 2005.pdf

A bird repellent composition containing a combination of anthraquinone and a visual cue; or anthraquinone and d-pulegone; or anthraquinone, a visual cue and d-pulegone is disclosed. The combinations have been found to produce a synergistic and unexpected effect of increased repellence to birds. One application is the area of pest control baits where the repellent composition is applied to the surface of the bait. Birds are less likely to be harmed by the toxins contained within the bait because they are repelled from the bait. A second application is for horticulture use, whereby the repellent composition is applied to the plant, fruit or ground around an orchard or vineyard thus repelling the birds.

31. Day, T. D., L. R. Matthews, and J. R. Waas. 2003. Repellents to deter New Zealand's North Island robin *Petroica australis longipes* from pest control baits. Biological Conservation 114: 309-316. Day et al. 2003.pdf

North Island robins, *Petroica australis longipes*, are among the non-target animals at risk during poisoning operations aimed at introduced mammalian pests in New Zealand. Adding an avian repellent to the bait may reduce the risk to native birds. In this study we report on two experiments that aimed to: (1) refine a methodology for testing repellents; and (2) determine the effects of a repellent combination on bird feeding behaviour. In Experiment 1, a highly preferred base material (in which repellents could be incorporated) was identified from the choices made when robins were presented simultaneously with cereal, carrot and dough materials over 4 consecutive days on a test arena on the forest floor. Robins pecked at and ate all materials, but consistently directed more pecks at dough ($P<0.001$), so this material was selected for use in the subsequent study. In Experiment 2, robins were offered repellent treated (green and surface coated with a combination of d-pulegone and Avex™) and standard (green and coated with cinnamon oil; the bait formulation currently used for pest control operations in New Zealand) dough in choice tests over 4 days. The dough had either been sprayed with or dipped into the repellent combination. Robins pecked at standard dough more frequently than at repellent dough

(P<0.05), with the frequency of pecking at repellent dough declining (P<0.05) over the four days. Male robins offered dipped dough pecked at the repellent dough more frequently than females. On occasions the base material was removed from the arena: standard dough removed was consumed readily but repellent-treated dough was not. The results demonstrated that the combination of d-pulegone and Avex effectively deterred robins from feeding. Green dye and cinnamon oil did not prevent feeding on cereal, carrot or dough by robins, and thus cannot be considered as effective repellents. Since d-pulegone and Avex were effective in preventing feeding on a highly preferred base material they are likely to reduce the propensity for robins to feed on toxic possum baits.

32. Defauce, C., and L. Enriquez. 1968. Trials with repellents. Bol-Serv-Plagas-For, -Madrid 11: 135-136. De Fauce.docx

Seed treatment and foliar treatment of AQ on seeds (Forestry and nursery application). Paper translated from Spanish using Google Translate.

33. Devers, P., P. Reichert, and R. Poche. Field trial using Flight Control as a repellent for Canada goose (*Branta canadensis)* control in Fort Collins, Colorado. Proceedings of the Vertebrate Pest Conference 18: 345-349. Devers et al. 1998

Flight control, containing anthraquinone, was field tested during 1997 in Colorado as a repellent to keep Canada geese off turf. The product was sprayed at a rate of 1.9 kg per ha, using a boom sprayer towed by a golf cart. The reduction in goose numbers on the treatment plot was 95.1 percent ten days after application.

34. Dolbeer, R. A., T. W. Seamans, B. F. Blackwell, and J. L. Belant. 1998. Anthraquinone formulation (Flight Control) shows promise as avian feeding repellent. Journal of Wildlife Management 62: 1558-1564. Dolbeer et al. 1998.pdf

We evaluated the effectiveness of Flight Control™ (FC), which contains 50% anthraquinone (AQ), as a grazing repellent for Canada geese (*Branta canadensis*) and as a seed-treatment repellent for brown-headed cowbirds (*Molothrus ater*) in northern Ohio in 1997. For the turf test, FC was applied at 4.5 L/ha in 6 18.3- x 30.5-m pens. There were 2.5 times more ($P < 0.01$) bill contacts/min observed on untreated plots (26.4 ± 6.0; ± SE) compared to treated plots (10.4 ± 3.8) during a 7-day test with captive geese. Mean numbers of geese per observation were also greater ($P = 0.02$) on untreated plots (2.6 ± 0.4) compared to treated plots (1.4 ± 0.4). Residue analyses indicated AQ declined from 2.02 kg/ha at application to 0.22 kg/ha after 1 week. Individually caged cowbirds were presented untreated millet or millet treated with FC at 0.1, 0.5 and 1.0% (g/g) levels in 1- and 2-choice tests for 3-4 days. Flight Control™ was repellent to cowbirds at all levels in both 1- and 2-choice tests. In the 2-choice test, birds in the 1.0% treatment level lost body mass ($P = 0.04$), whereas birds at the other levels did not. Each group of treated birds in the 1-choice test lost mass ($P \leq 0.01$), whereas the control group did not. Birds in the 0.5 and 1.0% groups ate minimal amounts; 3 of 12 birds died. We conclude that FC was an effective foraging repellent for Canada geese in a 7-day pen experiment and for brown-headed cowbirds as a seed repellent in aviary experiments. Flight Control™ shows promise as an avian feeding repellent. Further lab and field studies are needed to refine minimum repellent levels and to enhance retention of AQ on treated vegetation.

35. Dowden, B. F., and H. J. Bennett. 1965. Toxicity of selected chemicals to certain animals. Water Pollution Control Federation 37: 1308-1316. Dowden and Bennet 1965.pdf

36. Duncan, C. J., 1963. The response of the feral pigeon when offered the active ingredients of commercial repellents in solution. Annals of Applied Biology 51: 127-134. Duncan 1963.pdf

This paper describes the response of the feral pigeon to solutions of the active ingredients of commercial repellents. Among the repellents tested, marked rejection of solutions of β-naphthol was found.
It is suggested that some commercial repellents may operate by an irritant action rather than by true gustatory repellency.
When offered many of the solutions, the pigeons demonstrated a surprisingly high degree of discriminatory ability.

37. Dunning, R. A. 1974. Bird damage to sugar beet. Annals of Applied Biology 76: 325-366. Dunning 1974.pdf

Pest damage to sugar beet, including that by birds, has been recorded since 1957. During that time damage by rooks has decreased almost to nil, but some other bird damage has greatly increased, most probably as a result of changing agronomic practices, especially the extensive use of herbicides, the introduction of monogerm seed, and the increasing practice of 'planting-to-a-stand'. The most severe bird damage in the spring is grazing by several species, and in early summer localized felling of plants by pheasants. Observations in the mid-1960's of causes of seedling and plant losses suggested that birds were then of minor importance; the British Sugar Corporation currently consider that birds are the most serious pest of sugar beet. The distribution of the reported damage does not seem to follow any national pattern. In small-plot field trials possible repellent materials such as anthraquinone, methiocarb or thiram, applied to seed or foliage, did not decrease the extent of grazing.

38. Espelta, J. M., J. Retana, and A. Habrouk. 2003. An economic and ecological multi-criteria evaluation of resforestation methods to recover burned *Pinus nigra* forests in NE Spain. Forest Ecology and Management 180: 185-198. Espelta 2003.pdf

Recurrence of recent large wildfires is threatening the permanence of *Pinus nigra* Arnold (Black pine) forests in central Catalonia (NE Spain), due to the almost nil post-fire regeneration of this non-serotinous pine. Potential practices to carry out extensive reforestation programs with P. nigra may differ widely in terms of their final success, economic cost and undesired ecological impact. In this framework, we have analysed different types of vegetation clearing (mechanical, controlled burning or grazing), soil preparation (ripping or planting holes) and reforestation methods (broadcast seeding, spot seeding and planting) to restore *P. nigra* forests. We have compared these practices in terms of seedling establishment, but also in the light of their economic costs and ecological impact, through a new multi-criteria analysis. Seedling establishment after sowing was very poor and not influenced by vegetation clearing. In plantations, seedling survival was higher in the ripper treatment than in planting holes for all vegetation clearing treatments except the control one. Nevertheless, the higher economic cost of the planting holes treatment and the negative impact of mechanical clearing and burning on the small mammals community made the stated differences in seedling survival irrelevant. Thus, the multi-criteria analysis revealed that the two most preferred options were planting in uncleared or lightly grazed areas with soil preparation through ripping. This study gives some valuable insights about the use of new decision-support tools in restoration programs and provides practical guidelines concerning the restoration of extensive burned *P. nigra* forests.

39. Evans, J. 1987. Animal damage and its control in ponderosa pine forests. *In* Ponderosa Pine: the species and its management (D. M. Baumgartner and J. E. Lotan Eds). 5pp. Evans 1987.pdf

In this paper, animal damage problems to ponderosa pine regeneration are described. Particular attention is given to a review of the present knowledge of wildlife species causing damage and to current methods and materials available to control the damage. An extensive bibliography of publications on forest animal damage control is presented for those with further interest in the subject. The paper also point out a need for research on wildlife—reforestation interactions in ponderosa pine and other timber types in western United States.

40. Frank, V. H., and M. von U. Dischner. 1970. The testing of repellents intended to prevent consumption of seed grain by pheasants. Research Centre for Wildlife Management and Game Loss Prevention. Frank and Dischner 1970.pdf

In the years 1968 and 1969 ten different repellents were tested on penned pheasants. Five of these repellents are registered with the Biologischen Bundesanstalt fur Land- und Forstwirtschaft, and are intended to reduce birds', especially crows', eating of seed grain. Four of these repellents contain the compound anthrachinon, one contains ziram, as the effective repellent. Three further repellents, which are not registered, have almost the same composition. They contain up to 18 % tar oil, 15% naphthalene, and 75% or more bitumen and mineral oil. Two repellents were not on the market at the time of investigation. A repelling effectivity of almost 100 ~ was observed for the products with bases of tar oil, naphthalene, and bitumen; the same was true for one registered product with a ziram base, and one product not yet obtainable on the market. The remaining repellents were either unsatisfactory or insufficiently effective against pheasants. Germination tests on wheat exhibited slightly delayed germination when treated with unregistered products as compared with untreated wheat or wheat treated with registered repellents.

41. Georges, K. B. Jayaprakasam, S. S. Dalavoy, M .G. Nair. 2008. Pest-managing activities of plant extracts and anthraquinones from *Cassia nigricans* from Burkina Faso. Bioresource Technology 99: 2037-2045. Georges et al 2008.pdf

Insecticidal activity of eight plants collected from Burkina Faso was studied using mosquito (*Ochlerotatus triseriatus*), *Helicoverpa zea* and *Heliothis virescens* larvae and adult white fly (*Bemisia tabaci*). The n-hexane, ethyl acetate and methanol extracts of *Pseudocedrela kotschyi*, *Strophantus hispidus*, *Securidaca longepedunculata*, *Sapium grahamii*, *Swartzia adagascariensis*, *Cassia nigricans*, *Jatropha curcas* and *Datura innoxia* were used in this study. Extracts were tested at 250 lg/mL concentration. All three extracts of *C. nigricans*, *J. curcas* (skin and seeds) and *D. innoxia* exhibited 100% mortality on fourth instar mosquito (*O. triseriatus*) larvae. In addition, the n-hexane and ethyl acetate extracts of *S. hispidus, S. longepedunculata, S. grahamii* showed 100% mortality. The ethyl acetate extract of *S. madagascariensis* was the most active on adult white fly and exhibited 80% mortality. Extracts of all other plants exhibited 30–50% mortality on *B. tabaci*. In the antifeedant assays against *H. ze*a and *H. virescens*, the MeOH extracts of *C. nigricans, S. madagascarensis and S. hispidus* were more effective against H. zea as indicated by 74% larval weight reduction as compared to the control. Since *C. nigricans* is commonly used in West Africa to protect grain storage from insects, we have characterized the insecticidal components present in its extract. Bioassay directed isolation of *C. nigricans* leaf extract yielded anthraquinones emodin, citreorosein, and emodic acid and a flavonoid, luteolin. Emodin, the most abundant and active anthraquinone in *C. nigricans* showed approximately 85% mortality on mosquito larvae Anopheles gambiaea and adult *B. tabaci* at 50 and 25 lg/mL, respectively, in 24 h. These results suggest that the extract of *C. nigricans* has the potential to be used as an organic approach to manage some of the agricultural pests.

42. Gordon, S. E., and N. Lyman. 2000. Flight Control™ as a grazing repellent for Canada geese at Portland International Airport. International Bird Strike Committee 25: 265-281. Gordon and Lyman 2000.pdf

The anthraquinone formula marketed as Flight Control™ (FC) is advertised as a goose repellant with both an ultraviolet and post-ingestional repellency when applied to turf. Two studies have been conducted with FC, one at the National Wildlife Research Center in the U.S., and one at the Mumbay, India airport, but neither included the information necessary to determine if it is practical to use at Portland International Airport (PDX).

The Port of Portland wanted to determine: 1) If FC is effective in deterring geese from grass. 2) Whether geese will avoid the entire project area or just the treated plots. 3) How long FC will last in our rainy climate. 4) If geese will avoid the test plots after the product has reduced in concentration. 5) Whether the product effects non-target species. 6) Whether FC will have any negative effect on treated grass. 7) If FC is a cost-effective way to reduce birdstrikes at PDX.

A field with heavy goose activity was divided into five transects, which were monitored morning and afternoon for 13 weeks. Two test plots, which had goose activity 65 percent of monitoring events, were selected for application. The product was then sprayed using a mixture of one-half gallon FC, five gallons of water, and eight ounces of an agricultural sticker. This was applied at a rate of one-half gallon per acre.

Monitoring continued twice a day with the following results. Geese were not observed in the treated areas for the first 10 days. After 10 days, geese were present in the treated plots five of the next 11 days, or 21 percent of monitoring events. Total post-treatment monitoring showed that goose activity in treated areas rose gradually each week, but continued to be lower than in control areas.

Our test results showed that Flight Control could be used as a goose deterrent on turf with marked avoidance of treated areas. For airports with heavy rainfall, the effectiveness of the product may diminish after 10 days. We also found that geese did not avoid the entire project site, only the treated plots. In addition, goose activity in treated areas, after the product had decreased in concentration, was only slightly lower than in untreated areas. There were no observed effects to non-target birds, and no adverse effects on treated grass.

In conclusion, Flight Control can be used to deter geese from specific areas for as long as the concentration of the material lasts. It did not, however, cause geese to learn to avoid the treated areas in our test. Research into making the chemical longer lasting would increase its cost-effectiveness.

43. Gupta, B.K., and P. K. Sen-Sarma. 1978. Antitermite properties of some anthraquinone derivatives. Holzforschung und Holzverwertung, 30(3): 57-58. Gupta and Sen-Sarma 1978.pdf

Heartwood of teak is known for its durability against various biodegrading agencies including termites. This property is attributed to the presence of various anthraquinone derivatives. Da Costa, Rudman and Gay have reported that 2-methylanthraquinone deters termite attack although this chemical has no antifungal property. In this communication results of investigation on the antitermite properties of six anthraquinone derviatives have been given.

44. Gwaze, D., D. Henken, and M. Johanson. 2005. Direct seeding of shortleaf pine (*Pinus echinata* Mill.): A review. Forest Research Report No. 5. Missouri Department of Conservation. Gwaze et al. 2005.pdf

Restoration of shortleaf pine (*Pinus echinata* Mill.) is a high priority for Missouri's resource managers. Shortleaf pine once occupied 6.6 million acres and now is found on only 397,100 acres. Extensive logging from 1880 to 1920, frequent wildfires and overgrazing are collectively suggested as the primary causes of shortleaf population decline. Restoration efforts have been motivated by the fact that shortleaf pine is a major component of Missouri's biodiversity and natural heritage, and it provides habitat and food for a diverse array of wildlife. This review examines the use of direct seeding for shortleaf pine restoration. It suggests that direct seeding is a potentially viable method for restoring shortleaf pine in Missouri. The keys to successful restoration of shortleaf pine using direct seeding involve good site preparation, sowing on competition-free sites, using quality seed, proper timing of sowing, protection of seed from birds and rodents, adequate moisture during germination and establishment and sufficient light on the site.

45. Habrouk, A. 2002. Natural regeneration and restoration of the area affected by the great fire of 1994, Bages and Bergueda. Doctoral Thesis. Autonomous University of Barcelona, Barcelona, Spain. Habrouk 2002.pdf

46. Heckmanns, F., and M. Meisenheimer. 1944. Protection of seeds against birds. U.S. Patent Number 2,389,335. Heckmans and Meisenheimer 1944.pdf

This invention relates to the protection of seeds to prevent them from being devoured by birds, to the treatment of seeds whereby they are made unattractive to birds and to compositions suitable for this purpose.

47. Hilker, M., and A. Kopf. 1994. Evaluation of the palatability of chrysomelid larvae containing anthraquinones to birds. Oecologia 100:421-429. Hilker and Kopf 1994.pdf

Chrysomelid larvae of the subfamily Galerucinae, tribe Galerucini, are known to contain 1,8-dihydrox-ylated 9,10-anthraquinones. Since nonhydroxylated 9,10- anthraquinone is the active agent in several commercial products sold to protect seeds against birds, we suggested that the naturally occurring dihydroxylated anthraquinones of galerucine larvae may also act as protective devices against bird predation. Tits (Parus spp.) are potential predators of larvae of the tansy leaf beetle, *Galeruca tanaceti*, and the elm leaf beetle, *Xanthogaleruca luteola*. To investigate the palatability of these chrysomelid larvae to birds, we offered them with mealworms and Calliphora pupae, respectively, as controls in dual choice bioassays to eight singly kept, naive tits (five P. major and three P. ater individuals). The bioassays were limited to 5 days, during which larvae were offered daily for 2 h (*X. luteola*) and 3 h (*G. tanaceti*), respectively. Every day, the birds significantly avoided uptake of G. tanaceti and X. luteola. More than 98% of the control food was consumed daily, whereas the percentage of chrysomelid larvae totally eaten never surpassed 6.6% for *G. tanaceti* and 51.8% for *X. luteola*. In order to determine whether this avoidance was due to the anthraquinones of the chrysomelid larvae, mealworms and Calliphora pupae, respectively, were treated with these compounds in con-centrations equivalent to the natural ones. Dual choice bioassays with treated and untreated prey were conduct-ed, again for 5 days with a daily 2- or 3-h test period, respectively. The tits ate all or nearly all treated and un-treated food items every day. However, during the 5-day test period the tits learnt to take up the control insects significantly earlier than the treated ones; the food containing anthraquinones was not consumed as readily as the control, which suggests aversive learning based on distastefulness. The efficiency of anthraquinones in protecting galerucine larvae against bird predation is discussed with special respect to learning behavior and factors which might delay or mask learning of avoidance.

48. Hodne-Fischer, E. A. 2009. Anthraquinone corn seed treatment (Avitec) as a feeding repellent for ring-necked pheasants (*Phasianus colchicus*) on newly planted corn in Eastern South Dakota. Masters Thesis South Dakota State University. Hodne-Fischer 2009.pdf

49. Hunter, G. W. III, R. E. Freytag, and L. S. Ritchie. 1952. Potential molluscacides screened in the laboratory and the results of preliminary field plot tests. Journal of Parasitology 38: 509-516. Hunter et al. 1952.pdf

Since 1947 this laboratory has tested various chemicals in an attempt to find a satisfactory molluscacide for Oncomelania nosophora, the snail intermediate host of Schistosoma japonicum in Japan. At present sodium pentachlorophenate (Santo-brite)* and dinitro-o-cyclo-hexylphenol or its dicyclo-hexylamine salt (K-604) have been found to be the most effective molluscacides for this snail (1, 2, 3, 4). Through the cooperation of the Laboratory of Tropical Diseases** of the Na-tional Institutes of Health, Bethesda, Maryland, and the several chemical companies which supplied them, 137 organic compounds were made available for this study. Most of these chemicals had been previously tested on the aquatic snail Australorbis glabratus by the National Institutes of Health and several have proved effective in controlling this snail (5). Hence, it was of practical interest to know the effect of these chemicals on the amphibious snail Oncomelania nosophora (6).

50. Kandel, H., J. Burton, C. Deplazes, G. Linz, and M. Santer. 2009. Sunflower treated with Avipel (Anthraquinone) bird repellent. 31st National Sunflower Association Research Forum, Fargo, North Dakota, USA. Kandel et al. 2009.pdf

51. Kear, J. 1965. The reaction of captive mallard to grain treated with a commercial bird repellent. Wildfowl Trust 16:47-48. Kear 1965.pdf

Wildfowl predation presents a very minor problem to agriculture as a whole in Britain, and only at certain times and in certain places does it become necessary to limit their activities (Kear, 1963). It is recognized that the application of a substance to a crop which will render it unattractive but not kill would be very advantageous, but the study of chemical protection against birds is still in its early stages. A variety of substances relying on the sense of taste, smell, touch or pain has been tried unsuccessfully with ducks in America (Neff and Meanley, 1956); whole barely soaked in gum turpentine and in kerosene was completely eaten and the commercial American repellent Pestex, dusted on to the grain, did not even slow down the birds' feeding rate. However, Neff and Meanley (1957) and Neff, Meanley and Brunton (1957) claimed consistent success against grackles, cowbirds, redwings and other birds when anthraquinone was used at heavy levels. Later, Duncan (1963) reported the reactions of feral pigeons to seven active ingredients of commercial repellents in solution. All solutions, with the exception of anthraquinone, produced a significant reduction of fluid intake and β-naphthol was markedly rejected. Duncan pointed out that, although insoluble anthraquinone showed no repellent action when tested in this way, this does not mean that it is valueless when used as a powder. Anthraquinone (a harmless, yellow crystalline ketone, $C_6H_4(CO)_2C_6H_4$) is in fact a basic ingredient of a German-made bird repellent marketed in Britain as Morkit. At the Wildfowl Trust, a few preliminary tests have been made in which four caged hand-reared Mallard were offered grain treated with Morkit.

52. Kennedy, T. F., and J. Connery. 2008 An investigation of seed treatments for the control of crow damage to newly-sown wheat. Irish Journal of Agricultural and Food Research 47: 79-91. Kennedy and Connery 2008.pdf

Seed treatments for the control of crow damage to seed and seedling in winter and spring wheat were evaluated in field trials from 2004 to 2007. Treatments included six fungicides, three insecticides, a product marketed as a bird repellent and three potential repellents. Various rates of selected compounds were investigated. Winter wheat was sown in December and spring wheat in late-January to mid-February. Sowing depth was 2 to 4 cm while some selected treatments were also sown at a depth of 5 to 8 cm. Crow damage was assessed by plant density and grain yield.

Severe damage by crows was recorded. The plant population from untreated spring wheat seed in 2004, 2005 and 2006 was reduced by 59%, 69% and 89%, respectively. The corresponding reductions caused by crows to winter wheat sown in 2004, 2005 and 2006 were 96%, 88% and 96%. Best control of crow damage was provided by the fungicide Thiram. Increasing the rate of Thiram applied to seed reduced crow damage and increased plant density in the range 42 to 70% and 36 to 57%, respectively, for spring and winter wheat when compared with untreated seed. Anchor, which contains the fungicides Thiram and Carboxin, also gave reasonably good control. The commonly used fungicide product Panoctine gave poor control of crow damage. Other treatments investigated were ineffective in controlling damage. Increasing the sowing depth to more than 4.6 cm significantly reduced damage to both treated and untreated seed when compared with similar treatments sown less deep.

53. Knauer, R. F. Jr., K. E. Ballinger Jr., and M. K. Gilmore. 2000. Practical application techniques for Flight Control, a new bird repellent for the aviation industry. International Bird Strike Committee Amsterdam 2000. Knauer et al. 2000.pdf

54. Knittle, C. E., and R. D. Porter. 1988. Waterfowl damage and control methods in ripening grain: An overview. US Dep. of the Interior, Fish and Wildlife Ser. Tech. Rep. 14. Washington DC, 17 pp. AX Knittle and Porter 1988.pdf

Damage to swathed grains by ducks, geese, and cranes is a long-standing problem in many parts of central North America. We describe the history of the problem, its nature and extent, its causes, and control tactics used; we also make recommendations for research and management.

55. Kung, L. Jr., K. A. Smith, A.M. Smagala, K. M. Endres, C. A. Bessett, N. K. Ranjit, and J. Yaissle. 2003. Effects of 9,10 anthraquinone on ruminal fermentation, total-tract digestion, and blood metabolite concentrations in sheep. Journal of Animal Science 81: 323-328. Kung et al. 2003.pdf

The objective of this study was to evaluate the effects of adding 9,10 anthraquinone, a known inhibitor of methanogenesis and sulfate reduction, on blood metabolites, digestibility, and distribution of gas in sheep. In all experiments, we fed a complete pelleted diet that contained 17.5% crude protein and 24.5% acid detergent fiber. In an 8-wk study, feeding up to 66 ppm (dry matter basis) of 9,10 anthraquinone had no adverse effects on blood metabolites including indicators of normal enzyme function, mineral concentrations, and hematological measurements. Feeding 9,10 anthraquinone had no effect on average daily gain, although sheep fed a diet containing 66 ppm of 9,10 anthraquinone numerically gained the least weight. The ruminal molar proportions of acetic acid were decreased ($P < 0.05$) and the molar proportions of propionic acid were increased ($P < 0.05$) in sheep fed 1.5 and 66 ppm 9,10 anthraquinone when compared to those fed an unsupplemented diet. In a digestion trial, 9,10 anthraquinone (33 and 66 ppm) had no effect on the apparent digestion of nutrients in the total gastrointestinal tract. In a metabolism study, ruminal gasses were collected by rumenocentesis and analyzed for methane and hydrogen concentrations. Feeding 500 ppm of 9,10 anthraquinone to sheep resulted in a decrease ($P < 0.07$) in the concentration of methane, but an increase ($P < 0.05$) in hydrogen concentration of ruminal gas throughout the 19 d of feeding. There was no indication of ruminal adaptation throughout this time. These results are the first to show that 9,10 anthraquinone can partially inhibit in vivo rumen methanogenesis, which supports previous in vitro findings. In addition, at the concentrations used in this study, 9,10 anthraquinone was not toxic to ruminants.

56. Mann, W.F. Jr., and H. J. Derr. 1955. Not for the birds: Morkit, a chemical bird repellent, solves the most difficult problem in direct-seeding longleaf pine. USFS Publication. Mann and Derr 1955.pdf

Morkit, a dull gray powder that is repellent to birds, may remove the greatest obstacle to successful direct seeding of longleaf pine.

In the past, many Louisiana landowners have tried to restock their longleaf lands by sowing pine seed directly in the field--in contrast to the usual procedure of planting 1-year-old stock grown in a nursery. Most of these direct-seeding attempts failed, largely because there was no practical way of preventing birds from eating the seed.

Resident and migratory birds concentrate in November, when conditions are best for sowing, and usually cause heavy losses or even complete failure in a few weeks. Patrolling the seeded area during the germinating period reduces bird depredations, but it is expensive and never fully effective. A satisfactory bird repellent that can be applied to the seed would make seeding more reliable and reduce the quantity of seed required to establish a stand.

57. Mann, W. F. Jr. and H. J. Derr. 1955. Not for the birds. Forests and People 5: 32-33.

Report on promising bird repellent, Morkit, which consists of anthraquinone and inert ingredients. It is manufactured in Germany specifically as a bird repellent. It has no distinctive taste or odor and its mode of action is unknown. It is not known to be harmful to livestock, wildlife, or people. It did not kill birds in the tests. But it did protect longleaf pine seed from birds in field tests, thereby making direct seeding of this species practical for the first time. Rodents and rabbits were not repelled by it. Longleaf pine seed can be coated with Morkit for 15 cents a pound. This cost includes all labor and materials, including the asphalt sticker. The paper provides details of tests, costs, and method of application.

58. Mann, W. F. Jr., H. J. Derr, and B. Meanley. 1955. A bird repellent for longleaf seedling. USFS Southern Forestry Extension Station, Southern Forestry Notes No. 99 p. 1-2.
Morkit, which contains anthraquinone, is best bird repellent known for treating seed of longleaf pine. Total cost of chemical, sticker, and labor has so far averaged about 15¢ per lb. of seed. The treatment was successful in both 1953 and 1954. 3,050 to 4,500 seedlings per acre were obtained under adverse conditions after sowing about 12,500 seeds (3 lbs.) per acre. Untreated seed gave very poor results.

59. Mann, W. F. Jr., H. J. Derr, and B. Meanley. 1956. Bird repellents for direct seeding longleaf pine. Forests and People 6: 16-17, 48.

Morkit has been withdrawn from the Am. market and a substitute, also based on crude anthraquinone, put out by the holder of Am. patent rights, has not been tested. Sublimed synthetic anthraquinone and crude anthraquinone both did well in tests reported here. Neither

will be available unless licensing agreements are consumated. None of these compounds repels rodents. Arasan Seed Disinfectant and Protectant (50% tetramethyl thiuram disulphide) used at 15% level effectively protects seeds from both birds and rodents and is recommended. It is irritating to eyes, nose, and throat. It is harmful to stratified seed of loblolly and slash pine. Whether it affects unstratified seed is unknown. The producer is replacing this compound with a similar one that has not yet been tested by the authors, but good supplies of the 50% Arasan remain in stock. "Arasan Seed Disinfectant and Protectant...should not be confused with other 'Arasan' products, of which there are several. Some of these are known to reduce germination of some species of pine seed, and others are as yet untested.

60. Mann, W. F. Jr., and C. E. Kingsley. 1958. Bird control in forest nurseries. USFS Note 113.

Sublimed anthraquinone seems to be best repellent for protecting seeds from birds. It has little or no effect on germination. Arasan and Arasan 75 are also good repellents but reduce germination by 5-10%. Best sticker is Dcw Latex 512-R; second best is asphalt emulsion. The smooth latex surface allows seeds to feed through drill uniformly. Anthraquinone should be applied at rate of 15 lbs. per 100 lbs. of seed. Sticker is made by diluting 1 part latex to 9 parts water.

61. Meanley, B., W. F. Mann Jr., H. J. Derr. 1956. New bird repellents for longleaf seed. USFS notes no. 105.

Morkit, a good bird repellent, has been withdrawn from the U. S. market. Fortunately, recent tests show that Arasan Seed Disinfectant and Protectant is as good or better. This compound (50% tetramethyl thiuram disulphide) gave somewhat better results in field tests than either Morkit or crude anthraquinone. The latter cannot be sold as a bird repellent until licensing negotiations are completed. Observations in all tests indicated that Arasan has rodent-repellent as well as bird-repellent qualities. Although 50% Arasan is an effective repellent, it is slightly irritating to eyes, nose, and throat. Treated seed should be sown as soon as possible, as viability may be impaired by storage. Recommended rate of application is 1 lb. of 50% Arasan to 6 lbs. of seed.

62. Mony, C. C. 1958. Seed pelleting process for bird and disease control. Tree Planters' Notes 32: 2 pp. Mony 1958.pdf

63. Neff, J. A. and B. Meanley. 1956. A review of studies on bird repellents. Wildlife Research Laboratory Denver, Colorado: Progress Report 1. 15 pp. Neff and Meanley 1956.pdf

64. Neff, J. A. and B. Meanley. 1957. Bird repellent studies in the eastern Arkansas rice fields. Wildlife Research Laboratory Denver, Colorado: Progress Report 2. 22 pp. Neff and Meanley 1957.pdf

65. Neff, J. A., B. Meanley, and R. B. Brunton. 1957. Basic screening tests with caged birds and other related studies with candidate repellent formulations 1955-1957. Wildlife Research Laboratory Denver, Colorado: Progress Report 3. 22 pp. Neff et al. 1957.pdf

66. Ordonez, J. L., and J. Retana. 2004. Early reduction of post-fire recruitment of *Pinus nigra* by post-dispersal seed predation in different time-since-fire habitats. Ecography 27: 449-458. Ordonez and Retana 2004.pdf

This study analyses the effects of post-dispersal predation of *Pinus nigra* seeds on the initial recruitment of this species in areas burned by large wildfires, where *P. nigra* shows very low regeneration. In three different habitats obtained in a gradient of time since fire in Catalonia (NE Spain), we have evaluated the effects of seed predators (ants, rodents and birds) on post-dispersal seed removal and early seedling establishment of *P. nigra* by using selective exclosures limiting their access to seeds. Ants were the most efficient seed predator group, followed by rodents and birds. The contribution of each group to overall predation showed large seasonal variations. The first seeds dispersed in winter were mainly predated by rodents, which also registered their highest abundance in this season of the year. In spring, at the end of the natural dissemination period of *P. nigra* seeds, ants became the major predators, this fact coinciding with their increased abundance. Birds showed the lowest predation values. In the seedling establishment experiment, only in the exclusion treatment of the three predator groups was there initial establishment in all habitats, especially in the recently burned area, where there was seedling establishment in all exclusion treatments. The post-dispersal seed predation by different animal groups and low seedling emergence in the different habitats obtained in this study, together with the low seed availability of *P. nigra* seeds in burned areas, do not predict a favourable outlook for the natural post-fire recolonization of this species, which might even affect its overall distribution area in the region.

67. Orr-Walker, T., and L. G. Roberts. 2010. Creative use of captive populations for wildlife conservation. CMaG: ARAZPA NZ 2010 Conference Proceedings. Orr-Walker and Roberts2010.pdf

The importance of captive populations to research methods of wildlife conservation should not be underestimated. In-situ research may often be expensive and monitoring of mobile species logistically difficult over large areas. Conversely ex-situ research may allow manipulation of key environmental factors and accurate monitoring of behaviour over an unlimited period. With highly mobile species such as kea that inhabit terrain which is often difficult and resource expensive to access, this is certainly the case.
Aerial drops of 1080, used for control of introduced pest species, have been identified as a cause of death of wild kea. A collaborative project involving captive testing of a combination of two repellents in non toxic cereal pellets has returned results which may provide a potentially ingenious solution to an otherwise difficult problem. Results show a significant decrease in the amount of pellets ingested between untreated pellets and repellent treated pellets suggesting that the repellent concentrations are effective at deterring kea from ingesting the cereal pellets. Furthermore the amount ingested increased on provision of post treatment untreated cereal pellets suggesting that the repellents were required to ensure a continued aversive response. There are further problems impacting on wild kea which will not only require continued collaboration between stakeholders (e.g. the Kea Conservation Trust, Department of Conservation and captive kea facilities in New Zealand) but also require some very real use of

kiwi ingenuity and cooperation to ensure that another iconic New Zealand species continues to be conserved in the wild.

68. Orr-Walker, T., N. Adams, L. Roberts, and J. Kemp. Evaluation of the bird repellents anthraquinone and d-pulegone to prevent ingestion of 1080 toxin by kea (*Nestor notabilis*) during aerial operations. Source unknown… Orr-Walker et al.2010.pdf

69. Osbrink, W. L. A., M. R. Tellez, M. Kobaisy, A. R. Lax. 2003. Assessment of natural products for control of Formosan Subterranean Termites. *In:* Semiochemicals in Pest and Weed Control (R. J. Petroski M. R. Tellez, and R.W. Behle, Eds.) American Chemical Society publication. Osbrink et al. 2003.pdf

Numerous plant species have been reported to be resistant to attack from subterranean termites. Many of these plants and extracts derived from them were tested for leads as potential natural product based pesticides. Forty plant and tree extracts reported to be active against termites displayed poor activity against the Formosan subterranean termite at rates < 0.5% wt/wt. Most naphthoquinones were active with a non-polar substitution in the 2-position. Anthroquinones generally had little termiticidal activity. None of the plant extracts or natural products tested were sufficiently active to be considered useful for control of the Formosan subterranean termite without structural modification.

70. Pinowski, J. 1973. The problem of protecting crops against harmful birds in Poland. OEPP/EPPO Bulletin 3: 107-110. Pinowski 1973.pdf

From the point of view of Polish agriculture, the rook ***(****Corvus frugilegus* L.) causes the most damage. Jackdaws (C. *monedulu* L.) usually forage together with rooks and are equally abundant as a breeding species in the southern and central regions of Poland. Fields under spring oats, barley, wheat, maize, peas and winter wheat are the main feeding grounds of rooks and jackdaws. Unlike the corvine birds, starlings *(Sturnus vulguris* I,.), in Poland, only cause damage to cherry orchards, although in certain areas they also attack strawberries and currants. The house sparrows ***(****Passer domesticus* L.) cause considerable damage to ripening crops of wheat, barley, and sunflowers. Domestic pigeons cause considerable damage to crops of peas, wheat and maize grown within a 50 km radius of a town.

71. Poche, R. M., 1998. Development of a new bird repellent, Flight Control. Proceedings of the Vertebrate Pest Conference 18: 338-344. Poche 1998.pdf

In August 1995 the development of a new bird repellent, Flight Control, which contains anthraquinone, was initiated. Genesis Laboratories examined the efficacy of Flight Control when used to repel key target bird species. The model revealed that to achieve 90 percent repellency with Flight Control, the treated material should receive 1,131 ppm of anthraquinone.

72. Riggle, B. D. 1996. Proposal for the classification of a new biochemical pesticide 1,4 Dihydroxy-anthraquinone for use as a bird repellent. Platte Chemical Co. Regulatory Department publication. 14 pp. Riggle 1996.pdf

Platte Chemical Co. (Platte) seeks to develop 1,4-dihydroxy-anthraquinone (also referred to as quinizarin) as a biochemical bird repellent for use as a seed treatment and as a coating for granulated insecticides (organo-phosphates and carbamates). Platte believes the registration of 1,4-dihydroxy-anthraquinone as a biochemical bird repellent will further advance the U.S. Environmental Protection Agency's (EPA) (also referred to as the Agency) goal of replacing conventional toxic pesticides with reduced risk products. 1,4-Dihydroxy-anthraquinone can potentially reduce bird predation on many important crops. Crops to be grown from treated seed include corn, rice, wheat, sunflowers, lettuce, sorghum, and sugarbeets. 1,4-Dihyrdoxy-anthraquinone coatings can also potentially reduce bird deaths resulting from field applied insecticide granules. 1,4-Dihydroxy-anthraquinone is structurally very similar to 9,10-anthraquinone, which was recently classified by the Agency as a biopesticide. EPA acceptance of this proposed biopesticide could ultimately result in reduced crop loses and a reduction in song and game bird deaths resulting from field applied insecticides. In addition, a viable non-toxic bird repellent, such as 1,4-dihydroxy-anthraquinone, potentially offers protection for endangered bird species.

73. Rodriguez, E. N., G. Tiscornia, and M. E. Tobin. 2004. Bird depredations in Uruguayan Vineyards. Proceedings of the Vertebrate Pest Conference 21: 136-139.
Rodriguez et al. 2004.pdf

Many species of birds in Uruguay frequent vineyards and damage grapes, both species that are considered crop pests and species that are protected by law because their conservation and protection are desirable. We surveyed 70 farmers in the Department of Canalones, the main grape growing region in Uruguay, to determine their perceptions about the nature and severity of bird depredations and the methods being employed to reduce such damage. Sixty-seven percent of respondents reported receiving damage from birds. Bird depredations were considered a serious problem by 58% of respondents, a moderate problem by 19% of respondents, and a minor problem by 19% of respondents. The species most often cited as causing damage were Picazuro pigeons, great kiscadees, and creamy-bellied thrushes. Respondents use a variety of methods to deter bird depredations including firearms, toxic baits, visual deterrents, and chemical repellents. We describe a research proposal to determine more precisely the magnitude of bird depredations in Uruguayan vineyards, to adapt and/or develop management tools, and to formulate and implement a pilot management plan for reducing bird depredations.

74. Royall, W. C. Jr., and J. A. Neff. 1961. Bird repellents for pine seeds in the mid-southern states. North American Wildlife and Natural Resources Conference 26: 234-238.
Royall and Neff 1961.pdf

Bird repellent chemicals applied as powder coatings to pine seeds are gradually solving the problem. The use of repellents in direct seeding longleaf, loblolly, and slash pine has been particularly successful (Mann, et al. 1956; Mann 1958), and promising results also have been obtained on shortleaf pine. Effective, practical seed treatments have resulted in initial seedling stands of five to ten thousand trees per acre. This progress has been possible through cooperative efforts of the Denver Wildlife Research Center and the Southern Forest Experiment Station over the past 14 years.

75. Santilli, F., L. Galardi, and C. Russo. 2005. Corn appetibility reduction in wild boar (*Sus scrofa L.*) in relationship to the use of commercial repellents. Annali Fac Med. Vet. 58: 213-218. Santilli et al. 2005.pdf

The aim of this pilot trial was to compare the effectiveness of three commercial repellents in decreasing corn intake by captive wild boar and if it should be a strategy to reduce wild boar damage to seeded corn. Three adult wild boars were simultaneously offered untreated corn (control) and corn treated with one of the following repellents: - Morkit®, an antraquinone based repellent used to control bird damage on sprouting cereals; - Tree guard® a denatonim benzoate repellent used to protect trees by deer browsing; - Hot Sauce® a capsaicine based repellent. Five tests were carried out, each lasting 6-7 days and 3-7 days apart from each other. Results showed that: Hot sauce failed to reduce corn consumption when added at 10 g/kg of corn, but when added at 25 g/kg reduced daily consumption by 80.5%; Morkit (5 g/kg) reduced daily consumption by 86.5%. Tree guard (sold ready to use) reduced consumption by 86.5%. In the last test, with only treated corn offered to the animals, Morkit and Hot Sauce - treated corn were consumed less then Tree Guard - treated corn (40% and 41% respectively). Use of repellents to reduce damage immediately after the sowing can be evaluated in presence of abundant alternative food.

76. Saxton, V. P. 2004. Influence of ripening grape compounds on behavioural responses of birds. PhD Dissertation Lincoln University, Lincoln, Canterbury, New Zealand. saxton 2004.pdf

Vineyards in New Zealand suffer bird damage caused by several avian species, including blackbirds and silvereyes. The introduced European blackbird takes whole grapes which reduces yield. The self-introduced Australasian silvereye pecks on grapes, leaving them on the vine to be further attacked by fungi and bacteria, and the subsequent off-odours can cause grapes to be refused by the winery or to suffer a price-reduction. Bird control methods remain primitive and largely ineffective during the long ripening period of wine grapes. An ecologically sound method to manage and reduce bird pressure requires deeper understanding of why some birds eat grapes, especially since grapes are not particularly nutritious. This work investigated the extent to which blackbirds and silvereyes are attracted by various compounds in ripening grapes. Since in natural grapes these compounds develop and change simultaneously, I developed an artificial grape in which a single parameter could be investigated. Artificial grapes (and sometimes nectar) were presented on a bird feeder table and the responses of birds to hexose sugars, the aromas 2-3-isobutylmethoxypyrazine and geraniol, tartaric and malic acids, grape tannins, and purple and green colour were recorded on timelapse video and analysed.

77. Schafer, E.W. Jr., W. A. Bowles, Jr., and J. Hurlbut. 1983. The acute oral toxicity, repellency, and hazard potential of 998 chemicals to one or more species of wild birds. Archives of Environmental Contamination and Toxicology 12:355-382. Schafer et al. 1983.pdf

The acute oral toxicity, repellency, and hazard potential of 998 chemicals to one or more of 68 species of wild and domestic birds was determined by standardized testing procedures. Red-winged blackbirds were the most sensitive of the bird species tested on a large number of chemicals, and an index based on redwing toxicity and repellency may provide an appropriate indication of the probability of acute avian poisoning episodes. Avian repellency and toxicity were not positively correlated *(i.e.* toxicity varied independently with repellency).

78. Schafer, E. W. Jr. and W. A. Bowles, Jr. 1985. Acute oral toxicity and repellency of 933 chemicals to house and deer mice. Archives of Environmental Contamination and Toxicology 14: 111-129. Schafer and Bowles 1985.pdf

Five individual bioassay repellency or toxicity variables were estimated or determined for deer mice *(Peromyscus maniculatus)* and house mice *(Mus musculus)* under laboratory conditions. ALD's (Approximate Lethal Doses) or LD50's of 230 chemicals to deer mice are presented, as are food reduction (FR) values (3-day feeding test as a 2.0% treatment rate) for white wheat seeds *(Triticum aestivum)* for 696 chemicals and Douglas fir seeds *(Pseudotsuga menziesii)* for 81 chemicals. A similar repellency evaluation (REP) using a 5-day test with white wheat seeds at a 2.0% treatment rate was conducted with house mice and the results for 347 chemicals are presented. These toxicity and repellency data should be useful to those desiring to predict the potential for acute toxicity in wild mammals following exposure to a wide variety of chemicals. A calculation of the daily chemical dose ingested in mg/kg/day during the wheat test on deer mice and its resultant effects on mortality are also presented for most of the 696 chemicals. This calculated value, when used along with the ALD or LD50, should permit a rough estimate of the potential subacute toxicity of any tested chemical on wild mammals for which both types of data are available.

79. Sorensen, A. E. 1983. Taste aversion and frugivore preference. Oecologia 56: 117-120. Sorensen 1983.pdf

I tested the hypothesis that thrushes avoid certain species of fruits because of their taste. It was found that thrushes had significant preferences and aversions for the flavours of certain species of fruit. Several species of fruit which thrushes avoided contained identified toxins. It is speculated that some species of plants have evolved fruit toxins to prevent thrushes from consuming fruits and dispersing seeds to unfavourable habitats.

80. Sydiskis, R. J., D. G. Owen, J. L. Lohr, K.-H. A. Rosler, and R. N. Blomster. 1991. Inactivation of enveloped viruses by anthraquinones extracted from plants. Antimicrobial Agents and Chemotherapy 35: 2463-2466. Sydiskis et al. 1991.pdf

To determine the extent of antiviral activity present in a number of plant extracts, hot glycerin extracts were prepared from *Rheum officinale, Aloe barbadensis*, *Rhamnus frangula*, *Rhamnus purshianus*, and *Cassia angustifolia* and their virucidal effects were tested against herpes simplex virus type 1. All the plant extracts inactivated the virus. The active components in these plants were separated by thin-layer chromatography and identified as anthraquinones. A purified sample of aloe emodin was prepared from aloin, and its effects on the infectivity of herpes simplex virus type 1 and type 2, varicella-zoster virus, pseudorabies virus, influenza virus, adenovirus, and rhinovirus were tested by mixing virus with dilutions of aloe emodin for 15 min at 37°C, immediately diluting the sample, and assaying the amount of infectious virus remaining in the sample. The results showed that aloe emodin inactivated all of the viruses tested except adenovirus and rhinovirus. Electron microscopic examination of anthraquinone-treated herpes simplex virus demonstrated that the envelopes were partially disrupted. These results show that anthraquinones extracted from a variety of plants are directly virucidal to enveloped viruses.

81. Trial, H. Jr., and J. B. Dimond. 1979. Emodin in buckthorn: a feeding deterrent to phytophagous insects. The Canadian Entomologist 111: 207:212. Trial and Dimond 1979.pdf

Emodin, a mixture of anthraquiones, occurs in the Rhamnaceae and functions as a deterrent to foliage-feeding insects. There was little attack on foliage of *Rhamnus alnifolia* in wild stands compared with associated species of woody plants. Anthraquiones extracted from foliage of *R. alnifolia* were similar to purchased emodin in thin-layer chromatographic and infra-red spectroscopic analyses. Quantities of emodin in foliage samples were high in May, declining to low levels in August. Leaf powders, leaf extracts, and purchased emodin all showed feeding deterrent activity when mixed with artificial diets and assayed with gypsy moth larvae. Purchased emodin showed similar activity when sprayed on foliage of small cherry trees and assayed with eastern tent caterpillar larvae.

82. Tsahar, E., J. Friedman, and I. Izhaki. 2003. Secondary metabolite emodin increases food assimilation efficiency of yellow-vented bulbuls (*Pycnonotus xanthopygos*). The Auk 120: 411-417. Tsahar et al. 2003.pdf

We studied the effect of the secondary metabolite emodin on food intake, food assimilation mass coefficient (AMC), feeding bout rate, and defecation rate in a frugivorous bird, the Yellow-vented Bulbul (*Pycnonotusx anthopygos*). Emodin is found in the ripe fruits of Mediterranean buckthorn (*Rhamnus alaternus*), which is commonly eaten by *P. xanthopygos*. Emodin (0.005 and 0.01% wet mass) increased dry matter AMC by 8-10% after isolating the effect of food intake. At a concentration of 0.001%, emodin increased the AMC of nitrogen, fat, and organic remains (mainly carbohydrates and proteins). Apart from emodin, fruits of *R. alaternus* contain a variety of secondary metabolites that may interact with each other and influence bird digestion. Artificial food laced with crude Rhamnus fruit extract increased food intake and dry matter AMC. Emodin (0.01% wet mass) increased the average time between defecations, but did not affect the time interval between feeding bouts nor the average amount consumed per feeding bout. We speculate that emodin increases food retention time. Longer retention time may explain the observed increase in AMC. Our results suggest that sometimes secondary metabolites in ripe fruit may not be detrimental to frugivores and the presence of emodin in the pulp of ripe buckthorn fruits might be selectively adaptive to the plant.

83. Vaudry, A. L. 1974. Cereal crop depredation by ducks and its control in the Canadian prairies. Master's Thesis Simon Fraser University, British Columbia, Canada. Vaudry 1974.pdf

84. Voss, K. A., and L. H. Brennecke. 1991. Toxicological and hematological effects of sicklepod (*Cassia obtusifolia*) seeds in Sprague-Dawley rats: a subchronic feeding study. Toxicon 29: 1329-1336. Voss and Brennecke 1991.pdf

Cassia obtusifolia and its seeds, common contaminants of agricultural commodities, are toxic to cattle and poultry. Toxicity has been attributed to anthraquinones which are major constituents of

C. obtusifolia, but studies of the subchronic and chronic toxicity of naturally occurring anthraquinones are limited. To investigate the subchronic (> 30 days) toxicity of *C. obtusifolia* seed, ten rats/sex were fed diets containing 0, 0.15, 0.50, I .5 or 5.0% *C. obtusifolia* seed for 13 weeks. Intermittent mild diarrhea was found in high-dose animals and body weights of high-dose males were decreased to week 10. Myeloid hyperplasia with peripheral leukocytosis, thrombocytosis and mild anemia were found in males and females fed diets containing, 0.50% C. obtusifolia seed. Leukocytosis resulted from neutrophilia, whereas peripheral lymphocyte counts were unaffected. Lymphoid hyperplasia and/or histiocytosis were found in the mesenteric lymph nodes in groups fed *C. obtusifolia* seed. Thus, a dietary no observable effect level' for subchronic ingestion of *C. obtusifolia* seed in rats was < 0.15%.

85. Waser, M., B. Lackner, J. Zuschrader, N. Muller, and H. Falk. 2005. An efficient regioselective synthesis of endocrocin and structural related natural anthraquinones starting from emodin. Tetrahedron Letters 46:2377-2380. Waser et al. 2005.pdf

Endocrocin and related naturally occurring anthraquinone pigments like cinnalutein could be synthesized regioselectively via a Marschalk type reaction, starting from the natural hydroxy anthraquinone emodin. Furthermore, the new tri-O-methyl protected emodin-2-carbaldehyde may serve as a promising synthon for new bathochromically shifted, higher generation photodynamically active hypericin derivatives.

86. Werner, S. J., J. C. Carlson, S. K. Tupper, M. M. Santer, and G. M. Linz. 2009. Threshold concentrations of an anthraquinone-based repellent for Canada geese, red-winged blackbirds, and ring-necked pheasants. Applied Animal Behaviour Science 121:190-196. Werner et al. 2009.pdf

Wildlife repellents provide a non-lethal alternative for managing the monetary impacts of agricultural depredation. For the purpose of developing of an effective avian repellent, we established repellency thresholds of an anthraquinone-based repellent for Canada geese (*Branta canadensis*), red-winged blackbirds (*Agelaius phoeniceus*), and ring-necked pheasants (*Phasianus colchicus*) in captivity.We conducted a concentration–response experiment with Canada geese offered cornseeds treated with six concentrations of Avipel1repellent (a.i.50% 9,10-anthraquinone). Based upon our laboratory efficacy data, we used non-linear regression to predict a threshold concentration of 1450 ppm anthraquinone for geese offered treated corn seeds (i.e., 80% repellency; r2 = 0.85, P = 0.009). We also observed a positive concentration–response relationship among red-winged blackbirds offered Avipel1-treated rice (r2 = 0.70, P = 0.039) and sunflower seeds (r2 = 0.84, P = 0.010). We predicted a threshold concentration of 1475 ppm anthraquinone for blackbirds offered treated sunflower seeds. Blackbirds also reliably discriminated between untreated food and rice treated with 2325 ppm anthraquinone (F1,10 = 3414.05, P< 0.0001) or sunflower treated with 1778 ppm anthraquinone (F1,10 = 175.39, P< 0.0001). We observed a positive concentration–response relationship among ring-necked pheasants offered corn (r2 = 0.95, P = 0.001) and sunflower seeds (r2 = 0.99, P< 0.001) treated with Avipel1. We predicted a threshold concentration of 10,450 ppm anthraquinone for pheasants offered treated corn seeds. Pheasants also reliably discriminated between untreated food and corn treated with 1900 ppm anthraquinone (F1,10 = 919.86, P < 0.0001) or hulled sunflower treated with 1140 ppm anthraquinone (F1,10 = 177.35, P< 0.0001). Avipel1 seed treatments effectively conditioned avoidance of treated seeds among Canada geese, red-winged blackbirds, and ring-necked pheasants. Our laboratory efficacy data provide a reliable basis for planning future field applications of anthraquinone-based bird repellents for protection of agricultural crops, property, and related natural resources. Supplemental field efficacy studies are necessary for registration of anthraquinone-based repellents for managing agricultural depredation caused by wild birds.

87. Werner, S. J., and F. D. Provenza. 2010. Reconciling sensory cues and varied consequences of avian repellents. Physiology & Behavior 102:158-163. Werner and Provenza 2010.pdf

We learned previously that red-winged blackbirds (*Agelaius phoeniceus*) use affective processes to shift flavor preference, and cognitive associations (colors) to avoid food, subsequent to avoidance conditioning. We conducted three experiments with captive red-winged blackbirds to reconcile varied consequences of treated food with conditioned sensory cues. In Experiment 1, we compared food avoidance conditioned with lithium chloride (LiCl) or naloxone hydrochloride (NHCl) to evaluate cue–consequence specificity. All blackbirds conditioned with LiCl (gastrointestinal toxin) avoided the color (red) and flavor (NaCl) of food experienced during conditioning; birds conditioned with NHCl (opioid antagonist) avoided only the color (not the flavor) of food subsequent to conditioning. In Experiment 2, we conditioned experimentally naïve blackbirds using free choice of colored (red) and flavored (NaCl) food paired with an anthraquinone- (postingestive, cathartic purgative), methiocarb- (postingestive, cholinesterase inhibitor), or methyl anthranilate-based repellent (preingestive, trigeminal irritant). Birds conditioned with the postingestive repellents avoided the color and flavor of foods experienced during conditioning; methyl anthranilate conditioned only color (not flavor) avoidance. In Experiment 3, we used a third group of blackbirds to evaluate effects of novel comparison cues (blue, citric acid) subsequent to conditioning with red and NaCl paired with anthraquinone or methiocarb. Birds conditioned with the postingestive repellents did not avoid conditioned color or flavor cues when novel comparison cues were presented during the test. Thus, blackbirds cognitively associate pre- and postingestive consequences with visual cues, and reliably integrate visual and gustatory experience with postingestive consequences to procure nutrients and avoid toxins.

88. Werner, S. J., G. M. Linz, J. C. Carlson, S. E. Pettit, S. K. Tupper, and M. M. Santer. 2011. Anthraquinone-based bird repellent for sunflower crops. Applied Animal Behaviour Science 129: 162-169. Werner et al. 2011.pdf

Non-lethal alternativesareneededtomanagebirddamagetoconfectioneryandoilseed sunflower crops (*Helianthus annuus*). Ring-necked pheasants (*Phasianus colchicus*) can cause localized damage to newly planted sunflower, and blackbirds (Icterids) damage ripening sunflower annually in the United States of America. We conducted seed germination experiments, a repellent efficacy study with ring-necked pheasants and Avipel® repellent (a.i.50%9,10-anthraquinone), and laboratory and field efficacy studies with common grackles (*Quiscalus quiscula*) and Avipel®-treated confectionery sunflower. Compared to the germination of seeds not treated with anthraquinone, we observed no negative effects of up to 12,223 ppm, 14,104 ppm, and 11,569 ppm anthraquinone seed treatments for germination of confectionery sunflower, oilseed sunflower, and canola seeds, respectively. Pheasants avoided emergent sunflower seedlings (12days post-planting) from 15,800 ppm anthraquinone seed treatments during a caged preference test (P = 0.045).We observed a positive concentration–response relationship (P = 0.001) and predicted a threshold concentration (i.e., 80% repellency) of 9200 ppm anthraquinone for common grackles offered Avipel®-treated confectionery sunflower seeds. Grackles also reliably discriminated between untreated sunflower and seeds treated with 1300 ppm anthraquinone in captivity (P < 0.001). During our field efficacy study for ripening confectionery sunflower, we observed 18%damage among anthraquinone-treated enclosures and 64% damage among untreated enclosures populated with common grackles (P < 0.001). Harvested seed mass averaged 2.54 kg (dry weight) among treated enclosures and 1.24 kg among untreated enclosures (P < 0.001). Our laboratory and field efficacy data provide a reliable basis for planning future field applications of anthraquinone-based repellents for protection of sunflower crops. Supplemental field efficacy studies are necessary for development of an effective avian repellent and management of avian depredation of ripening agricultural crops, including oil seed sunflower.

89. Xie, J., B. Liu, Q. Zhou, Y. Su, Y. He, L. Pan, X. Ge, and P. Xu. 2008. Effects of anthraquinone extract from rhubarb *Rheum officinale* Bail on the crowding stress response and growth of common carp *Cyprinus carpio* var. *Jian*. Aquaculture 281: 5-11. Xie et al. 2008.pdf

A total of 750 common carp, *Cyprinus carpio* var. Jian, fingerlings were divided randomly into five groups: a control group on a basal diet, four treatment groups fed a basal diet supplemented with 0.5%, 1.0%, 2.0%, and 4.0% anthraquinone extract, respectively. After 10 weeks, the fish were exposed to crowding stress for 1 and 7 days. In treated fish before the stress an increase was found in the specific growth rate, fullness coefficient, and activities of blood lysozyme, hepatic catalase and superoxide dismutase, whereas a decrease was observed in the feed conversion rate, hepatic malondialdehyde contents and the mortality rate. Noteworthily, these variations did not show dose-dependency of anthraquinone extract. The blood cortisol, glucose, lysozyme and hepatic malondialdehyde levels significantly increased in all groups after 1 and 7 days of crowding stress. Amongst those in the control were the highest. At 7 days after crowding stress, the blood cortisol levels and hepatic malondialdehyde contents remained higher in all groups. Additionally, the blood glucose and lysozyme levels decreased to some extent, but still higher than those before stress. The hepatic catalase and superoxide dismutase activities could decrease in all groups after 1 and 7 days of crowding stress, but the activities in treatment groups, supplemented with 1–2.0% anthraquinone extract, kept higher than those in the control. Before the crowding stress the artificial infection with *Aeromonas hydrophila* resulted in mortality in all groups except for the groups supplemented with 1–2.0% anthraquinone extract. The present study suggested that ingestion of 1%–2.0% anthraquinone extract supplemented a basal diet has the potential to prevent the pathogenic infection, mitigate the negative effects of crowding stress, and promote growth of the fish.

90. Yang, Y.-C., M.-Y. Lim, and H.-S. Lee. 2003. Emodin isolated from *Cassia obtusifolia* (Leguminosae) seed shows larvicidal activity against three mosquito species. Journal of Agricultural and Food Chemistry 51: 7629-7631. Yang et al. 2003.pdf

Mosquito larvicidal activity of *Cassia obtusifolia* (Leguminosae) seed-derived materials against the fourth-instar larvae of *Aedes aegypti*, *Aedes togoi*, and *Culex pipiens pallens* was examined. The chloroform fraction of *C. obtusifolia* extract showed a strong larvicidal activity of 100% mortality at 25 mg/L. The biologically active component of *C. obtusifolia* seeds was characterized as emodin by spectroscopic analyses. The LC50 values of emodin were 1.4, 1.9, and 2.2 mg/L against *C. pipiens pallens*, *A. aegypti*, and *A. togoi*, respectively. Pirimiphos-methyl acts as a positive control directly compared to emodin. Pirimiphos-methyl was a much more potent mosquito larvicide than emodin. Nonetheless, emodin may be useful as a lead compound and new agent for a naturally occurring mosquito larvicidal agent. In tests with hydroxyanthraquinones, no activity was observed with alizarin, danthron, and quinizarin, but purpurin has an apparent LC50 value of ~19.6 mg/L against *A. aegypti*.

91. York, D. L., J. L. Cummings, R. M. Engeman, and J. E. Davis, Jr. 2000. Evaluation of Flight Control and Mesurol as repellents to reduce horned lark (*Eremophila alpestris*) damage to lettuce seedlings. Crop Protection 19:201-203. York et al. 2000.pdf

We conducted enclosure trials near Huron, CA in the San Joaquin Valley from 12 to 23 January 1999 to determine the efficacy of Flight Control ™ (50% anthraquinone) and Mesurol (75% methiocarb) in preventing horned lark damage to lettuce seedlings. Flight Control ™ (FC) and Mesurol were evaluated as foliar sprays at application rates of 2.79 and 2.27 kg ha~1, respectively. Horned lark damage to lettuce seedlings treated with anthraquinone was greater (*p*"0.015) than for methiocarb, 60 versus 20%, respectively, and seedlings in control plots were 100% destroyed. While this level of damage is probably unacceptable to lettuce growers, it should be remembered that the enclosure situation caused an artificially high bird pressure on the crop. Further studies in open fields under a more normal bird pressure are warranted.