REVIEW OF EFFECTIVENESS OF VISUAL AND AUDITORY BIRD SCARING TECHNIQUES IN AGRICULTURE

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Abstract. Pests cause huge damage that leads to high losses in crops and implicitly to lower yields in the agricultural sector. Of these, birds are also harmful in terms of crop damage, especially for high value crops (vineyards, trees, cereals, vegetables). In the pre-harvest period, birds (starlings, blackbirds, pigeons, sparrows, sowing crows) can be able to destroy about 60-70% of the crop in a very short time. Complete crop loss is possible if no deterring mechanisms are used. Farmers want to find an easy and cost-effective way to keep birds away from their crops because uncontrolled birds can completely destroy the whole crop. Finding a balance is difficult, so even modern equipment and great efforts will not prevent all the damage caused by bird attack, some of these devices may cause disturbing environments for people if they are not properly managed. However, the right tools and good management can reduce the attack of birds and conserve more crops. Currently, large research is oriented toward the development of agricultural robots as tools in ecological research, but with extraordinary potential for biodiversity sampling, studies of population dynamics and ecosystem functioning, experimental biology and behavioral studies. Recently, drones have become increasingly accessible, and this currently leads to their widespread use for wildlife observation, the study of bird behavior. At present, there is no bird control technique that provides maximum protection for crops, so it is recommended to use a combination of scaring methods at the same time, namely: acoustics (propane cannons, pyrotechnic cartridges, speakers, etc.), visually (balloons, mirrors, reflective tapes, kites, lasers, drones, etc.) and physical (nets). In this context, this paper aims to identify the losses from different crops due to the attack of birds and proposes an integrated approach to effective visual and auditory removal techniques, such as to preserve the role of birds in the global balance of the environment.

Keywords: visual and auditory techniques, pests, agricultural crops.

Introduction

Globally, birds are a major threat to agriculture, causing considerable economic damage to crops. Damage caused by some birds is a serious problem for many farmers, as uncontrolled birds can completely destroy the whole crop. According to the Australian Department of Agriculture, there are at least 60 different species of birds known to feed and harm horticultural crops. As each species has different ways and strategies of feeding and movement, it is difficult to find an effective method of scaring them. In Olanda, farmers who grow celery and lettuce have as harmful the duck with hawk eyes or the forest duck. In Kombornia, Polonia, the attack on the wine grapes is produced by starling of the genus *Sturnus*, golden woodpeckers (*Colaptes auratus*) and small blackbirds (*Icterus galbula*). In Tunuyan, Mendoza, Argentina, the attack on sunflower crops is made by pigeons (genus *Columbidae*) and parrots (genus *Psittaciformes*). Skylark of field (*Alauda arvensis*) attacks the seeds of the crops from Tasmania. In Leongatha, Victoria, Australia crows and ravens (genus *Corvidae*) attack pea and bean crops [1].

A large study in New Zealand involved assessing the views of 100 farmers about the nature and extent of bird damage to crops. 26 crops were studied (cereals, broccoli, spinach, peas, radishes, cabbage, turnips, primrose, chicory and Chinese mustard), the extent of reported damage varied between crops, with losses in most cereals: wheat (31%), barley (28%) and peas (54%). Also, losses greater than 20% were recorded in spinach, turnips, radishes, primrose. Among the harmful birds, sparrows, pigeons, ducks and migratory birds were the most [2].

In Romania, the house sparrow (*Paser domesticus*), Spanish sparrow (*Passer hispaniolensis*), collared dove (*Streptopelia turtur*), pigeon (*Columba livia*) and the rooks (*Corvus frugilegus*) cause damage in pre-harvest sunflower crops [3]. A review [4] describes the damage caused by birds to sunflowers grown worldwide. Also, the first „attack" of starlings in Romania was manifested on ripe cherries, in the months of May-June, then the attack breaks out on elderflowers and red plums. Significant damages also occur in vines, in autumn, when the grapes are ripe [5]. Wine grapes are also vulnerable cultures in Australia. Research has shown that up to 83% of grape yield can be lost due to bird damage [6; 7]. The extent of the damage caused by birds to any crop depends on several factors,

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such as [8]: the concentration of the local bird population, the total area of the culture, the culture pattern, the habitat of the area, the season and the physiological condition of the birds.

This paper is a review that identifies the problems caused by birds in agricultural crops and identifies visual and acoustic deterrence devices for birds in crops for an integrated approach in bird control.

Bird pest management

Birds have a significant role in nature, although due to the change in the way they process and use agricultural land, they have lost their natural habitats (meadows, forests, wetlands). Thus, in order to obtain food, the birds have come to based on man-made habitats and agricultural crops, causing economic damage to field crops, houses, warehouses, equipment and soiling the area of human life. More and more bird populations have adapted to living in agricultural crops and have become pests. Such species, labeled as pests, belong to granivorous and frugivorous birds (pigeons, parakeets, blackbirds, crows, sparrows, starlings, etc), which cause serious damage to agriculture (cereal crops and fruit orchards), and their population becomes the target for pest management and control [9].

Complete loss of agricultural crops is possible without the use of mechanisms to discourage birds, especially in the run-up to their harvest [10]. Managing birds is complex because they are very mobile; they quickly get used to discouraging elements; some species may be beneficial because of consumption of harmful insects, rodents and other birds, and because birds are generally very appreciated by many people. Therefore, the adoption by farmers of sustainable agricultural practices must be supported for an integrated pest management [11].

Agriculture conservation practices include modern techniques to increase “functional biodiversity”, which can be useful in adjustment of pests through natural predators. A study [12] of European apple farmers (*Malus* spp.), reported that they are adopting a number of techniques in support of “functional biodiversity”, from the installation of bird nests to the maintenance of hedges. Hedges and other uncultivated vegetation in agricultural areas help beneficial birds that attack the harmful insects of crops [13,14], although vegetation can also be used by birds that eat fruit [11]. Farmers often implement “multi-functional biodiversity” using different techniques simultaneously, although it is difficult for them to assess whether there are safe techniques that can reduce damage and/or pests. Farmers need specific advice and training to meet their needs [12]. This conclusion was similar to those in other recent studies conducted in the USA [15; 16].

Over time, a lot of methods have been used to control bird attacks in crops and reduce damage to them. Among the simple methods used by farmers to scare birds are the use of kites, balloons, coloured and reflective strips, mirrors, scarecrows with human and artificial shapes, trained predators, such as dogs or natural predators, such as falcons, eagles, owls. These methods are very expensive and inefficient, as birds quickly get used to them, realize that the threat is not real and ignore them whenever they come to feed.

Physical repellents can also be used, such as: thorns, nets, artificial nests, habitat modification. Physical exclusion of birds from crops using nets is the best way to ensure crop protection, but it is an expensive option and does not guarantee total protection, as birds can find a way to get into the crop. The use of trap cages helps reduce the population, but it is not cost-effective because it fails to significantly reduce damage to crops. Habitat modification involves removal and/or modification of habitat characteristics, actions of cutting trees, revegetation of the barren areas and allows to grow taller grass, excluding puddles and ponds.

Chemical repellents involve the use of sticky substances, taste repellents with unpleasant smell and taste, repellents derived from natural products, synthetic agrochemical pesticides, which are toxic to birds and cause them disorientation and improper behaviour, these can be fatal if ingested in too high doses. They have a higher success rate than other approaches, but due to toxicity to humans and other living organisms around the agricultural field their use is limited and very discouraged.

Electronic bird rejection devices produce highly effective audio and visual threats that scare, irritate and disorient birds, forcing them to look for other areas and conditioning them to stay away from target areas. An electronic bird repeller has many advantages over a regular bird repeller, namely easy installation, energy efficiency, large coverage area, compactness, simple design [9].

Visual and acoustic devices to scare birds are presented in Table 1. Worldwide, the use of intelligent protection systems in agriculture is constantly increasing, because compared to other methods of protecting agricultural crops from pests, they generate more and more accurate data about the condition of crops, bird species, their pests, etc. Also, the economic nature of using intelligent crop control systems is not to be neglected for the protection of agricultural holdings and the efficient management of pests. Thus, various devices were developed for scaring of birds from agricultural crops to adjust the damage caused by them, like a smart light emitter to scare birds that intend to feed in a particular crop area [1].

Table 1

Visual and acoustic devices

Name	Type description
Scare-eye balloon	A scare-eye balloon with a flash tape, the beach balls move freely with the wind and can scare birds from crops. Yellow balloons showed the best results in Ontario, especially on blackbirds [8].
Strip and streamers	Strip and streamers arranged along the rows reflect the sunlight and move with the wind, the whole field seems to be in motion. Red or silver bicolour strips are scaring a wide range of species [8].
Kites in the form of falcons	Kites fly in the wind and appear as predators hunting in the field. The presence of kites above the crop, tied up to the poles so that they can freely float in the wind, is threatening and can keep the birds away [8].
Drones	Incorporating visual devices (reflective plates, models with predatory birds, fixed and/or rotating wing models) and auditory devices (ultrasonic speakers, predator sounds) on a drone can be used to scare birds, but the drone must be run continuously [28].
Lasers	*Hawk-Laser* is a type of laser that uses precision lenses and optical components used to drive away birds [30]. *Bird-X Indoor Laser* is a remote controlled laser device for removal and control of birds in target areas, intended for indoor use and emitting laser beams at irregular intervals in combination with red and green colours, colours that disturb birds [31].
Propane cannon	Propane produces loud, random, unexpected sounds. Modern devices shoot sets of 3 explosions as they rotate to cover a larger area. They must be used in accordance with best management practices [8].
Pyrotechnic articles	They are launched from a handgun and “fly” directly into a flock of birds, where they explode and produce powerful sound and/or visual effects. They can quickly frighten an entire flock, but must be manually operated with caution [8].
Electronic sound device	These devices diffuse either electronic noises to irritate birds and disrupt their sensory system, or emergency calls from specific bird species and predator calls. Some farmers report that emergency calls actually attract birds to prey, which can help scare problems birds [8].

However, this method needs workforce, and the noise transmitted by explosions and sound devices annoys the inhabitants around the farm, and birds can get used to them if they are not varied regularly. Ultrasonic devices are commercial, popular, often used for scaring birds, they are different from the rest because they emit very disturbing sounds for birds that are not heard by the human ear.

Another solution identified is the use of a sound system to scare birds, powered by solar energy, the system uses 22 sounds of predatory birds (eagles, owls, hawks) to scare birds from an experimental study area in India. The hawk cries have been identified as the most effective for scaring ravens as well as other species of birds. It was observed that the birds would try to see where the sound emanates from before moving away, to determine if the threat is real. The efficiency of using this system depends mainly on the type of the sound of the predator, its volume, its quality and its repetitive character [19].

The use of multiple bioacoustic vocalization can increase the effectiveness of protective systems and delay the adaptability (habituation) of birds to them. First, the species of birds must be identified on the basis of their appearance and sounds when approaching the crop to be protected. Depending on the variation of bird species approaching the crop, the repulsion mode corresponding to the identified bird species will be selected. This system is effective in the long run and useful for reducing the probability of damage caused by birds [20].

The use of ultrasonic sound waves to discourage birds involves the use of sounds at certain frequencies. The sounds cover a wide area of acoustics, the infrasonic acoustic spectrum being below what people perceive and the ultrasound spectrum being above the hearing range. Infrasonic represents the range of sounds below 20 Hz, while ultrasonic represents the range of sounds above 18000 Hz. Sounds outside this range (20-18000 Hz) are not perceived by the human ear, but pests can detect and hear sounds over 20 kHz. The hearing capacity of birds is approximately 29 kHz [21], repellent systems operating between 20-29 kHz. Depending on the species, birds may be irritated and discontented with certain frequencies, which compel them to leave the limit area covered by the sound [21-24].

Use of ultrasonic waves (above the capacity of the human ear), which are perceived by small birds is a new technology that can effectively repel such birds from the designated places. In the paper [24], ultrasonic waves with an automatic frequency range of 15 kHz to 25 kHz were successfully generated from two solar-powered electronic devices, amplified and diffused at high sound pressure. The power of the first device 7.98 W produced 118 dB ultrasound, which covered a distance of 45.02 m^2, while the second device 23.98 W produced 123 dB ultrasound that covered a distance of 232.26 m^2 when placed at an altitude of 0.78 m, but when placed at an altitude of 1.86 m, their average coverage area was 175.83 m^2 and respectively 429.53 m^2. The ultrasonic waves created a hostile environment for the harmful birds and had a repulsive influence on them, eventually driving the birds away from the studied locations. About 5-6 pieces of the 23.98 W device were needed to cover one hectare of field.

In the paper [21], the researchers developed and designed a rejection prototype that produces ultrasonic waves of different frequencies based on the classification and grouping of birds. The model implemented was provided with three modules: the video camera module that tracks the data live, then it is transmitted to the detector module based on a code written in python, and if the bird is detected, the rejection module is activated, which triggers a certain frequency depending on the species identified, so that the bird will be disturbed by the repellent frequency and will move away from it. The results obtained in the experiment are mainly focused on the bird detection system, which is able to work on a detection distance between 2-500 meters by using sensors for bird detection, the python algorithm increases the detection range of the bird from 500 cm to 500 meters and continues through the process of repelling birds by playing high frequency sounds.

The paper [18] presents the design and development of a robust sound-based, energy efficient rejection system for Nigeria’s rice fields, with a convolutional neural network model embedded (CNN) for detecting birds. The model CNN was equipped with a data set containing images of 275 species of birds obtained from the Kaggle database. The system supports multiple production of different sounds to prevent birds from adapting to fixed sounds. The built-in camera helped detect birds, thereby reducing the inherent noise pollution of conventional audio devices. The developed system used 53.52% of the reported average power for conventional audio systems.

New bird management techniques include the use of unmanned aerial vehicles (drones). Unmanned aerial vehicles are becoming more accessible and can be easily programmed to mimic fixed or rotating wing movements at different altitudes, disseminating predator cries and imitating predator behaviour. They have the advantage of covering large vineyards or agricultural land in a short period of time compared to ground vehicles, and operator costs can be reduced with autonomous technologies. At this point, drones still require substantial human involvement and cannot be used when the wind is strong, the rains are heavy or at night. Unmanned aerial vehicles have been developed by various researchers over the years to scaring birds. This is an effective and reliable method of preventing bird invasion using a bird tracking system based on vision systems [25]. The system is easy to configure and can be executed on a quadcopter, which has integrated software and autopilot hardware with a radio-controlled base structure. Another paper [26] shows the use of a drone that has attached a crow model so that it would appear to be a captured prey and a speaker that sent distress calls to study the reaction of harmful birds, the system scaring the birds. Also, drones that had attached a raven mock-up (*Corvus* spp.) have been used to discourage large and small birds from vineyards in Australia for different periods of time [27].

The purpose of the paper [28] was to conduct experiments on the activity of sparrows in rice crops in Malaysia. A drone was used with an ultrasonic diffuser and predator sounds, as well as a reflective plate for scaring birds. The determined parameters were: the effectiveness of methods of scaring sparrows, the influence of flight intervals (4 minutes, 10 minutes and random) and the altitude (5 and 10 meters). The results showed that the drone can be used to scare birds, but must be run all the time. The technique of combining reflective plates and sounds (ultrasound and predators) was effective compared to using a single device. However, increasing the flight altitude to 10 m showed reduced effectiveness. For the drone's flight time interval, flight times were found to have no significant difference from the number of birds being tracked. It was also found that the interference of the experiment with land vehicles passing through the area had an immediate beneficial effect in scaring birds from rice fields and the combination of air and land methods should be further analyzed.

The problem with all these devices is the habit. For sound-emitting devices, birds get used to the noise because they see it as non-threatening. Ultrasound devices still require too much technical information to be effective. As for light or laser emitters, birds, although disturbed by them, continue to feed on the farm. Unmanned aerial devices are promising, but have the disadvantage of short flight times. Birds need to see the repellent device as a real threat in order to have positive results in scaring them away.

At present, there is no bird control technique that provides maximum protection for crops, therefore, it is recommended for small farms to use one or more simple methods (nets, propane cannons, kites, rounders, inflatable scarecrows, speakers, light nets) and for large farms, intelligent devices can be used that combine visual and auditory techniques (a drone equipped with diffuser, hawk models, reflective plates or a mixed system equipped with ultrasound and laser or bio-acoustic sonic scarecrows). Visual and auditory methods are accessible, costs can be reduced with autonomous technologies, they can be easily programmed, they can manage a large area of crops in a short period of time.

Effectiveness of bird scaring devices

Farmers want a simple and cost-effective way to keep birds away from their crops. Modern equipment and best efforts will not prevent all bird damage, and some devices can create a social disorder if not managed properly. However, the right tools and good management can reduce bird pressure and preserve multiple crops while reducing environmental and human impact [8]. In order to solve the problem of bird control, it is necessary to identify the species of birds with problems, the concentration of the local population of birds and the crops at risk, the total area of the crop, the crop pattern, the habitat of the area, the season and the physiological condition of the birds; understand the behavior of birds because they act on the basis of instincts and the environment; to identify crop losses due to bird attacks [8].

Farmers need to adopt a form of bird control to protect their crops so that the total expenditure on bird control is much lower than the amount of damage [2]. The most effective control of birds balances the needs of the crop with the integration of combined methods of expulsion in order to increase the effectiveness and protection of the environment and the neighborhood. Therefore, the integrated approach is needed: a combination of techniques of scaring at the same time (acoustic, visual and physical), so as to obtain the most effective control system against bird attacks [8]. Farmers must adopt conservation practices related to the issues such as soil, nutrient and pest management, improving agricultural productivity and protecting the environment [29].

Conclusions

1. Birds are an example of pests for farmers, they are very harmful to farmers as birds attack in large numbers, in colonies or groups.
2. Pests can contribute to huge losses in agricultural crops and implicitly to lower yields, so complete crop loss is possible if there is no form of scaring.
3. Most of the devices developed for choosing birds fail because of their habit of getting used to the methods used, so choosing the right techniques to scare off pests from agricultural crops and good management can reduce the attack of birds and preserve agricultural crops.
4. The most effective bird control balances the needs of the crop with integration of combined scaring techniques, using mixed devices capable of discouraging birds from agricultural crops and perceived as a real threat in order to ensure protection of crops, increase effectiveness and protect the environment and the neighborhood.

5. Sonic wave devices should emit low frequencies to discourage birds when an environmentally friendly method is desired.
6. Incorporating visual and auditory devices on a drone creates a new way of dynamically approaching bird control methods, with low costs.
7. In order to be implemented by farmers, all the techniques mentioned in this paper must be improved by randomization and combined/integrated both sound and visual devices.

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Author contributions

Indicate the contribution of each author. Conceptualization, A.P., D.C.; methodology, N.V., I.G. and D.C.; investigation, A.P., N.V., M.N., D.C. and I.G.; writing – original draft preparation, A.P., N.V. and M.N.; writing – review and editing, P.A., I.G. and D.C.; project administration, A.P. All authors have read and agreed to the published version of the manuscript.

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