The Pharma Innovation Journal 2022; SP-11(7): 2300-2314

www.ThePharmaJournal.com

The Pharma Innovation

ISSN (E): 2277-7695
ISSN (P): 2349-8242
NAAS Rating: 5.23
TPI 2022; SP-11(7): 2300-2314

www.thepharmajournal.com
Received: 13-04-2022
Accepted: 02-06-2022

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# Role of birds in agroecosystem: A review on agricultural and economic ornithology

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**Abstract**
Agricultural ornithology describes relationship between birds and agro ecosystems; it's an emerging field of keen interest among ornithologists of agriculture dominating countries. Indian subcontinent provides habitat to about 1300 resident or migratory bird species (13% of the world's avifauna) including 141 endemic species. Agro-ecosystems are mainly dominated by granivorous, insectivorous and omnivorous species and gets food in the form of seeds, grains, fruits, insects and rodents. A huge diversity can be observed at roosting sites based on the species-specific preference for a particular habitat, safety and need of the food and water sources. Economic ornithology accounts for costs and benefits of avian species to mankind and resources like agriculture, horticulture, sports and trade etc. Ecosystem services by birds are pest control, scavenging, pollination, seed dispersal etc. and are imperious for nature and mankind. Predatory and insectivorous birds play vital roles for biocontrol services in agricultural landscapes possibly leading to an increase in agricultural yield. This review concludes with cost benefit assessment of avifauna in agriculture, ecosystem services rendered by birds, sustainable pest management and conservation practices.

**Keywords:** Agricultural ornithology, bird community, roosting site, Agro-ecosystem services**,** natural pest control

## 1. Introduction

Asia, specifically the Indian subcontinent provides habitat to about 1300 resident or migratory bird species (13% of the world's avifauna) including 141 endemic species (Grimmett *et al.*, 1999) [40]. The term economic (applied) ornithology deals with the study of favourable and unfavourable aspects of birds to mankind in relation to horticulture, agriculture, trade and sport. The Science of birds with respect to agriculture and their management in agro-ecosystems is known as agricultural ornithology, a narrower axiom than economic ornithology. Birds are important components of agro-ecosystems well known for their dual role in agriculture (Ali, 1971) [2]. The presence of birds in certain ecosystems is highly dependent on the availability of food, nesting, and roosting sites and diversity of bird species is linked to the type of habitat available. Agro-ecosystems provide highly predictable and diverse food resources like seeds, fruits, grains, green vegetation in form of grasses or crop plants, arthropods particularly insects and rodents found in the soil and crops and breeding grounds to birds (O'Connor & Shrubb, 1986) [75]. Agricultural landscapes in intensively cultivated field areas in India possess a large number of fish, dairy, honey bee and poultry farms dispersed among farmlands. Such farms provide additional food sources to birds in the form of fishes, animal feeds, bees, nectar and fruit trees or fruits. Thus, agricultural birds include granivorous, frugivorous, nectarivorous, insectivorous, carnivorous and omnivorous species. Few omnivorous and granivorous species are capable of reproducing efficiently in agro-ecosystems leading to development of large populations and sometimes cause economic loss in agricultural production by causing damage to different crops and orchards whereas Carnivorous and insectivorous species, are less abundant and have been found useful as they keep a persuasive check on insect and rodent pests of agricultural crops. Economic and ecological importance of birds has raised interest of people towards their management. Management of birds includes not only the conservation of beneficial species but also includes control of pest species and environmental impact assessment. The Study of associations of birds to agriculture is broad, comprehensive and highly intricate and to understand these associations to formulate management practices, consummate information on ecological aspects such as feeding, breeding, roosting behaviours, damage potential and population dynamics is required. The foremost task for an agricultural ornithologist is to assess the impact of all positive and negative activities of species and then prepare a balance sheet to conclude that a particular species is beneficial, harmful or neutral. The objectives of the current review article are:

i) To review the ecological aspects of avifauna with respect to agriculture.
ii) To highlight the economic role of birds in agriculture.
iii) To propose management practices for beneficial and harmful bird species.
iv) To chalk out the strategies for conservation of important bird species and future perspective in related field.

## 2. Agricultural status of birds in India

Agriculture provides livelihood to 65% of population of India. Furthermore, a number of other vital sectors contributing to Indian economy are poultry, dairy and fish farming etc. are interlaced with this sector. According to ICAR (Indian Council of Agricultural Research), human population is increasing rapidly in India at annual growth rate of 1.8 percent for which an additional amount of 2 million tons of food grains per year would be required. On the contrary, production is on decreasing trends because of some major constraints like pests, weeds and diseases. Evidently, keeping a check on agricultural pests is a major concern. Tracey *et al*. 2015 [108] reported an estimated loss of $300 million in horticultural crops by more than 60 bird species. Pesticides' use for pest management is an outdated practice which has led to disastrous consequences on soil health, water, air and biodiversity as they contain toxic substances and heavy metals. Indiscriminate use of pesticide in agriculture has led many of common birds like house sparrow and Sarus crane at the verge of extinction. Above mentioned aspects sturdily insist on to ban or practicing alternatively safer use of pesticides and also to find some effective alternatives like bio-control or bio pesticides. Presently good enough, although insufficient, information is available on agricultural ornithology which has enabled us to chalk out strategy for avian management.

### 2.1 Community organization

Nearly one third of the total bird species often use agricultural habitats regularly to occasionally providing vital eco-services such as pollination, pest control, seed dispersal, etc. (Sekercioglu, 2012) [96]. Mostly insectivorous and only a few omnivorous and granivorous species dominate the bird community in agro-ecosystems. Dominant presence of a few most common species is archetypal of distributed habitats such as agricultural areas (MacArthur, 1972) [64]. Thorough knowledge on population dynamics is unavailable even for most common species of birds. Population structure like natality, mortality, pattern of distribution, etc. are almost non-existent. Though, some estimates about density of breeding and seasonal variations in population densities of very few species are known (Dhindsa, 1986) [30]. Community organization of birds in Punjab has been recorded where *Passer domesticus* was found as most abundant species (Toor *et al.*, 1986) [107]. 10 omnivorous, 10 granivorous, 38 insectivorous and 8 other species were described to constitute bird community in an intensively cultivated land at Ludhiana. Some species prefer diverse environmental habitats rather than the homogeneous ones. For instance, shaded coffee polycultures and greater landscape elemental diversity in Hungarian vineyards harbored more avian diversity (Perfecto *et al.*, 2004) [78]. A rapid decline in number of 20 most endangered bird species of agricultural landscapes has been observed due to loss of food resources which included *Falco tinnunculus* (common kestrel), *Emberiza citronella* (yellow hammer), *Vanellus vanellus* (northern lapwing) and *Alauda arvensis* (Eurasian skylark) (Vickery *et al.*, 2004) [116]. Similar trend was observed for *Perdix perdix* (grey partridges) and other agricultural species in Europe (Vaclavik, 2006) [114]. The northern lapwing and Eurasian skylark are placed at first in the midst of the most strikingly vanishing species. *Lanius senator* (woodchat shrike), *Lanius minor* (the lesser grey shrike) and *Coracias garrulus* (European roller) has disappeared entirely while *Otis tarda* (the great bustard), *Numenius arquata* (Eurasian curlew) and *Burhinus oedicnemus* (Eurasian stone-curlew) are on the brink of extermination (Stastny *et al.*, 2006) [104]. So, birds act as bioindicators where agricultural lands are intensified with unsuitable farming methods (Baldi & Farago, 2007) [9].

**Table 1:** Community organization of different birds in agricultural crops

| Name of the crop | Preparatory tillage | Sowing | Seedling | Ripening |
|---|---|---|---|---|
| 1. Wheat | 19 species belonging to orders Passeriformes, ciconiiformes, accipitriformes, pelecaniformes and coraciformes | 21species belonging to orders Passeriformes, ciconiiformes, accipitriformes, pelecaniformes, columbiformes, upupiformes and coraciformes | 25 species belonging to orders Passeriformes, columbiformes, accipitriformes, ciconiiformes, charadriformes, galliformes, upupiformes and coraciformes | 32 species belonging to orders Passeriformes, columbiformes, accipitriformes, ciconiiformes, charadriformes, galliformes, psittaciformes, upupiformes and coraciformes |
| 2. Mustard | 15 species belonging to orders Passeriformes and columbiformes | 19 species belonging to orders Passeriformes, columbiformes, accipitriformes, galliformes and upupiformes | 19 species belonging to orders Passeriformes, accipitriformes, ciconiiformes and upupiformes | 35 species belonging to orders Passeriformes, columbiformes, accipitriformes, ciconiiformes, charadriformes, galliformes, psittaciformes and upupiformes |
| 3. Winter Maize | species belonging to orders Passeriformes, ciconiiformes and upupiformes | species belonging to orders Passeriformes andupupiformes | species belonging to orders Passeriformes, columbiformes, charadriformes, galliformes, psittaciformes and upupiformes | species belonging to orders Passeriformes, columbiformes, accipitriformes, ciconiiformes, charadriformes and psittaciformes |

**Source:** Kler, 2010 [56]

Existence of birds in agricultural lands is largely dependent on the crop type, landscape composition and structural heterogeneity of crops as well as management practices adopted (Wretenberg *et al.*, 2010) [125]. Less intensive agro-management practices and low stratification provide higher stability and resilience to bird community whereas intensive management practices cause drastic reduction in community richness (Karp *et al.*, 2011) [50]. Either bare lands or diversified farmlands with increased temporal and structural heterogeneity of crops and local vegetation by enhancing ecological niches are found to favour bird community organization (Kremen *et al.*, 2012) [57]. Similar observations were made by Mulwa *et al.* (2012) [73] in agricultural polycultures. Non-crop structures such as hedgerows may also play an important role as habitat during winter in agro-ecosystems. Community organization in temperate agro-ecosystems is additionally affected by seasonal abiotic changes and associated food resources availability (Kelt *et al.*, 2012) [53]. Organic farming can is considered to be favourable for conservation of agricultural biodiversity. Organic farming system by reducing pesticidal poisoning and increasing food abundance in form of weeds, seeds and invertebrates is found to shore-up nearly 30% more species comparable to conventional farming (Tuck *et al*., 2014) [113]. Increased abundance has been recorded during winter in low intense agriculture where diverse annual crops are grown in small farms, small woodlots and orchards in Himalayas and vineyards in Switzerland (Guyot *et al.*, 2017) [42].

## 2.2 Feeding ecology

Dietary habits plays key role in distribution and life history of any organism. Feeding ecology depends upon the food preferences of different species. Data on food preferences may help in management of pest species since the preferred crops can be used as a lure to trim down the damage to other more important crops. Stomach contents of an oriole, downy woodpecker, crow and black-capped chickadee were carefully examined and they were found feeding on agricultural pests such as weevils, beetles, moths, grubs, grasshoppers and small borers (McAtee, 1906) [70]. Seasonal changes affect the prey population and hence the feeding behaviour of egrets forcing them to change their ecosystem towards dry and marshy habitats with the end of rainy season (Elgood, 1979) [31]. *Egretta garzetta* (Cattle Egret), possessing limited nomadic behaviour (Maddock, 1990) [65], are insectivorous which forage, capture, kill and tear any available invertebrate agricultural pests as prey species (orthopterans are the preferred ones) as well as some vertebrates (fishes, frogs and lizards) despite the size of prey with the help of their hard, robust and sharp bill (Sharah, 1998) [100].

An overlap of 95-99% and 85-97% in adults and nestlings respectively was recorded in diet of three coexisting weaverbird species and food preferences of *Ploceus philippinus* (baya weaverbirds) in captivity were investigated by Dhindsa & Toor (1990) [28] in Punjab. While studying feeding ecology of birds, field observations and gut content analysis are important for identifying precise food resources of the species. For example, rice was found to be the principal food in gut content of three weaverbirds *Ploceus* spp. while field observations disclosed that rice grains collected by these birds were either shed or left in stored straw and hence wasted. Little attention has been given on this aspect; feeding ecology may also help in assessing the extent of damage caused by pest birds, for instance, quantity of food ingested by wild or captive birds may assist in calculating damage potential indirectly (Saini & Toor, 1991) [90].

Knowledge on feeding habits of a few common bird species in natural and cultivated lands is quite good. Some information is purely preliminary and qualitative whereas rest of the data is based upon quantitative and methodical studies. Feeding behaviour and gut content analysis of 13 bird species (9 granivorous, 7 omnivorous and 1 insectivorous) of agricultural significance was analyzed on the basis of field observations and captivity experiments (Saini & Dhindsa, 1993) [89]. Agro-ecosystem supplies highly predictable food resources to many bird species in form of seeds, grains, fruits, insects and rodents (Dhindsa & Saini, 1994) [26]. Seasonal variations in food diversity and overlapping diet of some coexisting species have also been estimated to some extent (Saini *et al.*, 1994) [91]. Birds by nature feed upon the substances that are available most abundantly. Diets of most of the granivorous birds is composed of *Avena* and *Triticum* species (cereal grains), *Polygonum* spp., seeds of *Chenopodium* and *Stellaria*, while insectivorous preferably feeds on Arachnida (spiders), Coleoptera (leaf-beetles and weevils), Diptera (craneflies and larvae), Hemiptera (aphids), Hymenoptera (sawfly adults and larvae), Lepidoptera (caterpillars), and Orthoptera (grasshoppers) (Wilson *et al.*, 1999) [123].

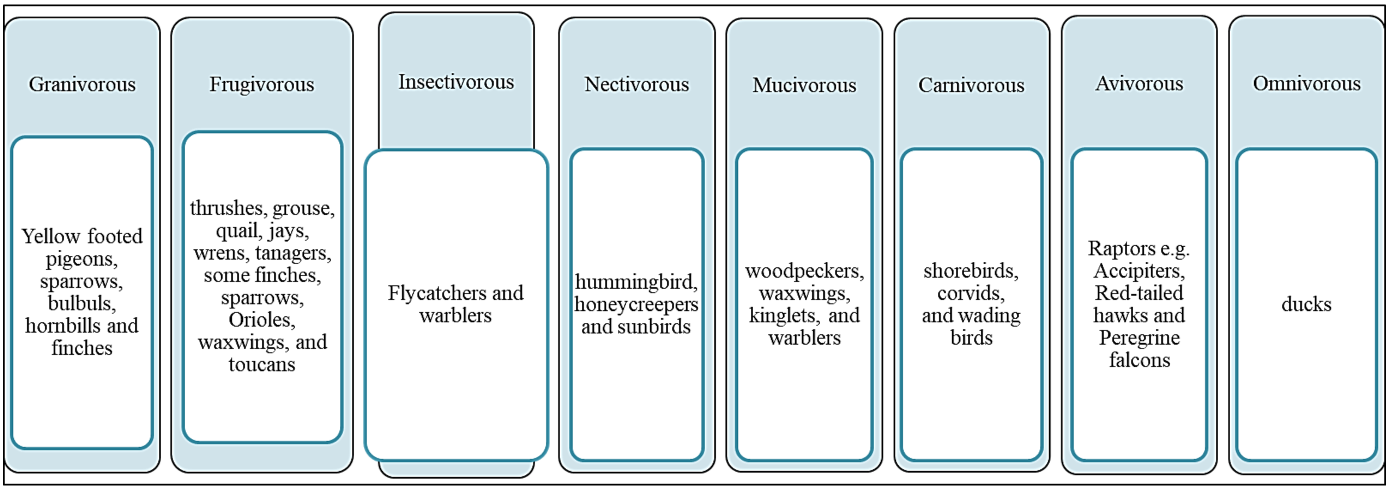



**Fig 1:** Diet type of birds

Some information on feeding behaviour of common myna (*Acridotheres tristis*) reveals that myna is an opportunistic omnivore feeding on both the plant/vegetable matter (grains, seeds, fruits and berries) and animals (Arachnids, Crustatian, Insects, repltile and small mammals) (Crisp & Lill 2006 [22]; Whistler, 2007) [122]. Asokan *et al.* (2009) [5] studied the dietary composition of Small Bee-eater (*Merops orientalis);* White-breasted Kingfisher (*Halcyon smyrnensis)* and Black Drongo (*Dicrurus macrocercus)* and recorded that the diet of the three species includes mainly arthropods (Coleoptera, Hymenoptera, Hemiptera, Orthoptera, Odonata, Lepidoptera and Diptera) and some vertebrates. Birds feeding on insects act as bio-controllers by keeping a check on population of agricultural insect pest species. So, the knowledge about the feeding ecology of bird species is vital to predict the community structure, co-existence, services provided and resource utilization in any habitat (Kaur & Kler, 2018) [51]. Chestnut-tailed Starling is well known as a bio controlling agent was found omnivorous feeding chiefly on insect larvae (Rahman *et al.*, 2019) [83].

**2.3 Roosting ecology**

'Roost' a word derived from German language refers to "A sleeping house of fowls" is a resting (sleeping) period or period of inactivity for winged animals particularly birds/bats (Ward & Zahvi, 1973) [119]. Though, a little is known about roosting of birds, some information on mixed (Gadgil, 1972) [36] and communal (Gadgil & Ali, 1975) [35] roosting is available. The roosting site is considered as the centre of information (about food, predator or enemy) gathered by one bird is passed on to the rest of members of the group. Roosting sites can be located and identified either by direct methods involves walking along study sites during early morning or evening hours or by indirect methods such as searching droppings below trees. A huge diversity can be observed at roosting sites selected on the basis of species-specific preference for a particular habitat, safety and availability of food and water resources (Buttemer, 1985) [17]. Some birds can be seen roosting on tree branches or in vines/shrubs while others in tree cavities. Community roosting can be seen when large flocks of birds roost together in trees with hundreds in number, for instance, in densely populated cities, common birds such as house sparrows, house crows and starlings roost communally in large numbers. Roosting habits also varies seasonally in some species like male red-winged blackbirds roost alone but during breeding season roost together for rest of the time of year. Physical features (structure) of a tree are important attributes for selection of roosting site (Trivedi, 1993) [112]. The notable factor was avoidance from road side rather than food and water availability at roosting sites by the peafowls of Gir National Park was (Trivedi & Johansingh, 1996) [111]. Geographical distribution of prey also contributes to roost site selection (Ward *et al.*, 1998) [118]. Generally, dense vegetation with good canopy and height is preferred for roosting (Thompson, 2003) [106].

A roosting place may be solitary or communal; temporary or permanent. Site selection and roosting behaviour are vital in determining individual fitness with respect to energy stores and predator dodging (Fisher *et al.*, 2004) [32]. Importance of roosting sites has been described as centre for diurnal activities and resting place for night by Gordo (2006) [38] while studying roosting behaviour of *Hirundo rustica* (Barn Swallows). Many ground birds like quails and pheasants roosts in trees. A few parrots of the genus *Loriculus* roosts hanging upside down while some birds sleep even during flight (Rattenborg, 2006) [85]. Geese prefer collective roosting near water bodies far away from forest sites so as to minimize predation risk and thermoregulation demands as well as to maximize the foraging efficiency to increase their survival and fitness during migration (Si *et al.*, 2011) [101]. Investigation has on roosting ecology of common myna, *A. tristis* (Sengupta, 1973) [99]; rosy pastor, *Sturnus roseus* (Mahabal & Bastawade, 1980) [66]; weaverbirds, *Ploceus* spp. (Dhindsa & Toor, 1981) [29]; pariah kite, *Milvus migrans* (Mahabal & Bastawade, 1984) [67]; bank myna, *Acridotheres ginginianus* (Khera & Kalsi, 1986) [54] and rose-necked parakeet, *Psittacula krameri* (Prajapati & Prajapati, 2012) [79] revealed that roosting time varies with activity period of birds as diurnal birds roost at night whereas nocturnal rest during daytime (Jayson, 2018) [45].

**2.4 Breeding biology**

Breeding biology of birds has engrossed the keenest interest of ornithologists. Initially, studies on breeding behavior of the birds were found in the natural history notes. Perhaps, earliest detailed picture of breeding of baya- weaverbird was presented by Ali (1931) [1] succeeded by Crook (1963) [24]. A great work was done by Baker (1930-1935) [8] on nest building of Indian birds. Breeding in *Corvus splendens* (house crow) and brood parasitism by *Eudynamys scolopacea* (koel) were recorded by Lamba (1976) [60]. Knowledge on breeding of *Passer domesticus* (house sparrow) is available from Punjab (Simwat, 1977) [102], Andhra Pradesh (Kumudanathan *et al.*, 1983) [58], Gujarat (Mathew & Naik, 1986) [69] and Rajasthan (Rana & Idris, 1989) [84]. Being a hole nesting species, much detail is not available on breeding biology of *Psittacula krameri* (ring-necked parakeet). Breeding of some other birds of agricultural importance including babblers, bulbuls, doves, mynas, etc. has been studied in detail. Several aspects of breeding ecology such as site selection for nest, nest building behaviour, clutch size, mortality factors, brood parasitism and reproductive biology of baya-weaverbird and of three other species of weaverbirds have also been described (Dhindsa & Toor, 1994) [27]. Despite having fair enough information on breeding of many of common bird species, experimental studies are so far lacking regarding impact of a variety of factors on their reproductive success (Dhindsa & Saini, 1994) [26]. Farmlands always have been the prominent habitat for birds, nowadays, due to intensified agricultural practices that include excessive agrochemical and pesticide use the breeding populations of species have been declining at alarming rate (Fig 2) with major effect on some specialized ones over most of Europe, more evidently in Central and Western Europe (Chiverton, 1999) [20].

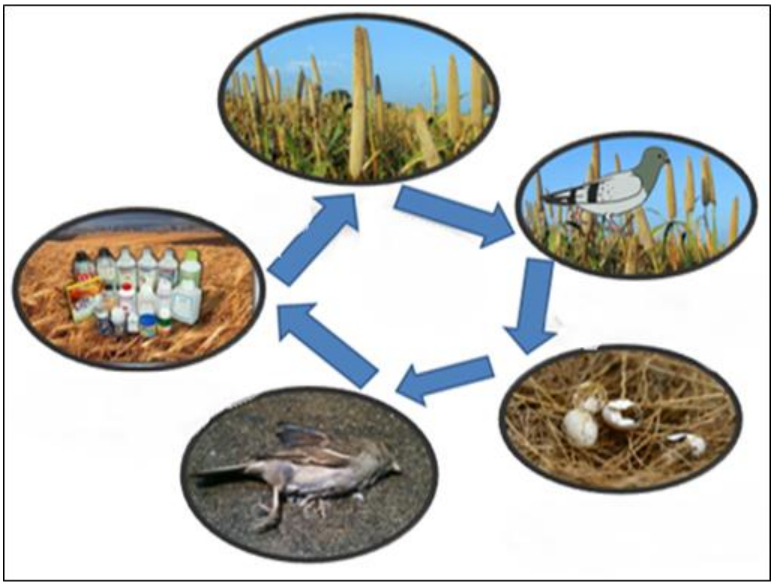


**Fig 2:** Effect of pesticides on the life cycle and reproductive success of birds

Large fields with fast growing and dense vegetation become unprofitable or unreachable for ground feeding species which leads to increased expenditure of time and energy in exploiting alternative source of food. As a result, species breeding in such farmlands with reduced habitat, food resources and structural diversity suffer from poor body conditions of broods as well as parent birds, lower survival and abridged breeding success (Schifferli *et al.,* 1999) [93]. Some species, presently, are suspected to be "sink" populations in modern farmland habitats due to their failure to produce and maintain sufficient numbers (Schifferli, 2001) [94].

## 3. Economic perspective of agricultural ornithology

Information related to ecological aspects of some of the common bird species has made it possible to comment on their economic status in agriculture. Avian fauna plays dual role as friends as well as foes in agriculture. Insectivorous and predatory birds are well known bio control agents as they keep a check on pests of agriculture. However, passerine species are considered harmful to agriculture. Pros and cons of avian fauna in relation to agriculture are phrased below in brief.

### 3.1 Beneficial roles of birds

Apart from predatory role in pest control, birds provide several other ecosystem services including scavenging, pollination of horticultural crops and seed dispersal.

#### 3.1.1 Pest control

A pest can be defined as a species that can wreak considerable harm to man or any valuable ecosystem resource due to its number and behaviour or feeding habits. Insects are the major ones among various categories of pests which cause substantial economic damage to agricultural resources especially in absence of any effective control measure. Approximately 70,000 pest species are estimated to attack agricultural farms worldwide. Biological control is gaining importance now a days as pest species are becoming resistant to pesticides day by day and use of chemical has to be restricted because of their residual effects on human and animal health. Evidences for this are available from use of falconry to reduce bird damage in horticulture and that of raptors to drive away pest bird species. *Corvus splendens* (House crow) has been found feeding on carrion, offal, dead sewer rat, locusts, termites, crabs (extremely destructive to paddy) etc. by several investigators. Crow pheasants feed largely on softer parts of *Achatina fulica* (Garden snail). Various species such as *Bubulcus ibis, Merops philippinus, Merops orientalis, Acridotheris tristris, Centropus sinensis, Acridotheris ginginianus, Corvus splendens, Dendrocitta vegabunda* and *Pycnonotus cafer* were found feeding on Grasshoper. Magpie robin, Black drongo and Jungle babbler was recorded as controlling agent of moths and butterflies' species. Aphids were controlled by *Motacilla maderaspatensis* (Large-pied wagtail). Most destructive pests, mice and rats are eaten by Owl, Jungle crow and Housecrow (Regmi, 2003) [86]. Besides the well-known fact that predatory and insectivorous birds are key components in controlling rodent and insect pests of agriculture, very few efforts have been done to assess their role. Some evidential information is available only about the insectivorous birds. Predators of *Mus musculus* (house mouse) are recorded to eat same number of mice irrespective of their population density as they get satiated once consumed up to certain level. However, behavioural modification of pests such as limited movement and feeding activities and increased surveillance to cope up with exposure to predation may reduce their effects on agriculture (Brown & Kotler, 2004) [16]. Predatory and insectivorous birds play vital role in natural pest control over invertebrate and several vertebrate pest species in agricultural landscapes and may lead to an increase in agricultural yield (Preisser *et al.*, 2005) [81]. Perhaps, it is the most widely documented service offered by birds in agriculture (Table 1).

Impact of birds on invertebrate population control is stronger during breeding season of birds because the energy-rich diet is on high demand to meet the energy requirements of breeding and feeding. Many of the grainivorous and omnivorous species turn out to be extremely insectivorous during their breeding times to boost the reproductive efficiency and nestling's growth (Jones *et al.*, 2005) [47] which increase the availability of birds to control pests. In addition to insectivores, predatory birds help in reducing impacts of vertebrate pests via direct predation, behaviour modification and scaring (Sekercioglu, 2006) [97].

**Table 2:** Recorded observations to assess the benefits (invertebrate and vertebrate pest control) of birds in agricultural landscapes

| Crop type | Avian species | Benefits | Source |
|---|---|---|---|
| Apple | Mainly great tit, blue tit, marsh tit, willow tit and Pine siskin | Codling moth larvae density reduced upto 94-95%. Winter moth larval population also reduced. Increase in fruit yield from 4.7 to 7.8 kg per tree. | Solomon *et al.*,1976 [103]; Mols and Visser, 2007 [72] |
| Corn | Red-winged Blackbird (A. phoeniceus) | Predatory to northern corn rootworm, cutworms and weevils. Less significant reduction in population of aphids and European corn borer | Bollinger & Caslick, 1985 [13]; Tremblay *et al.*, 2001 [110] |
| Field beans | House crow, house sparrow, golden oriole, black drongo, common mynah and some other insectivorous birds | Control of pod borer of field beans as the seed yield was found positively correlated with species richness of birds | Chakravarthy, 1988 [19] |
| Soybean | Raptors | Reduction in density and growth rate of house mouse populations due to increased pressure for hunting as a result of artificial perches placed for raptors | Kay *et al.*,1994 [52] |
| Coffee | Various birds | Large arthropods reduced by 64-80%. Increased damage reported in absence of birds Abundance of insects (principally the Flatid plant hopper, *Metcalfa pruinosa)* negatively correlated to birds' presence. Coffee berry borers infestation reduced in presence of birds that led to increase in quantity of saleable fruits | Greenberg *et al.*, 2000 [39]; Perfecto *et al.*, 2004 [78]; Borkhataria *et al.*, 2006 [14] |

### 3.1.2 Pollination
Pollination is a vital service for humanity. Out of 115 worldwide important agricultural crops, 87 (35%) crop species are reported to be benefitted significantly by wild pollinators (Klein *et al.*, 2007) [55]. Although not so prevalent anciently, avian pollination (ornithophily) occurred in several regions of world. It is comparatively lacking in North Africa and Europe (Ford, 1985) [34]. Detailed evidences related to avian pollination in agricultural crops are lacking but are evident to some extent in case of horticultural crops. Birds may confer some benefits over other pollinators especially during unpredictable climate changes and flowering seasons and also for the crops that flower in winters as they can function actively over a wider array of temperatures as compared to insects (Ford, 1985) [34]. Sometimes, role of birds in pollination is seen underestimated as in a study, honeybees were reported as pollen thieves while birds were much more effective pollinators for pineapple and guava (Stewart & Craig, 1989) [105]. Out of a total of 1,330 crops investigated by Roubik (1995) [87], 52 (4%) were found to be pollinated by birds. Pineapple (*Ananas comosus*) and pineapple guava *(Feijoa sellowiana)* are examples of birds' pollinated crops (Westerkamp & Gottsberger, 2000) [120]. Now days, however, avian pollination can be seen as an emerging field for ornithologists as evolutionary shifts to ornithophily have been observed in many lineages of the flowering plants. Hummingbirds in continental United States, honeycreepers in Hawaii and honeyeaters in Australia are key species for pollination in wildflowers. Many of the floral features are affected by this especially those that are responsible for avian attraction and deterrence of illegitimate visitors of flowers (e.g. bees) (Cronk & Alayon, 2008) [23]. Birds are beneficial as pollinators for the plants that are separated by larger distances. Nectarivorous birds have a propensity to acclimatize their foraging behaviour more quickly than insects (Luck & Spooner, 2012) [63].

### 3.1.3 Scavenging
Scavenging birds may often be wronged as harmful to livestock instead they perform an imperative service of carcass removal. They also help in suppressing undesirable scavengers such as rats and feral dogs (Prakash *et al.*, 2003) [80]. Larger birds that rely entirely on carrion feeding and have ability to search larger areas, e.g. vultures, are good scavengers (Ruxton & Houston, 2004) [88]. Old world (Falconiformes) and New World (Ciconiiformes) vultures are obligatory scavengers while many other bird species such as herons (Ardeidae), skuas (Stercorariidae), rails (Rallidae), willet and turnstones (Scolopacidae), plovers (Charadriidae), gulls (Laridae), woodpeckers (Picidae), raptors (Accipitridae) and some passerines are facultative scavengers (Selva & Fortuna, 2007) [98]. These facultative scavengers unlike vultures cannot kill the pathogens and may cause spreading of infectious diseases. Previously, scavenging avifauna was thought to spread diseases but because of their carcass (provides breeding ground for various disease-causing agents like canine distemper virus, canine parvovirus, *Leptospira* spp., etc.) removal service, these species actually lessen the risk of disease outbreaks to humans and livestock (Markandya *et al.*, 2008) [68]. Vultures possess the ability to consume and detoxify bacterial toxins present in decomposing flesh which limits the spread of bacteria. Highly acidic environment of vulture stomach can kill even the spores that are found to be most resistant. Vultures are thought to be more important in developing countries where sanitary facilities and programs are limited. In Spain alone, the scavenging service provided by vultures benefitted annual savings of approximately €1million. Sadly, vulture populations have declined almost to extinction. In India, populations of vultures crashed in 1990s when these species got poisoned by drug diclofenac present in carcasses of livestock. Disappearance of vultures caused an increase in number of potential disease vectors like rats and feral dogs that led to increased cases of rabies and possibly the bubonic plague outbreak of 1994 in western India (Sekercioglu, 2017) [95].

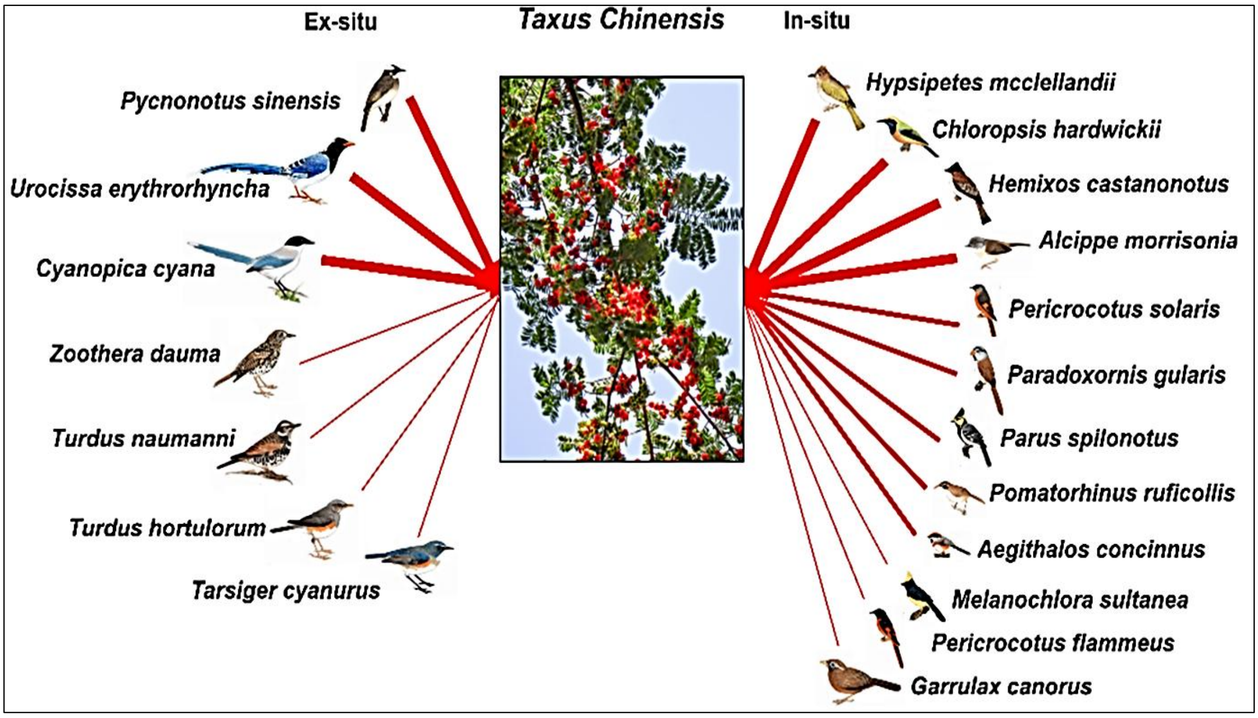
### 3.1.4 Seed dispersal
Seed dispersal facilitates germination of seeds, a key process in natural ecosystems and restoration of degraded systems is yet another vital service provided by birds but less emphasized. Seed dispersal by birds can assist gene flow among restored vegetation, remnant and scattered trees; escape from regions with high mortality and dispersal to favourable sites (Harms *et al.*, 2000) [43]. Importance of birds in seed dispersal can be seen in their absence. For instance, seed dispersal failure has been suspected in South Pacific

Island and New Zealand due to absence of frugivorous birds especially in case of large seeded plants (Meehan *et al.,* 2002) [71]. Birds can disperse seeds via various mechanisms, most common being endozoochory in which the birds consume fleshy fruits and defecate or regurgitate the seed(s). Endozoochory is beneficial in case of seeds that cannot germinate out of an intact fruit but are germinated after removal of fruit skin from seeds during plant-avian interaction (Samuels & Levey, 2005) [92]. Another mechanism for seed dispersal is synzoochory in which birds cache the seeds, mostly the pines (*Pinus* spp.) and the oaks (*Quercus* spp.) observed in northern temperate regions. Less often mechanism of seed dispersal accomplished by birds is epizoochory, i.e., by adhesion to feathers, legs or bill (Whelan *et al.*, 2008) [121]. Seed dispersal services by birds are yet to be quantified. However, economic benefits of seed dispersal aided by *Garrulus glandarius* (Eurasian jays) to oak forests in National Urban Park (Stockholm, Sweden) were estimated by Hougner *et al.* (2006) [44]. Birds being able to travel across long distances can be considered as mobile links between habitats particularly in extremely fragmented agricultural lands (Breitbach *et al.,* 2010) [15].

Seed dispersal by birds has been reported in about 92% of tree and woody species with 85 timber species, 153 medicinal species, 182 edible genera, 84 genera of cultural or economic values and 146 ornamental plants in some tropical regions. Some species like *African mahoganies* belonging to Meliaceae depend on some particular avian dispersers. Absence of large frugivores (curassows and hornbills) is economically unfavourable; many timber species have large seeds which can be dispersed only by large birds (Sekercioglu, 2017) [95].

**Table 3:** A few examples of seed dispersal by birds

| S. No. | Name of bird species | Seed dispersal in crops | Source |
|---|---|---|---|
| 1. | Black-rumped Flameback (*Dinopium bengalense*) | *Lannea coromandelica* fruits | David *et al.,* 2015 [25] |
| 2. | Palebilled Flower-pecker (*Dicaeum erythrorhynchos*) | Loranthus (*Dendrophthoe falcate*) fruits | David *et al.,* 2015 [25] |
| 3. | *Pycnonotus sinensis, Urocissa erythroryncha, Cyanopica cyanus, Chloropsis hardwickii, Hemixos castanonotus* and *Hypsipetes mcclellandii* | *Taxus chinensis* | Li *et al.,* 2019 [61] |




**Source:** Li *et al.*, 2019 [61]

**Fig 3:** Seed dispersal by various bird species in *Taxus sinensis*

As per Diana Tomback (University of Colourado, Denver) estimated cost for replacing seed dispersal in white bark pine by Clark's Nutcrackers was $1,980-$2,405 per hectare and $11.4-$13.9 billion across whole U.S. (Sekercioglu, 2017) [95].

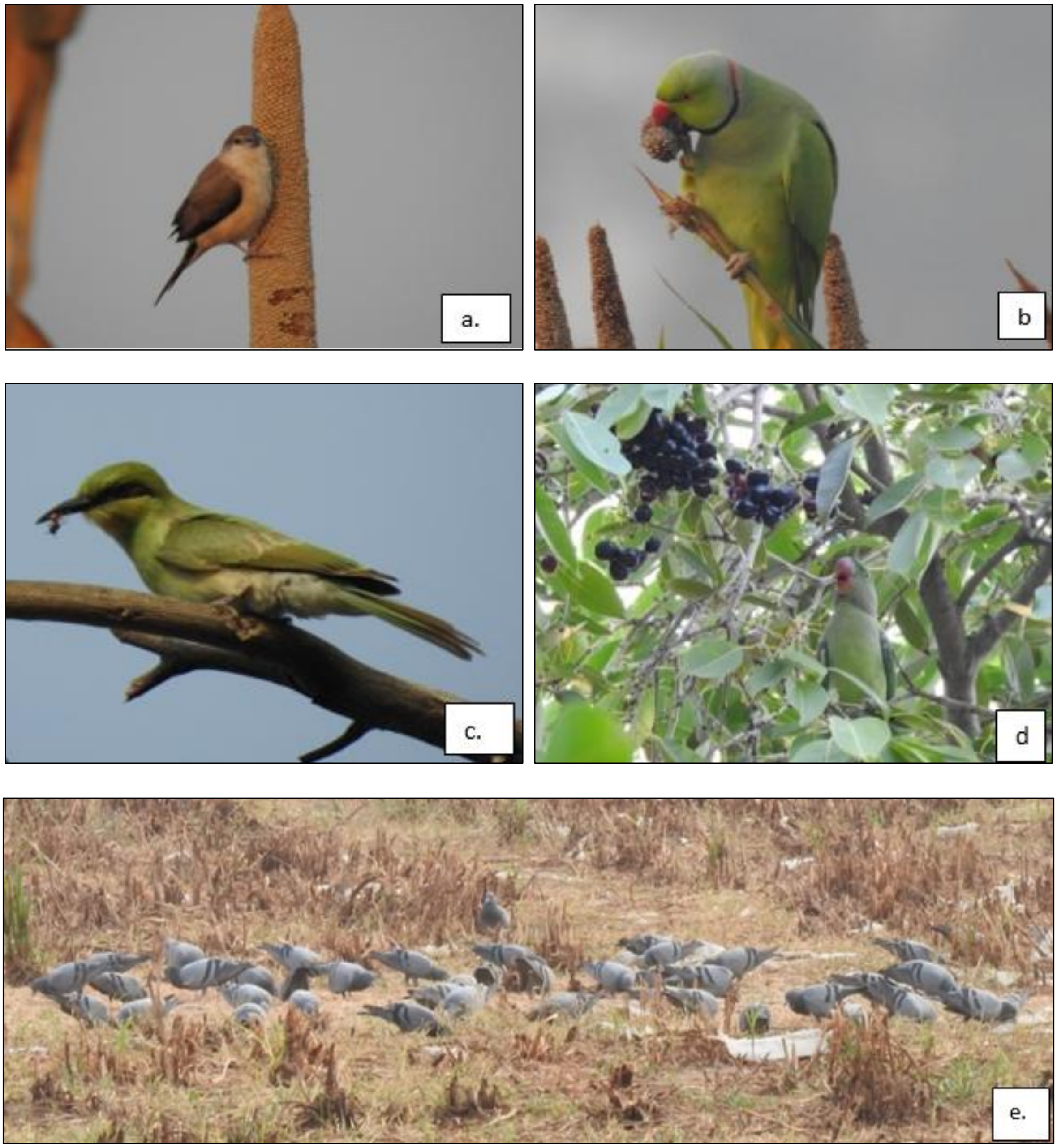



**Fig 5.** *a. Euodice malabarica* foraging in *Pennisetum glaucum* field., *b. Psittacula krameri* foraging in *Pennisetum glaucum* field. *c. Psittacula krameri* foraging in *Syzygium cumini* orchard., *d. Merops orientalis* eating insect., *Columba livia* flock feeding on grains.
©priyadahiya, 2018-2020 Hisar region.

### 3.2 Damage potential

It is quite interesting to note that only around 2% (05 out of 1000) of avian species in India have been found inflicting damage to horticultural and agricultural crops. Damage potential of several species to various crops has been estimated by a number of investigators in different parts of the world. Damage is primarily caused directly via removal or chewing of plant stems, shoots, buds, foliage, fruits and seeds (Table 2). Most of the damage is inflicted to annual or perennial crops and loss is experienced by the growers in case they have to change either the type of crop (e.g. bird resistant sorghum instead of corn) or growing practices (e.g. early harvesting) to reduce impact of birds. Other means of damage by birds to agriculture may include infrastructure damage such as chewing of the irrigation pipes (Barnea & Yom-Tov, 1984) [10] or disease transmission to crops and livestock (e.g. thread blight in forest trees) (Kusunoki *et al.*, 1997) [59]. Loss to crops varies temporally and spatially depending on the crop type, phenology and location and also on the behaviour and population dynamics of birds. Pattern of damage also varies from highest at the edges to decreasing directly with distance moving into interior of the field (Fleming *et al.*, 2002) [33]. For instance, highest damage (buds removed up to nearly 80%) at the periphery while negligible towards the centre of the pear orchards was inflicted by bullfinch (*Pyrrhula pyrrhula*), a flower-bud feeding species. Birds usually forage in the centre either when the resources at margin are depleted completely or when birds descend on fields in flocks (Fleming *et al.*, 2002) [33]. Characteristics that influence the susceptibility to damage may include plant vigour, crop age, crop height, foliage thickness and size, variety, hardness, ripeness, pulpiness, colour, texture, nutrient contents of fruits or grains (Avery, 2002) [7]. Seasonal availability of food in broader environments is also thought to influence damage potential.

Raptors may also inflict damage to agriculture by preying on livestock (Winkel, 2007) [124]. Area of foraging in fields also depends on field layout, habitat affinity, surrounding landscapes, predation risk, roosting and breeding sites, food availability, food gathering economics, and food preferences (Puckett *et al.*, 2009) [82].

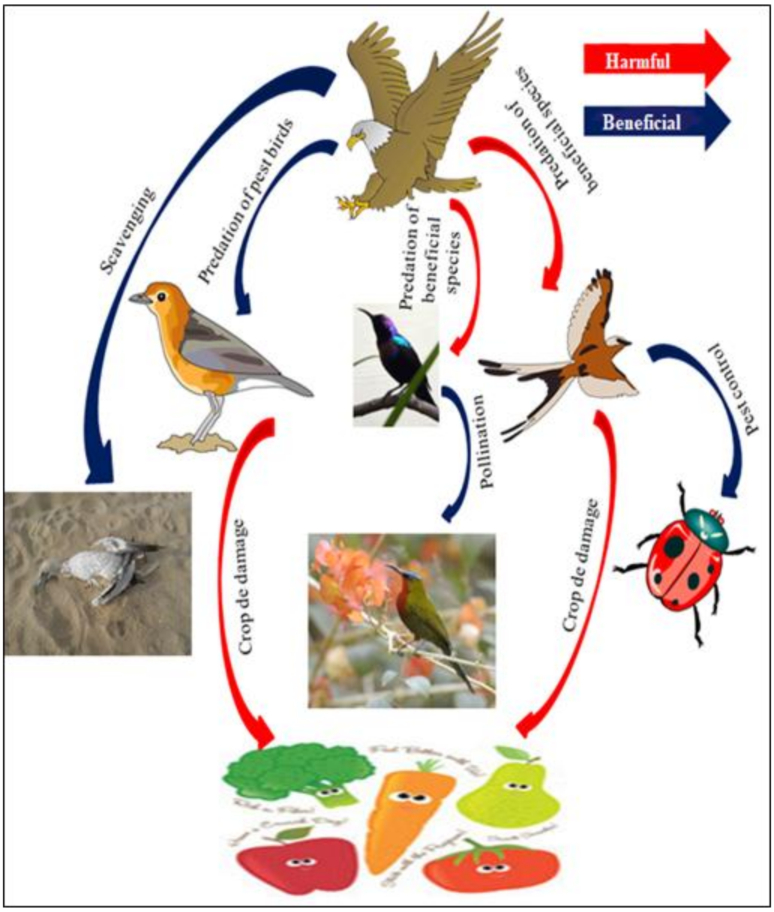



**Fig 4:** Services provided by birds in agroecosystems

**Table 4:** Observations to estimate the damage inflicted by birds in agricultural landscapes

| Crop type | Avian species | Damage estimation | Source |
|---|---|---|---|
| Cherry | European starling, American robin, Common grackle | >50% tart cherries and >45% sweet cherries damaged | Guarino *et al.*, 1974 [41] |
| Fruit orchards | Various | US$34,378 in Pennsylvania (estimated via cost of control measures) | Anthony & Fisher, 1977 [4] |
| Sunflower, sorghum, wheat/barley | Galah, Sulphur-crested cockatoo | Average loss of AUD$28 to $354 per season | Noske, 1980 [74] |
| Apple, pear, plum, peach, nectarine, apricot | Western rosella, Red-capped parrot, White-tailed black Cockatoo, Port Lincoln parrot | Estimated damage of AUD$100-$600/ farm | Long, 1985 [62] |
| Corn | Common grackle, Red-winged blackbird | 22% reduction in yield | Besser & Brady, 1986 [12] |
| Grain store | Ring Doves, Sparrows and Weaver birds | consumed 4074 kg of rice in five months Besides this direct loss of grains, these birds damaged gunny bags, spoiled the site and contaminated grains with their droppings | Toor *et al.*, 1986 [107] |
| Grapefruit | Great-tailed grackle | Average loss of US$295 ±71.5/ha | Johnson *et al.*, 1989 [46] |
| Maize, pulses, lentil, gram | Blue-rock Pigeon | 15 kg/day sprouting pulses, 18 kg/day sprouting maize, 18 kg/day maturing lentil and 01 kg/day maturing gram consumed by a flock of around 1000 pigeons | Saini & Toor, 1991 [90] |
| Blueberry | Cedar waxwing | 17-75% damage reported | Avery *et al.*, 1992 [6] |
| Pistachio nut | American crow, Scrub jay | 18-99% damage to trees | Crabb *et al.*, 1994 [21] |
| Rice and sorghum | Dickcissel | Average crop loss up to 25% in 92 farms | Basili & Temple, 1999 [11] |
| Sunflower | Blackbirds, American goldfinch, House finch | Average loss of US$18/acre to 0-5% of fields. | Peer *et al.*, 2003 [77] |

| | | | |
|---|---|---|---|
| Grape | Various including European starling, House finch | 2±1.1% out of 140 blocks worth US$0.75 million damaged | Tracey & Saunders, 2003 [109] |
| Millet | Black-cheeked lovebird | Approximately 19% damage to seed heads in 18% of the crop had | Warburton & Perrin, 2006 [117] |
| Groundnut, pearl millet, peas, sorghum and sunflower | Sparrows, baya weavers, rose-ringed parakeets and blue rock pigeons | 52% damage in sorghum, 42% damage in groundnut crop and 26% damage in the peas crop (chick peas and pigeon peas) estimated in Pune, Akola and Amravati | Kale *et al.*, 2014 [49] |
| Horticultural crops | Various species | $300 million loss estimated | Tracey *et al.*, 2015 [108] |
| Corn crops | Various species | 9.4% damage of the total production of 24 corn crops was estimated in Mexico | Can-Hernández *et al.*, 2019 [18] |

**Table 5:** Observations recorded on damage studied under AICRP on economic ornithology

| Crop type | Species reported | Study site | % Damage |
|---|---|---|---|
| Bajra | Rose-ringed parakeet<br>House sparrow<br>Indian baya<br>Munias | IARI, New Delhi | 75% |
| | | APAU, Hyderabad | 5.02%-9.75% |
| | | GAU, Anand | 0.90%-5.72% |
| Sorghum | Rose-ringed parakeet<br>House sparrow<br>Indian baya<br>Munias | Andhra Pradesh | 0.0%-8.10% |
| | | Gujarat | 7.90%-18.60% |
| | | Raj asthan | 7.08%-19.68% |
| Wheat | Dove<br>Pigeon<br>Rose-ringed parakeet<br>House sparrow<br>Indian baya | PAU, Ludhiana | 0.15%-1.5% |
| Maize | Rose-ringed parakeet<br>House crow | PAU, Ludhiana | 1.37%-20.73% |
| | | Rajasthan | 0.0%-19.5% |
| Sunflower | Rose-ringed parakeet | PAU, Ludhiana | 6.6%-60.4% |
| Paddy | Rose-ringed parakeet<br>House sparrow<br>Indian baya | PAU, Ludhiana | 0.15%-1.5% |

**Source:** Annual report, All India Coordinated Research Project on Economic Ornithology (1988) [3]

## 4. Management practices

It is hardly possible to quantify the costs and benefits of bird activities in agriculture, it is likely to reduce their damage potential and increase the chances ecosystem services provided by these fascinating creatures. Thus, there is a need for sustainable management approaches to manage cost-benefit tradeoffs based on the available understanding of interactions between species and agricultural ecosystems.

### 4.1 Conservation of beneficial species

Despite global awareness for conservation of species and their ecological importance, a little has been done to protect the threatened or endangered avifauna in intensively cultivated lands. While examining the status and distribution of various endemic passerine bird species in areas of India and Pakistan, Gaston (1984) [37] suggested that these species may befall to extinction in the areas where habitats are destructed extensively. Agricultural farms in India perhaps are experiencing the most indiscriminate and heavy doses of herbicides and pesticides which lead to high mortality of frugivorous and predatory species. Abundance of birds of prey has been declined significantly due to food chain poisoning and habitat destruction. Populations of Sarus crane were found dwindling in India because of agricultural expansion (Parasharya *et al.*, 1988) [76]. Woody habitats are often found supporting the highest abundance and species richness of birds in agricultural landscaped (Jones *et al.*, 2005) [47]. There is hardly any information available on residue analysis in birds found in agricultural habitats. Enhancing the benefits cost effectively may be possible by encouraging the species with some particular beneficial behavioural or functional trait. It would be an aim to agriculture managing system to enhance species with particular beneficial functional traits. Benefits of promoting desirable trait specific species were confirmed when intercropping sunflower in organic vegetable crops was observed to increase the number and foraging activity of the insectivorous bird species that consumed pest species without inflicting any damage to crops (Jones & Sieving 2006) [48]. Thus, such management plans that favour one dietary component over other (e.g. supporting habitat provided for insectivores in previously cited study) can benefit sustainable agricultural productivity. Other approaches may include targeted control of damage inflicting or pest species by habitat manipulation instead of unsystematic control techniques which may affect the whole community like scaring devices, reducing agricultural intensification, providing resources to advantageous species and promoting diversity. Increase in agricultural species diversity may promote the species responsible for pollination whereas agricultural uniformity and intensification conversely may enhance damage indirectly by reducing avian species that could keep a check on agricultural pests (Vandermeer *et al.*, 2010) [115].

### 4.2 Control of pest species

Both the lethal (shooting and trapping) and non-lethal (scaring, falconry, exclusion from the crop, adjusting planting times and crop cultivars, chemical repellents, blocking pest bird access to farm buildings) methods have been tried to control various birds in distinct regions across the nation. Among all, killing is thought to be the most certain means of getting rid of pest birds but the public opinion and legal proceedings have swayed against it. Moreover, lethal methods of bird control are not always able to solve the problem as it is evident from the results observed of mass killing efforts in Africa against queleas and starlings in Europe. However, in some situations, farmers strictly need to shoot a few birds so as to scare the others which are very costly due to high labor requirements. Non-lethal methods of control are therefore in need of special research investigations and attention. Some traps instead can be made easily to trap crows or other birds. Nest destruction and fumigation of the nest holes to reduce populations of pest birds are another preventive measure against damage but is labor intensive. Some studies have been carried out related to chemical and physical repellents of birds in germinating or maturing crops. A management plan suitable to fields and neighboring lands should be prepared long before the arrival of pest birds as it becomes harder to discourage them once they start eating the crop. Such plan may include several kinds of deterrents and scouting about the presence and damage caused by birds. Scouting in early morning and around dusk may provide a fair indication of birds' abundance as it is the time during which birds are most active. This can provide the valuable information about the type, pattern and extent of damage caused by species based on which adaptive management strategies may be planned in much better way.

**5. Problems, lacunae and future prospects**

Ornithology, especially agricultural and economic ornithology, has always been and still is an area of low priority in the field of research, particularly in India. The major problem faced by ornithologists is lack of financial aid. There was no funding available in the related field until about mid-1960s. However, some local projects were funded by state governments and ICAR in Punjab and Andhra Pradesh. All India Coordinated Research Project on Agricultural Ornithology has been continuously run by ICAR since 1983 but at lowest priority in terms of allocation of funds. Secondly, dearth of scientists in concerned field of research is yet another problem. However, the situation in the past few years is not as worst as was previously since the number of researcher preferring this field still very low but increasing slowly as compared to other areas in Zoology. The problems may be because of scanty job opportunities available in these fields and also because applied research is considered to be less prestigious and less attractive in academic circle. The first problem can be solved by appreciating the importance of avian species in agriculture by funding agencies as birds are an important part of agro-ecosystems and necessary in balanced numbers in cultivated lands for sustainable agricultural production. In order to keep them existing, research and funds in this field are required necessarily. The ease of availability of funds would certainly enhance the job opportunities and may solve the second problem to some extent. However, only the self-realization about the importance of applied research by ornithologists can eliminate this problem for which interaction among ornithologists doing applied and basic research is must to put together the theory and practice. There have been many challenges faced by economic and agricultural ornithologists in India and many more are to be faced to combat with which future research aimed at meeting such challenges is must. The foremost challenge in agricultural field is the management of the most injurious pest species, rose- necked parakeet. Despite having enough data on costs and benefits of several common species of agricultural importance from some parts of the nation, such data is lacking from most of the regions of the country, even from Haryana, Karnataka, Uttar Pradesh, etc. which are states of intensive cultivation. Therefore, stress should be given on survey regarding bird problems from different agriculture practicing regions and on surfacing the cost-effective strategies based on integrated approach for control of this species. These surveys may specify the most crucial regions in agricultural ornithology research which require intensive research. Information related to bird problems in agricultural areas such as bee keeping, fish and dairy farming is almost negligible and hence requires intensive research approach. Furthermore, studies are also essential on conservation and ecology of birds of prey, populations of whom are declining in cultivated lands. Indiscriminate and heavy use of herbicides and pesticides in agricultural regions must have contaminated the birds with their residues and the birds of prey present at top of the food chain are most probable victims of such contamination. An important query or issue for future research in concerned field is whether the benefits obtained from conserving birds and habitats within agricultural lands can outweigh the costs arisen due to support to pest birds that also become liable of using these habitats.

**6. Conclusions**

Science of birds with respect to agriculture and their management in agro-ecosystems is known as agricultural ornithology, a narrower axiom than economic ornithology. An ornithologist must be neutral and only after assessing positive and negative impacts of bird species on agriculture, the species must be concluded as beneficial, harmful or neutral. Many of the common species are on the verge of extinction because of the excessive use of agrochemicals. Harmful pesticides must be banned and there should be safer and judicious use of these chemicals under tolerable concentration. Bio pesticides might be the best alternative to the lethal pesticides. Agro-ecosystems are dominated by the insectivorous birds followed by omnivorous and granivorous birds. Field observations along with gut content analysis are important to study the feeding ecology of birds. Roosting time varies with activity pattern of birds. Nocturnal birds roost at the places during day time while diurnal birds which are more active during day time roost at night. Roosting place is the epicenter to gather information regarding food, predator or enemy. The same information gathered by one bird is passed on to the rest of members of group/ community. Birds have many other roles in ecosystem like pest control, scavenging, pollinators for horticultural crops and seed dispersal. Birds cause damage to plants by removal or chewing of plant stems, shoots, buds, foliage and fruits. To reduce impact of birds, farmers have to change either the type of crop (e.g. bird resistant sorghum instead of corn) or growing practices (e.g. early harvesting).

**7. Acknowledgement**

The authors are highly grateful for the kind support and scientific atmosphere provided by the Department of Zoology & Aquaculture, COBS&H, CCSHAU, Hisar. We are also thankful to CSIR, New Delhi for financial assistance.

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