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Natural regulation of white grub (*Holotrichia* sp: Scarabidae) by birds in agroecosystem

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Abstract. The white grub (*Holotrichia* sp: Scarabidae) is an important subterranean pest damaging root systems of several crops. Experiments conducted during I985 and I986 showed that at least I4 species of birds picked up the grubs exposed during ploughing operation. The important bird predators were mynas *Acridotheres tristis* (Linnaeus) and *Acridotheres ginginianus* (Latham), crows *Corvus splendens* (Vieillot), *Corvus macrorhynchos* (Sykes), drongo *Dicrurus adsimilis* (Hodgson) and cattle egret *Bubulcus ibis.* The birds were found to reduce 45 to 65% grub population during 3 subsequent ploughings. The plant stand of second crop raised in bird exposed field was higher in experimental plot compared to the control. The number of birds attracted to the plough was not consistent with the density of grubs exposed but oh many extraneous factors. Factors affecting the extent of bird predation were presence of insectivorous birds in the surroundings, proximity to their breeding sites and timing of ploughing. White grub control by birds is economically cheaper and environmentally safe compared to the chemical control.

Keywords. Natural regulation; bird predation; white grub; insectivorous birds; agro-ecosystem.

1. Introduction

White grub (*Holotrichia* sp: Scarabidae) are noxious subterranean pests damaging root system of several crops. Its infestation is severe during the kharif season (south-west monsoon, June to October) causing serious damages to groundnut *Arachis hypogaea* Linnaeus, pearl millet *Pennisetum typhoides* Linnaeus, sorghum *Sorghum vulgare* Linnaeus, maize *Zea mays* Linnaeus and sesamum *Sesamum orientale* Linnaeus (Desai and Patel 1965; Patel *et al* 1967). The species of white grubs involved are *Holotrichia consanguinea* Blanchard, *H. serrata* Fabricious, *H. fregei* Mittel and *Autoserica nathani* Frey. *H. consanguinea* is the most abundantly found species during August–September. Major damage to the crop occurs during this period, since chemical control of the grubs is ineffective. According to the severity of the infestation, the crop is either harvested early or uprooted for the second crop.

As the field is prepared using traditional bullock driven plough, a large number of birds follow it and pick up white grubs and other insects which are exposed (Yadava *et al* 1971). Although birds are reported to feed on white grubs (Kalra and Kulshreshtra 1961; Bhattacharjee and Bhatia 1981; Nath and Singh 1984) there exists no quantitative information on the extent of control brought about by birds during the ploughing operation and the benefits gained thereby. Therefore, experiments were conducted through 1985 and 1986 to quantify the extent of white grub control by insectivorous birds during traditional ploughing operation, to assess the impact

of bird predation on the second crop raised in the same field and to evolve a technique to maximize bird predation on grubs.

2. Materials and methods

Experiments were conducted in farmers fields in the Kapadvanj (22°25' N, 73°35' E,) tahsil (unit for revenue division of a district) of Kheda district, Gujarat through 1985 and 1986. During late August or early September, crop fields with signs of severe white grub damage were identified and their owners were consulted and convinced for cooperating with the experiment. Whenever necessary, charges were paid for hiring a bullock plough and irrigation of the field as per the prevailing local rates. In the first 3 experiments the fields were irrigated 2 days prior to the ploughing operation to soften the soil and thereby allowing the grubs to return to the top soil.

The experimental fields varied from 0·1 to 03 ha. In each experiment, the field was divided into 2 halves. In one half, the birds were manually scared away and not allowed to feed on the grubs that were exposed during ploughing operation (control) and in the second half they were allowed to follow the plough and feed on the grubs exposed. Usually the fields were ploughed for three consecutive days in the morning between 0700 and 0800 h. The bullock drawn country plough exposed the soil to 30 cm depth and 25 cm width. The number of white grubs exposed during the ploughing were counted by following the plough. If the furrow length was less than 100 m, the count was extrapolated to 100 m. The bird species and their number following the plough were counted at every 15 min interval and it is represented as average number of birds per each 15 min of ploughing. At the end of the third day ploughing maize was sown and raised to determine the impact of white grub reduction by birds, if any. A group of 50 plants from a small area were slightly pulled out to check grub damage to seedlings on 20th and 17th days after sowing in experiments I and II respectively. Per cent plant damage was calculated from the data collected from 15 such points.

3. Results

Out of the total 7 experiments conducted, results of 4 experiments are presented in tables 1 to 4. Only these experiments are considered for reaching major conclusions of the study. Results of the remaining experiments were useful only in perfecting the experimental procedures and formulating some useful conclusions.

3.1 *Experiment I*

The experiment was done in a groundnut field adjoining a small village, Udapura. For the experiment a 725 m^2 area was available whereas remaining 1421 m^2 area was kept as the control. On the first day of ploughing, grub density was the same in both experimental and control plots (table 1; t = 0·26; P > 0·5 NS). The mean number of grubs decreased subsequently in both the plots but the differences between the experimental and control plots were highly significant during both the

second (t = 2·65; P < 0·05) and third (t = 3·00; P < 0·05) ploughing. The difference in the grub number was mainly due to the predatory activity of birds during the first 2 ploughings. The impact of birds feeding on grubs number after the completion of the third ploughing was not determined. However the feeding activities of birds during the third ploughing must have reduced the grub population to a further low level. In the experimental plot, the reduction in grub number was 65·06% whereas in the control it was 43·01%. Even in the absence of avian predators, reduction in grub number was observed in control plot. This could be attributed to other possible factors such as loss of moisture in the upper layer of the soil, disturbance due to turning of soil, mortality due to injury, etc. Reduction in grub number was also observed in all other experiments to variable extents. The reasons for this variability can not be determined from these experiments. Eight species of insectivorous birds were observed feeding throughout the course of the experiment (table 5). At any given point of time, 5 to 8 birds were observed following the plough (table 1).

Table 1. Effect of birds predation on white grub and its subsequent impact on second crop at Udapura, September, 1985.

Dates of ploughing	Sample size	Mean number grubs/100 m		t value level	Significance	Average no. birds
		Exp.	Cont.			
23	15	19·06 ± 6·63	19·66 ± 5·96	0·26	P > 0·15	5·04
24	20	9·40 ± 3·85	14·60 ± 7·86	2·65	P < 0·05	5·67
25	15	6·66 ± 3·06	11·20 ± 4·77	3·60	P < 0·05	7·68
Grub reduction (%)		65·06	43·03			
Second crop: Maize sown on 9 October						
Plant damage (%) (29 Oct)	15*	4·9	5·5			

*A single sample constituted group of 50 plants.

On 9 October the second crop, maize, was sown in the same field. Plant damage by white grub was estimated after 20 days and it was slightly higher in the experimental area as compared to the control. This was attributed to grub reduction by birds during ploughing.

3.2 *Experiment II*

This experiment was conducted in a pearl millet field in Hirapura village. The crop was harvested very early because of white grub damage and a long dry spell. The sizes of experimental and control areas were 788 m^2 and 225 m^2 respectively.

Due to the heavy bird predation during the first 2 ploughings, the grub number was reduced by 59·62% in the experimental area whereas the reduction was only 10·88% in the control. The difference in grub number between the two areas at the end of the third ploughing was statistically significant (t = 5·95; P < 0·001).

Significant reduction in grub number in the experimental plot was responsible for the lower percentage of plant damage of the second crop (table 2).

Table 2. Effect of bird predation on white grub and its subsequent impact on second crop maize at Hirapura, September, 1986.

Dates of ploughing	Sample size	Mean number grubs/100 m		*t* value level	Significance	Average no. birds
		Exp.	Cont.			
10	16	13·62 ± 3·49	12·87 ± 2·39	0·72	NS	7·00
11	–	–	–			13·20
12	16	5·50 ± 2·87	11·43 ± 2·78	5·92	$P < 0·01$	9·40
Grub reduction (%)		59·62	10·88			
Second crop; Maize sown on 13 October						
Plant damage (%) (30 Sep)	15*	2·84	13·49			

*A single sample constituted groups of 50 plants.
Ploughing on 11 th was done at right angle to the 10th and 12th and hence data are not comparable.

At least 6 species of birds were attracted to feed on the white grub during ploughing operation (table 5) and the number of birds following the plough ranged from 7 to 13 (table 2). A grain flour based eatable locally known as *'papadi'* was thrown as bait for crows on the 2nd day before starting the ploughing. This certainly attracted the crows. Maximum numbers of house crow *Corvus splendens* Vieillot and jungle crow *Corvus macrorhynchos* Sykes reached 11 and 16 respectively.

3.3 *Experiment III*

This experiment was conducted in a vitiated field of groundnut at Udapura village. Both experimental and control areas were of 1677 m^2. Initially, the grub count was significantly low in control area as compared to the experimental one. However due to heavy bird predation during the first two ploughings the grub count was significantly reduced (63·5%) in the experimental area so that it reached a significantly lower level compared to that in the control (table 3; $t = 2·06$; $P < 0·05$). Six bird species were recorded feeding on the grubs (table 5) and their average number progressively increased from 6 to 16 during the subsequent ploughings (table 3). It was noticeable here that despite the significant reduction in the number of grubs during successive ploughings, the average number of birds attending the plough increased substantially.

3.4 *Experiment IV*

On 6 September, 1986 we saw 32 house crows following 2 ploughs and feeding

Table 3. Effect of bird predation on white grub during ploughing at Udapura, September 1986.

Dates of ploughing	Sample size	Mean number grubs/100 m		*t* value level	Significance	Average no. birds
		Exp.	Cont.			
10	20	6·85 ± 2·65	4·95 ± 1·59	2·75	$P < 0·01$	6·20
11*	–	–	–			9·00
12	22	2·50 ± 1·19	3·18 ± 1·02	2·06	$P < 0·05$	15·50
Grub reduction (%)		63·50	35·76			

*Ploughing on 11th was done at right angle to the 10th and 12th and hence data are not comparable.

on white grubs at 1700 h. The crop maize was harvested for fodder purpose of the field due to heavy grub infestation. The field was being ploughed since the morning. More than 50 house crows passing by were attracted to the field by the farmer by throwing the bait *'papadi'*. Our observations were started with the second ploughing in the evening and the birds were allowed to feed only in the experimental field. To determine the immediate impact of house crow on grub number the same area was ploughed once again and grubs were counted. It was found that the heavy predation of 32 house crows reduced 44·86% of the grub population in experimental area whereas in control, there was no reduction. Although a reduction in the grub number was observed in control plots of all the earlier experiments, as the second ploughing was done soon after the first one in this experiment, there was no apparent decrease in its number. This suggests that the factors responsible for the grub number reduction are expressed only after some time as 24 h in the first 3 experiments.

3.5 *Other observations*

Within the soil, grubs are concentrated near the root and can easily move along the row length as the soil is comparatively loose. This was evident from an experiment where the first ploughing was done at right angle to the existing plant rows which exposed only 6·80±6·70 (n = 20) grubs per 100m plough row. The same field, when ploughed along the existing plant rows, 17·80 ± 6·82 (n = 10) grubs were exposed. Exposure of maximum number of grubs during ploughing is

Table 4. Effect of bird predation on white grub during second ploughing at Narsinhpura, 6 September 1986.

Ploughing No.	Sample size	Mean number grubs/100 m		*t* value level	Significance	Average no. birds
		Exp.	Cont.			
1	–	–	–			50·00
2	6	8·16 ± 2·40	8·50 ± 2·21	0·26	NS	36·00
3	6	4·50 ± 0·95	8·50 ± 2·06	4·30	$P < 0·01$	
Grub reduction (%)		44·85	0·00			

required because that is an important factor in attracting and retaining insectivorous birds to that area. Therefore the ploughing should be done always parallel to the plant rows to expose the maximum number of grubs. The second important factor was the timing of ploughing which affects both the number of grubs exposed and number of birds attracted. In an experiment conducted on 25 September, 1985, 14·20 ± 4·58 (n = 20) grubs were exposed when the field was ploughed at 0900h and a total of 81 birds (chiefly 60 house crow, 10 jungle crow) were attracted. When the remaining part of the field was ploughed at 1400 h only 4·40 ± 3·40 (n = 00) grubs were exposed which attracted only 9 birds (4 house crow, 1 jungle crow, 1 black drongo, 1 kingfisher). These observations clearly indicate that the grubs must be moving deep into the soil due to an increase in the soil temperature in the middle of the day. Birds are also inactive during this period because of high temperature and satiation after morning food. Hence ploughing in the afternoon hours is disadvantageous since both the number of birds attracted to the field and their feeding rate will be less.

3.6 *Avian predators of white grub*

In these four experiments, total 10 bird species were recorded feeding on the white grub exposed during ploughing operation (table 5). All the birds observed were resident species feeding and breeding around the agriculture fields. Mynas (Sturnidae) were the most common and frequently encountered species during this study. During the experimental period, all the 3 species of mynas, common myna *Acridotheres tristis* (Linnaeus), bank myna *A. ginginianus* (Latham) and brahminy myna *Sturnus Pagodarum* (Gmelin) had nestlings, and feeding nestlings with white grubs was confirmed. Common and bank mynas were the most abundant species. Hence, the actual predatory pressure of the mynas was much greater than expected from the total numbers observed. The black drongo *Dicrurus adsimills* (Hodgson) is another important avian species occurring in one or two pairs. A single bird consumed at

Table 5. Composition of avian community feeding on white grub during ploughing operation.

Particulars	Exp. I	Exp. II	Exp. III
Proportion of bird species;			
Common myna	0·31 (5)	0·04 (3)	0·10 (2)
Bank myna	0·21 (4)	0·21 (10)	0·56 (13)
Brahminy myna	0·05 (2)	–	0·06 (2)
Black drongo	0·14 (2)	0·04 (2)	0·21 (4)
House crow	0·03 (2)	0·46 (11)	0·03 (2)
Jungle crow	–	0·19 (16)	–
House sparrow	0·15 (4)	–	–
Indian robin	0·05 (2)	–	–
WB Kingfisher	0·05 (1)	–	0·04 (1)
Green bee-eater	–	0·06 (4)	–
No. of observations	22	18	20
Total birds	133	184	190
No. birds/observation	6·05	10·22	9·50

Numbers in parentheses indicate the maximum number of individuals observed in a single count.

least 16 grubs during one of the experiments. Because of their high feeding potential, the crows are important predators. They were attracted to the field being ploughed by throwing bait around the field in the early morning as the crows start dispersing from their communal roost. The crows could be very easily attracted with baits and their activity in the field provide interspecific signals also regarding food availability. Other birds were occasional predators of white grub. Once, a family of white breasted kingfisher *Halcyon smyrnensis* (Boddaert) was seen picking up the grub from a perch. They fed at least 11 grubs to their fledglings. House sparrow *Passer domesticus* Jardine and Selby and Indian robin *Sexicoloides fulicata* (Latham) were observed only during experiment I. Although the green bee-eater *Merops orientalis* Latham is an aerial feeder, we have observed them twice feeding on the grubs during experiment II. Other species recorded feeding on the grubs were cattle egrets *Bubulcus ibis* (Boddaert), Indian roller *Coracias benghalensis* (Linnaeus), redwinged bush lark *Mirafra erypthroptera* Blyth, rosy pastor *Sturnus roseus*, (Linnaeus) and domestic fowl *Gallus gallus* (Linnaeus). Cattle egrets are known to follow ploughs and tractors (Kushlan 1978) but during the breeding season their foraging is restricted close to the heronry. That is why this species was not encountered in any of the 4 experiments described. Once an egret was observed consuming 51 grubs within 01 min. An analysis of the regurgitate of cattle egret nestlings from a heronry near Torna village in September 1984 showed that 09·81% of their food items were Coleoptera in which 19·88% was grubs of *H. consanguinea* (unpublished data). Keeping domestic fowl is not a common practice in Gujarat. But one of the observations suggests that if the infested field is near to a habitation with these birds, then the possibility of their being a major white grub controlling agent should be explored.

4. Discussion

The impact of white grub infestation becomes prominent only during late August and early September when the grub attains its maximum size (28·00±3·97 mm length and 7·95 ± 0·80 mm breadth in third instar) and becomes an voracious feeder. The use of pesticides recommended as preventive measure against white grub has to be applied at the time of sowing. Cost of the pesticides recommended is as follows:

Phorate 10 G (Themet 10 G) 05 kg/ha	Rs. 805-900/ha
Or	
Lindane (Gama BHC) 105 kg/ha	Rs. 325/ha

These pesticides fail to bring any effective control on the grubs if applied at the later stage of their development and hence chemical control becomes uneconomical. In such situations, as there is no hope for getting any return, the premature crop is harvested and further damage by grubs is avoided by some agronomical practice or by delayed sowing of the second crop. By adopting the second technique, the farmer delays sowing of the crop until the grub enters pupation. The disadvantage is that the farmer loses time and at the same time the

grub matures in the soil and remains in dormant stage till the next season to cause fresh infestation. In such situation, agronomical practice of repeated ploughings of the soil appears to be highly advantageous. The expenditure involved in repeated ploughing of one hectare field is as follows:

Irrigation	Rs. 75
3 repeated ploughing using builock plough	Rs. 225
Baiting birds	Rs. 20
Total	Rs. 320

If the farmer has his own irrigation facility and bullock plough the total expenditure becomes quite negligible. This method leads to more than 60% control of the grubs. Due to the grub reduction, lesser plant damage and higher plant stand of the second crop provide additional profit from the yield, though the exact profit has not been calculated. This control method also ensures that fewer beetles will emerge in the next season to start fresh infestation. The greatest extra merit of this method is that it avoids environmental pollution.

Birds are indiscriminate feeders and while following a plough, they pick up both healthy and diseased grubs. Laboratory experiments have confirmed that predatory birds like house sparrow and common myna are the dispersal agents of the milky disease *Bacillus popilliae* var. *holotrichiae* organisms (Vyas *et al* 1988). The birds being long distance fliers, they indirectly help in the dispersal of this pathogen and create natural epizootic control.

It is obvious from the study that the number of birds attracted to the plough within the field or between the field was not consistent with the number of grubs exposed during the successive ploughings. The major factors for variation in numbers of birds in the present experiments are the availability ‘of the grubs to birds for a short time and in a limited space, the visibility (depends on the trees surrounding the field) of plough to birds, and the density of the birds in the surroundings. Other contributing factors could be the relative availability of food elsewhere, relative timing of ploughing in relation to birds dispersal from their roosts and proximity to birds breeding sites.

As enemies of insects, birds stand supreme among vertebrates (Sweetman 1958). However, little importance has been assigned to the role of vertebrate predators in the natural control of agricultural pests (Van den Bosch and Messenger 1971; Stehr 1975) and it appears unlikely that vertebrates play a vital role within any modern agroecosystem (Campbell and Sloan 1977). However several studies have shown that they have a dominant role in maintaining many insect pests at innocuous level in forest ecosystem (Morris *et al* 1958; Tinbergen 1960; Dickson *et al* 1979; Torgersen and Campbell 1980; Torgersen and Mason 1987). In many developing countries, like India, agro-ecosystem is not completely modernized. The use of pesticides to control insect pests is completely avoided in certain areas and for low priced crops like pearl millet, maize, etc. In such situations, the agroecosystem resembles a forest ecosystem over a short period. Hence the birds become important biocontrol agents, suppressing the insect pests. Therefore important predators like insectivorous birds need to be maintained in the agroecosystem and be exploited using appropriate management practices.

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