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BREEDING BEHAVIOUR OF RED-WATTLED LAPWING, VANELLUS INDICUS (BODDAERT, 1783) IN AGRICULTURAL LANDSCAPE OF PUNJAB

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AUTHORS' CONTRIBUTIONS

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

During the breeding seasons 2017-2019, breeding behaviour of the Red-wattled Lapwing (RL), *Vanellus indicus* was studied in agricultural fields and non-agricultural nesting grounds located in the northern rural and semi-urban outskirts of Khanna city in Punjab. Observations on nest structure, egg laying, incubation, hatching and other behavioural aspects of the parents/chicks were inferred from video-records, photographs and direct field observations made on 35 clutches containing 117 eggs. In the study area the breeding season extended from April to July and the mean value of the nest structure parameters namely, outer diameter, inner diameter and depth were 21±3.02 cm, 12.08±1.13 cm and 3.05±0.63 cm respectively. The mean clutch size was 3.34±0.81 (range 1-4) and it differed between the agricultural field clutches (2.91±0.94, range: 1-4) and non-agricultural sites (3.54±0.66, range: 2-4). The egg length, breadth, initial weight, egg shape index and volume measured 42.08±1.20 cm, 30.21±0.80 cm, 19.44±1.15 gm, 71.85±2.79 and 17.56±1.04 cm3 respectively. The incubation period varied from 27 to 30 days (n=12) with a mean value of 28.75±0.97 days. A review of the video records spanning 64.55 hours total observation time (TOT) recorded over 06 days of full incubation including the hatching day revealed that the RL parents spent 58.8 hours (91.09% TOT) and 5.75 hours (8.91% TOT) as attentive periods and inattentive periods respectively. Synchronous hatching was completed in one or two successive days (within 24 hours) in 18 clutches/61 eggs and two three-egged hatched asynchronously over three days. Further, the continuous video records made during the present study revealed that the minimum interval between two successive hatching may be as short as 1.72 hours. The newly hatched chick weighed on average 13.65 gm (n=4). A comparison of the hatching success calculated as per the Mayfield Method revealed that it was only 6.90% in agricultural field sites and 64.80% in non-agricultural sites (sparsely grassy vacant plots, low grassy lawns/grounds, cattle dung heaps and rooftops).

Keywords: Red-wattled lapwing; *Vanellus indicus*; Punjab; hatching; incubation; breeding.

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1. INTRODUCTION AND BACKGROUND

Lapwings are medium sized birds referable to Family Charadriidae. They have compact bodies, short and thick necks, and long pointed wings. All the 07 species of lapwings from the Indian region [1,2] are also reported in the Northern India and out of these 05 species occur in Punjab [3]. The Red-wattled Lapwing (hereafter referred to as RL), *Vanellus indicus*, currently classified as Least Concern according to the IUCN Red List [4] is a common resident bird in Punjab. Sexes are alike, bronze-brown above, white below, with black face, breast and crown, and a crimson wattle above and in front of each eye [3,5].

RL is an important bird species of agricultural landscape [6,7] and feeds on insects, grubs and mollusks [5,8].

The pioneer works during the pre-independence period [5,9,10] presented brief morpho-ecological notes on RL from the Indian region. Brief notes on behavioural aspects like belly soaking and nest wetting [11], interactions with dog and snake [12,13], use of hare droppings as nest material [14] and unusual nesting on rooftops [15,16,17] have been reported from different localities. In addition to some notes on incubation behavior [18,19, 20,21,22], studies on effect of agricultural activities on breeding success in Maharashtra [6], hatching success and developmental threats in Kurukshetra [23], comparison of hatching success between roof and ground nests in Haridwar [24], growth of morphometric parameters in Junagadh [25] and the agonistic, distraction and maintenance behavior [26,27] of RL have been attempted by respective workers.

The bird life history strategies often vary among habitat types and presently, the information on the critical breeding parameters (clutch size, incubation period and nestling period) is available only for one third of the all extant species of birds world over [28]. Studies on the breeding biology of birds are crucial for improving information about avian life-history theory and also for implementation of effective management and conservation [29]. Punjab is primarily an agrarian state with only 5.20 percent area under forest cover [30]. During and after the Green Revolution, local environment scenario of Punjab has changed profoundly and the present day Punjab has lost much of its forest and dominant wildlife. Intensive agriculture has caused changes in the abundance and distribution of many avian species in Punjab [31,32]. There exists a dire need to investigate the varied aspects of breeding biology of different species of birds dwelling in the present day agricultural landscape in Punjab. Information on egg parameters of RL in agricultural landscape in Punjab has been contributed by [7,33]. As a common resident bird in Punjab, RL the plays an important role as a natural biological control agent for insect pest control in agricultural fields [8,31]. The present field study was undertaken to gather information on varied aspects of breeding biology of RL from agricultural landscape in Punjab.

2. METHODOLOGY

The study was undertaken during three consecutive breeding seasons (2017-2019) in the northern rural and semi-urban outskirts of Khanna city in Punjab. All the agricultural field (11 clutches/32 eggs) and non agricultural nests (24 clutches/85 eggs) were located following the behavioral clues of RL pairs. As the nests are never left unattended during mid-day hours, mid-day visits were conducted to mark the tentative location of nests that was confirmed in the following evenings. As per field requirements, the position of some nests were marked [34] by placing some brick halves (in vacant plots) or mud-lumps (in agricultural fields) at an indicative distance so that the nests were easily relocated during subsequent field visits. Of the 35 nests monitored during the present study, 04 nests were found before the start of egg laying, 16 nests during egg laying period and 15 nests after completion of egg laying. After locating a nest, regular visits were conducted twice a day in morning and evening. More frequent visits were conducted during hatching period of the clutches. From the appropriate vantage points, field observations on RL behavior were also made using Olympus 10X50 DPS Binoculars. Field photography was done using a Sony A-77 DSLR camera fitted with Tamron 70-300 mm telephoto lens. Except for a single egg and nest data collection visit that lasted for less than 3 minutes, we quickly took a distant glance of the nesting site for few seconds during subsequent field visits, making our visits oblivious to the birds and care was taken not to disturb the bird/chicks in the nest [35].

A clutch containing four eggs (Nest No. 29, Table 2) laid in a nest built on rooftop of an isolated office building (Latitude: 30°43’14.48”N & Longitude: 76°13’14.22”E) was video recorded for 64.55 hours total observation time (TOT) over 06 days of full incubation including the hatching day. The attentive and inattentive periods [36,37,38], parental changeovers and other behavior aspects during incubation and hatching were video recorded using a Hikvision IR Network Camera with inbuilt-SD Card (64GB) installed at this nest at a distance of about 1m from the nest. Video-monitoring of nests has become a very useful tool for documenting behavioural data

without causing any damage and disruption at the nest [39,40,41]. In comparison to direct observations, the technique records detailed, continuous and natural behavior as the birds are oblivious to the camera and data can be reviewed as desired.

Nest and egg parameters were measured with SF-400C Digital Weighing Scale (Least Count 0.01 mg), Digital Vernier Caliper (Range 01-15 cm, Least Count 0.01 mm), a 12" ruler and a 50m Open Reel Measuring Tape. From two linear egg dimensions, maximum length (L) and maximum breadth (B), Fresh Egg Weight (W) and Egg Volume (V) were determined using the equations, $W= K_w. LB^2$ and $V=K_v. LB^2$ given by [42], where $K_w = 0.506$ was the Species-Specific Weight Coefficient calculated from [43] and $K_v= 0.457$ is volume coefficient calibrated for Northern Lapwing by [44]. Egg Shape Index [ESI= (B/L) x100] was determined as per [45].

Nest locations were recorded by a Global Positioning System of the camera. In the present study, Incubation Period (I.P) was taken as the number of days between laying to hatching of the last egg in a clutch [46]. We defined the Egg Laying Period and Hatching Period as the number of successive days for completion of respective event. Details about nest building, incubation, hatching and other behavioural activities of the parents/chicks were inferred from video-records, photographs and direct observations. A nest was considered as a failure if it was found empty before the expected hatching or was damaged due to human activities or predation. Hatching success was estimated using traditional method (%age of eggs that hatched successfully out of the total eggs) and the Mayfield Method [47].

3. OBSERVATIONS AND RESULTS

3.1 Nest Sites and Nest Building

The varied nesting sites (Plate 1) recorded during the present study (2017-2019) included agricultural field sites (11 nests), non-agricultural vacant plots in thinly populated residential colonies (14 nests), cattle dung heaps (02), low grassy grounds/lawns (07) and rooftops (01).

In case of non-agricultural sites, the RL generally selected moderate sized nesting grounds with well marked boundaries and built solitary nests. However, in the vast agricultural fields and larger plots, it shared the nesting grounds with Black-winged Stilt (n=2) and Yellow-wattled Lapwing (n=2). After selecting a promising nesting site, a RL pair used to monitor the same for few days as its nesting ground before starting egg laying. A pair may occupy the site about two weeks prior to commencement of egg laying. Eggs are laid generally in a shallow scrape ringed with a variety of nest material. In ploughed agricultural fields, the shallow depressions present between soil lumps directly serve as ill defined nest scrapes. Determined by the habitat conditions, the RL was observed creating a shallow nest scrape by pressing its breast against the ground and then rotating the body sideways (Fig. 3.1). In this effort it kept its tail directed upwards and repeated the action many times for creating a depression in the nesting ground. The scrape lining material pebbles and dry sticks were collected by lateral tossing. In the study area the RL used a variety of materials in its nest scrapes depending upon location and habitat type (Plate 2). The nest materials included coarse gravel, brick pebbles, cement plaster scrapings, mud pebbles, dry grass twigs, grass roots, dried grass blades, dry bark chips, wheat straw, pieces of weed sticks, bits of cattle dung, pieces of wood charcoal, limestone pebbles, dried leaves (Silver Oak, Sheesham), porcelain chips, soiled cloth pieces, polythene etc. The variety and quantity of nest material used in nests differed among habitats. Generally, RL used the materials available in the immediate surroundings of a nesting site and was never noticed conducting material collection sorties from other sites or habitats. Depending upon variety of the nest material available nearby, the nests in agricultural fields predominantly contained mud pebbles and some wheat straw and or/weed roots, nests on rooftops contained only plaster scrapings, whereas, the nests made in non-agricultural plots contained a variety of materials like coarse gravel, brick pieces, soil pebbles and cattle dung etc. Nest scrapes on cattle dung heaps were not ringed with any material as nothing else was available in the immediate surroundings and similarly the nest scrapes made in open low grassy grounds predominantly contained crop straw (if available) or a combination of bits of cattle dung, small dry twigs and some pebbles, as per availability at the site. This nesting material presented a good background camouflaging to the eggs in respective nesting sites. As a part of survival strategies, nests must themselves be inconspicuous but also must hide the eggs contained inside. Nests and eggs must function together to conceal the developing embryo [48].

The mean outer diameter of the nest scrape (Table 1) measured 21±3.02 cm (range 16 - 26 cm, n=15) and the mean inner diameter was 12.08±3.02 cm (range 9.5 – 13.5 cm, n=19). The mean depth of scrape was 3.05±0.63 cm (range 2.0 – 4.2 cm, n=19). Most of the nests (88%), were devoid of any tree in their vicinity that could serve as a perching site for predators and the nearest perching site was electric supply line at a distance of 10m - 75 m. However, some scattered

Calotropis procera plants were present in non-agricultural plots (Fig 1.4) occupied as nesting sites. Except for the nests in school lawns, the distance of the nearest human passage from nest varied from 14 m – 95 m. Of the total, 31.5% clutches (11 clutches) were laid in agricultural field sites and 68.5% clutches (24 clutches) were laid in non-agricultural sites.

Fig. 1.1. Postharvest agricultural field

Fig. 1.2. Ploughed agricultural field

Fig. 1.3. Undisturbed rooftop

Fig. 1.4. Non-agricultural plots

Fig. 1.5. Cattle dung heap

Fig. 1.6. Grassy lawn/playground

Plate 1. Some nesting sites used by redwattled lapwing

Fig. 2.1. Nest in agricultural field

Fig. 2.2. Nest on rooftop

Fig. 2.3. Nest in vacant non-agricultural plot

Fig. 2.4. Nest on a cattle dung heap

Fig. 2.5. Nest in open ground with crop straw

Fig. 2.6. Nest in a grassy ground

Plate 2. Nest material used at different sites

Fig. 3.1. Nest building by RL pair

Fig. 3.2. Maiting pair of RL

Fig. 3.3. Clutch of four eggs

Fig. 3.4. Egg variation

Fig. 3.5. Incubation

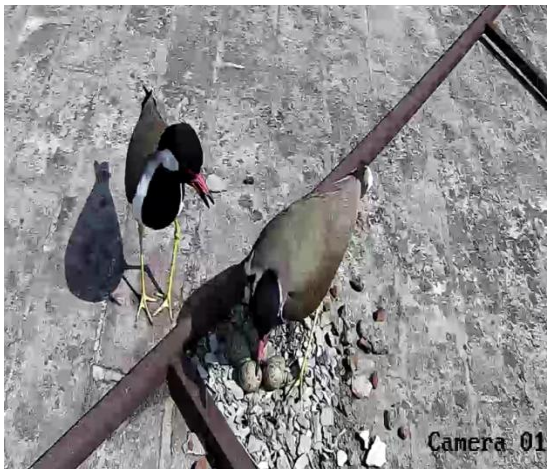

Fig. 3.6. Incubation changeover

Plate 3. Egg laying and incubation

Table 1. Nest Measurements at Some representative nesting sites of Redwattled Lapwing

Nest Sr. No. (As per Table-2)	Nest Site & breeding season	Nest measurements			Nearest human passage		Nearest perching site	
		Outer Diameter (cm)	Inner Diameter (cm)	Depth (cm)	Type of Passage	Distance from Nest (m)	Type of Perching Site	Distance from Nest (m)
1	NAS Vacant Plot	19	13	3	Road	26.5	Electric Supply Line	22
3	NAS Vacant Plot	23	13	3	Tiled Pathway	50	Silver Oaks & Eucalyptus trees	25
7	NAS Grassy Lawn	26	12	3.5	Tiled Pathway	0.5	Silver Oaks	23
8	NAS Vacant Plot	26	13	3	Road	24.5	Electric Supply Line	20
9	NAS Vacant Plot	not defined	13	3.5	Road	67.5	Electric Supply Line	63
10	NAS Playground Boundary	22	13	3.5	Walker's Track	23	Silver Oak & Golden Shower trees	10
11	AFS Post-harvest Wheat Field	23	13	2	Road	54.5	Electric Supply Line	50
16	AFS Ploughed Field	21	12	3	Road	19.5	Electric Supply Line	15
17	NAS Vacant Plot	not defined	10	3	Road	46.5	Boundary wall	4
18	AFS Ploughed Field	18	12.5	3.5	Road	79.5	Electric Supply Line	75
19	AFS Ploughed Field	Flat Platform protected by soil lumps			Road	19.5	Electric Supply Line	15
20	AFS Ploughed Field	Flat Platform protected by soil lumps			Road	54.5	Electric Supply Line	50
21	AFS Ploughed Field	23	12	3	Road	50	Electric Supply Line	10
22	AFS Post-harvest Wheat Field	not defined	13	4.2	Road	60	Electric Supply Line	30

Nest Sr. No. (As per Table-2)	Nest Site & breeding season	Nest measurements			Nearest human passage		Nearest perching site	
		Outer Diameter (cm)	Inner Diameter (cm)	Depth (cm)	Type of Passage	Distance from Nest (m)	Type of Perching Site	Distance from Nest (m)
23	NAS Grassy Ground Near Pond	22	12	3.5	Road	58	Electric Supply Line	64
24	AFS Ploughed Field	Flat Platform protected by soil lumps			Road	50	Electric Supply Line	15
25	AFS Ploughed Field	not defined	10.5	3.5	Road	24	Electric Supply Line	20
26	NAS Grassy Lawn	18	9.5	2.6	Tiled Pathway	6	Silver Oaks	12
27	NAS Vacant Plot	Shallow Scrape protected by Bricks			Road	18	Electric Supply Line & Indian Lilac trees	14
29	NAS Office Rooftop	21	13.5	2	Undisturbed		Indian Lilac tree	10
30	NAS Cattle Dung Heap	Flat Platform protected by dung lumps			Road	14	Electric Supply Line	10
31	NAS Vacant Plot	17	12	2.4	Road	16	Electric Supply Line	12
32	NAS Grassy Ground Near Pond	16	11.5	3.8	Road	65	Electric Supply Line	61
33	NAS Vacant Plot	20	11	2	Road	22	Electric Supply Line	18
34	AFS Ploughed Field	Flat Platform protected by soil lumps			Road	95	Electric Supply Line over the nest	

Table 2. Egg parameters and incubation data of Redwattled Lapwing Clutches (2017-2019)

Nest no.	Nesting site	Location latitude & longitude	Egg No. /Chick	Laid on	Found on	L (mm)	B (mm)	W (gm)	ESI	EV (cm^3)	Hatched on	IP (Days)
1	NAS	30°43’13.9” N	E-1	-	06.04.17	41.56	30.63	19.72	73.7	17.81	Clutch Lost after 03	-
	Vacant Plot	76°13’14.88” E	E-2	06.04.17	-	40.7	31.05	19.85	76.29	17.93	days on 11.04.17	
			E-3	08.04.17	-	41.5	31.13	20.34	75.01	18.37	due to predation	
2	NAS	30°43’54.49” N	E1	-	22.04.17	42.92	28.92	18.16	67.38	16.4	Clutch lost on	-
	Grassy Lawn	76°12’11.2” E	E2	-	22.04.17	43.45	29.28	18.85	67.39	17.02	23.04.17 due to	
			E3	-	22.04.17	42.61	29.49	18.75	69.21	16.93	students’ activity	
			E4	-	22.04.17	43.46	29.19	18.74	67.17	16.92		
3	NAS	30°43’56.45” N	E1	-	01.05.17	43.1	30.09	19.75	69.81	17.83	22.05.17	-
	Vacant Plot	76°12’8.06” E	E2	-	01.05.17	43.67	29.09	18.7	66.61	16.89	22.05.17	
			E3	-	01.05.17	42.58	30.19	19.64	70.9	17.74	22.05.17	
			E4	-	01.05.17	43.07	29.39	18.82	68.24	17	23.05.17	
4	NAS	30°43’9.15” N	E1	-	30.04.17	42.41	29.59	18.79	69.77	16.97	29.05.17	30
	Vacant Plot	76°13’24.55” E	E2	-	30.04.17	41.88	29.96	19.02	71.54	17.18	29.05.17	
			E3	-	30.04.17	42.62	28.84	17.94	67.67	16.2	30.05.17	
			E4	01.05.17	-	42.77	29.61	18.97	69.23	17.14	31.05.17	
5	NAS	30°43’9.15” N	E1	07.05.17	-	-	-	-	-	-	Clutch Lost on	-
	Cattle Dung Heap at Pond	76°13’24.55” E	E2	08.05.17	-	-	-	-	-	-	10.05.17	
			E3	09.05.17	-	-	-	-	-	-		
6	NAS	30°43’21.58” N	Chick-1		09.05.17	Weight upon Hatching:12.99					09.05.17	-
	Vacant Plot	76°13’17.14” E	Chick-2		09.05.17	Weight upon Hatching: 12.86					09.05.17	
			E-3	-	09.05.17	Weight at end of incubation:14.45					10.05.17	
			E-4	-	09.05.17	Weight at end of incubation: 14.80					10.05.17	
7	NAS	30°43’54.49” N	E1	-	09.05.17	42.69	29.82	19.21	69.85	17.35	Clutch lost on	-
	Grassy Lawn	76°12’11.2” E	E2	-	10.05.17	42.59	29.71	19.02	69.76	17.18	19.05.17 due to	
			E3	-	10.05.17	44.07	28.95	18.69	65.69	16.88	predation	
			E4	-	10.05.17	42.89	29.83	19.31	69.55	17.44		
8	NAS	30°43’12.77” N	E1	04.05.17	-	41.14	30.57	19.45	74.31	17.57	04.06.17	30
	Vacant Plot	76°13’28.85” E	E2	05.05.17	-	41.58	30.69	19.82	73.81	17.9	04.06.17	
9	NAS	30°43’10.83” N	E1	-	13.05.17	41.25	30.59	19.53	74.16	17.64	Clutch lost after 08	-
	Vacant Plot	76°12’37.17” E	E2	-	13.05.17	40.75	31	19.82	76.07	17.9	days on 24.05.17	
			E3	15.05.17	-	41.6	31.25	20.56	75.12	18.57	due to predation	
			E4	16.05.17	-	40.8	30.96	19.79	75.88	17.87		

Nest no.	Nesting site	Location latitude & longitude	Egg No. /Chick	Laid on	Found on	L (mm)	B (mm)	W (gm)	ESI	EV (cm^3)	Hatched on	IP (Days)
10	NAS	30°44'12.41" N	E-1	-	13.05.17	43.63	30.45	20.47	69.79	18.49	12.06.17	28
	Playground Boundary	76°13'11.99" E	E-2	14.05.17	-	42.81	30.84	20.6	72.04	18.61	12.06.17	
			E-3	15.05.17	-	42.76	30.65	20.33	71.68	18.36	13.06.17	
11	AFS	30°43'25.01" N	E1	-	23.05.17	42.3	30.67	20.13	72.51	18.18	12.06.17	-
	Post-harvest Wheat Field	76°13'18.25" E	E2	-	23.05.17	41.8	30.87	20.16	73.85	18.2	12.06.17	
			E3	-	23.05.17	42.15	30.06	19.27	71.32	17.41	12.06.17	
			E4	-	23.05.17	41.17	30.45	19.32	73.96	17.45	13.06.17	
12	NAS	30°43'22.17" N	E4	-	25.05.17	40.28	30.42	18.86	75.52	17.03	10.06.17	-
	Vacant Plot	76°13'9.34" E	E2	-	25.05.17	42.52	30.28	19.73	71.21	17.82	10.06.17	
			E3	-	25.05.17	41.2	30.57	19.48	74.2	17.6	10.06.17	
			E4	-	25.05.17	40.08	31.26	19.82	77.99	17.9	10.06.17	
13	NAS	30°43'19.88" N	Chick-1		25.05.17	Weight upon Hatching: 13.67					25.05.17	-
	Vacant Plot	76°13'12.66" E	E2	-	25.05.17	43.32	31.08	21.17	71.75	19.12	27.05.17	
			E3	-	25.05.17	42.31	30.3	19.66	71.61	17.75	27.05.17	
14	NAS	30°43'9.76" N	E1	-	02.06.17	40.66	31.12	19.92	76.54	18	02.07.17	28
	Vacant Plot	76°13'31.64" E	E2	-	02.06.17	39.71	30.95	19.25	77.94	17.38	02.07.17	
			E3	03.06.17	-	40.56	30.77	19.43	75.86	17.55	02.07.17	
			E4	04.06.17	-	41.46	31.15	20.36	75.13	18.38	02.07.17	
15	NAS	30°43'36.21" N	E1	-	03.06.17	43.14	31.2	21.25	72.32	19.19	Clutch lost after 04 days on 09.06.17 due to flooding by rain	-
	Grassy Ground Near Pond	76°13'21.24" E	E2	04.06.17	-	43	30.66	20.45	71.3	18.47		
			E-3	05.06.17	-	44.35	30.69	21.14	69.2	19.09		
16	AFS	30°43'49.32" N	E2	-	05.06.17	41.04	28.83	17.26	70.25	15.59	Clutch lost after 07 days on 14.06.17 due to ploughing	-
	Ploughed Field	76°13'18.45" E	E2	-	05.06.17	40.41	27.95	15.97	69.17	14.43		
			E3	06.06.17	-	40.93	28.82	17.2	70.41	15.54		
			E4	07.06.17	-	41.63	28.62	17.25	68.75	15.58		
17	NAS	30°43'14.71" N	E1	-	06.06.17	42.98	29.18	18.52	67.89	16.72	Clutch lost on 09.06.17 due to predation	-
	Vacant Plot	76°13'7.38" E	E2	-	06.06.17	42.9	29.26	18.58	68.21	16.79		
			E3	-	06.06.17	42.85	29.55	18.93	68.96	17.1		
18	AFS	30°43'43.47" N	E1	-	05.06.17	45.17	30.36	21.07	67.21	19.03	Clutch lost after 04 days on 10.06.17 due to ploughing	-
	Ploughed Field	76°13'23.97" E	E2	-	05.06.17	42.21	30.34	19.66	71.88	17.76		
			E3	06.06.17	-	44.15	30.22	20.4	68.45	18.43		

Nest no.	Nesting site	Location latitude & longitude	Egg No. /Chick	Laid on	Found on	L (mm)	B (mm)	W (gm)	ESI	EV (cm^3)	Hatched on	IP (Days)
19	AFS	30°44’2.06” N	Chick-1		14.06.17	Weight upon Hatching:15.08					14.06.17	-
	Ploughed Field	76°12’58.38” E	E2	-	14.06.17	42.88	30.92	20.74	72.11	18.73	15.06.17	
			E3	-	14.06.17	43.34	30.87	20.9	71.23	18.87	15.06.17	
20	AFS	30°43’43.47” N	E1	-	14.06.17	42.72	29.26	18.51	68.49	16.71	28.06.17	-
	Ploughed Field	76°13’23.97” E										
21	AFS	30°44’35.68” N	E1	-	14.06.17	40.48	30.19	18.67	74.58	16.86	Clutch lost after 14	-
	Ploughed Field	76°13’4.27” E	E2	15.06.17	-	42.14	29.53	18.59	70.08	16.79	days on 29.06.17 due to predation	
22	AFS	30°43’56.75” N	E1	-	15.06.17	42.42	30.34	19.76	71.52	17.85	Clutch lost on	-
	Post-harvest Wheat Field	76°13’22.58” E	E2	-	15.06.17	41.77	30.09	19.14	72.04	17.28	19.06.17 due to ploughing	
23	NAS	30°43’35.18” N	E1	26.06.17	-	43.4	32	22.49	73.73	20.31	25.07.18	27
	Grassy Ground Near Pond	76°13’17.31” E	E2	27.06.17	-	43.24	31.76	22.06	73.45	19.93	25.07.18	
			E3	28.06.17	-	42.1	31.8	21.54	75.53	19.45	25.07.18	
24	AFS	30°44’35.41” N	E1	-	28.06.17	43.26	29.67	19.27	68.59	17.4	Clutch lost after 07	-
	Ploughed Field	76°13’4.78” E	E2	-	28.06.17	43.01	30.05	19.65	69.87	17.75	days on 06.07.17	
			E3	29.06.17	-	40.7	30.66	19.36	75.33	17.48	due to predation	
25	AFS	30°43’46.75” N	E1	-	04.07.17	41.9	29.82	18.85	71.17	17.03	Clutch lost on	-
	Ploughed Field	76°14’17.72” E	E2	-	04.07.17	41.12	29.99	18.71	72.93	16.9	09.07.17 due to	
			E3	-	04.07.17	40.7	30.3	18.91	74.45	17.08	flooding for rice transplantation	
26	NAS	30°43’54.13” N	E1	-	15.07.17	43.64	29.03	18.61	66.52	16.81	02.08.17	-
	Grassy Lawn	76°12’11.0” E	E2	-	15.07.17	43.67	29.41	19.11	67.35	17.26	02.08.17	
			E3	-	15.07.17	43.43	29.99	19.76	69.05	17.85	02.08.17	
			E4	-	15.07.17	44.51	29.9	20.13	67.18	18.19	02.08.17	
27	NAS	30°43’14.32” N	E1	-	13.05.18	40.79	30.93	19.75	75.83	17.83	13.06.18	29
	Vacant Plot	76°13’28.39” E	E2	-	13.05.18	40.6	31.22	20.02	76.9	18.08	13.06.18	
			E3	14.05.18	-	41.4	30.72	19.77	74.2	17.85	13.06.18	
			E4	15.05.18	-	41.22	30.31	19.16	73.53	17.31	13.06.18	

Table 2. Egg and incubation data of Redwattled lapwing clutches (2017-2019) (Continue….)

Nest No.	Nesting Site	Location latitude & longitude	Egg No. /Chick	Laid on	Found on	L (mm)	B (mm)	W (gm)	ESI	EV (cm^3)	Hatched on	IP (Days)
28	NAS	30°43'16.28" N	E1	20.06.18	-	40.85	30.11	18.74	73.71	16.93	21.07.19	28
	Vacant Plot	76°13'14.33" E	E2	21.06.18	-	43.06	30.67	20.5	71.23	18.51	21.07.19	
			E3	22.06.18	-	41.55	30.57	19.65	73.57	17.75	21.07.19	
			E4	23.06.18	-	40.85	30.65	19.42	75.03	17.54	21.07.19	
29	NAS	30°43'14.48" N	E1	-	16.04.19	41.82	30.38	19.53	72.64	17.64	17.05.19 (6:38pm)	29
	Office Rooftop	76°13'14.22" E	E2	17.04.19	-	40.95	30.18	18.87	73.7	17.05	18.05.19 (6:52am)	
			E3	18.04.19	-	41.53	30.23	19.2	72.79	17.34	18.05.19 (8:35am)	
			E4	19.04.19	-	41.09	30	18.71	73.01	16.9	18.05.19 (11:08am)	
30	NAS	30°44'30.44" N	E1	-	13.04.19	41.94	30.31	19.5	72.27	17.61	14.05.19	30
	Cattle Dung Heap	76°13'13.13" E	E2	-	13.04.19	42.85	30.46	20.12	71.09	18.17	14.05.19	
			E3	-	13.04.19	42.01	31.09	20.55	74.01	18.56	14.05.19	
			E4	14.04.19	-	41.95	31.18	20.64	74.33	18.64	14.05.19	
31	NAS	30°42'26.97" N	E1	-	17.04.19	41.2	29.64	18.31	71.94	16.54	17.05.19	29
	Vacant Plot	76°13'36.22" E	E2	-	17.04.19	41.86	29.76	18.76	71.09	16.94	18.05.19	
			E3	18.04.19	-	41.69	29.74	18.66	71.34	16.85	18.05.19	
			E4	19.04.19	-	42.3	29.5	18.63	69.74	16.82	18.05.19	
32	NAS	30°43'31.63" N	E1	-	27.04.19	41.21	31.09	20.16	75.44	18.2	26.05.19	28
	Grassy Ground Near Pond	76°13'15.44" E	E2	28.04.19	-	41.85	30.52	19.72	72.93	17.81	26.05.19	
33	NAS	30°43'19.82" N	E1	-	05.05.19	38.54	28.79	16.16	74.7	14.6	Lost on 28.05.19	29
	Vacant Plot	76°13'20.57" E	E2	-	05.05.19	39.39	29.07	16.84	73.8	15.21	05.06.19	
			E3	06.05.19	-	40.24	28.37	16.39	70.5	14.8	05.06.19	
			E4	07.05.19	-	39.98	28.74	16.71	71.89	15.09	05.06.19	
34	AFS	30°43'57.13" N	E1	-	14.06.19	42.59	31.14	20.9	73.12	18.87	Clutch lost on 18.06.19	-
	Ploughed Field	76°13'23.97" E	E2	-	14.06.19	43.16	30.8	20.72	71.36	18.71	due to flooding for rice	
			E3	-	14.06.19	42.3	30.98	20.54	73.24	18.55	transplantation	
			E4	-	14.06.19	41.67	30.56	19.69	73.34	17.78		
35	AFS	30°44'19.40" N	E1	-	14.06.19	42.95	30.91	20.76	71.97	18.75	Clutch lost on 18.06.19	-
	Ploughed Field	76°13'44.04" E	E2	-	14.06.19	43.26	30.33	20.14	70.11	18.19	due to flooding for rice	
			E3	-	14.06.19	43.94	30.61	20.83	69.66	18.81	transplantation	

Table 3. Comparison of egg measurements on basis of type of nesting grounds

Basis of comparison	Category	No. of clutches/ eggs measured	Mean value of egg measurements				
			Length (L) (mm)	Breadth (B) (mm)	Weight (W) (gm)	Egg Shape Index (ESI)	Volume (V) (cm^3)
Type of Nesting Grounds	Agricultural Field Sites	11/31	42.23 ±1.14	30.14 ±0.77	19.43 ±1.26	71.39 ±2.07	17.55 ±1.14
	Non-agricultural Sites	24/77	42.01 ±1.22	30.24 ±0.81	19.45 ±1.11	72.04 ±3.02	17.56 ±1.00
Months of Breeding Cycle	April & May	18/56	41.90 ±1.12	30.12 ±0.75	19.24 ±1.03	71.94 ±2.73	17.38 ±0.93
	June & July	17/52	42.26 ±1.27	30.30 ±0.84	19.65 ±0.84	71.76 ±2.87	17.75 ±1.12
Size of Clutch	1 Egg	01/01	42.72	29.26	18.51	68.49	16.71
	2 Eggs	04/08	41.57 ±0.62	30.38 ±0.46	19.41 ±0.57	73.09 ±1.79	17.53 ±0.51
	3 Eggs	12/31	42.75 ±1.08	30.56 ±0.68	20.20 ±1.03	71.53 ±2.42	18.25 ±0.93
	4 Eggs	18/68	41.82 ±1.20	30.04 ±0.83	19.11 ±1.10	71.91 ±3.01	17.26 ±0.99
Over all Egg Parameters		35/108	42.08 ±1.20	30.21 ±0.80	19.44 ±1.15	71.85 ±2.79	17.56 ±1.04

Table 4. Incubation time budgeting of redwattled lapwing

Day	Duration of observation time (OT) (hours)	Observation time under attentive periods (hours)	Inattentive periods			Parental changeovers occurred at the nest	
			Observation time under inattentive periods (hours)	No.	Mean Duration (minutes)	No.	Average interval per changeover (hours)
10.05.19	7.47	7.24 (96.92% OT)	0.23 (3.08% OT)	07	1.81±2.28 (range: 0.38-6.5)	10	0.75
14.05.19	6.51	5.7 (87.56% OT)	0.81 (12.44% OT)	12	4.21±6.87 (range: 0.27-24.7)	07	0.93
15.05.19	14.31	12.48 (87.21% OT)	1.83 (12.79% OT)	29	3.80±7.66 (range: 0.2-40.97)	09	1.59
16.05.19	15.00	13.21 (88.07% OT)	1.79 (11.93% OT)	34	3.16±2.54 (range: 0.5-14.07)	09	1.67
17.05.19	14.56	13.56 (93.13% OT)	1.0 (6.87% OT)	36	1.67±1.28 (range: 0.2-5.10)	04	3.64
18.05.19	6.70	6.61 (98.66% OT)	0.09 (1.34% OT)	09	0.57±0.26 (range: 0.22-0.82)	11	0.60
06 days	64.55 (TOT)	58.8 (91.09% TOT)	5.75 (8.91% TOT)	127	2.73±4.56 (range: 0.2-40.97)	50	1.3

Table 5. Record of inattentive periods

Day: 10.05.2019		Day: 15.05.2019		Day: 16.05.2019	
Time (hh:mm:ss)	Duration (minutes)	Time (hh:mm:ss)	Duration (minutes)	Time (hh:mm:ss)	Duration (minutes)
09:20:00-09:20:34	0.57	19:10:00-19:11:33	1.55	06:12:50-06:16:04	3.28
09:30:54-09:31:25	0.52	19:15:20-19:17:40	2.33	06:30:54-06:31:28	0.57
14:28:12-14:29:24	1.20	19:21:13-19:23:25	2.20	06:41:28-06:42:07	0.65
16:11:06-16:11:31	0.42	19:39:05-19:40:28	1.38	07:15:59-07:16:36	0.62
16:24:30-16:31:00	6.50	19:42:41-19:44:44	2.05	07:22:11-07:23:32	1.35
16:34:02-16:36:25	0.38	19:52:05-19:52:45	0.67	07:43:30-07:44:15	0.75
17:24:56-17:28:00	3.07	**Day: 16.05.2019**		07:45:43-07:46:53	1.12
Day: 14.05.2019		05:42:07-05:42:37	0.50	08:27:40-08:29:46	1.82
15:07:15-15:07:38	0.38	06:27:07-06:29:35	2.47	08:58:25-09:01:25	3.00
15:16:51-15:17:09	0.27	06:54:05-06:54:56	0.85	09:28:25-09:29:25	1.00
18:24:43-18:49:25	24.70	07:26:57-07:30:17	3.33	10:03:34-10:04:45	1.18
18:54:53-18:55:18	0.42	07:44:54-07:46:08	2.23	10:10:19-10:14:20	4.02
18:58:41-19:07:28	8.78	07:47:40-07:50:59	3.32	10:31:25-10:32:41	1.27

Day: 10.05.2019		Day: 15.05.2019		Day: 16.05.2019	
Time (hh:mm:ss)	**Duration (minutes)**	**Time (hh:mm:ss)**	**Duration (minutes)**	**Time (hh:mm:ss)**	**Duration (minutes)**
19:14:44-19:17:09	2.42	07:54:47-08:00:00	5.22	10:40:46-10:41:16	0.50
19:24:20-19:28:36	4.27	08:01:02-08:04:05	2.95	11:29:55-11:30:18	0.38
19:34:10-19:35:54	1.73	08:08:09-08:09:25	1.27	12:59:34-13:02:19	2.75
19:42:14-19:44:14	2.00	08:26:40-08:40:44	14.07	13:30:30-13:31:21	0.85
19:47:25-19:48:59	1.57	09:10:38-09:12:05	1.45	13:52:32-13:53:23	0.85
19:54:59-19:58:18	3.32	13:52:10-13:53:31	1.52	13:53:40-13:54:15	0.58
20:00:19-20:01:00	0.68	13:59:11-13:59:53	0.70	14:35:12-14:35:58	0.77
Day: 15.05.2019		15:21:59-15:22:44	0.75	14:50:30-14:52:59	2.48
05:41:54-05:42:06	0.20	15:41:19-15:46:59	5.68	15:01:01-15:03:48	2.78
05:54:18-05:54:58	0.67	16:03:00-16:08:39	5.65	15:28:00-15:30:34	2.57
06:04:22-06:05:06	0.73	16:16:40-16:18:44	2.07	15:35:39-15:37:02	1.38
06:28:44-06:30:48	2.07	16:35:57-16:38:16	2.32	15:45:38-15:50:44	5.10
06:40:44-06:43:57	3.22	16:40:51-16:44:14	3.38	16:03:10-16:04:55	1.75
06:45:31-06:48:37	3.10	16:51:00-16:52:22	1.37	16:07:58-16:09:35	1.62
08:18:52:08:19:20	0.47	16:59:22-17:02:16	2.90	16:43:23-16:44:38	1.25
08:20:38-08:21:11	0.55	17:13:02-17:17:16	4.23	17:07:16-17:11:00	3.73
10:13:15-10:14:16	0.43	17:46:28-17:47:44	1.27	17:20:51-17:25:46	4.92
10:30:46-10:37:45	6.98	17:50:18-17:53:19	3.02	17:32:31-17:33:47	1.27
11:21:56-11:24:34	2.63	18:01:43-18:06:38	4.92	18:39:56-18:41:09	1.22
11:29:40-11:32:14	2.57	18:13:36-18:16:36	3.00	18:45:36-18:46:15	0.65
11:43:40-11:50:56	7.27	18:16:57-18:23:35	6.63	19:10:23-19:10:35	0.20
12:04:30-12:05:00	0.50	18:26:32-18:30:53	4.35	**Day: 18.05.2019**	
12:16:48-12:17:46	0.80	18:39:45-18:42:59	3.23	06:53:00-06:53:44	0.73
12:35:20-12:37:21	2.02	18:52:30-18:55:20	2.83	06:56:59-06:57:12	0.22
12:40:38-12:42:06	1.47	19:05:02-19:10:36	5.57	07:20:13-07:21:02	0.82
17:14:37-17:17:38	2.88	19:34:25-19:35:33	1.13	08:29:03-08:29:29	0.43
17:24:44-18:05:42	40.97	19:44:16-19:46:27	2.18	08:35:56-08:36:24	0.80
18:08:36-18:22:22	13.77	19:57:15-19:59:22	2.12	09:21:48-09:22:30	0.87
18:49:10-18:52:10	3.00	**Day: 17.05.2019**		09:37:52-09:38:09	0.28
18:58:18-19:00:24	2.13	05:41:54-05:42:17	0.38	11:38:43-11:39:24	0.68
19:04:58-19:06:33	1.58	06:02:00-06:03:30	1.50	11:41:44-11:42:00	0.27
Total No. of Inattentive Periods: 127, **Duration**: 5.75 hours (8.91% TOT)					

Table 6. Comparison of hatching success in agricultural and non-agricultural nesting sites

Type of nesting site	No. of clutches/eggs laid	Mean clutch size	No. of nest failures/nesting days	No. of successful clutches/eggs	Hatching success (%)	
					Mayfield method	Traditional method
Agricultural Field Sites	11/32	2.91±0.94 (range 1-4)	08/90	03/08	6.90	25
Non-agricultural Sites	24/85	3.54±0.66 (range 2-4)	07/466	17/60	64.80	70.58
Total	35/117	3.34±0.81 (range 1-4)	15/556	20/68	45	58.11

3.2 Egg Laying and Morpho-metric Measurements

In the study area, the breeding season of RL extended from April to July. During the breeding seasons 2017 – 2019, a total of 35 clutches/108 eggs (Table 2) were monitored for making observations on egg laying and determination of egg morpho-metric data. The clutch size varied from one to four eggs and there were one (2.85%), four (11.43%), twelve (34.29%) and eighteen (51.43%) clutches containing one, two, three and four eggs each respectively. The mean clutch size was 3.34±0.81 (range 1-4) and it differed between the agricultural field clutches (2.91±0.94, range: 1-4) and non-agricultural sites (3.54±0.66, range: 2-4). Owing to highly cryptic nature of the nest/eggs, the clutches were found at different stages of egg laying when the RLs were seen actually in the nests. However, once recorded, all subsequent eggs in a clutch were laid at dawn on successive days (n=19) except for one clutch of three eggs (Table 2, Nest No. 1) where the third egg was laid after two days. The eggs were pyriform with mean egg shape index (ESI) measuring 71.85±2.79 (range 65.69-77.99). The non-glossy egg surface was olive green to light brownish yellow coloured and was marked with irregular sized dark brownish black blotches and streaks. In the nests the eggs were generally placed with narrower ends pointing towards the centre of the scrape. The egg markings and nest material made the nests highly concealed against the background. The mean egg length (L) and breadth (B) measured 42.08±1.20 mm (range 38.54-45.18mm) and 30.21±0.80 mm (range 27.95-32.00 mm) respectively. The calculated mean values of initial egg weight (W) and egg volume (V) were 19.44±1.15 gm (range 16.16-22.49 gm) and 17.56±1.04 cm^3 (range 14.43-20.31 cm^3). The mean final weight of four eggs (Table 2, Nest No. 13 & 19) at the end of incubation period measured 18.29 gm against their mean initial weight of 20.62 gm thus indicating a weight loss of 2.33 gm (11.3% W) during the incubation period. A comparison of the egg parameters viz., maximum length (L), maximum breadth (B), fresh weight (W) and Volume (V) revealed that the mean values for these parameters (Table 3) are relatively higher in case of eggs laid during second half of the breeding season (June and July) than those laid in first half (April and May). Similarly, the eggs in 3 egged clutches showed the highest mean values for L (42.75±1.08 mm), B (30.56±0.68 mm), W (20.20±1.03 gm) and V (18.25±0.93 cm^3).

3.3 Incubation

Incubation was biparental and synchronous. Full incubation [37] started after completion of the clutch though the birds were seen engaged in irregular incubation during the egg laying period. The incubation period [46] varied from 27 to 30 days (n=12) with a mean value of 28.75±0.97 days (Table 3). During full incubation days the RL parents adopted long attentive periods (in the nest) and much shorter inattentive periods (off the nest). A thorough review of the video records (Table 2, Nest No. 29) of 64.55 hours total observation time (TOT) recorded over 06 days of full incubation including the hatching day revealed that the RL parents spent 58.8 hours (91.09% TOT) and 5.75 hours (8.91% TOT) as attentive periods and inattentive periods respectively (Table 4). During this TOT, the parents left the nest 127 times, each inattentive period averaging 2.73 minutes. Except for four inattentive periods of 24.7 minutes (14.05.19), 40.97 minutes and 13.77 minutes (15.05.19), and 14.07 minutes (16.05.19) on respective days, the duration of the rest of the 122 inattentive periods ranged between 0.2-8.78 minutes (Table 5). Depending upon the daily weather conditions, the frequency of the inattentive breaks varied during different parts of the day. The incubating RLs did not afford to leave the nest contents uncovered during peak sunlight between 11:00 to 15:00 hours. Only 15% of the inattentive periods occurred during these hot hours, whereas, 85% of the inattentive periods occurred in the relatively cooler hours before and after this interval. During these short inattentive breaks, the incubating RL was seen engaged in lateral tossing of small pebbles in the immediate surroundings of the nest. The incubating RL was never seen turning the egg/s using its bill and the egg/s never rolled out of the shallow nest scrape. However, it periodically changed its sitting position in nest, 93 times during the 64.55 hour TOT. At these changes, the RL maintained a crouched stance, rotated its body in the nest and readopted the incubation position. The quick movements of the legs against the trunk helped in exposing its ventral surface for ensuring the desired contact with eggs. However, [20] reported regular egg turning by RL using its bill.

As per the nest video records, there occurred a total of 50 incubation changeovers at an interval rate of 1.3 hours. At time of an incubation changeover, the outgoing parent displayed a sort of ritualistic behavior. No vocal cues were ever produced by the outgoing RL at time of incubation changeovers. As the incoming RL approached the nest for changeover, the outgoing RL performed lateral tossing (3-6 times) of small pebbles from outer edge of the scrape towards the inner side before leaving the nest. Most of the changeovers at nest were completed within a time less than 7 seconds. After leaving the nest, the outgoing RL again performed lateral tossing in the

immediate surroundings of the nest. At times, the soiled and soggy appearance of the ventral feathers of the incoming RL also indicated the wetting of the eggs. In the open vacant plots, the *Calotropis* plants growing in vicinity of a nest served as a shady shelter for the non-incubating RL during the hot noon hours. During the very hot mid-day hours, the incubating RL carried out gular fluttering with open bill. As no individual was marked during the study, the changeovers, if any, occurred during the inattentive periods (out of nest) could not be recorded.

Lateral tossing, displacement brooding and displacement feeding [20] was the most common behavior attributes displayed by the adults during nest building the incubation. Lateral tossing involving the picking and lateral throwing of small gravel pieces and mud pebbles (Fig. 5.1) was the most frequently performed while sitting in the nest as well as walking in the nest periphery. In case of displacement brooding, the RL adopted incubation posture (Fig. 5.2) while sitting away from the nest and this behavior was seen when the intruders, humans and dogs were too nearer the nest and were approaching directly towards the nest. Displacement feeding requiring false ground pecking moves of the head was carried out in response to trespassing in the nesting territory. At times, the incubating RL sitting in the nest displayed the characteristic freezing pose [18] with raised tail displaying black and white bands to the human who approached too nearer the nest (Fig. 5.3). The RL pairs were seen mobbing the stray dogs and House Crows entering their nesting grounds. There occurred no allo-feeding or allo-preening between the RL adults during the incubation period.

3.4 Hatching of Chicks

The 20 clutches containing 68 eggs successfully hatched over a period of 1-3 successive days. Amongst these successful clutches, synchronous hatching [36,49] was completed in a single day in11 clutches containing 35 eggs and in two successive days (within 24 hours) in 07 clutches containing 26 eggs. However, in case of 02 three egged clutches (Table 2, Nest no. 4 &13) hatching was asynchronous and was completed in 03 successive days. Hatching mostly took place during cooler morning hours, occasionally in the evening and never during the hot mid day hours. Simultaneous completion of hatching of two chicks (Fig. 4.2) out of four in a clutch was also observed. The continuous video records of synchronous hatching of a four egged clutch (Nest no. 29) reveals that the hatching of first chick was completed at 18:38:31 hours (1.63 hours after pipping at the broader end of the egg by the chick at 17:00 hours) in the evening of first hatching day. The second, third and fourth chick hatched at 06:52:40 hours, 08:35:56 hours and 11:08:23 hours respectively on the second successive hatching day. All the four eggs hatched within 18.14 hours after start of pipping of the first egg and the intervals between successive hatchings after the first one were 11.76 hours, 1.72 hours and 2.54 hours.

Both the parents contributed in hatching and never left an egg uncovered in the nest when its hatching was in progress. The 'egg in hatching' was kept firmly on one side of body between the wing and trunk. In fact, the cooperating body maneuvers and probing of the egg at times indicated that incubating parent assisted the chick in coming out of the egg shell. The parent used to walk out of the nest immediately after completion of hatching of an egg. The foremost task after hatching was to remove the empty egg shell from the nest. Within a few seconds its partner picked up the empty egg shell and disposed it away from the nest (n=3). In one case, the partner was not available near the nest, the outgoing parent self picked up the egg shell while leaving the nest and disposed it away from the nest. A smaller shell fragment was also removed in the same manner. Presence of the egg shell evokes this behavioural response by the parent [50]. An experimental study conducted on egg shell removal by Black-headed Gulls [51], concluded that the most likely function of this behavior seemed to be the maintenance of the camouflage of the brood.

On the main hatching day, the inattentive periods occurred only for 1.34% of the day OT and the average duration of inattentive period was 0.57±0.26 minute (range: 0.22-0.82). However, the frequency of parental changeovers was higher than the normal incubation days (Table 4) and there occurred a total of 11 changeovers with an interval of 0.60 hour.

3.5 Hatching Success and Habitats

Out of a total of 35 clutches containing 117 eggs, 15 clutches containing 48 eggs were entirely lost during the incubation period. A single egg was lost from another successful clutch (Table 2, Nest no. 33). None of the eggs remained unhatched. Using traditional method the overall proportion of eggs that hatched successfully was 58.11% (68 out of 117 eggs) and the non-agricultural sites showed a higher hatching success (70.58%) than the agricultural field sites (25%). As per the Mayfield Method, the estimated mortality for incubation period of RL in present study was 0.027 (15 failures/556 nest days) failures per nest day. The probability of survival was 0.973 (1.0 - 0.027) per nest day. Conclusively, the probability of survival of a nest after an incubation period of 28.75 days was 0.45 ($0.973^{28.75}$) indicating a hatching

success of 45%. A comparison the hatching success calculated as per the Mayfield Method (Table 6) revealed that it was only 6.90% in agricultural field sites and 64.80% in non-agricultural sites (sparsely grassy vacant plots, low grassy lawns/grounds, cattle dung heaps and rooftops).

Fig. 4.1. Pipping of egg

Fig. 4.2. Simultaneous hatching of two chicks

Fig. 4.3. Removal of egg shell from nest

Fig. 4.4. Chick-Day 1

Fig. 4.5. Chick- day 9

Fig. 4.6. Fully feathered young- week 5

Plate 4. Hatching of chicks in red-wattled lapwing

Fig. 5.1. Lateral tossing by outgoing RL

Fig. 5.2. Displacement brooding

Fig. 5.3. Freezing posture

Fig. 5.4. Wetting of eggs by RL

Fig. 5.5.Water squeezing by chicks

Fig. 5.6. Crouching posture by chick

Plate 5. Behaviour of adults and chicks

In the agricultural field sites, the major factor responsible for clutch loss was the preparation of the fields for rice sowing and transplantation that run concurrently with the breeding season of RL during the months of May and June. In the study area, the RL used to lay clutches in the post-harvest wheat fields expecting the availability of these breeding grounds at least for the incubation period. However, the fields were left vacant only for 2-3 weeks after harvesting the wheat crop in April and sowing of paddy continued during May and June. Hence, most of the clutches laid in agricultural fields were/are lost due to repeated ploughing and flooding of fields for rice cultivation. The nests that hatched successfully were

noticed by the farmers while ploughing and they left the nest patches unploughed (n=2) or there occurred no reploughing of the field for cultivation (n=1). Marking of the lapwing nests may reduce the accidental damage during agricultural operations [34,52].

In the non-agricultural nesting grounds, the clutch loss occurred mainly due to predation by unknown predators. Except for damage of a four egged clutches (no. 2) due to human activity, the other 06 clutches/20 eggs were entirely lost and nests were found totally empty without any egg remains. Grazing and human trespassing were quite uncommon. However, these sites were more susceptible to common terrestrial predators like stray dogs, feral cats, mongoose and rat snakes. The common aerial predators in the study area include House Crow *Corvus splendens*, Spotted Owlet *Anthene brama* , Black Kite *Milvus migrans*, Shikra *Accipiter badius* and Black-shouldered Kite *Elanus caeruleus*. The RL pairs were commonly seen mobbing the stray dogs and chasing away the House Crows frequenting their nesting grounds.

3.6 Chicks and their Behaviour

The newly hatched chicks were precocial with fully opened eyes and body covered with wet downs that soon dried. Head and trunk were brownish above with black irregular spots. The throat, back of neck and under surface of trunk were mostly white. The body is cryptically patterned against the background. A whitish egg tooth was visible at tip of the dark bill (Fig. 4.4). Weight of the newly hatched chick measured on average 13.65 gm (n=4). The chicks did not move farther from the nest until the hatching of entire clutch completed. However, just half an hour after hatching, a chick could walk out of nest and seen pecking on the ground near the nest. At time of hatching of the fourth chick the elder two were capable of exploring the nest surroundings whereas the third one was being brooded by the parent in nest.

At times during hatching, the parent kept the chicks hidden in the 'wing chambers' formed between the wings and lateral sides of trunk by adopting a dome like posture in nest. Generally, the parents along with chicks left the nest after completion of hatching and ventured the adjoining field to ensure protection and feeding of chicks. None of the chicks were seen being fed by the parents. During the first week, the chicks were observed squeezing water from the wet belly feathers of parents. The chicks reacted immediately to the alarm calls produced by the parents, either they crouched (Fig. 5.6) and remained still, or ran fast for cover in grass. In case of some isolated nesting sites (Table 2, Nest no. 3, 6, 10) the chicks were again seen after about a week (Fig. 4.5), foraging in the same wet field under vigil of their parents. In the month of July, fully feathered young (Fig. 4.6) accompanied by their parents were seen in the agricultural fields. Fledging occurs at age of 35-38 days [25].

4. DISCUSSION

The present study on breeding behavior of RL contributes information on nesting, egg laying, incubation, hatching and some other behavioural activities of RL in the rapidly changing agricultural landscape in Punjab. In the study area the RL breeding season extended from April to July and the active breeding months are same as reported in other studies [6,7,20,23,24,25,53] from various regions.

The mean egg length (L) x breadth (B) measured 42.08 mm x 30.21 mm respectively. The corresponding pattern of average values of these parameters reported in earlier studies, 41.7 mm x 33.5 mm [19], 40.66 mm x 30.42 mm [20] and 42.42 mm x 30.61 mm [7] indicate a uniform population attribute in egg morphometric parameters of RL. The mean values of these parameters, 12.2 mm x 10.6 mm reported from Southern Punjab in Pakistan [53] are quite doubtful.

Mean fresh egg weight (W) and egg volume (V) were maximum for clutches containing three eggs (W= 20.20±1.03 gm, V=18.25±0.93 cm^3) and minimum for clutch containing single egg (W= 18.51 gm, V= 16.71 cm^3). An egg begins to lose weight by diffusion of water vapors immediately after its laying. Hence, the fresh weight of an egg can only be determined at the time of laying and this daily loss of water is proportional to 0.74 power of egg weight and totals to 16% of the initial weight by end of the incubation period [42]. The calculated mean value of fresh egg weight (W) was 19.44±1.15 gm. (range 16.16-22.49 gm) and was in consonance with average weight of 19.25 gm [19] reported for RL eggs in Delhi National Park. The mean egg weight value of 17.75 gm [7] appears to be based on egg data collected after completion of the clutches.

The present study from agricultural landscape in Punjab gave a mean clutch size of 3.34±0.81 eggs with a mean incubation period of 28.75±0.97 days ranging from 27-30 days. These results corroborate the findings of earlier studies yielding mean clutch size of 3.25 eggs with mean incubation period (interval between laying and hatching of an egg) of 28.7 days ranging from 27-30 days [20], mean incubation period (interval from day of laying to day of hatching of an egg, both days included) of 29.2 days ranging from 28-30 days [19], mean clutch size

3.43 eggs [6] and 3.6 eggs [24]. However, [7] observed an incubation period of 28-38 days for RL in agricultural fields in Punjab.

Hatching period ranged from one to three successive days. In 90% (18 out of 20) of the successful clutches, hatching was synchronous and completed within 24 hours spanning over one or two successive days. In case of two three-egged clutches asynchronous hatching [36,49] was completed in three successive days. [20] and [19] reported hatching periods of 'one day' and 'two to three days' respectively in studies involving hatching of four clutches each. [24] observed many cases of asynchronous hatching that took 20-43 for completion. Undoubtedly, the present study coupled with these studies postulates that there exists a degree of hatching asynchrony in RL. Contrarily, some of the reports seem quite doubtful with regard to the hatching pattern. [22] documented that "young hatched out one after the other starting on 4 May 2010, at an interval of 46-48 hours, in the order in which they were laid. Hatching was synchronous". Similarly, [53] stated "young hatched out one after the other starting on 4 May 2016, at an interval of 24 h, in the order in which they were laid. Hatching was Synchronous". The continuous video records made during the present study revealed that the minimum interval between two successive hatching may be as short as 1.72 hours. The newly hatched chick weighed on average 13.65 gm (n=4) was in conformity with average weight of 14.02 gm (n=10) [19] and 13.60 gm [7]. Contrary to the observations reporting biparental feeding of the RL chicks by providing them food including insects, earthworms, spiders, mollusks and millipedes [7], no such feeding of the chicks or allo-feeding between the adults were noted in video-records or direct filed observations made during the present study. Rather, at times, the newly hatched chicks were seen pecking on the ground near nest just half an hour after hatching.

A comparison between habitats revealed that the clutch size in agricultural field sites (2.91±0.94 eggs, range 1-4) was lower than that of non-agricultural sites (3.54±0.66 eggs, range 2-4). The calculations made from published data of 19 clutches [7] laid in the agricultural fields (harvested wheat fields and preparatory ploughed fields) also yield a mean clutch size of 2.89±1.10 eggs. The Nest Predation Risk Hypothesis [54] states that higher probability of nest predation can favor smaller clutch size. Birds can assess nest predation risk at large and that nest predation plays a key role in the expression of avian reproductive strategies [55]. Further, in safer environments parents increased investment in young through increased egg size, clutch mass, and the rate they fed nestlings.

5. CONCLUSION

The present study from agricultural landscape in Punjab revealed that the variety and quantity of nest material used by RL in nests differed among habitats. Generally, RL used the materials available in the immediate surroundings of a nesting site and was never noticed conducting material collection sorties from other sites or habitats. The study gave a mean clutch size of 3.34±0.81 eggs with a mean incubation period of 28.75±0.97 days ranging from 27-30 days. The mean egg length (L) x breadth (B) measured 42.08 mm x 30.21 mm respectively. Incubation was biparental and the review of the video records over 06 days of full incubation revealed that the RL parents spent 58.8 hours (91.09% TOT) and 5.75 hours (8.91% TOT) as attentive periods and inattentive periods respectively. The results of the study postulate that there exists a degree of hatching asynchrony in RL. A comparison between habitats showed that the clutch size in non-agricultural sites was higher (3.54±0.66 eggs, range 2-4) than that of agricultural field sites (2.91±0.94 eggs, range 1-4). In the non-agricultural nesting grounds, the clutch loss occurred mainly due to predation by unknown predators. However, the non-agricultural sites showed a higher hatching success (70.58%) than the agricultural field sites (25%).The intensive agricultural practices particularly during the peak breeding months of May and June have heightened the chances of nest loss/failure in the agricultural fields and a lower clutch size in the agricultural fields apparently indicates an adaptive modification. The aspect urges further studies in the State. As such, the present study contributes information on breeding behavior of RL that may be effectively utilized for devising appropriate avian conservation strategies in the agricultural landscape in Punjab.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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