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Source: Wildlife Biology, 22(6) : 277-283

Published By: Nordic Board for Wildlife Research

URL: https://doi.org/10.2981/wlb.00233

Wildlife Biology 22: 277–283, 2016
doi: 10.2981/wlb.00233

Subject Editor: Gernot Segelbacher. Editor-in-Chief: Ilse Storch. Accepted 7 June 2016

Nesting success of the oriental magpie robin *Copsychus saularis* in nest boxes and tree cavities

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Information on the nesting success of birds in the Indian subcontinent is almost negligible. In the present study factors affecting nesting success were studied over four years (i.e. 2011–2014) in a color ringed population of the oriental magpie robin (OMR) in an urban habitat of Haridwar district (29°55′N, 78°08′E), Uttarakhand, India. Objectives of our study were 1) to assess whether nest box affects nesting success in the OMR or not 2) to compare breeding data obtained from nest boxes with tree cavities.

Out of total 114 nests built in both nest boxes and tree cavities, 80 nests were successful in producing at least one fledgling resulting 69.25% nesting success. Nesting success did not differ significantly between nest boxes and tree cavities or during different years. No correlation was found between territory size and nesting success (correlation coefficient = 0.41). Observations indicated that predation accounted for the maximum egg loss and nestling mortality. Predation rate was higher in tree cavities but did not differ significantly during different years and between nest boxes and tree cavities. In all years but 2011 clutch size was significantly higher in nest boxes than in tree cavities. However, incubation period, provisioning period, number of eggs hatched and number of young fledged did not differ significantly between nest boxes and tree cavities. When provided, nest boxes were occupied more frequently at all study sites indicating that nest box may act as an alternative nesting site for the OMR and perhaps for other secondary cavity nesters facing scarcity of nesting sites due to rapid urbanization.

Breeding is an important phase in bird's life, as birds spend a lot of time and energy in various breeding activities like nest site selection, nest building, incubation and provisioning of young. The breeding population of the secondary cavity nesters depends on the availability of suitable nest sites. Information on the nesting success and monitoring of the factors influencing nesting success in cavity nesters is necessary for better conservation and population management of the species. Studies on secondary cavity nesters breeding especially in nest boxes have a long history, particularly in temperate forests of Europe and America (Fargallo et al. 2001, Stamp et al. 2002, de León and Mínguez 2003, Mänd et al. 2005, Lambrechts et al. 2012, Rahman et al. 2014). Some researchers have studied secondary cavity nesters breeding in natural cavities also (Nilsson 1984, Alatalo et al. 1991, Cockle et al. 2008, Martínez et al. 2015). Many authors have revealed that nest boxes enhance the breeding success in birds (Nilsson 1975, Møller 1989, 1992, Purcell et al. 1997) while others have not found any effect of nest box on nesting success (Bortolotti 1994, Frederick 1994, Miller 2002). Unfortunately, such data on avian species in the Indian subcontinent are almost negligible (Kumar and Bhatt 2002, Bhatt et al. 2014).

Inter- and intra-specific fights for nesting cavities are common in the OMR indicating the nest site scarcity for hole-nesting birds mainly due to habitat degradation and/or urbanization in major parts of the Indian subcontinent (Bhatt et al. 2014). It may be mentioned that the nesting sites for cavity nesting birds are decreasing day by day because of the deforestation and urbanization (Small and Hunter 1988, Santos and Tellería 1992, Newton 1994, Beckerman et al. 2007). Several factors affect the nesting success and contribute to the nesting failure like inter and intra species competition, predation, habitat loss, habitat type, food availability etc. (Best and Stauffer 1980, Møller 1988, Joyce 1993). Among these factors, predation has been reported to be the main cause of nest loss by several authors (Ricklefs 1969, Martin and Roper 1988, Martin 1992, 1993, Martin et al. 2000). Nest predation has also been observed varying year to year in several studies (Petrinovich and Patterson 1983, Rotenberry and Wiens 1989, Miller 2002). Ornithologists have revealed that nest boxes may influence the predation rate in birds. Some authors found a decreased predation rate in nest boxes than tree cavities (Purcell et al. 1997, Fargallo et al. 2001),

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while, other studies showed an increased predation rate in nest boxes (Miller 2002, Dailey 2003, Czeszczewik 2004) or no effect (Purcell et al. 1997).

Selection on clutch size in birds has always received attention of ornithologists. Generally clutch size is thought to be the maximum number of eggs and offspring that parent birds can rear (Lack 1947). A number of factors have been observed affecting the clutch size like latitudinal variation (Hussell, 1972), egg laying date (Perrins and McCleery 1989), predation rate (Doligez and Clobert 2003), food availability (Lack 1947, Cody 1966, Hussell and Quinney 1987), habitat type (Kilpi and Lindström 1997), floor area of nest (Møller et al. 2014) etc. Many bird species increased their clutch size with an increase in floor area of nest (Karlsson and Nilsson 1977, Korpimäki 1985, Rendell and Robertson 1989, Møller et al. 2014), while others not (Pitts 1988).

We have done this comparative study on nesting success of the OMR using both nest boxes and tree cavities in urban habitat during 2011–2014. The causes of nest failure as well as the effect of territory size, if any, on nesting success of the OMR were studied. Also, different breeding parameters from nest boxes with tree cavities were compared.

Material and methods

Study area

The present study was conducted in the urban habitat of Haridwar district (29°55′ N, 78°08′ E), Uttarakhand, India. Breeding behaviour of the oriental magpie robin (OMR) was observed in different orchards near human habitations from March to August between 2011 and 2014. An area of about 1.77 km² was selected for this study. Temperature ranged between 25–44°C during summers and 6–24°C during winters. Dominant tree species in the study area included mango *Mangifera indica*, lychee *Litchi chinensis*, jackfruit *Artocarpus heterophyllus*, Asian pear *Pyrus pyrifolia* and guava *Psidium guajava*. The study area has been under continuous removal of the vegetative cover due to rapid urbanization for last many years (Fig. 1A–B).

Study species

The OMR, a secondary cavity nester, is a well-known passerine bird for its complex and melodious song (Bhatt et al. 2000, Kumar and Bhatt 2002). Male has black upperparts, head and throat apart from the white shoulder patch, under-parts and sides of the long tail are white (Fig. 2A). Females are grayish black above and grayish white under-parts (Fig. 2B), while young bird have scaly brown upperparts and head (Ali and Ripley 2002). Females join the territory of male during mid of February to end of March. It builds nest in the cavities found in the trees, hole of wall, metal boxes and nest boxes. This is a sedentary species and chiefly feeds on a variety of insects, larva and flies. The OMR can easily be seen foraging on the ground with cocked held tail in the gardens especially close to the human habitation. This species is least concerned at global level (IUCN 2012) except some places like Singapore where it is listed as endangered (Davison et al. 2008).

Methods

Systematic field visits were done daily or on alternate days (frequently on egg laying days, expected hatching and fledging days), as required for observing the breeding activities like nest site selection, nest building, egg laying, incubation and provisioning of young. Easily accessible natural nests (up to 2.5 meter height from ground) were observed during the study period, however four nests were found in trees cavities 8–10 m above the ground during study period. Most of the individuals (21 males and 14 females) were caught at start of the breeding season with the help of mist net and ringed with light weighted plastic color band for their individual identification. Territorial boundaries were marked where males were observed singing and male–male conflicts took place. Territory size was measured with the help of GPS. We walked along the edges of the territories with GPS. GPS recorded the distance travelled by us in all directions and exhibited the area. Bottom surface area and entrance area of tree cavities was measured with the help of

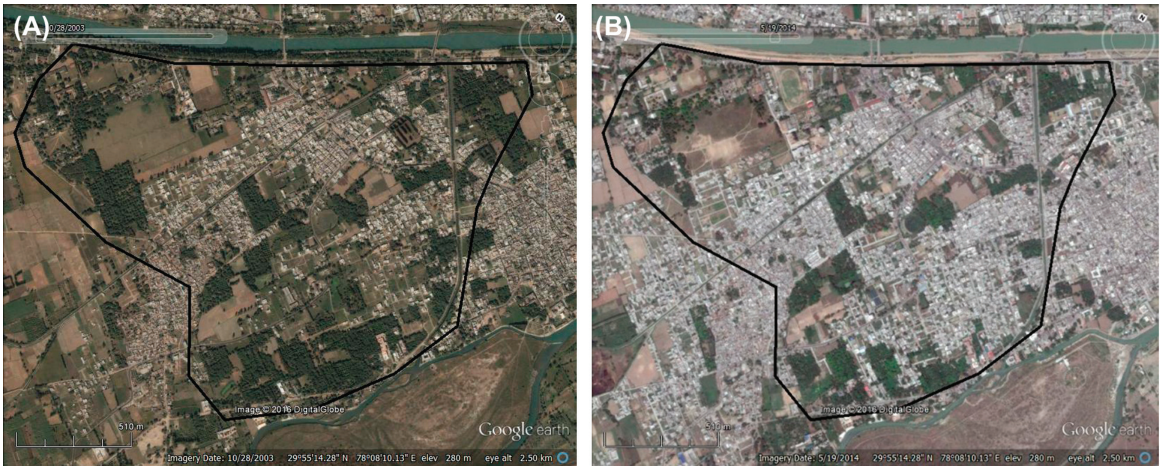

Figure 1. Maps of the study area showing sharp removal of the orchards from 2003 (A) to 2014 (B). The dark line indicates edges of study area (Source: Google Map).

Figure 2. (A) Male oriental magpie robin in its territory. (B) female at the nest box. Eggs in the nest box (inset).

weighted measuring tape (the area was estimated from the equation of an ellipse).

Nest box fixation, nest searching and nest occupation

During the first year of the study (2011), 82 and 8 nest boxes were nailed on the tree trunk and walls of the buildings respectively. Two to four nest boxes were fixed in each territory at the distance of 10–15 meter. All the nest boxes were of same dimensions (diameter of hole = 5 cm, depth of box = 10.0 cm, length = 10.0 cm, width of box = 11.5 cm, back height = 30 cm and front height = 17 cm). During consecutive years some of the nest boxes were found destroyed/missing and were reinstalled with new one at nearby locations. All nest boxes were cleaned before each breeding season.

Nest boxes were inspected weekly to know their occupancy. Nests in tree cavities were explored by observing the behaviour of male and female such as nest site selection, nest building, incubation and provisioning of young. Nest contents were checked with the help of ladder and convex mirror with handle. Breeding behaviour of the OMR and the predators in tree cavities and nest boxes were observed with the help of 10 × 50 binocular, still image camera with attached 80–400 mm zoom lens and handycam. In order to avoid attraction of the predators towards nests, nests were checked for their contents mostly during dawn when male and female were feeding. The OMR occupied 16–18 nest boxes and 6–8 tree cavities each breeding season.

Estimation of nesting success

Daily survival rate and nesting success were calculated following Mayfield (1975) method i.e. daily survival rate was calculated by the formula '1-(failed nest / total observation days)' and nesting success was calculated as (daily survival rate)$^{\text{nesting period}}$. Nests were included only if they were truly active (i.e. had at least one egg or nestling). Exposure days were counted from zero when the first egg was laid. On a nest located with eggs or young, we started counting on finding day. For nests whose outcome (fledge or fail) was known, we stopped counting exposure days in between the last date observed active and the subsequent nest check. For nests whose outcome was unknown, we stopped counting on the last active check. Nesting period was calculated by adding total exposure days (i.e. egg laying, incubation and nestling). Nests in which nestlings were not observed, number of young fledged from the nests was assumed to be equal the number of nestlings observed on the last nest visit only if the fledglings were found around the nest as the young do not leave the territory before 30 to 40 days after fledging (Kumar 1999). Clutch completion and hatching date for the nests observed during incubation and provisioning were determined by subtracting average incubation and provisioning period from hatching date and fledgling date respectively. Second and third clutches were raised after first and second successful clutches respectively.

Statistical analysis

The Mann–Whitney U-test (two sample non parametric test) was used to compare difference between two samples. For more than two samples, difference was compared by the Kruskal–Wallis test. Correlation test was used between territory size and breeding success. t-tests was used to find difference in bottom surface area and area of nest entrance hole between nest boxes and tree cavities. Statistical analysis was done following standard methods (Zar 2010). Difference between two percentages was calculated with the help of Garrett and Woodworth (1981). Results are shown as mean ± SD.

Results

Breeding ecology

During four breeding seasons (2011–2014) we found 114 active OMR nests, including 87 in nest boxes and 27 in tree cavities. Most females (n = 84) were single brooded, while 27 and 3 had two and three broods respectively. Only four second broods were found in tree cavities. During the study period nests with eggs or nestlings were observed between 10 April and 15 August with maximum number of active nests during May (Fig. 3). After pairing, male and female started to search for a suitable nesting site which lasted an average of 9.4 ± 2.89 days (range 08–14 days, n = 27). Female alone

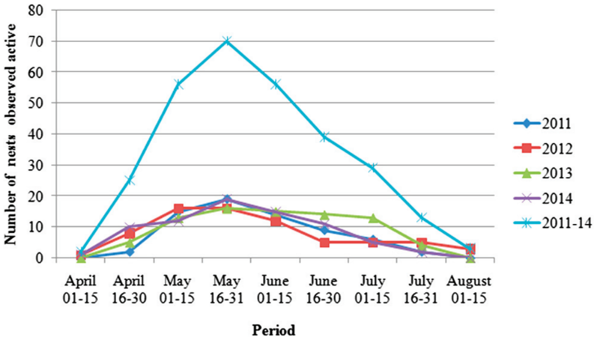

Figure 3. Showing number of active nests of oriental magpie robin observed during April to August.

built a nest and it took an average of 8.0 ± 1.2 days (range 5–11, n = 83).

Nesting cavities were found in nine tree cavities, in walls and in metal boxes (Table 1).

Bottom area of the natural cavities was significantly smaller (83.9 ± 4.21 cm^2, range 47–126, n = 9) than bottom area of the nest boxes (115 cm^2), p = 0.03, one tailed t-test. After 7–15 days of nest completion female started to lay one egg daily in the morning period (6.00–8.30 h). During egg laying and incubation period male guarded the nest singing nearby. Incubation (only female) began after the last egg was laid and lasted an average of 12.8 ± 0.82 days (11–14, n = 89) and did not differ between nest boxes and tree cavities (Z = 0.72, $p > 0.05$). Males sometimes provided food to the incubating female. Nestling period ranged from 13 to 16 days (13.8 ± 0.79 days, n = 80), and did not differ between nest boxes and tree cavities (Z = 0.62, $p > 0.05$). Both parents fed the nestlings. Other parameters such as number of eggs hatched (Z = 0.99, $p > 0.05$) and number of young fledged (Z = 0.19, $p > 0.05$) did not differ significantly between nest boxes and tree cavities.

Fledglings continued foraging for about 30–45 days within parental territory (n = 13). During this period male and female also provided food to fledglings but less frequently. Male and female again started to search the nesting site for raising next clutch. The OMR selected alternate nesting sites, but occasionally selected previous nesting site too. New nesting material was added to the nest when previous nesting site was used without removing previous nesting material in the same breeding season.

Clutch size

The average clutch size of first broods in nest boxes was 4.6 ± 0.70 eggs while in tree cavities 3.8 ± 0.28 eggs (Table 2). These differences were significant (Z = 3.1, $p < 0.001$) in nest boxes second clutches were slightly smaller each year (Table 2) but differences between first and second clutches were not significant ($p > 0.05$ in each year). Third clutches were laid only in nest boxes one in each year during 2012 to 2014 with 3, 4 and 4 eggs respectively. Clutches in nest boxes were significantly larger in all study years but 2011 (Table 2).

Nesting success (Mayfield method)

Out of 114 nests observed, 87 were built in the nest box and 27 in the tree cavity. Average nesting period was 30.2 ± 1.25 (n = 71) days for all nests during 2011–2014. Total observation days counted for 114 nests were 2793 days. When pooled the data for all years, daily survival rate as calculated by Mayfield (1975) method, was found 0.99 and 0.98 for nest box and tree cavities respectively. Nesting success (2011–2014) was found slightly higher in nest boxes (70.5%) than in tree cavities (65.1%) but the differences were not significant ($p > 0.05$; Table 3). Nesting success during different years did not differ significantly between nest box and tree cavity ($p > 0.05$ for all years).

Territory size ranged from 0.17 to 0.45 hectare (0.28 ± 0.09, n = 11) for different individuals during nesting period. No significant correlation was found between territory size and nesting success (r = 0.41).

Breeding losses

Out of total 114 nests in which at least one egg was laid, 34 (29.82%) nests were not successful. Most of the breeding losses were due to predation (94.12%). The other reason of breeding losses was desertion (one nest in nest box and one in tree cavity). Predation rate did not differ significantly between nest boxes and tree cavities (Mann–Whitney U-test, Z = 1.11, p = 0.26) and between years in nest boxes (Kruskal–Wallis, H = 4.24, p = 0.19) and tree cavities (Kruskal–Wallis, H = 0.15, p = 0.98).

Seven species of predators were identified: Indian palm squirrel *Funambulus palmarum*, house crow *Corvus splendens*, jungle crow *Corvus macrorhynchos*, shikra *Accipiter badius*,

Table 1. Characteristics of tree cavities used by oriental magpie robin for nesting.

Species of trees	No. of broods	Height of entrance Average ± SD (range)	Entrance dimensions Average ± SD (range)
Guava *Psidium guajava*	02*	1.82	88.02
Lychee *Litchi chinensis*	02*	2.05	35.8
Jackfruit *Artocarpus heterophyllus*	03	2.13 ± 0.85 (1.2–2.86)	230.36 ± 34.31 (206.1–278.9)
Mango *Mangifera indica*	09	1.68 ± 0.72 (0.5–2.4)	77.75 ± 30.14 (40.2–117.75)
Asian pear *Pyrus pyrifolia*	01	2.5	306.3
Loquat *Eriobotrya japonica*	01	2.4	34.55
Indian blackbery *Syzygium cumini*	03	2.13 ± 0.4 (1.7–2.5)	39.26 ± 3.91 (36.5–44.8)
Kadamb *Neolamarckia cadamba*	02*	2.35	106.02
Mulberry *Morus alba*	04	1.4 ± 0.46 (0.8–1.7)	144.51 ± 45.18 (66.25–170.6)
	27	2.06 ± 0.35 (0.8–2.86)	118.06 ± 94.45 (34.55–306.3)

*both the broods were in same cavity

Table 2. Clutch size of the oriental magpie robin breeding in tree cavities and nest boxes in 2011–2014 (sample size in parentheses).

	First broods			Second broods	
Year	Nest boxes	Tree cavities	Mann–Whitney test Z, p-value	Nest boxes	Tree cavities
2011	4.6 ± 0.49 (14)	4.4 ± 0.78 (7)	0.48, n.s.	4.2 ± 0.45 (5)	–
2012	4.9 ± 0.80 (16)	3.7 ± 1.21 (6)	2.30*	4.8 ± 0.45 (5)	–
2013	4.7 ± 0.70 (16)	3.8 ± 0.75 (6)	2.21*	4.2 ± 0.75 (6)	4.5 ± 0.71 (2)
2014	4.5 ± 0.74 (15)	3.5 ± 0.58 (4)	2.10*	4.3 ± 0.76 (7)	4.0 ± 1.41 (2)
2011–2014	4.6 ± 0.70 (61)	3.8 ± 0.28 (23)	3.51***	4.3 ± 0.65 (23)	

n.s. – non significant, *– $p < 0.05$, ***– $p < 0.001$.

Eurasian sparrow hawk *Accipiter nisus*, rufous treepie *Dendrocitta vagabunda*, snake (unidentified species).

Most of the nests were predated during egg laying and incubation period (61.3%) than in nestling stage (38.7%). Squirrel was observed dragging the eggs out of the nest boxes only during incubation period while other species were found predating on eggs and nestlings in both the nest types.

In successful nests 2 nests in tree cavities and 15 nests in nest boxes suffered partial content loss (8 eggs and 28 nestlings) 23 eggs were remained unhatched (number of nests = 19) and 11 nestlings (number of nests = 7) were found dead due to disease, rain etc. No significant difference was found ($Z = 0.88$, $p = 0.38$) in the entrance area (larger or smaller) of tree cavities between predated and successful nests.

Discussion

In general, most of the studies showed lower breeding success in tree cavities compared to nest boxes (Nilsson 1975, 1986, Balen et al. 1982, East and Perrins 1988, Alatalo et al. 1990, Lundberg and Alatalo 1992, Purcell et al. 1997). Contrary to these studies Ritter et al. (1978), Mitrus (2003) and Czeszczewik (2004) reported higher breeding success in tree cavities than nest boxes. While other studies have not reported any effect of nest box on nesting success (Johnson and Kermott 1994, Miller 2002).

The present study revealed that nesting success did not differ significantly between the nest boxes and tree cavities and between years in the oriental magpie robin. In American kestrels *Falco sparverius*, eastern screech owl *Otus asio* and ash-throated flycatchers *Myiarchus cinerascens*, there was no difference in nesting success between tree cavities and nest boxes (Bortolotti 1994, Frederick 1994, Purcell et al. 1997). However in the present study nesting success in both the nest types remained almost same every year, indicating constant but low predation pressure throughout the study period in both type of nests. Results also indicated that the entrance hole area does not seem to affect the predation pressure in tree cavities.

In this study, causes for nest failure were predation, hatching failure, mortality of nestlings and rejection of nest. Predators were responsible for most of the nest failures. Thus it can be inferred that nest boxes are not always safer from nest predation. In the study on plane titmice *Parus inornatus* and house wrens *Troglodytes aedon*, Purcell et al. (1997) found the marginally lower predation rate in nest boxes than in cavities. Contrary to these studies Miller (2002) documented higher rate of predation in nest boxes than in tree cavities probably because nest robbers found it easier to search nest boxes than natural holes.

If we compare the average value of first and second clutches in nest boxes in each study year, there appears a decreasing tendency of clutch size (Table 2), though statistically non-significant. Seasonal decline in clutch size has been observed in some temperate birds also (Czeszczewik 2004). Our results also indicated that out of four-year study, during second, third and fourth years, clutch size of first clutch and pooled data of first and second clutches of four years were significantly lager in nest boxes when compared to the tree cavities, probably due to the larger bottom surface area of nest boxes. Recently Møller et al. (2014) in their study on 21 species of hole and non-hole nesting birds, found a significantly positive relationship between clutch size and the base area of the nest box or nest and this relationship did not differ significantly between open nesting and hole nesting species. There are other reports also suggesting relationship between clutch size and base area of nest (great tits *Parus major,* Löhrl 1973, 1980; tree swallows *Tachycineta biclor*, Robertson and Rendell 1990; house wrens *Troglodytes aedon,* Purcell et al. 1997). But also there are studies showing no significant relationship between clutch size and base area of nest (Bortolotti 1994, Frederick 1994, Mitrus 2003). In natural habitat cavities may differ in size and shape resulting in the plasticity in clutch size in relation to

Table 3. Showing nesting success (%) in different years in nest boxes and tree cavities.

	Nesting success (%) (sample size in parenthesis)		Significance of the differences between two percentages (Garret and Woodworth 1981)
Years of observation	Nest box	Tree cavity	p-value
2011	61.17 (19)	69.58 (7)	> 0.05
2012	71.43 (22)	64.78 (6)	> 0.05
2013	73.71 (23)	62.50 (8)	> 0.05
2014	73.36 (23)	64.53 (6)	> 0.05
2011–2014	70.52 (87)	65.08 (27)	> 0.05

nest size. However, in the present study we did not find any difference in clutch size in relation to the narrow or broader bottom surface area of the tree cavities.

When provided with nest boxes in the study area, the OMR built more number of nests in nest boxes than tree cavities. It may be mentioned that in our study area gardens are being cut frequently due to rapid urbanization as is evident from Fig. 1A–B resulting scarcity of nesting habitat for secondary cavity nesters and competition among species to occupy the nest indicating scarcity of nesting holes in the study area. Under such circumstances, it may be argued that in the present study though nest boxes did not increase nesting success of the OMR when compared with tree cavities, yet they were successful in attracting the OMR to initiate breeding activities. In our study area, the ongoing removal of orchards is declining the density of tree cavities, therefore, more study on tree cavity resources is needed. In a nutshell, it can be concluded that in the OMR nesting success did not differ between nest boxes and tree cavities. Nest failure was mainly due to predation in both the nest types. Clutch size was, however, found larger in nest boxes as compared to tree cavities.

Acknowledgements – We thank Head, Dept. of Zoology and Environmental Science, Gurukula Kangri University, Haridwar for providing infrastructure facilities. Thanks are due to orchards' owners (Madan, Muniram, Pappu and Vinod) for their kind permission and cooperation.

Funding – Research fellowship (RGNF) provided by the University Grants commission, New Delhi is gratefully acknowledged.

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