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TWO NATIVE ANDRENID BEE POLLINATORS FACE SEVERE POPULATION DECLINES IN THE SEMI-ARID ENVIRONMENTS OF NORTHWEST INDIA

Ram Chander Sihag
Laboratory of Animal Behavior and Simulation Ecology
Department of Zoology
College of Basic Sciences and Humanities
CCS Haryana Agricultural University
Opposite Defence Colony, Rajgarh Road, Hisar, India, 125001
rcsihag@hau.ac.in

Abstract

Pollinator declines at the global level are the major concern of ecologists. Two ground nesting native andrenid bee species are important part of the pollination services of Northwest India. These include, *Andrena savignyi* Spinola an important wild pollinator of some major oilseed crops of the family Brassicaseae, and *Andrena leaena* Cameron an important wild pollinator of some spices crops of the family Umbelliferae, and vegetable crops of the families Brassicaceae, Apiaceae and Leguminoseae. Their importance in the agro-ecosystems of Northwest India notwithstanding, the actual status of their populations in such habitats is not known. The purpose of this study is to explore the latter aspect of these bees in Northwest India. A survey was conducted on the abundances of two andrenid species foraging on their respective host plants from 1990 to 2015 at an interval of 5 years. I counted the number of foraging bees of the two species on two crops viz. *Andrena savignyi* on a winter-flowering crop, raya (*Brassica juncea*) and *Andrena leaena* on a summer-flowering crop, carrot (*Daucus carota*). In 25 years, the foraging populations of *Andrena savignyi* declined from 4.16±0.168 bees/m^2 in 1990 to 1.2±0.09 bees/m^2 in 2015 and of *Andrena leaena* from 5.24±0.156 bees/m^2 in 1990 to 1.4±0.11 bees/m^2 in 2015. This decline in the numbers of foraging bees seemed to be caused by the habitat loss and poisoning of these bees due to the excessive and indiscriminate use of weedicides in the wheat and rice crops grown in this region. Viewing the importance of these bees in the pollination of crops, it is suggested that, habitat of these bees be conserved and, if at all necessary, weedicides safe to the soil nesting bees be used.

Keywords: Andrenid pollinators, *Andrena savignyi*, *Andrena leaena*, soil nesting bees, abundance, foraging populations, weedicides, population decline.

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1. Introduction

Pollination is an important ecosystem service. A large variety of pollinators perform this service. However, some pollinators are specialists and pollinate only selected taxa of plants. Any decline in the numbers and diversity of such pollinators is bound to influence the pollination process of the host plant(s). In recent years, many potential threats to the pollination services have been reported [1, 2] and the latter have been feared to be under the threat of disruption [1]. It is believed that any pollinator decline would result in loss of pollination services. Such changes would have dire ecosystem consequences having severe negative ecological and economic impacts. The result is expected to adversely affect the maintenance of wild plant diversity, ecosystem stability, crop production, food security and ultimately human welfare [1, 3–8]. Therefore, population status of the pollinators of each location needs to be studied.

Many earlier reports reveal that local and global pollinators have declined [9, 10]; in fact, both species diversity and richness of pollinators have declined [11–15]. This decline has been found in both wild pollinators [16–21] as well as honey bees [22–28]. Earlier, some researchers described the nature and extent of reported pollinator declines [9, 29] whereas others have reported the potential drivers of pollinator loss, including habitat loss [30, 31] and fragmentation [32], agro-chemicals [33, 34], pathogens [35], alien species [29], climate change [36, 37] and the interactions between them [38–40]. Of late, pollination ecologists are concerned about the declining status of wild pollinators of various regions and some reports are now available that explicitly warn the stake holders to be vigilant about their population status, protection and conservation [40–42].

In the northwestern region of India, raya (*Brassica juncea*) is grown in a vast area as a major oilseed winter crop and carrot (*Daucus carota*) is grown as a major winter vegetable crop. While raya (a self-pollinated crop) and other members of the family Brassicaseae, are excellent hosts of *Andrena savignyi*; onion, carrot, and other members of Umbelliferae family are excellent hosts of *Andrena leaena*. In this region, *Apis mellifera* was introduced only in early 1980s and the Indian hive bees, *Apis cerana* and *Apis indica* are absent. Therefore, crop growers have to rely on the wild bees (viz. *Apis dorsata*, *Apis florea* and other native bees) for the pollination of their crops. However, recent reports from northwest India reveal that the colonies of the giant honey bee (*Apis dorsata*) and the red dwarf honey bee (*Apis florea*) are declining [41, 42]. Therefore, other native solitary bees remain the most dependable pollinators of crops of this region. With the introduction of canal irrigation in this region crop growers practice intensive agriculture due to availability of enough canal water, excellent ploughing and mulching tools and machines and indiscriminate use of pesticides for crop protection [43, 44]. These agricultural practices have led to an intensive and massive change in the ecology and environment of this region. That has adversely affected the life of several non-target organisms; the ground nesting bees should be no exception. However, there is no report on the exact population status of these bees in the changed environment of this region. The present study is concerned about the status of two wild native ground nesting bees in the semi-arid environment of north-west India.

2. Material and Methods

This study was carried out at the Oilseeds and Vegetable Research Farms of CCS Haryana Agricultural University, Hisar (Haryana, India). Following studies were conducted.

2. 1. Pollination potential of two andrenid bees in the semi-arid environment of Northwest India

Two ground nesting native anrenid bees viz. *Andrena savignyi* Spinola (**Fig. 1**, [45]) and *Andrena leaena* Cameron (**Fig. 2**, [46]) were selected for this study.

The different crop plants which the foragers of these two native bees visited were identified and their flowering periods were recorded. The foraging behaviors of these bees visiting the flowers of respective crops were studied following method suggested by earlier researchers [47, 48]. If a foraging bee, while visiting a flower, worked from its top/front, such a forager virtually came in contact with the reproductive organs (anthers and stigma) of the flower. The foragers showing this behavior always collected and transferred pollen in each foraging effort/visit on the flowers. These foragers acted as the pollinators of the flowers of that crop. On the other hand, if a foraging bee worked from the side of the flower, such a bee did not come in contact with the reproductive organs (anthers and stigma) of the flower. This kind of a forager simply stole and collected nectar only. Such a forager was characterized as a non-pollinator (nectar thief) of the flowers of that crop. Therefore, based on the floral reward (pollen and nectar) the visiting forager collected, a host plant was characterized as a pollen and/or nectar source [47, 48]. Based on this evaluation of the foraging bees, the pollination potential of these two native andrenid species for the crops of semi-arid region of Northwestern India was determined.

Fig. 1. *Andrena savignyi* Spinola, female foraging on *Diplotaxis acris* flowers
(Photo: Gideon Pisanty [45])

Fig. 2. *Andrena leaena* Cameron female (Photo: British Natural History Museum, London [46]

2. 2. Number of foraging bees of two native andrenid species in the semi-arid environment of Northwest India

The numbers of foraging bees of the two native *Andrena* species of this study were recorded on their respective host. Therefore, for the study of number of foraging bees, raya (*Brassica juncea*) was selected for *Andrena savignyi* and carrot (*Daucus carota*) was selected for *Andrena leaena*. The observations were recorded in the crop seed production fields.

The observations were recorded on sunny days during the peak flowering of each crop e.g. at noon on the Raya plots and at 1100 h on the Carrot plots. The instant number of foraging bees present in 1×1 m^2 areas were recorded on randomly selected five plots and repeated at 5 weekly intervals (total 5×5=25 observations). These observations were repeated at five-year intervals from 1990 to 2015.

2. 3. Statistical analysis

For the comparison of 'number of foragers in different plots' and 'number of foragers in different years' the recorded data were analysed using 'Two Factor Analysis [49] and the treatments were tested at 5 percent level of confidence.

3. Results

3. 1. Pollination potential of two andrenid bees in the semi-arid environment of Northwest India

Two ground nesting anrenid bees viz. *Andrena savignyi* Spinola (**Fig. 1**) and *Andrena leaena* Cameron (**Fig. 2**) visited the flowers of many crops (**Table 1**). The foraging behavior of these bees revealed that all the foragers of these two bee species were invariable front/top foragers. That means, the foragers adopted the NP-foraging mode on the flowers of these crops [47, 48] and there were no nectar thieves. While doing so, the foragers always acted as pollinators of the flowers of these crops. Based on the foraging behavior, the potential of these bees as pollinators or non-pollinators was ascertained.

Table 1

Crop hosts and pollination potential of two andrenid bees in the semi-arid environment of Northwest India

Sr.No.	Crop	Flowering Time	Host for
1	2	3	4
	Andrena savignyi		
1	Toria (*Brassica campestris* L. var. toria)	Oct–Nov	NP
2	Rape (*Brassica napus* L.)	Dec–Feb	NP
3	Raya (*Brassica juncea* Czern. & Coss)	Dec–Feb	NP
4	Rocket Salad (*Eruca sativa* Mill.)	Feb–March	NP

Continuation of Table 1

1	2	3	4
	Andrena leaena		
1	Radish (*Raphanus sativus* L.)	Feb–March	NP
2	Turnip (*Brassica rapa* L.)	Feb–March	NP
3	Chinese cabbage (*Brassica chinensis* L. D.)	Feb–March	NP
4	Cauliflower (*Brassica oleracea* L. var. botrytis)	Feb–March	NP
5	Rocket Salad (*Eruca sativa* Mill.)	Feb–March	NP
6	Fennel (*Foeniculum vulgare* L.)	Feb–March	NP
7	Coriander (*Coriandrum sativum* L.)	Feb–March	NP
8	Cumin (*Cuminum cynimum* L.)	Feb–March	NP
9	Carrot (*Daucus carota* L. var sativa)	March–April	NP
10	Onion (*Allium cepa* L.)	March–April	NP
11	Fenugreek (*Trigonella foenum-graecum* L.)	Feb–March	NP
12	Lentil (*Lens culinaris* Medikus)	March	NP
13	Lemon (*Citrus limon* (L.) Burm. f.)	March	NP
14	Kinnow (*Citrus nobilis* × *Citrus deliciosa*)	March	NP
15	Peach (*Prunus persica*) (L.) Stokes	March	NP

Note: NP – collect nectar and pollen in each foraging visit, hence act as pollinators [47, 48].

2. 2. Number of foraging bees of two native andrenid species in the semi-arid environment of Northwest India

The number of foraging bees of the two native andrenid species of this study showed a continuous and fast decline over the period of 25 years (**Fig. 3**).

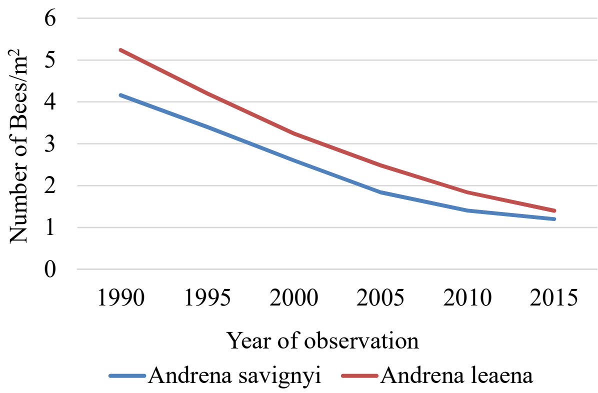

Fig. 3. Number of foraging bees (per m^2) of the two native andrenid species from 1990 to 2015

In the beginning of this study in 1990, the number of foraging bees of *Andrena savignyi* was 4.16±0.168 which over the years continuously declined to reach 1.2±0.09 bees/m^2 in 2015. This indicates that 71.15 percent foraging bees of this species vanished over a period of 25 years. Likewise, in the beginning of this study in 1990, the number of foraging bees of *Andrena leaena* was 5.24±0.156 bees/m^2 which too over the years continuously declined to reach 1.4±0.11 bees/m^2 in 2015. In this case too, a loss of about 75.28 percent of foraging bees of this species was witnessed over a period of 25 years. These declines in number of foraging bees along the years was highly significant (for *Andrena savignyi*: $F_{(5, 120)}$=77.06, P=0.000001, ANOVA, **Table 2**; *Andrena leaena*: $F_{(5, 120)}$=101.89, P=0.000001, ANOVA, **Table 3**) indicating that a significant decline in the number of foraging bees occurred between all the consecutive years. (**Tables 2, 3**). On the other hand, the differences among the numbers of foraging bees on sampled plots were non-significant (for *Andrena savignyi*: $F_{(4, 120)}$=0.149, P=0.963, ANOVA, **Table 2**; for *Andrena leaena*: $F_{(4, 120)}$=0.382, P=0.821, ANOVA, **Table 3**). These results indicate that numbers of foraging bees on the 5 sampled plots of a crop were statistically similar. Therefore, variation due to plots was non-significant. Interactions between year and plots too were non-significant (*Andrena savignyi*: $F_{(20, 120)}$=0.09, *P*=1.0, ANOVA, **Table 2**; *Andrena leaena*: $F_{(20, 120)}$=0.107, *P*=1.0, ANOVA, **Table 3**) indicating that years and plots did not significantly influence (interfere with) each other in their effects on the number of foraging bees.

Table 2

Analysis of variance (ANOVA) table on foraging numbers of *Andrena savignyi*

Source of Variation	Sums of Squares *SS*	Degrees of freedom *DF*	Mean Squares *MS*	$F_{(calculated)}$	*p*-value
Years (A)	*SSA*=172	*a*–1=5	*MSR*=1725=34	340=77.0657	0
Plots (B)	*SSB*=0	*b*–1=4	*MSC*=04=0	00=0.1493	0.963
A×B	*SSAB*=1	(*a*–1)(*b*–1)=20	*MSAB*=120=0	00=0.0955	1
Error (residual)	*SSE*=54	*rab*–*ab*=120	*MSE*=54120=0	–	–
Total	*SST*=227	*rab*–1=149	–	–	–

Table 3

Analysis of variance (ANOVA) table on foraging numbers of *Andrena leaena*

Source of Variation	Sums of Squares *SS*	Degrees of freedom *DF*	Mean Squares *MS*	$F_{(calculated)}$	*p*-value
Years (A)	*SSA*=267	*a*–1=5	*MSR*=2675=53	531=101.8904	0
Plots (B)	*SSB*=1	*b*–1=4	*MSC*=14=0	01=0.3822	0.821
A×B	*SSAB*=1	(*a*–1)(*b*–1)=20	*MSAB*=120=0	01=0.107	1
Error (residual)	*SSE*=63	*rab*–*ab*=120	*MSE*=63120=1	–	–
Total	*SST*=331	*rab*–1=149	–		

4. Discussion

The two native andrenid bees of this study are the natural, wild and important pollinators of many crops in India and adjoining countries (**Table 1**). *Andrena savignyi* is an important wild native pollinator of some important oilseed members of family Brassicaseae. On the other hand, *Andrena leaena* is an important pollinator of many vegetables, spices, pulses and fruits grown in the semi-arid environments of northwest India (**Table 1**). *Andrena savignyi* is distributed in various parts of northwest India, Pakistan, middle east, northern Africa and parts of southern Europe (**Fig. 4**, [50]), whereas *Andrena leaena* has been reported from Northwest India (**Fig. 5**, [51].

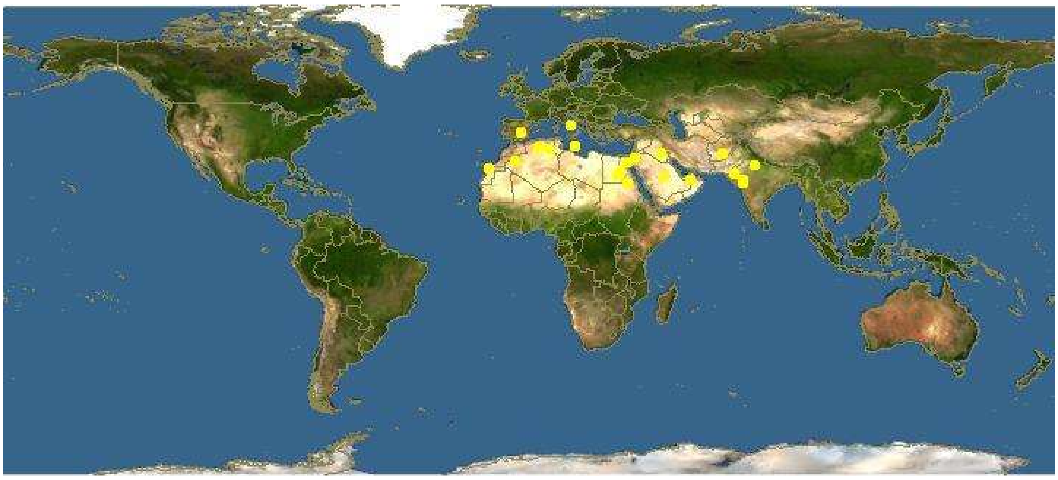

Fig. 4. Distribution of *Andrena savignyi* in various parts of globe. Yellow dots show the places where the presence of this bee was recorded (source: Discover Life: Global Mapper [50])

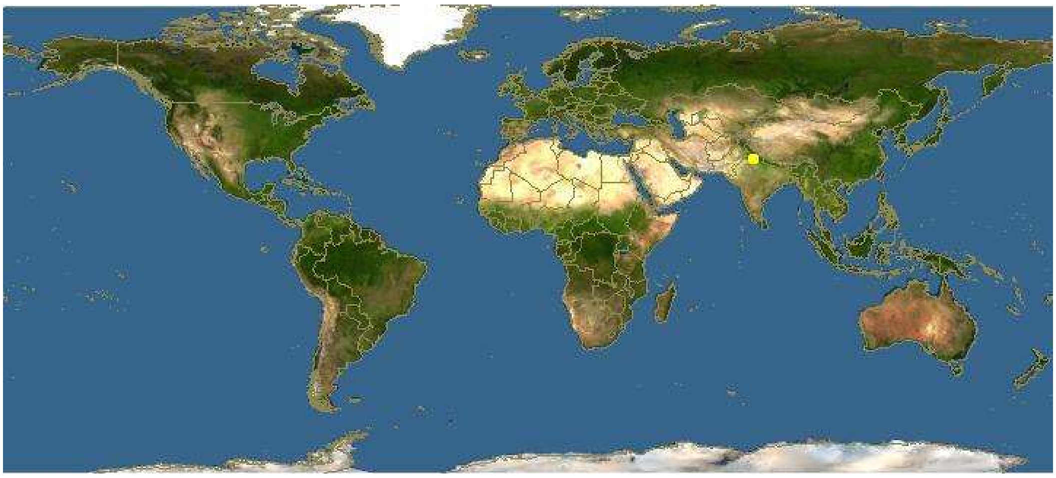

Fig. 5. Distribution of *Andrena leaena*. Yellow dot shows the place where the presence of this bee was recorded (source: Discover Life: Global Mapper [51])

However, in this region of India these bees showed a steep decline in their foraging populations (**Fig. 3**). In a span of 25 years, the foraging populations have reduced to about 25 percent of their original levels. That is why, these native bees in this region seemed to heading towards extirpation. The latter situation would lead to a likely significant loss of the pollination service to the natural and agro-ecosystems of this region. Some earlier reports too reveal the decline of native bees [16–21].

The reasons for losses in populations of two andrenid bees are not known. The ecological drivers responsible for such losses and declines are needed to be investigated and suitable strategies are needed to be devised/ adopted to reverse the processes of decline in the foraging populations of these bees. The following points could be of interest to guide such strategies.

4. 1. The incidence of diseases, pests, predators and other enemies

There are no reports on the occurrence of diseases, pests, predators and enemies of these bees. These factors do not seem to be the likely causes of large scale losses of the foraging populations of these bees. However, reports from other bees reveal the occurrence of these drivers from this region [52, 53]. Therefore, a detailed study on this aspect is required.

4. 2. Floral dearth

Andrenid bees are active only during some months of the year. During these months of the activity periods of these bees, plenty of bee forage is available (**Table 1**). Many crops like raya (*Brassica juncea*), carrot (*Daucus carota*), turnip (*Brassica rapa*), radish (*Raphanus sativus*) etc. are in blooms during this period and act as excellent sources of pollen and nectar. Therefore, floral dearth too was unlikely to be an ecological driver to cause the decline of foraging populations of the two native andrenid bees.

4. 3. Use of weedicides in wheat and rice fields

Wheat and rice, the two major crops (grown in several thousand hectares) of this region, are cultivated in this region. Both these crops require weedicides for the control of weeds [44]. February-March is the period of application of weedicides in the wheat crop whereas August and September are the months for weedicides application in the rice crop. These applications, although don't affect the bees directly, their residues are expected to adversely affect the life of ground nesting bees. The indiscriminate use of these weedicides has completely changed the environment and ecology of the region. The environment and habitat both have become highly polluted and toxic for non-target indigenous organisms including the ground nesting native andrenid bees. These weedicides are likely poisons for the ground nesting bees. Presence of these weedicides in the agro-ecosystem, therefore, seems to be the likely driver to cause the large scale demise of ground nesting bees.

4. 4. Loss of nesting area and habitat

Degradation or loss of nesting area and habitat can be considered as one of the most important ecological drivers responsible for the loss of bee diversity [54]. Two native andrenid species selected for this study are the ground nesting bees. During the past 75 years, introduction of canal irrigation in this region has led to massive expansion of cultivated lands and intensive ploughing/mulching of the agricultural lands. These practices might have extensively finished the nesting sites and nesting beds of these bees. This might have drastically reduced the availability of nesting areas across the whole of the northwestern region of India. Therefore, loss of nesting areas and habitat seems to be a most potential and likely ecological driver to cause the loss of foraging populations of these bees.

The present status of massive losses of number of foraging bees of the two native andrenid species should sound an alarm bell for making immediate conservation efforts to save these and other native bees from their complete extirpation from this region. Long term bee conservation strategies will have to be devised and implemented taking in to account the conservation of bee habitats, provision of their nesting beds and application of integrated pest management practices.

4. 5. Limitations of the study and prospects for future research

The declines in pollinator populations have been a concern of many pollination ecologists in recent years. There are only a few reports on native bees; the major concerns have been shown regarding the exotic species. Native bees are also important pollinators in the natural and agroecosystems, and require equal attention. Therefore, it is important to investigate the actual causes of their decline so that efforts can be made to conserve and restore their declining populations. In this study, the actual causes of decline in populations of two native ground nesting andrenid bee species were identified by simply elimination method. This, in fact, needs to be properly investigated. This study, therefore, opens research avenues for doing surveys on the population status of native pollinators, identify real causes of their population decline (if any), and taking appropriate steps for devising methods of their conservation.

5. Conclusions

The ground nesting two native andrenid bees of this study are important pollinators of crops of the semi-arid environments of Northwest India. However, these bees are facing severe decline in their foraging populations in this region. Indiscriminate use of weedicides on the wheat and rice crops and the excessive ploughing/mulching of fields seem to be the likely ecological drivers to cause declines in the number of foraging bees of these two andrenid species. A serious view has to be taken to halt the habitat loss, provide nesting beds and develop safe crop protection strategy which may ensure a safe environment to these bees so that the latter could be saved and revived from their extirpation from this region.

Conflict of interest

The author declares that he has no conflict of interest in relation to this research, whether financial, personal, authorship or otherwise, that could affect the research and its results presented in this paper.

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Data availability

All data are available within the article.

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