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Original article

Nesting behaviour and foraging characteristics of *Andrena cineraria* (Hymenoptera: Andrenidae)

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ABSTRACT

The current studies were carried out in the three experimental locations of Kashmir valley during 2013 to 2016. The species *Andrena cineraria* formed the dense nest aggregations in plan grounds, barren lands and hilly areas near the fruit orchards and other landscapes with clay loam soil type. The species start flying and foraging in the orchards from April till July. The nests were allodalous, 29–36 cm in depth, with cells located obliquely around the main barrow. The nests were dense with a maximum density of 11.09 nests/m^2 observed in landscapes of Budgam. The barrow diameters were found varying with depth from main entrance. The maximum barrow diameter recorded was 2.05 mm. At certain depth, the female constructs the first cell and the upper nest burrow is vertical and lower is oblique. The nest entrance is generally hidden under the tumulus. In the depth of average 30.48 cm, each cell directly opens to main burrow either alternately or unilaterally. The cell number, diameter, and length varied with depth. Foraging behaviour of *A. cineraria* on various fruit crops and other shrubs and social forestry trees were determined and the abundance, visitation rate, total visits and time spend per flower were found significant, especially on fruit crops. The significance of the studies is important for the melittologists, as it will help in the conservation of bee fauna. The study is also important in using this species for pollination purpose and would also help to detect and understand the possible pre-adaptation of species in temperate region of Kashmir valley.

1. Introduction

Diversity of insect pollinator community significantly affects the pollination of important agricultural crops (Albrecht et al., 2013). Insect pollination is one of the most important mechanisms in the maintenance and promotion of biodiversity, and in general, life on Earth. For the survival of the insect pollinators, the habitat requirement for nesting sites is of prime importance. Nesting sites comprise soil for endogeic (ground nesting) species and a variety of structures such as dead wood, plant stems, rock fissures or even

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empty snail shells for hypergeic (above ground nesting) species. Pollen sources and nesting sites are often distributed over different habitats (Westrich, 1996). Therefore, most bee species rely on several partial habitats to cover all needs, and these habitats have to lie within the flight range of the bee species, which is usually limited (Gathmann and Tscharntke 2002). For hypergeic bee species the nest sites are probably a more limiting factor than flower resources, because there is often a lack of suitable sites or material for nest construction in agricultural landscapes. Nests can be challenging to locate, therefore proxies are used as a means of quantifying potential nesting resources and habitat conditions within a landscape. In fields the characteristics, such as exposed bare ground (Potts et al., 2005), litter cover (Grundel et al., 2010), soil compaction (Wuellner, 1999), sloping ground (Burkle and Alarcon, 2011), and number of potential nesting cavities like cracks or holes in the ground (Potts et al., 2005) have been correlated to native bee community structure, but they have not been explicitly linked to within site nesting incidence. Additionally, the distribution of nesting sites within a location may influence the distribution of within site nesting for the species having strong nesting preferences (Wcsilo, 1996; Wuellner, 1999). Habitats may not be uniform in their ability to support populations of nesting bees (Grundel et al., 2010). However, models increasingly use nesting proxies and expert opinion regarding nesting suitability of landscapes. Most of Halictidae species nest in moist plain ground. The species *Anthophora pueblo* were found to dig nest in hard sandstones (Michael et al., 2016). Carder bees nest in hard clay soils, the nest wall is lined with intricate organic matrix (Parker et al., 2016), or organic lining (Paxton et al., 2016). The nest architecture of Andrena consists of a single, vertical main shaft and several horizontal laterals, each terminating into the single vertical cell. The nests usually varied in their depths even at same location (Miliczk, 2016). After locating a suitable hole, the bee begins to build little "cells" which are usually placed linearly along a tunnel, each one filled by pollen ball and one egg (Parker et al., 2016).

The species *Andrena patella*, *Andrena flordula*, *Andrena cineraria* have relative abundance of 3.05 ± 0.14, 1.83 ± 0.16 and 0.72 ± 0.09 bees/m^2/10 min, respectively on peach (Dar et al. 2020a); and the genus Andrena comprised of about > 5, 8 and 40 % of populations on various fruit crops (Abrol 2011, Dicks et al. 2015, Kimoto et al. 2012, Russo et al. 2015, Pellegrino 2015). Andrena species *Melandrena* is a potential pollinator of the apple crops (Park et al. 2015) exhibiting higher pollen deposition, few species emerged earlier in spring and pollinates the stone fruit crops (Moisset and Buchmann 2011, Wafa et al. 1975); and total visits, visitation rate and time (s) spend by *A. patella* on peach, plum and cherry were 0.76, 2.00, 2.34; 0.85, 0.76, 0.90 and 48 ± 1.69, 18 ± 0.03, 13 ± 0.04, respectively (Dar et al. 2020b). However, Thomson (2000) reported that the species *Andrena falvus* made 61 visits in 35 h, whileas the species *Andrena armata*, *A. carantonica* and *A. hoemorrhoa* were observed most frequently with longer flight periods than others, coincide with the peak blossoming of the fruit trees (Chasigaud, 1972) and have higher abundance (Cure and Laroca (2010). Normally in fruit orchards and other landscapes diverse communities of pollinators are present dominated by Andrenidae and Halictidae species (Watson et al., 2011). In Kashmir region, the species of genus Andrena were observed everywhere to reside in plan to sloppy fallow lands near the fruit orchards constructing the deep nests, with cavity guarded by tumulus. Therefore, in this article we are discussing the foraging beahviour of *A. cineraria*, so as to get better understanding of habitat and forage requirement of this important generalized insect pollinator.

2. Material and methods

2.1. Habitat

A. cineraria is a mining bee needs soil surface to nest on and it typically feeds on flowers of plants in fruit orchards. Among all species, the *A. cineraria* is second dominant after *A. patella* in fruit orchards of Kashmir valley, which are generally plan to sloppy in topography. The bee can forage on flowers when it is close to an area that can be used as a nesting site. The changing agricultural landscape at many places has reduced the bee habitat, because bees make nest aggregations in the undisturbed landscapes.

2.2. Study area

The survey was carried out on three separate landscapes of Kashmir valley, at altitudes ranging from 1613 to 2730 meters above the sea level (ASL) in the valley south-west during the years 2013, 2014, 2015 and 2016. (Fig. 5). The bee populations were situated on the plane and sloppy areas near the apple and stone fruit orchards. We studied the density of the nests in each location by measuring and throwing a 20 by 20 cm^2. We tossed the quadrat, so that multiple tosses did not cover the same patch of ground. Every nest entrance within the quadrat was counted and the number of nests per square meter (nests/m^2) were calculated. The nest density was assessed twice a year, in mid-May and again in late-July, observing the nest burrows and cells up to the final depth of the nest. The excavated soils were removed carefully to avoid the blocking of the nest cavity. The light dust from the depth of burrow and narrow cells were gently removed by an air pump. Then, we observed and counted the bees in each nest.

2.3. Foraging behavior

From the beginning (1st week of April) until the end of blooming season, insect pollinator visits per 1 m^2 branch length were observed for ten minutes on fruit crops. On each of the observation days, three branches of each plant species were chosen, and total numbers of the insect pollinators were counted visually for 10 minutes at the start of each hour. The time periods are planned to satisfy the various forms of insect pollinators' distinct activity patterns. The number of plants in the patch and the number of open flowers on each plant were also reported before each observation period. Every pollinator entering the flower patch, the number of the flowers visited in succession per foraging bout, and the time spent visiting the flowers during the foraging bout were all recorded during the observation period. In case of grasses and shrubs and other plants visited by *A. cineraria* all observations were made by selecting a 25 m^2 plots and taken regular reading daily with a hand tally counter and chronometer (stopwatch) according to the method given by Free (1993). As a result, a total of 20 different plots from the three landscapes and slope areas were chosen for the study. The abundance of insect pollinator in each plot according to equation (1). The time spent per flower and the number of visits per unit time by various insects on all plant species were recorded using a stopwatch with a 0.01 second accuracy. The stop watch was started when the insect approached the flower or entered the bout, and it was stopped when it left. A foraging session began when a pollinator entered the patch and ended when the same pollinator disappeared. The pollinator's efficiency was determined through their foraging behaviour (total visits, eq. 2; visitation rate: eq. 3 and visitation %: eq. 4)

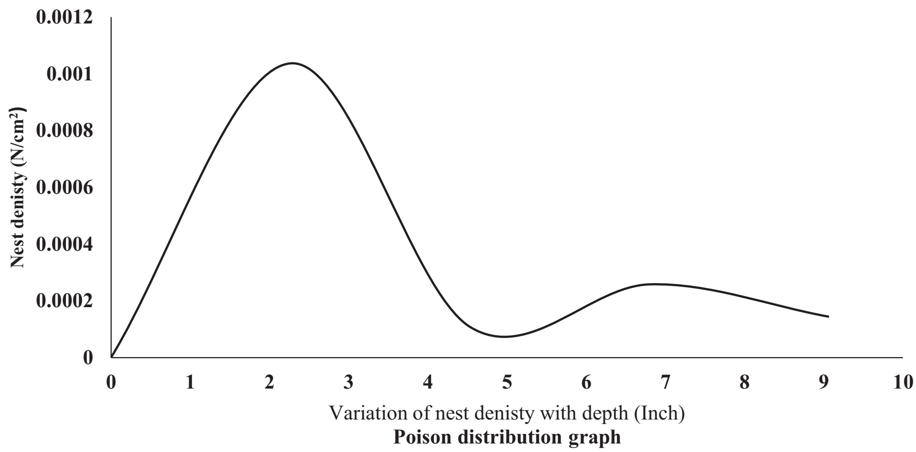

Fig. 1. Poison's probability distribution of nest density at various depths from the plan surface (Tails (N) = 10, probability = 50%).

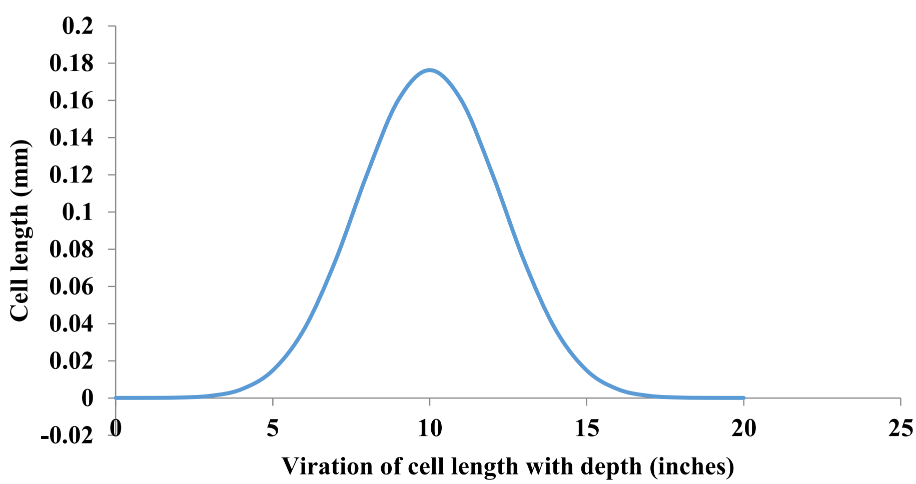

Fig. 2. Poison's probability distribution of nest cell length at various depths (inches) from the plan surface (Trails (N) = 20, Probability 50%).

Fig. 3. Andrena cineraria in nest cavity in sloppy areas of Budgam (CITH) observed during 2015, adult female block the nest entrance with head pointing outwards of the nest. During the day time female bees spends time in guarding the nest cavity after it comes from foraging.

Fig. 4. *A. cineraria inside* the nest cavity on sloppy area in after noon (adult bees went for foraging in nearby orchards); nest cavity is 20 m away from cherry orchards, but the nesting habitat is full of wild weeds and shrubs.

Fig. 5. Andrena cineraria nest excuvated for evaluation of various characteristics; figure showed that nest burrow is not straight nor the cells are in complete horizontal position, so the main tunnel excavation was done in zig-zag manner to determine the nest cells and cavity length.

Abundance =	Mean number of insect pollinators/ square meter branch length
	10 min

The efficiency of the pollinator was determined through their foraging behaviour. (Eq. 1)
Total visits (Eq. 2)

Number of visits
Flower bout of one meter square length (m^2)

2.4. Visitation rate (Eq.3)

Total number of visits
Insects/m^2/10 min

2.5. Visitation per cent (Eq.4)

Total Number of visits/m^2	x 100
Bout of one meter square length (m)	

2.6. Foraging distance from nesting cavity

The foraging distance was calculated on a 25 m^2 plot using agricultural landscape models (see for more information, Rands and Whitney, 2011).

2.7. Statistical analysis

We used SPSS, R-software, χ2-square test and poison's distribution for raw data analysis. The difference of the nest characteristics between the different experimental locations were estimated using One-way ANOVA.

3. Result

The nests were discovered during the blooming period of apple and stone fruit crops from 2013 to 2016. Ten nest aggregations were observed in the plan grass lands of Budgam (South), two in Srinagar and four from Pulwama, respectively from an area of 4 m wide and 10 m in length. The variation in bee nest aggregations is contributed by landscape composition, which intern has strong impact on female bee's ability to locate and obtain quality nesting and provisioning resources. Some of the nets observed were scattered; however, majority of them were aggregated and it showed that species has preference of some selected landscape areas for nesting. In the habitat once the foraging resources become scare, the bees are more likely to use resources farther from the nesting sites, which may result in reduction of spatial distribution across sites. The nests formed the dense aggregations within the range of 12.50 km length across all locations, within the compact clay loam soil. The maximum nest aggregations were reported from southern area on sloppy (>5% slope) (Fig. 4), dry and open lands with full sun screen. The sites were not normally hit by wind and had uniform microclimatic conditions. Nests observed were present on undisturbed sloppy to flat grounds, vertical walls (<5%), mostly with scattered grassy patches from 1st week of April (Table 1). Sometimes nests were also observed on sides of foot paths, bunds, banks, and other abandoned areas close to foraging resources and were observed on weekly basis at three times in the day at different places commencing from less activity periods of morning and evening, and higher nest construction activities were observed at noon hours.

The averages of 4.24 cells were recorded for each burrow (Table 1), with entrance provided with tumulus of 2.68 to 2.72 mm in diameter with turret height of 4 to 6 cm. Each burrow mostly contains 3 to 4 females and 1 males. The mandibles distinctly wear away in the course of active period, indicating the excavation of overnight burrows. In digging, female loosened soil into particles by biting, and pushed them behind with forelegs,

Table 1
Nesting characteristics of *Andrena cineraria*, Ashy mining bee observed from 2013 to 2016 in the landscapes of Kashmir valley.

S. No	Nest character	Mean
1	Flight season	1st week of April- 4th week of July
2	Nest site observed	Flat ground, sloppy surface, vertical walls
3	Nest type	Allodalous
4	Cell wall	Polished, 1–2 layers
5	Shape of cell	Oval to flattened, or oblong, semi-horizontal
6	Orientation of cell	Horizontal to 35-43° or 45-48°
7	Cells per barrow	4.04–4.44
8	Nest density (nest/m2)	11.09–12.44
9	Diameter of entrance (mm)	1.92–2.87
10	Diameter of burrow (mm)	2.05–2.66
11	Depth of nest bottom (cm)	59.51–64.95
12	Depth of cell (cm)	29–36
13	Cell diameter (mm)	1.02–1.10
14	Cell Length (mm)	9.03–10.18
	χ^2-square distribution T-test Significance (N = 16)	31.18 (24.09 at 15df) so, p-value < 0.05, N = 16 P-value $\leq$ 0.05 p $\leq$ 0.0198 (i.e. $\leq$ 0.05)

supporting herself with hind legs and often rotating the body irregularly. The digging at bare, lose and moist ground is less energy consuming, and may prevent the tearing of mandibles. The digging of burrow in the ground with fallen rotten leaves is always avoided, since the compact clay surface is preferred for nesting. The burrow diameter recorded ranged from 2.05 to 2.66 mm (Table 1). The female guards the burrow with his head (Fig. 3). Male appear prior to females and disappear before them in the start of June. On the nest entrance the females make short round flights of about 85 to 90 cm diameter and come back to nest entrance. Research suggested that air temperature may be a limiting factor for their short flights, and bee takes some time for warmth on the foliage or flowers (Fig. 6).

In soil, at 6 cm depth, the female constructs the first cell, and cell construction continues till the end of the burrow. The cell is mostly oval in shape inside, and on an average, 4 to 5 cells were prepared for each burrow. The upper nest burrow is vertical and lower is oblique to horizontal, but the two aspects are not always distinct (Fig. 5). Orientations of the cells were horizontal with angle varying from 35 to 48 degrees. The nest entrance is generally hidden under the tumulus, but soon exposed by disappearance of the loose soil or by wind movement. In the depth of average 12 in., each cell directly open to main burrow either alternately or unilaterally. The cells are oval, symmetrical or asymmetrical, elongated and concentrated around the main semi-circular burrow. Laterally, the cells are flatter and with convex lower end (Table 1). The cell wall is fine, very thin, waxy inner layer, and polished and cemented from outer side, and in most case cell wall is 2 layered and in few instances it was only single layered (especially in newly formed nests). The nest cells number and diameter, and length (Poison's distribution graph Fig. 2) varied with the depth. Generally, in upper 6 to 12 cm, maximum of the cell count was observed (Fig. 1). Determination of nesting habitat for this species is important to understand the possible pre-adaptation of species in temperate region of Kashmir valley.

Of particular significance to pollinators, the vegetations (crops and weeds) at Kashmir region showed a broad range of flowering phenology, with many of the plants blooming very early in the growing season and some later in summer. Plant species require insect interaction for pollination, and the insect visitation rates are important because it affects the overall likelihood of effective pollination. For efficient pollination to be performed by *A. cineraria* the foraging behavioral elements like total visits, visitation rate, and time spent by *A. cineraria* on different flowers (Table 2). My observations of the interaction between diverse flowers and *A. cineraria* indicated a wide range of foraging behavioral characteristics in Kashmir division. It was observed that the difference in flower size, anther position and pollen production between flower morphs might affect pollinator visitation patterns as shown in Table 2. The differences in floral display size and petal colour might also greatly affect pollinator behaviour. A considerable variation exists in total visits, visitation rate, per cent visitation rate and time spent by *A. cineraria* on different flowers (Table 2), which is almost entirely accounted for by differences in flower handling time. An interaction between *A. cineraria* and floral trait variation may be a potentially important feature of flower selection. This interaction is likely to be particularly important even a single species often show marked spatio-temporal variation in abundance and pollination effectiveness. Regardless of proboscis length, *A. cineraria* inherently have shorter handling times, showed higher visitation rate and spends comparatively less time on weeds and shrubs and more time on fruit crops as the visitation rate and total visits are inversely correlated with time spend on each flower type (Table 2). On fruit crops, the mean abundance, total visits, visitation rate and time (s) spend by *A. cineraria* on peach, plum, cherry, apricot, apple and pear (Kashmari Nakh) was 0.31, 0.28, 0.63, 38; 1.31, 0.19, 0.57, 28; 2.52, 1.10, 0.90, 20; 1.0, 0.28, 1.07, 21.0; 2.5, 1.09, 1.11, 25 and 0.55, 0.56, 1.21, 19.0 respectively. The time spend by species per bout or per individual flower varies for different plant species and minimum mean time was spend on fruit crops and maximum on weeds and shrubs. Mean distance for the attraction of the *A. cineraria* from nesting cavity were based on the nectar content, flower size and colour, that is much satisfactory and conducive from fruit crop species, therefore attracts bees from large distance compared to weeds and other plants observed during experiment. The nectar dissipates in the environment and bee sense it from large distances and makes movement towards the source.

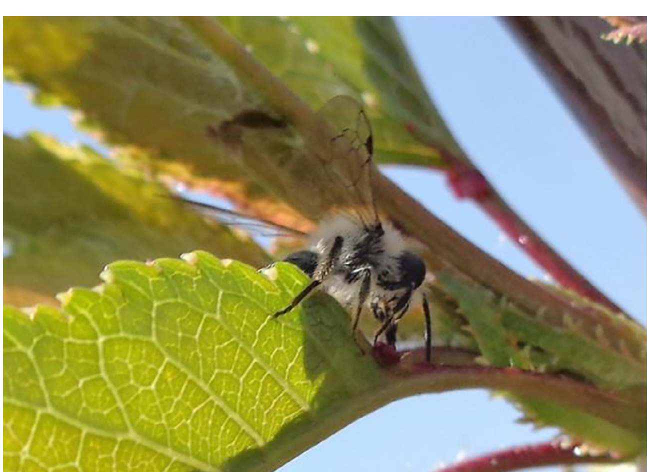

Fig. 6. Andrena cineraria resting on cherry leaf after foraging, probably searching mate in early of the season. In morning hours (before 10:45 am) the bee rest on leaves to warm up and gain energy, need for forage flight and visitation.

4. Discussion

In Kashmir region, the flower blooming periods range from 1st week of April to 4th week of July, and during this period maximum of the nests were discovered from 2013 to 2016. Total of 16 nest aggregations were observed in the plan areas of about 4-meter-wide, that is in collaboration with Antoine and Forrest (2020) who observed that 75% of the bees nest in plan soil. The variation in nest aggregations is contributed by landscape composition, which intern has strong impact on bee ability to locate and obtain quality nesting and provisioning resources. Some of the nets observed were scattered; however, majority of them were aggregated. The nest aggregation breaks once resources become scared and bee migrates to other areas of abundant food. Therefore, due to exhaustion of food resources bees are more likely to flight long distances from the nesting sites, which may result in reduction of spatial distribution across sites and showed a bimodal latitudinal gradient confirmed by the studies of Orr et al. (2020). In the current studies, the nests formed the dense aggregations within the range of 12.50 km length across all locations, with compact clay loam soil. The majority of nest aggregations were reported from southern area of the valley; similarly Falk (2016) observed that *Andrena clarkella* nest on south side, in sloppy, dry and barren lands with full sun screen.

The sites were prevented from wind, and provided with favorable microclimate. Nests were present in aggregations with an averages cell count of 4.24 recorded from each burrow (Table 1); and the nest entrance provided with the tumulus of 2.92–4.19 in. in diameter and mean tunnel depth of 60.50 to 67.05 cm from sur-

Table 2
Host plants/shrubs, abundance, foraging characteristics and foraging distance travelled in temperate areas.

S. No	Major Crop/weeds	Abundance (No. of insects /$m^2$10 m)	No. visits/10 m/m^2	Visitation rate	Time spend/flower (Seconds)	Mean distance travelled from nest cavity (25 m^2) in meters (m)
1	Peach	0.31	0.28	0.63	38 ± 2.45	13 ± 2
2	Plum	1.31	0.19	0.57	28 ± 1.50	14 ± 3
3	Cherry	2.52	1.10	0.90	20 ± 0.44	10 ± 1
4	Apricot	1.00	0.28	1.22	20 ± 0.11	11 ± 2
5	Apple	2.50	1.12	2.50	25 ± 0.23	12 ± 1
6	Quince	0.55	1.10	1.21	19 ± 0.14	14 ± 1
7	Pear	0.79	0.50	2.22	16 ± 0.53	12 ± 1
8	Robinia pseudoacacia	0.23	0.21	0.39	29 ± 0.74	16 ± 1
9	Crab apple	0.62	0.22	0.28	18 ± 0.30	15 ± 2
10	Rubus navus	0.61	0.30	0.20	29 ± 0.09	17 ± 1
11	Brassica compestris	2.12	0.20	0.38	44 ± 0.83	19 ± 2
12	Brassica rapa	2.00	0.20	0.27	33 ± 0.07	18 ± 2
13	Astragalus grahamianus	0.26	0.21	0.24	43 ± 0.34	22 ± 1
14	Bellis perennis	0.32	0.20	0.20	45 ± 0.42	23 ± 1
15	Carya illinoinensis	0.18	0.10	0.20	50 ± 0.64	23 ± 1
16	Centaurea iberica	0.15	0.10	0.31	23 ± 0.84	22 ± 2
17	Chrysanthe mum coronarium	0.23	0.22	0.25	35 ± 0.13	11 ± 1
18	Thymus serphyllum	0.20	0.30	0.10	39 ± 0.13	23 ± 1
19	Thymus linearis	0.38	0.10	0.20	36 ± 0.07	24 ± 1
20	Aconitum laeve	0.15	0.12	0.10	28 ± 0.01	18 ± 3
21	Alcea rosea	0.12	0.13	0.31	29 ± 0.35	17 ± 3
22	Antirrhinum majus	0.12	0.11	0.10	54 ± 0.53	19 ± 4
23	Aster thomsonii	0.30	0.11	0.10	49 ± 0.61	23 ± 1
24	Astragalus grahamianus	0.20	0.12	0.12	51 ± 0.90	22 ± 2
25	Bellis perennis	0.20	0.01	0.39	48 ± 0.21	24 ± 1
26	Berberis	0.11	0.21	0.24	26 ± 0.13	23 ± 1
27	Brassica compestris	0.11	0.22	0.28	39 ± 0.45	22 ± 2
28	Brassica rapa	0.10	0.20	0.27	20 ± 4.50	18 ± 3
29	Capsella bursa- pastoris	0.13	0.21	0.19	29 ± 0.94	17 ± 4
30	Carduus edelbergii	0.21	0.25	0.31	24 ± 0.81	20 ± 3
31	Centaurea iberica	0.10	0.15	0.25	45 ± 0.43	19 ± 4
32	Cercis Canadensis	0.15	0.24	0.20	29 ± 0.24	21 ± 2
33	Chrysanthe mum coronarium	0.13	0.26	0.23	36 ± 0.43	20 ± 3
34	Cirsium arvense	0.08	0.27	0.10	29 ± 0.24	21 ± 3
35	Cirsium vulagare	0.20	0.10	0.10	19 ± 0.31	24 ± 1
36	Cirsium falconeri	0.09	0.19	0.16	39 ± 0.19	17 ± 3
37	Clematis Montana	0.21	0.14	0.24	49 ± 0.01	20 ± 3
38	Convolvulus arvense	0.27	0.13	0.28	53 ± 0.57	23 ± 2
39	Coriandrum sativum	0.24	0.18	0.10	46 ± 0.30	15 ± 3
40	Cucumis melo	0.20	0.18	0.21	41 ± 0.22	16 ± 3
41	Cucumis sativus	0.09	0.17	0.21	53 ± 0.34	16 ± 1
42	Cucurbita maxima	0.20	0.11	0.26	25 ± 0.24	13 ± 1
43	Cucurbita pepo	0.12	0.11	0.19	30 ± 0.23	16 ± 1
44	Daucus carota	0.02	0.15	0.23	33 ± 0.23	14 ± 3
45	Euphorbia helioscopia	0.10	0.14	0.10	39 ± 0.27	13 ± 3
46	Forsythia viridissima	0.20	0.13	0.25	18 ± 0.21	14 ± 3
47	Iris decora	0.27	0.11	0.16	59 ± 0.05	16 ± 3
48	Iris hookeriana	0.31	0.09	0.21	58 ± 0.13	19 ± 5
49	Bergenia ligulata	0.25	0.06	0.17	40 ± 0.31	19 ± 5
50	Anthemis cotula	0.19	0.08	0.12	50 ± 0.10	15 ± 3
51	Lavandula officinalis	0.16	0.09	0.24	40 ± 0.11	21 ± 3
52	Lindelofia longiflora	0.10	0.12	0.14	22 ± 0.33	22 ± 2
53	Veronica arvensis	0.30	0.21	0.11	59 ± 0.54	24 ± 1
54	Veronica Persica	0.21	0.10	0.11	29 ± 0.84	23 ± 1
56	Thymus serphyllum	0.28	0.10	0.40	50 ± 0.13	19 ± 4
57	Trifolium pretense	0.03	0.10	0.11	39 ± 0.53	22 ± 1
58	Trifolium repens	0.20	0.21	0.08	59 ± 0.17	22 ± 1
59	Sonchus oleraceus	0.27	0.21	0.12	19 ± 0.51	21 ± 1
60	Sisymbrium	0.17	0.03	0.21	39 ± 0.15	20 ± 1
61	Rosa brunonii	0.06	0.09	0.23	59 ± 0.43	24 ± 5
62	Rosa canina	0.08	0.03	0.10	46 ± 0.61	24 ± 2
63	Rosa indica	0.25	0.06	0.30	40 ± 0.40	19 ± 2
64	Rubus elipticus	0.21	0.11	0.26	51 ± 0.51	20 ± 2
67	Rubus fruticosus	0.21	0.14	0.05	27 ± 0.43	20 ± 2
68	Rubus niveus	0.03	0.19	0.09	41 ± 0.01	17 ± 2
69	Rubus occidentalis	0.26	0.10	0.16	50 ± 0.24	16 ± 2
70	Rubus ulmifolius	0.09	0.01	0.60	20 ± 0.34	20 ± 3

N = 70, $P < 0.05$

face, similarly Vivallo (2020) who observed that oil collecting bees *Epicharis* (*Triepicharis*) *analis* nest in aggregations with tunnel depth of 45 cm from tumulus. The main tunnel contains on average 3 to 4 females and 1 to 1.25 males. The mandibles distinctly wear away in the course of active period, indicating the excavation of overnight burrows. Mizumoto et al. (2020) observed that building and excavation of the nest burrow by mandibles is a species-specific process and even varied between distinct morphological casts in termites. During nest construction process the female loosened soil into particles by biting, and pushed them behind with forelegs, supporting herself with hind legs and often rotating the body irregularly, almost same in reported in other bees species, especially supported by Cerna et al. (2012) based on the daily observations of nest construction by marked *Andrena vaga* using a sequence of behavioral elements for the digging of nesting burrow. *Andrena cineraria* prefer compact clay surfaces for nesting, and female guard the burrow with his head, and male appear prior to females and disappear in the start of June. Antoine and Forrest (2020) observed that Andrenidae species prefer comparatively compact surfaces for construction of their nesting cavity. Generally, among all wild bee species the clay soils are most preferred for nest construction; while as some wasp species prefer soils with higher proportion of sand (90%) (Lybrand et al.2020). Normally we observed, females make short round flights around the nest and come back to nest entrance, and it is assumed that low temperature may be responsible for their short flights. First cell construction occurred at certain depth, and the cell construction continues till the end of the burrow, making cells mostly of oval shaped. Nesting burrow is vertical from upper side and oblique to horizontal in lower area, with straight tumulus hiding nest entrance, supported by Levenson and Youngsteadt (2019) and Kline and Joshi (2020). Results showed that *A. cineraria* vary significantly in foraging characteristics on different plant species, for example *Andrena falvus* made 61 visits in 35 h; while as *Xylocopa* spp. make up to 4 visits on *Jasminum fruticans* (Thomson 2000); and are more active in or around the areas having abundant of dead wood for nesting (Dar et al., 2016). The possible reason for interspecific differences in flower visitation rates may be due to differences in tongue length, flight time, time spent on each visited flower. Further, the possible reason for long duration on many weeds may be small flower size, short tongue and less nectar content. *A. cineraria* perform two foraging behavior's patterns: first taking pollen with its mouth part from the stamen and then sucking nectar that too consumes much time per flower. Sung et al. (2006) observed that time spend by *Lasioglossum* species is 7.9 sec.; and the shortest time per flower in stone fruit crops were spend by *L. marginatum* and the longest time by ants (*Camponotus longs*) (Dar et al., 2020b). Further, Herrera (1989) in an experiment found that flower handling time for Hymenopteran taxa was 2.8 sec. compared to members of orders with possible difference made by increased proboscis length that produces a proportional decrease of log handling time in pollinators.

5. Conclusion

The landscapes of Kashmir region are suitable for the nesting of *A. cineraria*, that is one of the most distinctive and obvious of all the spring flying solitary bee species in orchards. The females are black, and have two broad ashy grey hair bands across the thorax. The bee has a single flight period each year and is active April to July. Males emerge well before the female with peak activity coincides with the blooming periods of flowering plants. The bees are non-aggressive and nests are constructed in the ground, and the nest entrances are surrounded by a volcano-like mound of excavated spoil called tumulus. Nests are often in dense aggregations in grass lands, barren lands and field margins. The nest density and aggregations were observed more in landscapes of Budgam as compared to Srinagar. *A. cineraria* is an important pollinator of fruit crops and also visits other flowers, therefore time spend by this species per bout or per individual flower varies for different plant species. *A. cineraria* is important not only for the dispersal and colonization of flowering plants but are also critical to agricultural fruit and berry crops and other weeds. Among the fruit crops, the shortest mean time *A. cineraria* bees were spent on fruit crops and the longest weeds and shrubs. Since, it is an important visitor of many flowering plants therefore conservation strategies must be taken to save its habitat.

More work is needed to investigate in detail the habitat requirements and foraging plants for this species. The brood parasites and other threats which are harmful to this species need to be explored. For pollination point of view, the conservation of the habitat and the habitat availability is most important.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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