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Diversity of carabids in *Gerbera* and *Gladiolus* crops of Jorhat, Assam

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Abstract
The present investigation was conducted to study the diversity of Carabids in *Gerbera* and *Gladiolus* crops of Jorhat, Assam during the year 2014 - 2015 and 2015 - 2016. The specimens were identified by following published keys and literature and described on the basis of observed morphological characteristics. Results found a total 8 species of carabids belonging to 4 genera *viz.*, *Clivina*, *Scarites*, *Harpalus*, and *Sparostes* under 3 tribes- Clivinini, Scaritini and Harpalini 2 subfamily (Scaritinae and Harpalinae) from the flower crop *Gerbera* and *Gladiolus*. Among these 8 species, 3 under genera *Clivina viz., C. assamensis, C. memnonia, C. lobata* and 2 under *Scarites* and *Harpalus, viz., S. indus, S. inconspicuous, H. rufipes, H. calceatus* and one from *Sparostes viz., Sparostes striatulus*. Among all the species, *S. indus, C. assamensis* and *S. inconspicuous* were relatively more abundance with 18.75%, 16.75%, 15%, respectively. The species richness, species diversity and species evenness were comparatively more in *Gladiolus* (1.511, 1.73 and 0.889, respectively) than *Gerbera* (0.910, 1.205 and 0.869, respectively).

Keywords: *Gerbera, Gladiolus*, carabidae, species richness, species diversity, species evenness, pitfall trap

1. Introduction
Carabidae are one of the largest and most successful families under coleoptera with over 40,000 species [15]. They are formidable predators in the insect world with their large eyes, spiny powerful legs and large jaws. They live on the surface of the soil where they explore and consume caterpillars, wireworms, maggots, ants, aphids and slugs. As a predator, they have prominent mandibles for capturing and devouring their prey. In fact, they can be identified and distinguished from similar-looking species by their ability to run quickly and their tendency to scurry for cover when disturbed. Carabids or ground beetle are one of the important natural biocontrol agents in agro-ecosystem and good indicators of environmental change. Usually carabids are predators while some species are omnivorous, some phytophagous and most of them are carnivorous [14]. They live in nearly every available habitat, although some species are associated with particular ecosystems, like meadows, woodlands, or crop fields. Due to the habitat specificity of some species, these beetles can be used as biological indicators to assess land use changes among different ecosystems [22]. They are considered to be mostly opportunistic feeders that consume a variety of foods. Most species locate food by random search, although some day-active (diurnal) species hunt by sight. A few species have also been observed to detect chemical cues from springtails, mollusks, and aphids [16]. Females tend to have more varied diet than males. A greater diversity of food types in females has been linked to greater egg size and egg number [16]. They employ a wide variety of ecological strategies. The abundance, species richness and attractive coloration of many species have made carabids popular objects of studies for entomologists [16]. In Assam, there is no detail report regarding the availability of carabids associated with floral ecosystem. The first record of carabid from Assam was found in 'Fauna of British India' (1929) with *Clivina*, *Scarites*, *Coryza* and *Oxygnathus* genus. Therefore, the present investigation on diversity of carabids was undertaken to know the status of carabids in commonly growing annual flower crop *Gerbera* and *Gladiolus*.

2. Materials and Methods
The present investigation was conducted in the Experimental Farm, Department of Horticulture, Assam Agricultural University, Jorhat during the year 2014 - 2015 and 2015 - 2016. The farm is situated at $94^0$12'E Longitude and $24^0$47'N Latitude, and at an altitude of

86.8 meters above mean sea level. The total area of the farm is 16.62 ha.

Beetles were collected by pitfall trap, light trap and hand collection. Pitfall traps of 500 ml (11.5 cm diameter, 9 cm deep) were placed randomly at *Gerbera* and *Gladiolus* growing areas (approx. 5 m^2 distance). Traps were filled with preservative (200 ml 95% labolene) and replaced after 48 hours [3]. The traps were active for 48 hours and these were changed at weekly intervals. Beetles collected in light traps and with hand collection were killed immediate by using ethyl acetate either in the killing bottle or by introducing cotton balls dipped into ethyl acetate in closed polythene bags. After killing, the beetles were pinned/cardened, stretched in an insect box. The collected carabid beetles were observed under Stemi 2000-C and MS 24 microscope in the laboratory and measurements were taken by using scale.

Collected specimens of carabids were preserved with proper labeling comprised of date and crop associated. The specimens were identified by following published Keys and literature, Fauna of British India (1929), Zoological Survey of India (1992), Handbooks for the identification of British insects (1992), Key and Catalogue of the tribe Clivinini from the Oriental realm: with revisions of the genera Thliboclivina (2001), Keys for identification of the British Carabidae (1974) and described on the basis of observed morphological characters *viz.*, shape, size, markings spots, setose etc. present in different body parts (head antennae, thorax, abdomen, mouth parts etc). The specimens were confirmed by Dr. (Mrs.) Chitra Srivastava, Head & Principal Scientist, Dept. of Entomology, IARI, New Delhi.

The relative abundance of each species was determined using the formula [6]:

$$\text{Relative Abundance (RA) of a species} = \frac{\text{No.of individuals of the species}}{\text{No.individuals of all species}} \text{ X } 100$$

The species richness is calculated by using Margalef index (R), R = S-1/ln(n)

Where,

S= number of species

n = total number of individuals of all the species

ln = natural logarithm

Diversity indices is calculated by computing Shannon-Weiner index of diversity

Shannon-Weiner index (H') = - $\sum (p_i \ln p_i)$

Where,

p_i = proportion of i^{th} species in the total sample

$p_i = n_i/N$

n_i= number of individuals of i^{th} species

N = total number of indivduals)

ln = natural logarithm (loge)

Evenness indices is calculated by using Kreb's formula

$$E = \frac{H}{H' max}$$

Where,

H'_{max} = natural logarithm of the number of species present

$0 < E \leq 1$, the maximum value being possible in a community in which all the species are equally abundant.

The statistical analysis of the collected specimens was done by the above mentioned formula and from the calculated data, mean and standard deviation was calculated.

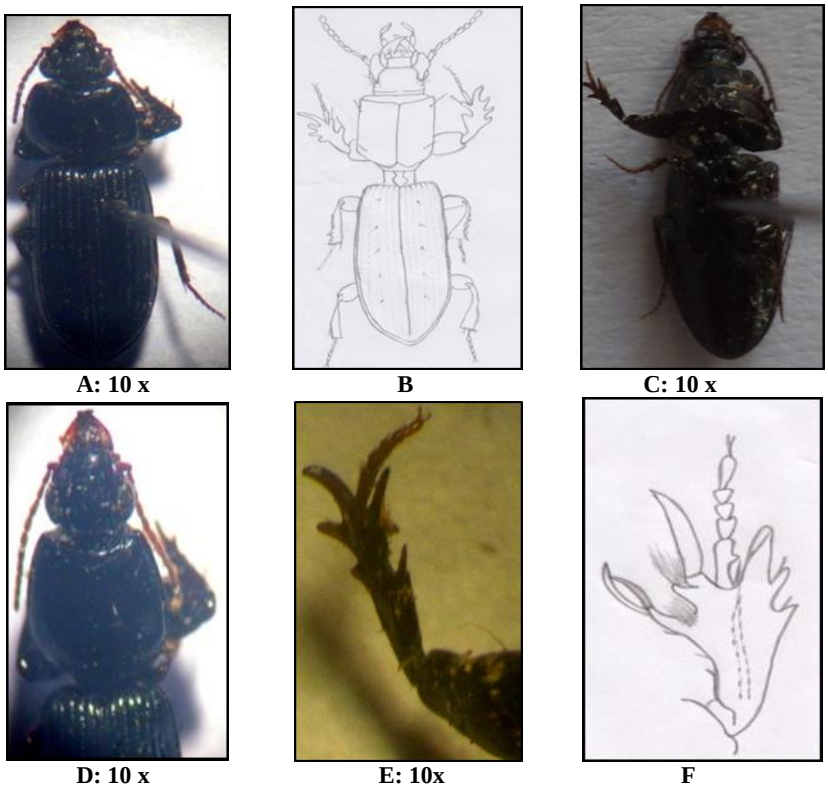
3. Results and Discussion

***Clivina assamensis* Putzeys, 1846 (Fig.1 A-F)**

Sub-family: Scaritinae Bonelli, 1810

Tribe: Clivinini Rafinasque, 1815

Sub-tribe: Clivinina Kult, 1947



A: 10 x **B** **C: 10 x**

D: 10 x **E: 10x** **F**

Fig 1(A-F): *C. assamensis*: (A) - Dorsal; (B)- Sketch of dorsal side (C) - Ventral; (D) - Mesothorax constricted as neck between pronotum and elytra; (E, F) - Basal tarsomere forelegs with rows of numerous bristles and its sketch

Description: Adult: Generally black, oval, convex and subcylindrical (Fig. 1 A, B,) but somewhat flattened species with mesothorax constricted as a "neck" between pronotum and elytra (Fig. 1 C, D). Head with one or two pairs of supraorbital setae, pronotum with or without small punctures. Basal tarsomere of front legs large, with rows of numerous bristles on dorsal surface (Fig. 1 E, F). Intervals of elytra without setigerous punctures. The present findings are similar with the findings of Andrewes (1929) [2], Saha *et al.* (1992) [19] and Kushwaha *et al.* (2015) [11]. Body length, body breadth, length of head, inter ocular distance, length of pronotum, length of abdomen were 8.85 mm ± 0.264, 2.97 mm ± 0.170, 0.95 mm ± 0.129, 0.92 mm ± 0.170, 1.62 mm ± 0.15, 6.17 mm ± 0.309, respectively and these were similar with the findings of Andrewes (1929)[1] who reported that the body length of *C. assamensis* was 9 mm and 6.3-9 mm respectively.

***Clivina memnonia* Dejean, 1831 (Fig.2 A - E)**

Synonyms: *Clivina indica* (Putzeys, 1875), *Clivina rugosifrons* (Nietner, 1856), *Clivina recta* (Walker, 1858)

Sub-family: Scaritinae, 1815

Tribe: Clivinini, Rafinasque, 1815

Sub-tribe: Clivinina, Rafinasque, 1815

Fig 2(A-E): *C. memnonia*; (A) - Dorsal; (B) - Sketch of dorsal side (C) - Ventral; (D) - 6 Setose; (E) - Sketch of 6 setose

Description: Adult: Head, pronotum and elytra dark brown, labrum, antennae, legs reddish brown (Fig. 2 A, B, C). Eyes large and convex, deep pit present on head, antennae short and moniliform, nearly smooth, only a row of punctures on the vertex. Presence of large elongate pore on middle of vertex. Pronotum convex, subquadrate, glabrous, median line prominent. Presence of 6-setose in the labrum (Fig. 2 D, E), mentum with a shallow sinus and a rounded tooth, neck constricted slightly interrupted at middle. Elytra elongate, striae deep and crenulate. Body length, body breadth, length of head, inter ocular distance, length of pronotum, length of abdomen were 6.55 mm ± 0.208, 2.85 mm ± 0.129, 0.72 mm ± 0.095, 0.72 mm ± 0.15, 1.55 mm ± 0.129, 4.02 mm ± 0.262, respectively. These findings are in conformity with the findings of Andrewes (1929) [2], and Saha *et al.* (1992) [19] and they reported 6-setose in the labrum and also reported that body length of *C. memnonia* varied from 6.5-11 mm.

***Clivina lobata* Bonelli, 1813 (Fig.3 A-E)**

Synonyms: *Clivina anceps* (Putzeys), *Clivina hydropica* (Putzeys), *Clivina angularis* (Putzeys, 1892), *Clivina capitata* (Putzeys), *Clivina divaricata* (Putzeys), *Clivina laviceps* (Bates, 1892).

Sub-family: Scaritinae, 1815

Tribe: Clivinini, Rafinasque, 1815

Sub-tribe: Clivinina, Rafinasque, 1815

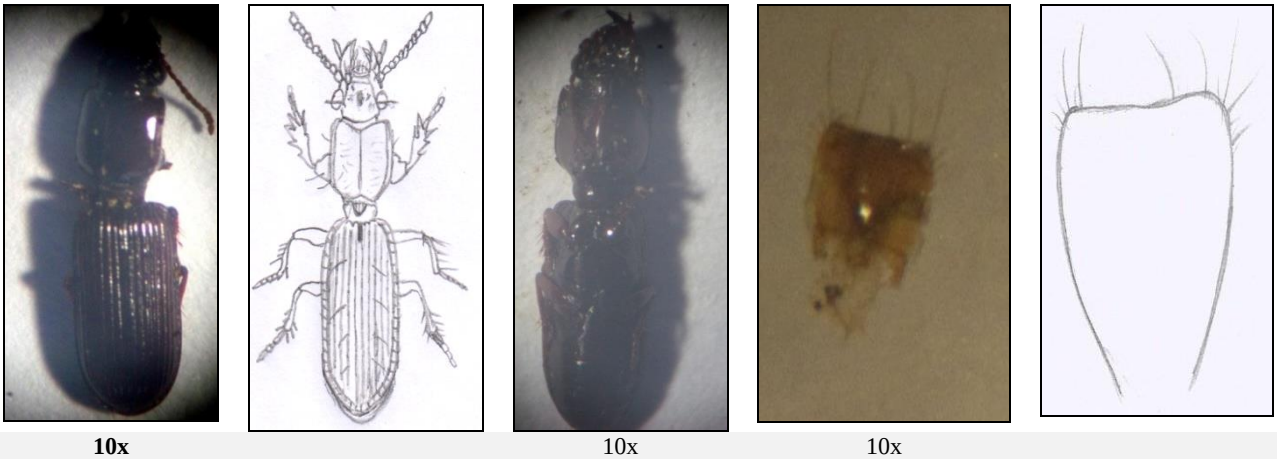


Fig 3(A - E): *C. lobata*; (A) - Dorsal; (B) - Sketch of dorsal side; (C) - Vental side (D) - setose; (E) - Sketch of setose

Description: Adult: Adults dark brown, labrum, antennae, legs reddish brown (Fig. 3 A, B, C). Eyes large and convex, deep pit present on head, antennae short and moniliform, nearly smooth, pore on the vertex. Presence of 7-setose in the labrum (Fig. 3 D, E), neck constriction slightly, minutely punctate. Presence of pore on vertex. Pronotum moderately convex, quadrate, glabrous, sides margined median line prominent. Elytra moderately convex, quadrate, striae fairly and minutely punctate, intervals moderately convex. Body length, body breadth, length of head, inter ocular distance, length of pronotum, length of abdomen were 6.05 mm ± 0.208, 2.92 mm ± 0.170, 0.82 mm ± 0.095, 0.8 mm ± 0.81, 1.47 mm ± 0.095, 3.72 mm ± 0.359, respectively and these findings corroborated the findings Andrewes (1929) [2] and Saha *et al.* (1992) [19] who reported that the body length of *C. lobata* varied from 4-7mm and 5-6mm, respectively and had 7 setose on labrum.

Table 1: Comparison between different species of *Clivina*

Characters	*C. assamensis*	*C. memnonia*	*C. lobata*
Colour	Black	Black, middle and hind legs dark red	Dark brown; antennae, labrum and leg reddish brown
Labrum Body length Elytral striae	6 setose 8.85mm ± 0.264 Not so deep	6-setose 6.55±0.208mm Deep, crenulate	7-setose 6.05±0.208mm Fairly deep and punctate
Vertex pore	No pore	Large elongate pore on middle of the vertex	Pore on vertex
Prothorax	Convex, subquadarte	Convex, subquadarte	Moderately convex, quadrate
Leg	Basal tarsomere of front legs large, with rows of numerous bristles on dorsal surface	Protibiae finely sulcate, 4-denticulate, mesotibiae densely fringed	Protibiae sulcate, small upper tooth, mesotibiae with long bristles

***Scarites (Parallelomorphus) indus* Oliver, 1795 (Fig.4 A - E)**
Synonyms: *Scarite smancus* (Bonelli, 1813), *Scarites terricola* (Andrews, 1921)

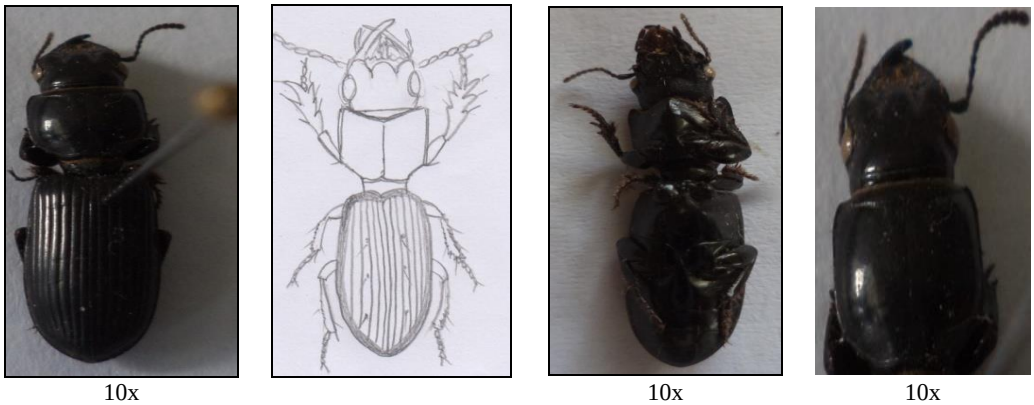
Sub-familiy: Scaritinae Bonelli, 1810
Tribe: Scaritini Bonelli, 1810
Sub-tribe: Scaritina Bonelli, 1810

10x A | 10x B | 10x C | 10x D | 10x E

Fig 4(A - E): *S. indus*; (A) - Dorsal; (b) - Sketch of dorsal side; (C) - Ventral; (D) - Bidentate mandibles; (E) - Sketch of bidentate mandibles

Description: Adult: Head, pronotum, elytra, mandible, labrum, clypeus black; whereas palpi, antennae and legs deep reddish black (Fig. 4 A, B, C). Mandibles bidentate (Fig. 4 D, E) Head with lateral projection. Eyes small and lateral. Pronotum little wider, apex less emerginate. Elytra with more rounded sides, striate shallower and lightly punctate. Body length, body breadth, length of head, inter ocular distance, length of pronotum, length of abdomen were 22.5 mm ± 0.129, 7.95 mm ± 0.129, 4.32 mm ± 0.170, 3.95 mm ± 0.129, 4.62 mm ± 0.298, 13.75 mm ± 0.208, respectively. Andrewes (1929) [2] and Saha *et al.* (1992) [19] reported that the body length of *S. indus* collected from Assam was 16-22 mm and from Calcutta was 19 mm, respectively.

***Scarites inconspicuous* (Fig.5 A - F)**
Sub-familiy: Scaritinae Bonelli, 1810
Tribe: Scaritini Bonelli, 1810
Sub-tribe: Scaritina Bonelli, 1810



10x A | B | 10x C | 10x D


10x
E F

Fig 5(A-F): *S. inconspicuous*; (A) - Dorsal; (B) - Sketch of dorsal side; (C) - Ventral; (D) - Prothorax; (E, F) - Protibia and mesotibia with 2 or 3 dentriculation and with 2 spurs, respectively

Description: Adult: Adults, black (Fig. 5 A, B, C) with lateral truncature straight, neck slightly constricted at sides and faintly punctate. Prothorax fifth wider than head (Fig. 5 D) and as much wider than long. Elytra very slightly dilated behind, about as wide as prothorax, sides of base curving gently backwards to shoulders; striae deep. Protibiae with 2 or 3 denticulations above upper tooth; mesotibiae with two sharp spurs, the upper shorter than the lower one (Fig. 5 E, F). Body length, body breadth, length of head, inter ocular distance, length of pronotum, length of abdomen were 18.17 mm ± 0.275, 5.97 mm ± 0.170, 2.95 mm ± 0.129, 3.3 mm ± 0.216, 4.1 mm ± 0.130, 10.72 mm ± 0.660, respectively. These findings are in conformity with the findings of Andrewes (1929) [2], who observed the similar type of characters for *S. inconspicuous*. He reported that the body length of *S. inconspicuous* varied from 18-21 mm.

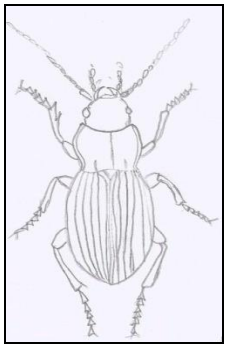
Table 2: Comparison between different species of *Scarites*

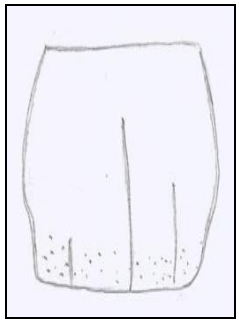
Characters	***Scarites indus***	***Scarites inconspicuous***
Head	Lateral projection therefore more conspicuous	Lateral truncature straight, no lateral projection therefore inconspicuous
Body length	22.5±0.129mm	18.17±0.275mm
Elytral striae	Shallow	Deep
Prothorax	Little wider, apex less emarginate	Wider than head

***Harpalus (pseudoophonus) calceatus* Duftschmid, 1812 (Fig.6 A - E)**

Synonyms: *Harpalus calcitrapus* (Motschulsky, 1844), *Harpalus itoshimanus* (Habu, 1954), *Harpalus nonsignatus* (Krynicki, 1832), *Ophonus calceatus*, *Pseudoophonus calceatus* (Duftschmid, 1812)

Sub-family: Harpalinae, Bonelli, 1810
Tribe: Harpalini Bonelli, 1810
Sub-tribe: Harpalina Bonelli, 1810

10x 10x 10x
A B C D E

Fig 6(A - E): *H. calceatus*; (A) - Dorsal; (B) - Sketch of dorsal side; (C) - Ventral; (D, E): Pronotum with punctures

Description: Adult: Adults were black with extreme sides of pronotum, antannae and legs were paler (Fig.6 A, B, C). Tarsi with short hairs on the upper surface. Third elytral interval without a dorsal puncture. Base of pronotum with large punctures (Fig.6 D, E) that run into one another. Eighth and ninth elytral intervals with very fine pubescence. Similar observations were also reported by Hackson (2014) [7]. Body length, body breadth, length of head, inter ocular distance, length of pronotum, length of abdomen were 12.07 mm ± 0.221, 5.97 mm ± 0.170, 1.97 mm ± 0.221, 1.67 mm ± 0.170, 2.82 mm ± 0.172, 7.02 mm ± 0.125, respectively.

***Harpalus rufipes* De Geer, 1774 (Fig.7 A - F)**

Synonyms: *Carabus rufipes* (De Geer, 1774), *Pseudophonus pubescens* (O.F. Muller, 1776), *Carabus pubescens* (O.F. Muller, 1776), *Carabus ruficornis* (Fabricius, 1775).

Sub-family: Harpalinae Bonelli, 1810
Tribe: Harpalini Bonelli, 1810
Sub-tribe: Harpalina Bonelli,1810

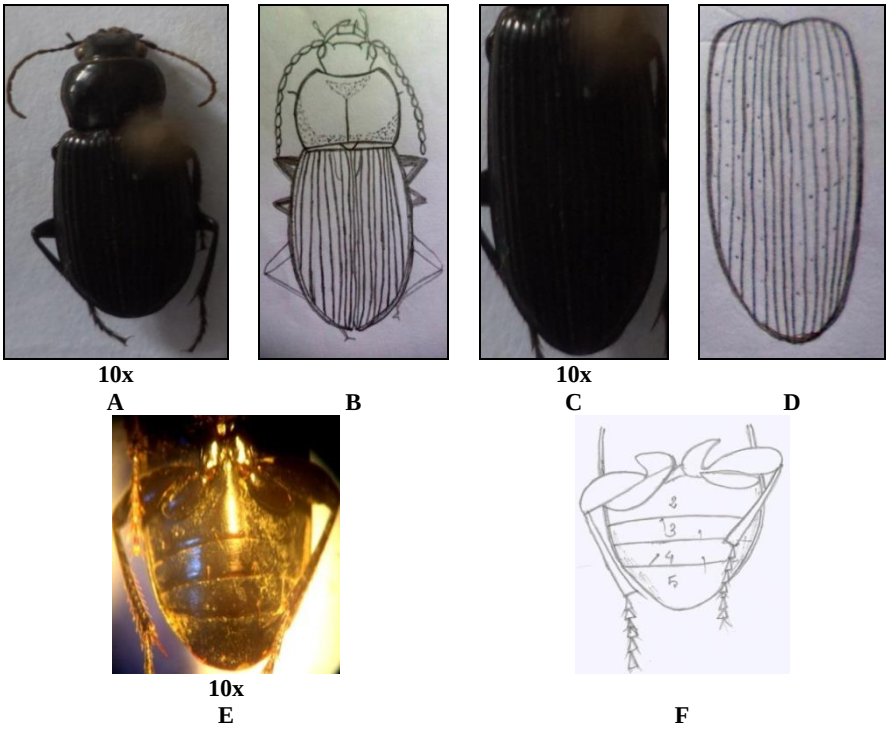


Fig 7(A - F): *H. rufipes*; (A) - Dorsal; (B) - Sketch of dorsal side; (C) - Elytra with punctures; (D): Sketch of elytra with punctures; (E, F): Last three abdominal segments have punctures and hairs towards the sides

Description: Adult: Adults were black (Fig.7 A, B) and all intervals of the elytra with punctures (Fig.7 C, D). On the underside, the last three abdominal segments have punctures and hairs towards the sides (Fig.7 E, F), but were smooth and hairless in the middle. Pronotum with the sides slightly curving inwards just short of the hind angles, which therefore look sharper. Similar observations were also reported by Hackston (2014) [7]. The body length, body breadth, length of head, inter ocular distance, length of pronotum, length of abdomen were 15.1 mm ± 0.258, 6.85 mm ± 0.264, 2.37 mm ± 0.170, 1.9 mm ± 0.182, 2.95 mm ± 0.129, 9.52 mm ± 0.441, respectively.

Table 3: Comparison between different species of *Harpalus*

Characters	***Harpalus rufipes***	***Harpalus calceatus***
Colour	Complete black	Black with extreme sides of sides of pronotum, antennae and legs paler
Body length	15.1mm±0.258	12.07mm±0.221
Elytral striae	All intervals of elytra with puncture	Third elytral intervals without punctures
Prothorax	Sides slightly curving inwards	Base with large punctures

***Sparostes striatulus* Putzeys, 1867 (Fig.8 A - E)**
Sub-family: Scaritinae Bonelli, 1810
Tribe: Clivinini Rafinasque, 1815
Sub-tribe: Clivinina Rafinasque, 1815

Fig 8(A - E): *S. striatulus*; (A) - Dorsal; (B) - Sketch of dorsal side; (C) - Ventral; (D, E): Striae finely punctate.

Description: Adult: Adults black in colour (Fig.8 A, B). Head narrower than prothorax, elytra elongate, base truncate. Elytra as wide as prothorax and twice as long as wide, rather sharply rounded at apex. Striae rather fine and finely punctate (Fig.8 D, E). Body length, body breadth, length of head, inter ocular distance, length of pronotum, length of abdomen were 22.57 mm ± 1.260, 6.95 mm ± 0.129, 3.77 mm ± 0.221, 3.5 mm ± 0.141, 4.95 mm ± 0.129, 13.85 mm ± 0.853,

respectively. These findings are similar with the findings of Andrewes (1929) [2] who reported that striae rather finely punctate, 1 to 5 free at base, 6 and 7 joining at the shoulder, the length of *S. striatulus* varied from 16-22 mm.

3.1 Distribution of Carabids
3.1.1 Monthly distribution of different carabids

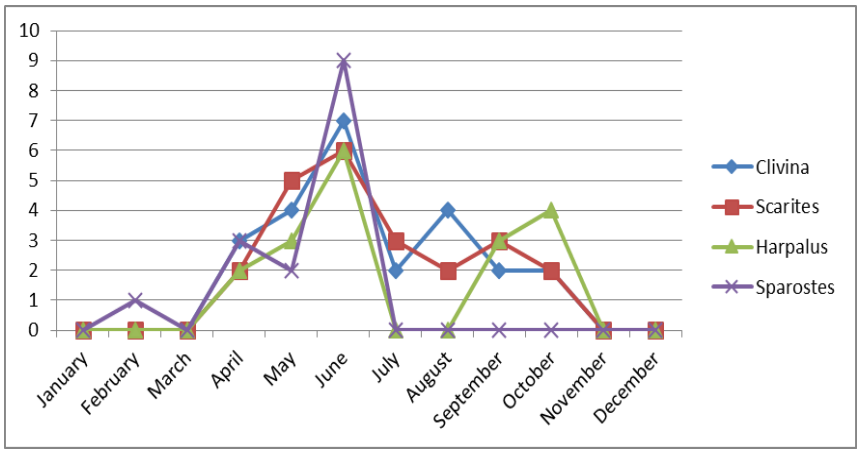


Fig 9: Monthly distribution of different genus of carabids

The monthly occurrence of different carabid beetles was recorded in the Experimental Farm, Department of Horticulture, Assam Agricultural University, Jorhat. Regular collection of beetles was made at weekly interval from January' 2015 to December 2015 to ascertain the presence of adult beetles. The initial appearance of carabids was observed during February' 2015. The peak activity of carabids was recorded during June 2015 with 28 number of total collection followed by May 2015 with 24 number of total collection. The population of carabids was found upto October' 2015. During November-December' 2015, no carabid beetles were recorded in different survey plots. While the activity of genus *Sparostes* was observed from January to July only where as the others from March to October' 2015. Kumar and Rajagopal (1996) [10], also reported that the genus *Scarites* was from May to September and *Clivina* from April to October. Talmaciu *et al.* (1996) [21] reported that highest number of carabids was collected in the month of July to August. Ali *et al.* (2015) [1] put forward a similar kind of observation in loquat and guava orchards located at the coastal area in Tartous, Syria. They reported that beetles were found in both orchards in spring and early summer. The population peak of beetle was observed in loquat orchard with total catch of 46 individuals during May, but two peaks in guava orchard in early May and early June with the same number of 22 individuals. The overall abundance of carabids was reduced in both orchards in the late summer.

3.2 Efficiency of different traps
3.2.1 Trap wise collection of carabids

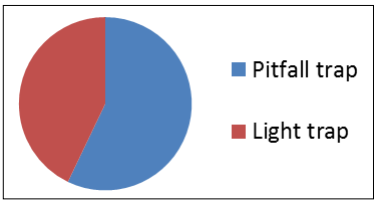


Fig 10: Carabid collections in different traps.

Among different types of traps used for collection of carabids, the highest collection of carabids was obtained from pitfall trap (57.13%), followed by light trap (42.89%) during January to December, 2015. These findings were similar with the findings of Kustasi and Marko (2007) [12], who reported that highest carabids were collected from horticultural orchards by using pitfall traps. Igondova and Majzlan (2015) [8] collected 1,627 individuals belonging to 55 species by using pitfall trap. Nagahata *et al.* (2002) [17] recorded 1135 ground beetles including 6 species of carabids from Honshu. A total of 658 carabids, representing 26 species in 14 genera, were collected using pitfall traps in wheat, oat, barley and rye fields in growing season, as reported by Dunn (1982) [4] from Michigan.

3.3 Relative abundance of carabids

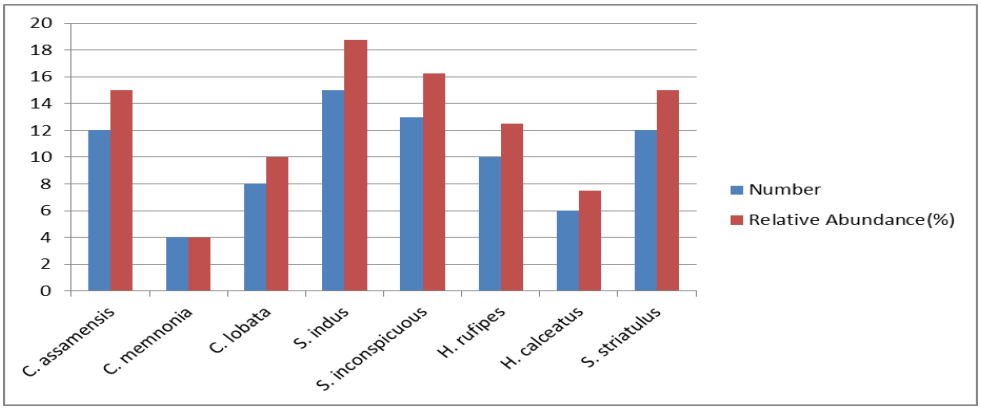


Fig 11: Relative abundance of carabids

The relative abundance of various carabid species, *S. striatulus* was the highly abundant species (18.75%) followed by *C.assamensis* (15%) and *H. calceatus* (15%) whereas *Pherosophus* sp. (0.476%) was the relatively less abundant species. Andrewes (1929) [2], reported that *Scarites* was the dominant genus in Assam with 14 species. In present findings the author found that the *Scarites* was the dominant genus. Kadar and Lovei (1992) [9] operated a light trap in experimental orchard for five years and collected a total of 13,763 individuals of 97 carabid species. The most abundant species were *Harpalus griseus* (33.3%), *H. calceatus* (16.2%), *H. rufipes* (13.0%), *Amara bifrons* (12.8%) and *H. froelichi* (4.0%), respectively. Carabid beetles were collected from olive, peach, and mixed peach-olive orchards by using pitfall traps in Azadshahr region, east of Golestan province in 2009-2010 by Nodeh *et al.* (2012) [18] from olive, peach, and mixed peach-olive orchards by using pitfall traps and found that the dominant species and were *Harpalus rufipes* and *Calathus peltatus*.

3.4 Diversity indices of carabids

Crop	Species richness	Species diversity	Evenness
Gladiolus	1.511	1.73	0.889
Gerbera	0.910	1.205	0.869

The species richness, species diversity and species evenness were comparatively more in *Gladiolus* (1.511, 1.73 and 0.889, respectively) than *Gerbera* (0.910, 1.205 and 0.869, respectively). This might be due to that there were fewer disturbances on the ground area of *Gladiolus* than *Gerbera*. Moreover, the rate of pesticide application was more in *Gerbera* crop to protect the crop from leaf and flower spot disease, mite and aphid infestation compared to *Gladiolus*. Benerjee (2014) [3], also reported that species richness and species diversity was more in less disturbed area in monsoon season. Kutasi *et al.* (2004) [13], investigated the species richness and composition of carabids in Hungary, from apple and pear orchards and reported that the species richness varied between 23 and 76. Viacin *et al.* (2015) [23] reported that carabid beetle individuals and species diversity was observed in arable soil and reached a higher species diversity in the plots with a higher pH and humus content.

4. Conclusion

The present study found 8 species under the genus *Clivina*, *Scarites*, *Harpalus* and *Sparostes* and among these genus *Harpalus* and *Sparostes* are reported for the first time from Assam. The present study may help in proper identification of different carabid species of Assam for future studies and the dominant species can be incorporated in future Integrated Pest Management programme as biological pest control agent. Also aid in preparation of checklist of different carabid species of different agro-ecosystem in Assam and their distribution map.

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