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COMMUNICATION

OCCURRENCE OF THE *APORRECTODEA CALIGINOSA CALIGINOSA* (SAVIGNY, 1826) (ANNELIDA: CLITELLATA: HAPLOTAXIDA) FROM KASHMIR VALLEY, JAMMU & KASHMIR, INDIA

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COMMUNICATION

Occurrence of the *Aporrectodea caliginosa caliginosa* (Savigny, 1826) (Annelida: Clitellata: Haplotaxida) from Kashmir Valley, Jammu & Kashmir, India

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Abstract: The paper describes the earthworm *Aporrectodea caliginosa caliginosa* (Savigny, 1826) of class Clitellata, order Opisthopora and family Lumbricidae, from Kashmir Valley, Jammu & Kashmir, India. Previously the species was recorded from Himachal Pradesh, and in the present study the species is reported from Gulmarg forest within the geographical coordinates of (34.050^{0}N & 74.388^{0}E). During the study the seasonal variation of *A.c. caliginosa* in terms of density and biomass along with the soil physiochemical characteristics were reported. *A.c. caliginosa* showed significant variation in density (t=3.34, p<0.044) and biomass (t=3.40, p<0.042) among different seasons, with maximum density (129.6/m^2) and biomass (26.90g/m^2) during spring, and minimal values of 34.33/m^2 and 6.94g/m^2 during winter respectively. Soil physiochemical characteristics also varied significantly among seasons.

Keywords: Biomass, density, earthworm, Kashmir Valley, soil physiochemical.

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Author contribution: ABK and IAN conceptualized the study. IAN conducted the field work and analysis of samples with technical support by AH. All the three authors contribute to the synthesis of manuscript, however ABK supervised the overall study.

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INTRODUCTION

Human activities are causing major shifts in the community composition of biological systems by transporting species across biogeographic barriers (Wardle & Peltzer 2017). Invasion of exotic earthworms is increasing worldwide (Lee 1985; Fragoso et al. 1999), apparently facilitated by global commerce with the importation of soil-containing materials (agricultural and horticultural products) for commercial applications (waste management and land bioremediation). Invasive earthworms are also continuing their expansion into earthworm-free zones (Tiunov et al. 2006), where they may have large ecological impacts (Bohlen et al. 2004; Frelich et al. 2006).

Globally, 4,400 earthworm species are known (Sinha 2009), most having restricted ranges (Reynolds 1994). Julka et al. (2009), Blakemore (2008), and Julka (2014) reported more than 500 species of earthworms from India, belonging to 10 families and 69 genera (Dash 2012; Kathireswari 2016). In comparison to other Asian countries, earthworms are well studied in India (Bisht et al. 2003; Tripathi & Bhardwaj 2004; Sathianarayanan & Khan 2006; Karmegam & Daniel 2007; Chaudhuri et al. 2008; Goswami & Mondal 2015; Deepthi & Kathireswari 2016; Narayanan et al. 2017, 2019; Rajwar et al. 2018; Lone et al. 2020), while there is paucity of information on the earthworms of the Kashmir Valley aside from the important contributions of Stephenson (1922), Sharma & Kaul (1974), Paliwal & Julka (2005), Najar & Khan (2011a,b,c, 2014), and Mir & Najar (2016). Earthworms play a key role in the improvement of soil, making nutrients available to plants and thus enhancing crop yields (Najar & Khan 2013a,b; Najar 2017).

The first record of earthworms from the Indian subcontinent was provided by Templeton (1844). Subsequently followed by Michaelsen (1907), Stephenson (1923, 1924, 1925, 1926, 1931), Gates (1940, 1945a,b, 1972a), Julka (1976, 1978, 1981, 1993), Kale & Krishnamoorty (1978a,b), Julka & Senapati (1987), Bhadauria & Ramakrishnan (1989), Ismail et al. (1990), Bano & Kale (1991), Blanchart & Julka (1997), Chaudhuri & Bhattacharjee (1999), Bhadauria et al. (2000), Bisht et al. (2003), Srivastava et al. (2003), Tripathi & Bhardwaj (2004), Paliwal & Julka (2005), Sathianarayanan & Khan (2006), Karmegam & Daniel (2007), Chaudhuri et al. (2008), Joshi & Aga (2009), Chaudhuri & Bhattacharjee (2011), Chaudhuri & Nath (2011) Verma & Shweta (2011), Najar & Khan (2011a,b,c, 2014), Chaudhuri & Dey (2012), Siddaraju et al. (2013), Dey & Chaudhuri (2013, 2014).

Aporrectodea caliginosa caliginosa is a typical synanthropic species and thrives in pastures, gardens and forests of the temperate zone. Miller et al. (1955) stated its possibility in every type of substrate, even in the poorest sandy soil. In disturbed ecosystems it can displace populations of native worms in a short span of time. According to Bouche's (1977) ecological characterization, *A.c. caliginosa* belongs to the endogeic group, living and feeding in the mineral soil layer.

Gulmarg is located in the Pir Pinjal range of the Himalayan Mountains of Kashmir Valley (Jammu & Kashmir) India. It is at a distance of 52km from Srinagar, the capital of Jammu & Kashmir to its southwest, at an altitude of 2,450m (Fig. 1). It is famous for retaining several rare and endangered species with a rich and varied avifauna. The area holds a rich cover of vegetation, the dominant forest consisting of conifers, which account for over 90%. The principal species are *Cedrus Deodara*, *Abies Pindrow*, and *Pinus wallichaina*. The dominant tree species at the site is *P. wallichaina* with a rich ground cover comprising of *Leucanthemu vulgare*, *Cyanodon dectylon*, and *Trifolium repens*.

MATERIALS AND METHODS

Earthworm and soil sampling

Earthworm samples were collected by digging soil monolith (25 x 25 x 30 cm) and hand sorting. Worms were sorted into clitellates, non-clitellates (>4cm, without clitellum but have genital markings) and juveniles (<4cm, lack of genital marking, tumescences and clitellum) following Zorn et al. (2005), preserved in 4% formalin and sent to Zoological Survey of India (ZSI), Kolkata for taxonomic identification. The specimens were deposited in the Museum, Department of Ecology and Environmental Sciences, Pondicherry Central University, (DEES-A: 03/2009) housed in Kalapet, Puducherry, India.

Soil analysis

Composite soil samples comprising of three subsamples were analyzed using standard protocols. Soil temperature measured by soil thermometer and soil moisture by gravimetric method (Gupta 1999); pH, electrical conductivity (EC) and organic nitrogen (ON) by micro Kjeldahl method (Jackson 1973); soil texture by the international pipette method (Gee & Bauder 1986); organic carbon (OC) by Walkley & Black (1934).

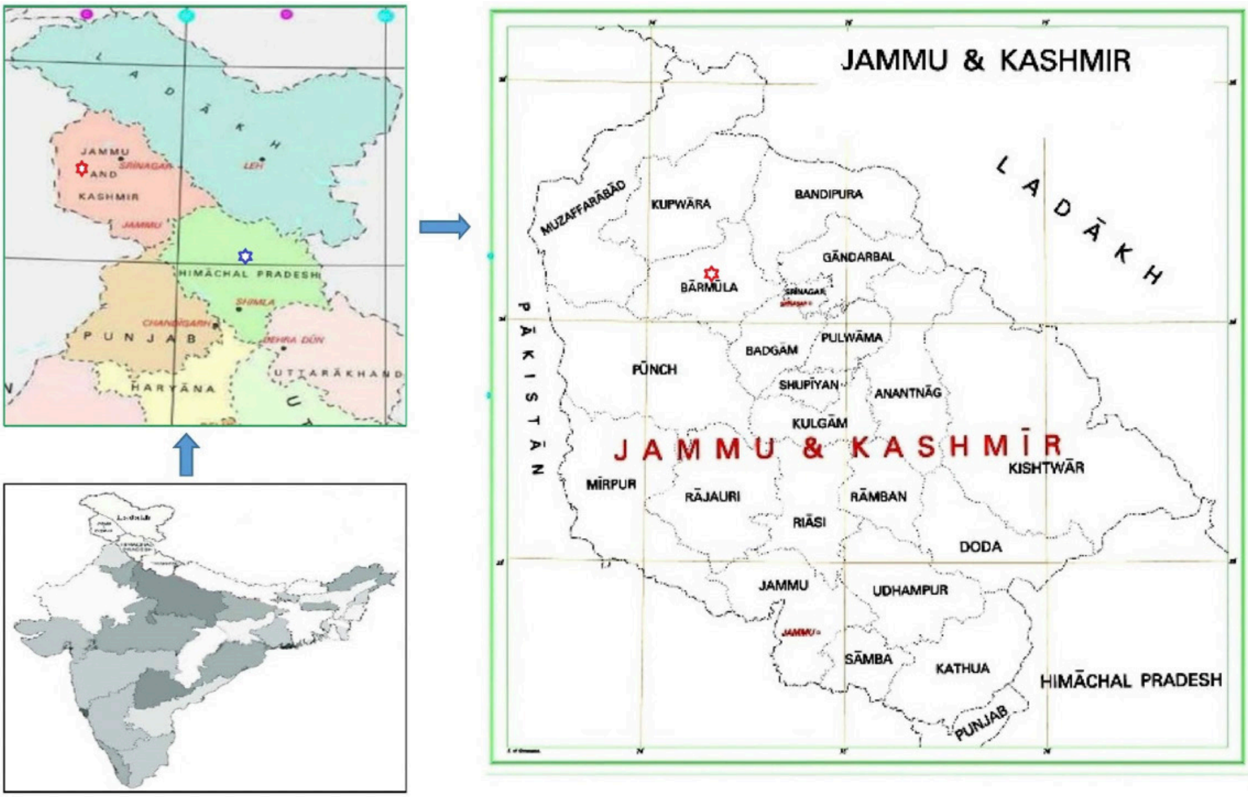

Figure 1. Distribution of *Aporrectodea caliginosa caliginosa*. Blue star - Himachal Pradesh (previous report) and red star - Jammu & Kashmir (new record).

Data analyses

Data sets were subjected to *t*-test in order to determine differences among the parameters. Statistical analyses and graphical presentations were performed using SPSS statistical software (Version 16) and PAST statistical software (Version 1.93).

RESULTS AND DISCUSSION

Aporrectodea caliginosa species complex includes three species, *A. caliginosa s.s.* (Savigny, 1826), *A. trapezoides* (Duges, 1828), and *A. nocturna* (Evans, 1946) and one subspecies, *A. c. tuberculata* (Eisen, 1874), although this view has been challenged several times. Because of their similarity, the taxonomic status of the taxa within *A. caliginosa* species complex is a matter of debate for more than a century. Based on morphological data, *A. caliginosa s.s.*, *A. trapezoides*, and *A. nocturna* were initially described as distinct species, whereas *A. tuberculata* was described as a subspecies of *A. caliginosa*. Michaelsen (1900) noticed that some of these taxa were closely related and included them in a species complex, but he suggested that they belong to a single species with two subspecies: *A. caliginosa caliginosa* and *A. c. trapezoides* and considered the other taxa as synonymous to *A. caliginosa*. Omodeo (1952) and Casellato (1987) considered *A. trapezoides* as the polyploidal variety of *A. caliginosa s.s.* Gates (1972b) disagreed with Michaelsen (1900) and separated them into four distinct species [*A. caliginosa s.s.* (namely, *A. turgida Eisen* 1874), *A. tuberculata*, *A. trapezoides*, and *A. nocturna*]. The same year, however, Bouche (1972) split them into two species and placed them into a different genus, *Nicodrilus caliginosus* (*A. caliginosa*) and *N. nocturnus* (*A. nocturna*), with the former species composed of three subspecies: *N. c. caliginosus* (*A. c. caliginosa*), *N. c. alternisetosus* (*A. tuberculata*) and *N. c. meridionalis* (*A. trapezoides*). Finally, almost a century after Michaelsen's study, Briones (1996) resurrected his initial proposal suggesting that the *A. caliginosa species complex* is composed of one species with two subspecies - *A. caliginosa caliginosa* and *A. c. trapezoides* (Pérez-Losada et al. 2009). Paliwal & Julka (2005) in the checklist of earthworms of western Himalaya reported *A. c. caliginosa* species from Himachal Pradesh.

Its diagnosis is summarized in Image 1 comprising: length 60–160 mm; diameter 4–6 mm. segments 104–

Image 1. *Aporrectodea caliginosa caliginosa*.

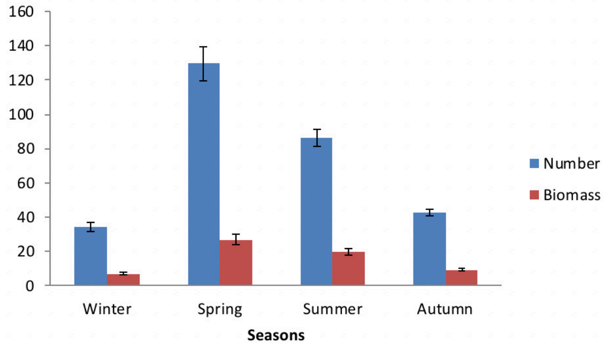

Figure 2. Density and biomass of *Aporrectodea caliginosa caliginosa* during different seasons.

248. Colour variable in life, grey, flesh-colour, brown, yellowish, slate-blue, but never purple. Prostomium epilobous 1/3, tongue cut off behind. Dorsal pores from 9/10 or less often 8/9. Setae closely paired, the lateral especially closely; aa greater than bc; dd=half the circumference or somewhat less. Clitellum saddle shaped, xxvi, xxvii, or xxviii to xxxiv or xxxv (= 7–10). Tubercles of puberty two pairs on xxxi and xxxiii. Male pores in transverse slits, on usually much elevated glandular areas, which take up xiv-xvi. Spermathecal pores two pairs, in 9/10 and 10/11, on cd. Setae ab of ix, x, and xi usually on broad papillae, transformed into genital setae, grooved, somewhat longer and thinner than the normal setae, slightly curved. Septa 5/6–9/10 thickened, 7/8 most so. Seminal vesicles of ix and x small (Stephensen 1923).

The natural rate of dispersal of an established earthworm population is relatively slow and is of rate of 5–10 m/year (Lee 1985; Marinissen & van den Bosch 1992; Dymond et al. 1997; Hale et al. 2005). Thus, anthrochorous dispersion has likely played a key role in the spreading of earthworm populations across different geographical regions. According to Hendrix (2006) there is mounting evidence that exotic earthworm invasions are increasing worldwide, sometimes with significant effects on soil processes and plant communities. At least 100 earthworm species have distributions beyond their places of origin (Lee 1985; Fragoso et al. 1999). Earthworm introductions to new geographical areas appear to be facilitated by global commerce, both inadvertently with the importation of soil-containing materials (agricultural and horticultural products) and intentionally for use in commercial applications (waste management and land bioremediation).

There are many theories regarding the dispersal of earthworms. Medium to long range dispersal is attributable to earthworms escaping to the soil surface after heavy rains, followed by wash-off of cocoons and earthworms, and eventual further transport by streams. Birds also import earthworm cocoons to new areas through mud on their feet (Eijsackers 2011). Lee (1985) and Schwert (1980) also attributed cocoon dispersal partly to avian phoresy. Earthworms have been recently introduced to the South Sea islands Gough and Marion, probably by birds, although human transport seems to have the greatest impact (Lee 1985; James & Hendrix 2004).

Humans play a dominant role in earthworm introduction and redistribution by transporting soil and plant materials (Eijsackers 2011). Plisko (2001) observed that the distribution of exotic species exhibited proximity to urban and agricultural areas, in addition to dispersal through plant material and adhering soil. Proulx (2003) and Hale & Host (2005) found a relationship between dispersal and an anthropogenic index. Holdsworth et al. (2007) found a relationship between earthworm distribution and distance to roads, whereas Cameron & Bayne (2009) correlated the distribution of exotic earthworm species with road age and reported transportation as the most important distribution factors.

According to Julka (1988), earthworms in India have been introduced to new areas by man and other agencies with the importation of soil-containing materials (plants, agricultural and horticultural products), and species colonize successfully due to their inherent ability to withstand disturbance and interference. Gonzalez et al. (2006) reported the reproductive biology of species as an important characteristic in successful establishment. Further, high fecundity, short incubation periods and high hatching success are also likely adaptive strategies that enable survival of drastic environmental changes (Bhattacharjee & Chaudhuri 2002). Environmental

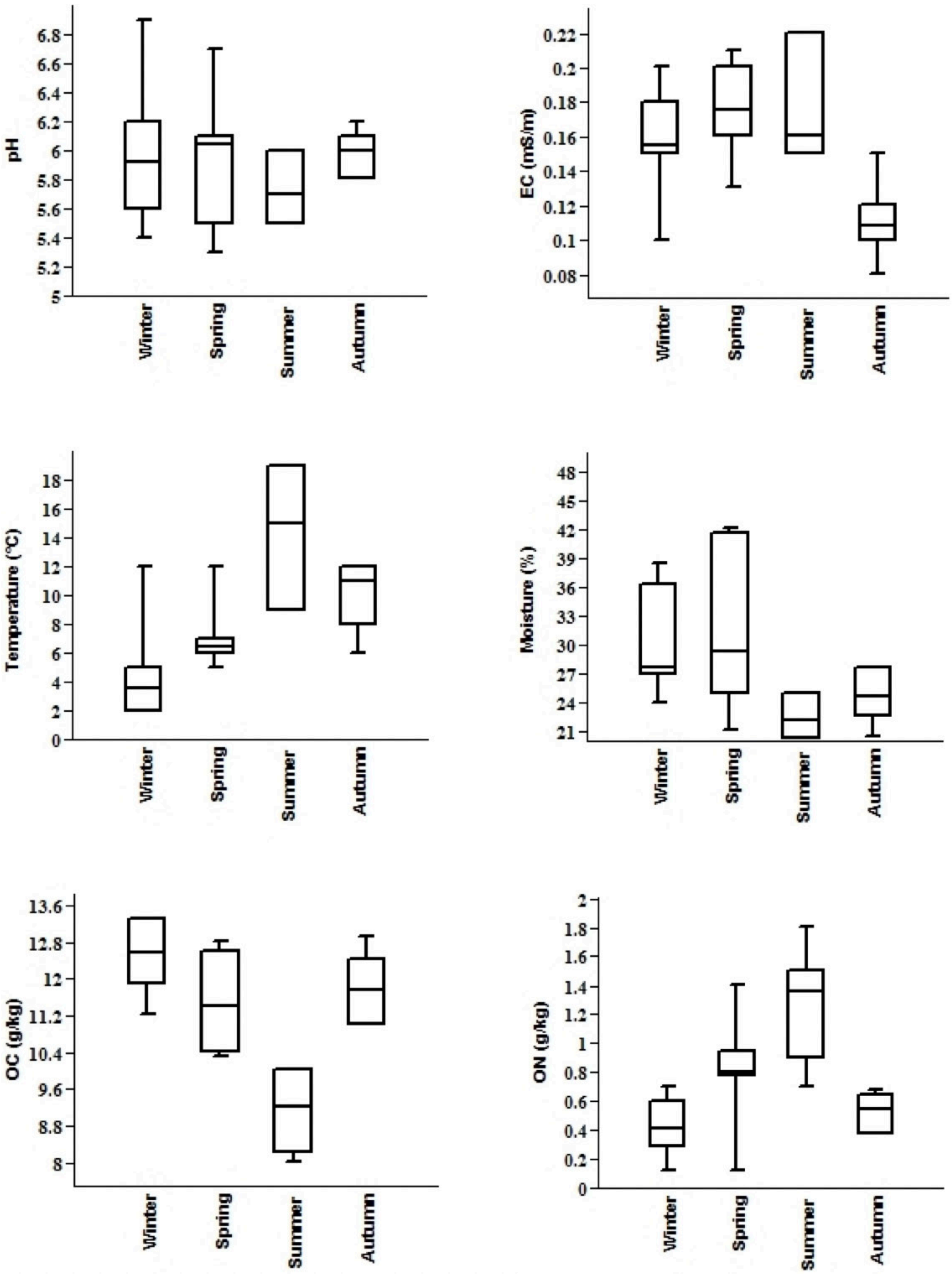

Figure 3. Soil physicochemical characteristics of the earthworm collection site.

plasticity and ability to aestivate appear to make some earthworms particularly successful as invaders (Fragoso et al. 1999; James & Hendrix 2004). According to Bengtson et al. (1979), the aestivation capability of *A. caliginosa* makes it a successful colonizer during adverse drought conditions and able to tolerate a wide range of soil moisture (35–65 %; Zorn et al. 2008) and pH (3.7–8.5). Further biological traits of *Aporrectodea* sp. such as tolerance to varying environmental conditions, rapid growth, and ability to live under a wide range of land uses and soils (Winsome et al. 2006), could give it a competitive advantage to successfully establish and dominate in different pedoecosystems.

The population size and species composition of earthworm communities is dependent upon soil texture, pH, moisture, and the palatability and quantity of litter (Lavelle 1997; Bohlen et al. 2004). *A. c. caliginosa* exhibited significant variation in population density (t=3.34, p<0.044) and biomass (t=3.40, p<0.042) among different seasons is shown in Figure 2. Population density varied from 34.33/m^2 to 129.6/m^2 during winter and spring respectively. The biomass also ranged from 6.94g/m^2 during winter to 26.90g/m^2 during spring. Population density was minimum during winter which is attributed to low temperature which causes delay in hatching of cocoons (Timmerman et al. 2006). Najar & Khan (2011a) also reported that earthworms were most abundant during spring and attributed it to the optimum moisture and temperature conditions. Complete cessation of cocoon production was observed by Nairw & Bennour (1998) during summer in *A. caliginosa* due to high temperature.

A variety of environmental factors such as soil texture, soil moisture, pH, temperature, organic content have been suggested as determinants for the distribution and abundance of earthworms (Bisht et al. 2003). Soil characteristics of the site are given in Figure 3. *A.c. caliginosa* was found within the pH range of 5.73 ± 0.09 to 5.99 ± 0.21. EC exhibited a value between 0.11 ± 0.01 to 0.17 ± 0.01 mS/m and varied significantly among the seasons (t = 10.40, p < 0.002). Moisture showed significant variation (t=12.64, p<0.001) among the seasons and ranged from 22.5±0.84 % to 31.4±3.52 %. Soil temperate was recorded 4.66±1.54 to 14.33±1.83 ^{0}C and exhibited significant variation (t=4.36, p<0.022) among the seasons during the study period. Organic nitrogen varied significantly (t=4.00, p<0.028) over the period and showed a range of 0.42 ± 0.08 to 1.26 ± 0.16 g/kg. Organic carbon significantly varied (t=15.72, p<0.001) with seasonal changes and ranged from 9.1±0.34 to 12.3±0.70 g/kg. The soil comprises 7.33% clay, 36.24% sand and 56.40% silt represented by silt loam class of soil texture Figure 4. According to Edwards, (2004) majority of the temperate earthworm species are found within the pH range 5.0 to 7.4 and *A. caliginosa* was reported at a pH range of 5.2 to 5.4 (Edwards & Lofty 1972). According to Nair & Bennour (1997) *A. caliginosa* can tolerate a wide range of temperature fluctuations and can be one of the reasons for its dominance in Benghazi soils (Libya). *A. caliginosa* is one of the most abundant earthworm species on agricultural lands in the temperate zone (Perez-Losada et al. 2009) and is found on all continents (except Antarctica) in agricultural and native ecosystems (Michaelsen 1903; Paoletti 1999; Baker et al. 2006; Hendrix et al. 2008; Blakemore 2009; Shekhovtsov et al. 2015). It is generally accepted that *A. caliginosa* is an European species that has been dispersed by means of human mediated transport to other parts of the world (Paoletti 1999) and in Russia, it is believed to displace native earthworms in some locations and to continue its eastward and northward expansion (Striganova & Porjadina 2005; Tiunov et al. 2006).

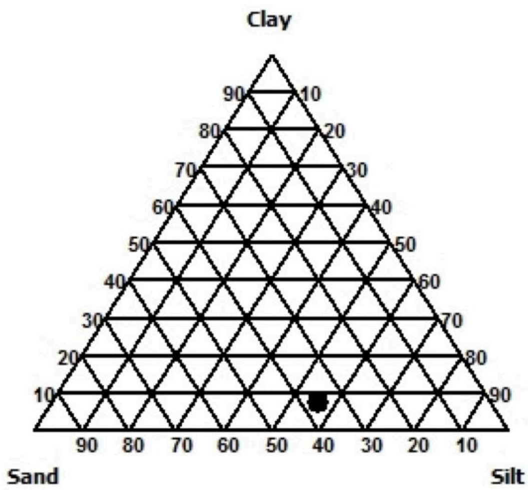

Figure 4. Ternary diagrams of soil texture.

Overall, the pattern of earthworm invasion closely resembles the ‘‘jump dispersal’’ model of Shigesada et al. (1995). There is a probability of colonization of distant localities which may be directly dependent on the availability of dispersal opportunities from the source and the time since initial colonization (MacIsaac et al. 2001).

CONCLUSION

A.c. caliginosa is an addition to the checklist of earthworms from Kashmir Valley, Jammu & Kashmir, India. It's biological characteristics and tolerance to varying environmental conditions helps them to encounter competitive challenges and make them successful to establish in new areas.

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