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Influence of the sugar-loving ant, *Camponotus compressus* (Fabricius, 1787) on soil physico-chemical characteristics

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Abstract

The present study focuses on the physico-chemical characteristics of the nest rim debris soil of a common, abundant, plant-visiting ant, *Camponotus compressus* (Fabricius, 1787). The results reveal that the colonies influence the nutrient content and the texture of the debris soil. The nest debris had significantly higher proportion of large-sized soil particles, along with higher total N, P, NO_3-N, and moisture content but lower concentrations of total C and NH_4-N as compared to the control soil. *Camponotus compressus* nests annually contributed about 3.1361 Kg of C, 1.5482 Kg of N, 0.05853 Kg of P, 0.14457 Kg of NO_3-N and 0.1744 Kg of NH_4-N per hectare via the debris soil of the long-lived primary nests. The short-lived satellite nests contributed, 1.7868 Kg of C, 0.7955 Kg of N, 0.0318 Kg of P, 0.0559 Kg NO_3-N and 0.09623 Kg of NH_4-N per hectare, annually. Thus, the activities of *C. compressus* colonies contribute to soil nutrient enhancement, alter the soil particle size distribution, shift the soil pH towards neutral and through their frequent satellite nest construction activities and enhance soil porosity. Since *C. compressus* is abundant in a variety of ecosystems including annual cropping systems, its nesting activities are suggested to enhance ecosystem productivity.

Keywords: *Ant nests, soil texture, soil nutrients, nutrient content.*

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Introduction

Soil health is essential for proper ecosystem functioning, for providing supporting ecosystem services (McBratney *et al*., 2014) and increasing agricultural productivity. The role of soil fauna in influencing the quality of nutrient cycling, soil nutrients, water use efficiencies and agricultural sustainability has recently gained a great deal of attention (Brussaard *et al.*, 2007; Bender and van der Heijden, 2014). An important challenge in agro-ecosystem research is to understand the role of soil organisms as ecosystem engineers (Folgarait, 1998; Sanders *et al*., 2014). Many ground-dwelling invertebrates such as earthworms, termites and ants, are ecosystem engineers which influence the food web structure and soil nutrients (Frouz and Jílková, 2008; Blouin, *et al.*, 2013; Shukla *et al.*, 2013). Extensive studies have been carried out on nutrient recycling, soil formation and structural modification of the soil by these ecosystem engineers. Significant increase in the mineralogical properties of mounds/nests built by termites and ants has been reported (Leprun and Roy-Nöel, 1976; Boyer, 1982; Mahaney *et al*., 1999). Nest excavation activities of ground - nesting ant species modify the soil by inversion of the soil layers while the nest chambers and galleries enhance soil porosity and aeration. Further, the colonies of many ant species dump plant and/or animal based refuse along with excreta, outside the nests (Frouz and Jilková, 2008; Shukla *et al.*, 2013). Moreover, one of the most conspicuous nest cleaning activities of ant colonies is the removal and dumping of dead nest-mates outside the nest (Wheeler, 1926; Wilson *et al*., 1958; Banik *et al*., 2010) which further enriches the nest rim debris soil. The debris generating activities of ant colonies in concert with the organic matter decomposing soil microorganisms regulate the physical and chemical processes which affect soil fertility and counteract the processes of soil degradation (Lee and Foster, 1991; Eldridge and Pickard, 1994). While the physical changes are related to the soil texture, the chemical changes vary with the soil characteristics or the ant species involved (Mc Ginley *et al.*, 1994). Since many ant species relocate their nest sites infrequently (Gordon, 1992) the nutrient accumulation continues for decades and sometimes even persist for a considerable time after nest abandonment (Wagner *et al*., 1997, 2004). In deciduous temperate forests, the influence of the European red wood ant, *Formica polyctena*, a mound-forming species with below-ground nests, on soil nutrients was detectable >20 years after abandonment (Kristiansen and Amelung, 2001). Such species can therefore have a lasting impact on nutrient heterogeneity in the landscape. Majority of investigations related to ant nest soil characteristics have documented the modifications in the nest chamber soil (Farji- Brener and Silva, 1995; Wagner, 1997; Kristiansen and Amelung, 2001; Moutinho *et al.*, 2003; Verchot *et al*., 2003; Dostál *et al*., 2005; Cerdà and Jurgensen, 2011; Jílková *et al*., 2011; Kotova *et al.*, 2015), and very few have studied the impact of their activities on the physico-chemical properties of the external debris pile soil (Gordon, 1992; Shukla *et al*., 2013).

The present study focuses on the physico-chemical characteristics of the ant nest crater rim debris soil of a locally common and abundant, plant-visiting carpenter ant, *Camponotus compressus* (Fabricius, 1787). Carpenter ants belong to the hyperdispersed genus *Camponotus* which includes polydomous species (Pfeiffer and Linsenmair, 1998; Buczkowski, 2011). Carpenter ant colonies are known to construct two types of nests: the primary nests and the associated satellite nests (Orr *et al*., 1996). *Camponotus compressus* is common in South and Southeast Asia, including India (Veena and Ganeshaiah, 1991; Bharti,*et al*., 2016; Nettimi and Iyer, 2015). The nests of this species are found to occur in a wide variety of ecosystems including annual and perennial agroecosystems (Rastogi, 2004; Agarwal *et al*., 2007).

A question very frequently raised (Frouz and Jílková, 2008) is: do ants really alter the soil or do they select soil spots with specific conditions to build their nests? Hence, in the present study we selected 3 study sites to find how the nest excavation and maintenance activities of *Camponotus compressus* colonies influence the soil in different areas. The following questions were addressed: i) What is the nutrient content of the debris soil from the 3 study areas? ii) What are the physical changes in the debris soil, in terms of the soil particle size? iii) What would be the annual contribution of *Camponotus compressus* nests in influencing soil nutrients?

Materials and Methods

Study site and system

The study on the physico-chemical characteristics of ant nest debris soil (hereafter referred to as the debris soil) was conducted from samples collected from 3 study sites: the Ayurvedic garden (AG), the Botanical garden (BG), and the unpaved roadside areas (RS). All the 3 sites are rich in plant diversity (Dubey, 2004) and are located within Banaras Hindu University campus of Varanasi, (25°18’ N, 83°01’ E) in Uttar Pradesh, India.

Camponotus compressus colonies make underground nests but the worker ants visit the extrafloral nectary-bearing plants for collecting nectar and honeydew, produced by plant - associated homopterans (Way, 1963; Agarwal and Rastogi, 2008, 2009).

Soil sample collection

Debris soil samples of the primary and the satellite nests were collected from the entrance rim of the active nests of *C. compressus*, from each of the 3 study sites. The soil samples (approximately 500 gm of each) were collected from the control site nest rim debris piles of the primary and satellite nests and put inside plastic bags. The control soil samples were collected from areas (n = 5) located at least 5 m away from any ant nest and was free from any type of vegetation. The control samples collected from a particular site were thoroughly mixed to yield one composite sample per study site.

Determination of the physico-chemical characteristics of soil

Soil samples were passed through a 2 mm sieve and analyzed according to the following methods: Fresh soil was used for analysis of ammonium-nitrogen (NH_4-N), nitrate-nitrogen (NO_3-N), pH and moisture content (MC) However, only dry soil was used for determination of the total Carbon, total Nitrogen (Kjeldahl N), and total Phosphorus.

Particle size distribution in experimental and control soil samples were analyzed by using a simple and rapid quantitative method developed by Kettler *et al.* (2001), and a combination of sieving (4 different mesh sizes: 2.0, 1.0, 0.5 and 0.2 mm of sieves used) method. Soil pH was measured in 1:2.5 mixture of soil and distilled water. Soil and water were mixed and after 30 minutes pH was recorded using a pH meter.

Total Nitrogen was determined by the micro-Kjeldahl method (Jackson, 1958). Ammonium Nitrogen (NH_4-N) was extracted by KCl and analyzed by the phenate method (APHA, 1985). NO_3- N was measured by Phenol disulphonic acid method using Calcium sulphate as an extractant (Jackson, 1958). Total P was determined through Aqua regia ($HClO_4$: HNO_3 : $H2SO_4$ = 1:5:1) digestion by phosphomolybdic acid blue colour method (Jackson, 1958).

Debris accumulation at the entrance rim of *C. compressus* active nests and soil nutrient changes per 100 m^2 area

Data pertaining to the duration of nest use by an ant colony, number of nests per unit area and quantity of debris accumulated per nest by *C. compressus* colonies, were collected from each of the 3 study sites and pooled for this part of the study. Ant nest age was assessed by monitoring each nest at fortnightly intervals. Number of nests per unit area was recorded in an area of 2000 m^2 per site.

To investigate the amount of debris accumulated per nest/month, 10 nests of each type (primary/satellite nests/site) were monitored from June, 2011 to May, 2012. Nest debris pile soil was collected from each nest per month, brought to the laboratory and its weight was recorded.

Data analysis

Analysis of variance (one way ANOVA) followed by Dunnett's *post-hoc* test was used to assess variations in the physical and chemical properties of the nest debris soil and also the variations in the soil properties due to site differences. The statistical software SPSS-16 was used.

Results

Nest location

Primary nests were found at or near a plant (shrub/tree) base while the satellite nests were located at a distance (range: 0.25 to 5 m) around each primary nest. The numbers of associated satellite nests per primary nest varied from 1 to 14. The life span of a primary nest was 6 month to 4 years (Some nests are active from June 2011 till date) while that of a satellite nest was 15 days to 4 months.

Physico-chemical characteristics of the debris soil

Soil particle size

Significant differences were found in the soil particle size categories of the debris and control soil. The percentage of large size particles (2.0-1.0 mm & 1.0-0.5 mm) was significantly higher ($p < 0.001$) in the debris soil from all the 3 sites (the exception being the BG debris in which the value though higher was not significantly so, in case of the 1.0-0.5 mm category). Moderate size particles (0.5- 0.2 mm) were found to be less (significantly less only in BG debris, $p < 0.01$) as compared to the control soil. The percentage of small size particles (< 0.2mm category) was lower ($p < 0.001$ in case of BG and RS) in nest debris from each of the 3 sites as compared to the control soil (Table 1).

The debris soil of both primary and satellite nests had lower pH value as compared to the respective control soil (Table 2). Debris soil moisture content was higher in case of each of the 2 types of nests from each of the 3 sites. The value was significantly higher ($p < 0.01$ and $p < 0.001$) for the primary and satellite nest debris from AG sites although significant differences were not found in BG and RS debris soil as compared to the respective control, from each site.

Table 1. Soil particle size (Mean ± SEM) of the control and nest debris soil of *Camponotus compressus* ants from 3 study sites: Ayurvedic and Botanical gardens and the unpaved roadside areas collected during June, 2011 to May, 2011, from Banaras Hindu University campus, Varanasi, India

Particle size range (mm)	Soil particle size (%)					
	Sites					
	Ayurvedic Garden		Botanical Garden		Roadside pavements	
	Control	Debris	Control	Debris	Control	Debris
2.0 - 1.0	4.256 ± 0.25	30.04 ± 1.85***	3.935 ± 0.41	42.56 ± 5.27***	3.129 ± 0.39	32.17 ± 1.2***
1.0 - 0.5	45.719 ± 0.83	28.49 ± 2.36***	45.878 ± 0.93	36.37 ± 4.67	44.542 ± 1.44	27.99 ± 1.84***
0.5– 0.2	26.469 ± 1.4	27.81 ± 2.01	26.565 ± 1.44	16.24 ± 1.82**	27.047 ± 1.11	27.02 ± 2.13
< 0.2	23.556 ± 1.17	13.66 ± 3.86	23.622 ± 1.11	4.83 ± 1.55***	25.282 ± 1.33	12.82 ± 2.8***

(Dunnett's *post hoc* test: * $p < 0.05$, ** $p < 0 .01$ and *** $p < 0.001$)

Debris soil from both types of nests had lower C content than the control soil, from each of the 3 sites (Fig. 1a). Significantly lower ($p < 0.001$ for each case) C concentrations were found in the primary and satellite nest debris soil from the BG area. The value was least significant ($p < 0.05$) in case of debris samples of satellite nests from the RS area. However, no significant differences were found in the C content in AG debris soil as compared to the control. Total N content was found to be consistently higher in both the primary and satellite nest debris as compared to the control soil, from each of the 3 sites (Fig. 1b). The total N value was significantly higher ($p < 0.01$ and $p < 0.5$) in the primary and satellite nest debris from the AG site and the value was least significant ($p < 0.05$) in case of debris from the primary nests of the BG area. However, no significant differences were found in the N content in BG satellite nest and RS primary and satellite nest debris soil as compared to the control. Total P content was found to be consistently higher in the primary and satellite nest debris soil (Fig. 1c), while no significant difference (with the exception of BG primary nest debris, $p < 0.05$) was found in the debris soil as compared to the control. Debris soil from both types of nests, from each of the 3 sites had higher concentration (values being significant in case of AG satellite nest debris, $p < 0.01$; BG primary nest debris, $p < 0.001$ and RS primary nest debris, $p < 0.05$) of NO_3-N as compared to the control (Fig. 1d). The debris concentration of NH_4-N was found to be significantly lower (AG primary and satellite nest: $p < 0.001$, BG and RS satellite nests: $p < 0.05$) (Fig.1e). However, no significant differences were found in BG and RS primary nest debris soil.

Debris accumulation at the entrance rim of *C. compressus* active nests and soil nutrient changes per 100 m^2 area

The mean number of active primary nests from each of the 3 study sites per month /100 m^2 ranged between 0.558 and 1.783 (AG: 0.558 ± 0.06, BG: 0.675 ± 0.034 and RS: 1.783 ± 0.02), while the number of satellite nests ranged between 1.125 and 3.575 (AG: 1.125 ± 0.122, BG: 1.592 ± 0.22 and RS: 3.575 ± 0.46). The amount of debris/nest/month generated by *C. compressus* primary nest was 0.788 ± 0.11, 1.054 ± 0.16 and 0.727 ± 0.08 kg while for satellite nest the amount was 0.262 ± 0.013, 0.267 ± 0.01 and 0.234 ± 0.01 kg, for AG, BG and RS sites, respectively.

The amount of debris/month/100 m^2 accumulated by *C. compressus* primary nests was 0.477 ± 0.12, 0.727 ± 0.12 and 1.297 ± 0.14 kg while that accumulated by the satellite nests was 0.30 ± 0.04, 0.424 ± 0.06 and 0.856 ± 0.133 kg, for AG, BG and RS sites, respectively. There were significant differences between the primary and satellite nests in the amount of nutrients generated/nest/month/100m^2, being higher in the primary nest debris as compared to the satellite nest debris (Table 3).

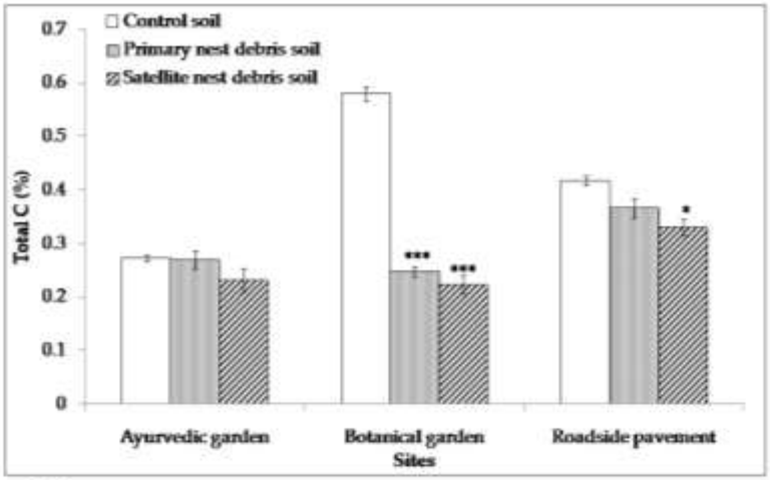
Table 2. Physico-chemical characteristics (Mean ± SEM) of the control and nest debris soil of *Camponotus compressus* ants, from 3 study sites: Ayurvedic and Botanical gardens and the unpaved roadside areas collected during June, 2011 to May, 2011, from Banaras Hindu University campus, Varanasi, India

Parameter	Sites								
	Ayurvedic Garden			Botanical Garden			Road side Pavement		
	Control soil	Nest debris soil		Control soil	Nest debris soil		Control soil	Nest debris soil	
		Primary	Satellite		Primary	Satellite		Primary	Satellite
pH	8.14 ± 0.02	7.99 ± 0.02	7.98 ± 0.05	7.62 ± 0.016	7.48 ± 0.04	7.44 ± 0.01	7.71 ± 0.01	7.53 ± 0.06	7.51 ± 0.03
Moisture Content (%)	1.75 ± 0.03	2.308 ± 0.13**	1.118 ± 0.01***	1.72 ± 0.05	2.25 ± 0.13	1.91 ± 0.18	1.54 ± 0.6	2.09 ± 0.157	2.10 ± 0.60
C:N	6.68 ± 4.68	3.02 ± 0.34**	2.33 ± 0.15***	6.05 ± 0.396	2.02 ± 0.20***	2.07 ± 0.21***	3.13 ± 0.06	2.998 ± 0.31	2.62 ± 0.28
N:P	14.23 ± 1.24	18.25 ± 1.63	19.05 ± 1.27	21.71 ± 1.65	23.67 ± 2.33	21.08 ± 1.18	29.60 ± 3.23	53.52 ± 18.49	32.79 ± 3.55
C:P	64.15 ± 3.05	50.52 ± 4.56	45.26 ± 4.65*	128 ± 6.6	42.18 ± 1.94***	42.07 ± 3.58***	92.46 ± 9.72	87.78 ± 12.66	74.01 ± 4.99
NO_3-N: NH_4-N	0.05 ± 00	0.23 ± 0.04	0.28 ± 0.05*	0.09 ± 0.0	0.82 ± 0.159**	0.405 ± 4.04	0.42 ± 0.0	1.08 ± 0.06	0.99 ± 0.23

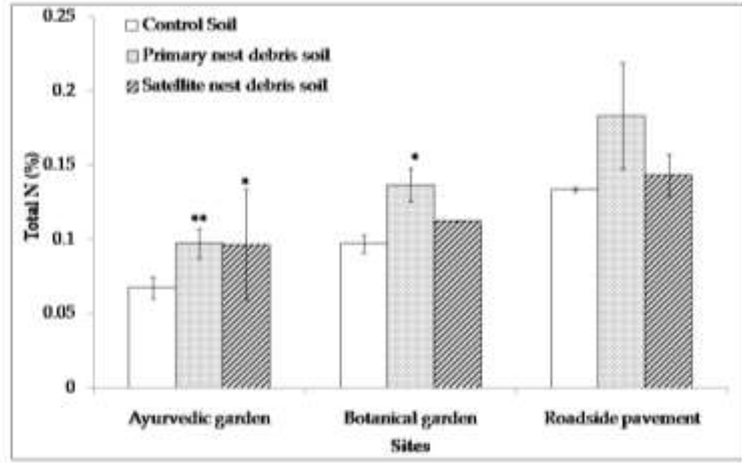
(Dunnett's *post hoc* test: * p < 0.05, ** p < 0 .01 and *** p < 0.001)

Table 3. Soil nutrients value (Mean ± SEM) in the debris soil of the primary and satellite nests of *Camponotus compressus* ants from 3 study sites: Ayurvedic garden (AG), Botanical garden (BG) and unpaved roadside areas (RS) collected during June, 2011 to May, 2011, from Banaras Hindu University campus, Varanasi, India

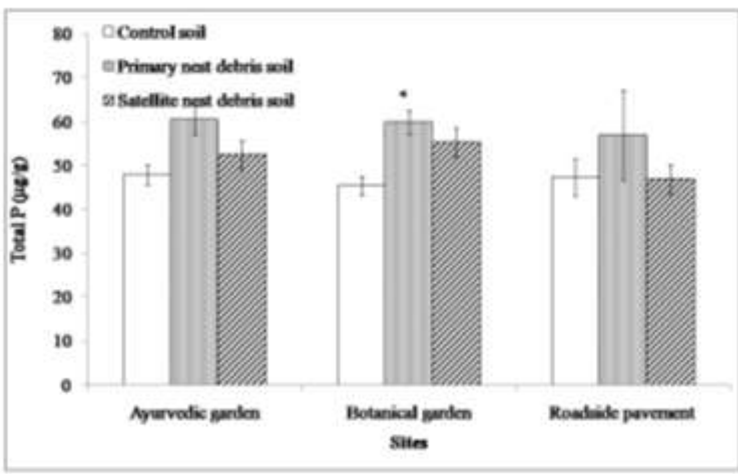
Nutrients	Sites	Primary nest			Satellite nest		
		Nutrients/ nest/month (gm)	Nutrients/ month/100 m^2 (gm)	Nutrients/year /hectare (Kg)	Nutrients/nest /month (gm)	Nutrients/month /100 m^2 (gm)	Nutrients/year/ hectare (Kg)
Total C	AG	2.1258 ± 0.282	1.2874 ± 0.318	1.5448 ± 0.382	0.6080 ± 0.030	0.6964 ± 0.088	0.8357 ± 0.106
	BG	2.6133 ± 0.388	1.8024 ± 0.296	2.1629 ± 0.355	0.5945 ± 0.027	0.9456 ± 0.137	1.1347 ± 0.164
	RS	2.6599 ± 0.289	4.7504 ± 0.527	5.7005 ± 0.633	0.7715 ± 0.031	2.8249 ± 0.439	3.3899 ± 0.528
Total N	AG	0.8273 ± 0.11	0.5010 ± 0.124	0.6012 ± 0.149	0.2529 ± 0.013	0.2897 ± 0.037	0.3476 ± 0.044
	BG	1.4415 ± 0.214	0.9942 ± 0.163	1.1931 ± 0.195	0.2986 ± 0.014	0.4749 ± 0.069	0.5699 ± 0.082
	RS	1.3299 ± 0.145	2.3752 ± 0.264	2.8503 ± 0.317	0.3343 ± 0.014	1.2241 ± 0.191	1.469 ± 0.229
Total P	AG	0.0477 ± 0.006	0.0289 ± 0.007	0.0346 ± 0.008	0.0138 ± 0.001	0.0158 ± 0.001	0.0189 ±0.002
	BG	0.0632 ± 0.009	0.0436 ± 0.007	0.0523 ± 0.008	0.0148 ± 0.001	0.0235 ± 0.003	0.0282 ± 0.004
	RS	0.0414 ± 0.004	0.0739 ± 0.008	0.0887 ± 0.009	0.01099 ± 0.00	0.0402 ± 0.006	0.0483 ± 0.007
NO_3-N	AG	0.0255 ± 0.003	0.0155 ± 0.004	0.0186 ± 0.004	0.0103 ± 0.001	0.0118 ± 0.001	0.0142 ± 0.002
	BG	0.0637 ± 0.009	0.0439 ± 0.007	0.0527 ± 0.009	0.0069 ± 0.000	0.0109 ± 0.001	0.0132 ± 0.001
	RS	0.1691 ± 0.018	0.3020 ± 0.033	0.3624 ± 0.040	0.0319 ± 0.001	0.117 ± 0.018	0.1404 ± 0.022
NH_4-N	AG	0.1403 ± 0.019	0.0849 ± 0.021	0.1019 ± 0.025	0.0440 ± 0.002	0.0505 ± 0.006	0.0605 ± 0.008
	BG	0.0900 ± 0.013	0.0621 ± 0.010	0.0745 ± 0.012	0.0181 ± 0.001	0.0288 ± 0.004	0.0345 ± 0.005
	RS	0.1618 ± 0.018	0.2890 ± 0.032	0.3468 ± 0.039	0.0441 ± 0.002	0.1615 ± 0.025	0.1937 ± 0.030


Control soil
Primary nest debris soil
Satellite nest debris soil
Total C (%)
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
***
***
***
*
Ayurvedic garden
Botanical garden
Roadside pavement
Sites

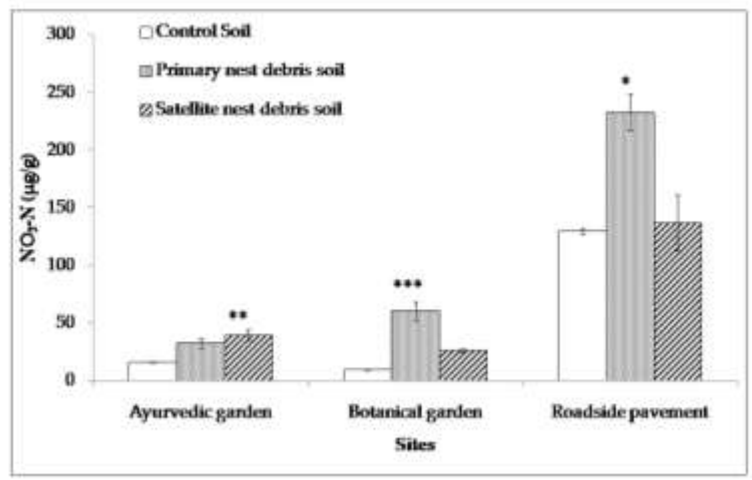
1 (a)


Control Soil
Primary nest debris soil
Satellite nest debris soil
Total N (%)
0.25
0.2
0.15
0.1
0.05
0
**
*
*
Ayurvedic garden
Botanical garden
Roadside pavement
Sites

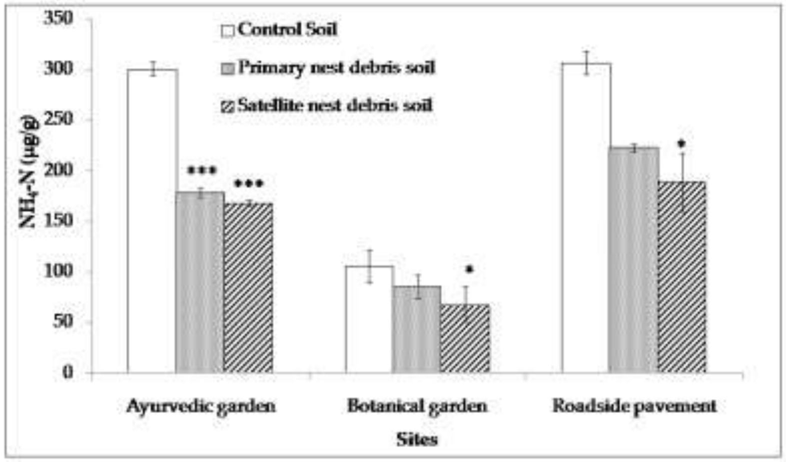
1 (b)


Control soil
Primary nest debris soil
Satellite nest debris soil
Total P (μg/g)
80
70
60
50
40
30
20
10
0
*
Ayurvedic garden
Botanical garden
Roadside pavement
Sites

1 (c)


Control Soil
Primary nest debris soil
Satellite nest debris soil
NO3-N (μg/g)
300
250
200
150
100
50
0
**
***
*
Ayurvedic garden
Botanical garden
Roadside pavement
Sites

1 (d)



1 (e)

Figure 1. Debris soil nutrient content (Mean ± SEM): (a) Total carbon (b) Total nitrogen (c) Total phosphorus (d) Nitrate-nitrogen (NO_3-N) and (e) Ammonium- nitrogen (NH_4-N) concentration in the nest (primary and satellite nests) debris and control soil sampled at the 3 sites, Ayurvedic garden, the Botanical garden and the unpaved roadside areas, located in Banaras Hindu University campus, in Varanasi, India. (One-way ANOVA followed by Dunnett's *post hoc* test: * $p < 0.05$, ** $p < 0.01$ and *** $p < 0.001$).

Discussion

The results reveal that nest excavation and maintenance activities of the sugar-loving ant, *C. compressus* have a significant impact on the physico-chemical characteristics of the debris soil (Fig. 1a-e). While the debris soil exhibited higher moisture, total N, P and NO_3-N content, the concentrations of total C and NH_4-N were lower as compared to the respective control soil. It demonstrated a greater proportion of particles in the large size (1.00 to 2.00 mm) category as compared to the control soil. Thus the debris soil texture was different as compared to the control. The changes in debris soil particle size distribution may increase aeration and influence water infiltration properties.

Most mineral nutrients are readily available to plants when soil pH is near neutral. The primary and satellite nest debris soil exhibited a neutral pH which makes the debris soil more suitable for growing crop plants. The shift in *C. compressus* debris soil pH toward neutrality is consistent with earlier reports of ant nest soil (Frouz *et al*., 2003; Wagner *et al*., 2004; Frouz and Jílková, 2008). It is suggested to be due to the increase of basic cations such as Ca^{2+}, Mg^{2+}, K^+, and Na^+ (Brady and Weil, 1999; Jílková *et al*., 2011, 2012) contributed by mineral compounds released from the decomposition of the organic matter carried to the ant nests. Our results support earlier studies on the nest chamber soil of a sugar-loving ant species, *Lasius flavus*, which was found to have low C (Dostál *et al*., 2005), high N and high P (Dostál *et al*., 2005; Hudson *et al*., 2009). Carbon-nitrogen ratio in the soil is extremely important, since carbon is important as energy - producing factor while nitrogen builds up the plant tissue. It is established that a low C-N ratio is responsible for the decrease in nitrogen immobilization during the soil organic matter decomposition by microorganisms which thereby increases the crop yield (Swift *et al.*, 1979). Our studies demonstrate a lower C-N ratio in *C. compressus* debris soil. Phosphorus is the non-mobile nutrient for plant. Root interception and diffusion is largely responsible for phosphorus uptake (Eash *et al*., 2015). *Camponotus compressus* debris soil exhibited a higher proportion of P as compared to the control soil. Our results thus support earlier studies of enhanced P in nest soil of many species such as the temperate grassland ants of Europe, *Lasius* spp. (Wagner *et al.*, 2004; Frouz *et al*., 2003; Dostál *et al*., 2005) and in the debris soil of *Pheidole latinoda*, (Shukla *et al*., 2013) a species commonly found in a wide variety of anthropogenically disturbed ecosystems in India (Agarwal *et al*., 2007).

While total N and NO_3-N content of debris soil was higher that of NH_4-N was lower than that found in the control soil. Atmospheric nitrogen is converted into NO_3^- and NH_4^+ forms in the soil by nitrogen fixation, which is performed by certain soil micro-organisms. Plants can absorb nitrogen either as Nitrate (NO_3^-) or as Ammonium (NH_4^+), and therefore, the total uptake of nitrogen usually consists of a combination of these two forms (Hodges, 2010). Ammonium and nitrate nitrogen are the predominant inorganic forms of nitrogen in soils. Both low pH and limited ammonium availability are suggested to reduce nitrification (Robertson, 1982).

Since new satellite nests are constructed with high frequency these nest constructions would lead to greater soil aeration and may even influence the rate of flow of water through the soil. Hummocks made by *Formica podzolica* in peatland soils are found not only to contribute to better aeration than the surrounding peat but also served as a habitat for diverse plant species (Lesica and Kannowski, 1998).

Our study indicates a significant contribution of *C. compressus* nest debris soil in enhancing soil nutrients particularly P and N, which could contribute to better growth of both the road side as well as garden plants. The nest density of satellite nests was about 2 times more than the primary nests, at each of the 3 sites but the debris accumulated by each primary nest was 3 to 5 times more than a satellite nest. So, the resultant output in the form of amount of the debris/100 m^2 was found to be about 2 times greater in a primary nest than a satellite nest.

The nest density of the primary and satellite nests of *C. compressus*, in each of the 3 sites per month/hectare was found to be respectively 55.83 ± 6.06 and 112.5 ± 12.22 from the AG site, 67.5 ± 3.46 and 159.17 ± 22.28 from the BG site, 178.33 ± 1.67 and 357.5 ± 45.97 from the RS site. As a result, even under anthropogenically disturbed conditions of managed ecosystems, about 3.1361 kg of C, 1.5482 kg of N, 0.05853 kg of P, 0.14457 kg of NO_3-N, 0.1744 kg of NH_4-N per hectare are annually added via the debris soil of the primary nests of *C. compressus*. Moreover, 1.7868 kg of C, 0.7955 kg of N, 0.0318 kg of P, 0.0559 kg NO_3-N, 0.09623 kg of NH_4-N per hectare are annually added via the debris soil of the satellite nests. Thus, nest construction and maintenance activities of *C. compressus* colonies not only influence the soil nutrients, particularly by enhancing P and N, but also affect the physical characteristics. The high turnover of the satellite nests may also affect the soil hydrological properties. Since *C. compressus* is a common and abundant ant species of annual cropping systems (Agarwal and Rastogi, 2008) this nutrient enhancement would contribute towards enhanced agroecosystem productivity.

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