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Fauna-associated Changes in Chemical and Biochemical Properties of Soil[1]

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Objective To study the impacts of abundance of woodlice, termites, and mites on some functional aspects of soil in order to elucidate the specific role of soil fauna in improving soil fertility in desert. **Methods** Fauna-rich sites were selected as experimental sites and adjacent areas were taken as control. Soil samples were collected from both sites. Soil respiration was measured at both sites. The soil samples were sent to laboratory, their chemical and biochemical properties were analyzed. **Results** Woodlice showed 25% decrease in organic carbon and organic matter as compared to control site. Whereas termites and mites showed 58% and 16% decrease in organic carbon and organic matter. In contrast, available nitrogen (nitrate and ammonical both) and phosphorus exhibited 2-fold and 1.2-fold increase, respectively. Soil respiration and dehydrogenase activity at the sites rich in woodlice, termites and mites produced 2.5-, 3.5- and 2-fold increases, respectively as compared to their control values. Fauna-associated increase in these biological parameters clearly reflected fauna-induced microbial activity in soil. Maximum decrease in organic carbon and increase in nitrate-nitrogen and ammonical-nitrogen, available phosphorus, soil respiration and dehydrogenase activity were produced by termites and minimum by mites reflecting termite as an efficient soil improver in desert environment. **Conclusion** The soil fauna-associated changes in chemical (organic carbon, nitrate-nitrogen, ammonical-nitrogen, phosphorus) and biochemical (soil respiration, dehydrogenase activity) properties of soil improve soil health and help in conservation of desert pedoecosystem.

Key words: Soil fauna; Organic carbon; Nitrogen; Phosphorus; Soil respiration; Dehydrogenase activity

INTRODUCTION

Plants, animals, fungi, and bacteria are closely associated and combined to influence physical, chemical and biological properties of soil[1]. Soil inhibiting-arthropods create chaff-frash piles around the nest perimeter that increase the organic matter content of the soil under the ejected material[2]. Soil arthropods acting as engineers can produce habitat for self and other species by their activities. They can indirectly affect plant growth by stimulating the activity of the soil biota or by supplying soluble nitrogen directly to the soil beneath the plant canopies[3]. Rapid growth of soil fauna as a result of inputs of high carbon, low nitrogen substrates results in the immobilization of soil nitrogen in the rapidly growing microbial biomass[4]. Soil arthropods affect soil quality directly and indirectly both depending on their size and specific activity. Depending on the densities of the arthropod populations, the effects of their activities range from minor to major. Some studies have demonstrated the importance of soil fauna as a regulator of nutrient cycling and bioindicator of soil quality[5-9].

Soil inhibiting-arthropods affect physical properties through mixing, ingesting and soil turnover[10-11], chemical properties through mineralization[12] and enhancement of soil microbial activity[13], and biological properties through organic matter dynamics, and turnover of biomass carbon[14]. The increase in organic carbon, soil nutrients and microbial activity is associated with the increase in soil faunal population. The objective of soil management should be to enhance soil biodiversity and biotic processes through stimulation of activity and species diversity of soil fauna by use of soil restorative measures and conservation-effective systems. Therefore, the impacts of selected groups of soil fauna on chemical and biological health of soil were studied in field condition. It may help in evolving strategies for environment of exhausted soil and rehabilitations of degraded lands through

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nurturing of soil biota.

MATERIALS AND METHODS

Study Area

Three different sites in a field of Bilara village of Jodhpur district of Rajasthan (26° 45′ North latitude and 72° 03′ East longitude) were marked where a sufficient number of termites, woodlice and mites were present. These fauna-rich sites were defined as experimental sites and adjacent areas were taken as control sites. Either there were none of these groups of soil fauna at the control site or the faunal density was almost negligible at the site. The soil samples were collected from both experimental and control sites. Soil respiration was measured at both sites. The collected soils were sent to laboratory and analyzed for organic carbon, available nitrogen (NO_3-N and NH_4-N) and phosphorus and dehydrogenase activity. The procedures adopted for estimation of these parameters were described as follows.

Nutrients Analysis

Organic carbon was determined by the partial oxidation method[15]. The organic matter was calculated by multiplying organic carbon content with Walkley-Black value (i.e., 1.724). The principles adopted for estimation of nitrate-nitrogen (NO_3-N) and ammonical-nitrogen (NH_4-N), and extractable phosphorus were mainly based on the methods described by Anderson and Ingram[16]. An autoanalyzer (Tecator Model Enviroflow-5012) was used to determine these soil nutrients.

Biochemical Analysis

Soil respiration was measured using 0.1 mol/L KOH solution that absorbs CO_2. This solution was exposed to CO_2 evolving from soil. It was then titrated with standardized 0.1 mol/L HCl after addition of saturated $BaCl_2$ solution. Absorbed CO_2 was calculated by taking 1 mL of 0.1 mol/L HCl equivalent to 2.2 mg CO_2. This was measured according to the method of Anderson[17]. Soil dehydrogenase activity was assayed as described by SINGH *et al.*[18]. One gram of air-dried soil was kept in an air-tight screw capped test tube, 0.2 mL of 3% TTC (triphenyl tetrazolium chloride) solution was added in each of the tubes to saturate the soil. Then 0.5 mL of 1% glucose solution was added in each tube. The bottom of the tube was gently tabbed to drive out all trapped oxygen and the water seal formed above the soil. The tube was incubated at 28℃±0.5℃ for 24 hours. After incubation, 10 mL of methanol was added and shaken vigorously. Then it was allowed to stand for 6 hours. The clear pink coloured supernatant was decanted and its absorbance was measured at a wavelength of 480 nm in a spectrophotometer.

RESULTS

Figure 1 shows the effects of abundance of woodlice, termites, mites on functional aspects of soil. The changes in organic carbon and organic matter due to variation in soil fauna approached to a significant level (P=0.059). However, the organic carbon content in soil at termite and mite sites differed significantly (P<0.05). Whereas variation due to control and experimental sites was highly significant (P<0.001). Similarly, the interaction between fauna and sites exerted a significant effect (P<0.05) on the changes in soil organic carbon and organic matter.

Variation in nitrate-nitrogen due to changes in soil fauna was insignificant (P>0.05). The nitrate-nitrogen content in soil harbouring woodlice, termites and mites did not differ significantly (P>0.05) among themselves. Whereas changes due to control and experimental sites were statistically significant (P<0.001). The interaction between fauna and sites was insignificant (P>0.05). Like nitrate-nitrogen, the changes in ammonical-nitrogen due to variation in soil fauna were not significant (P>0.05). The woodlice, termite and mite dependent changes in ammonical-nitrogen of soil did not differ significantly (P>0.05) among themselves. However, the variation due to control and experimental sites was significant (P<0.001). The interaction between fauna and sites was insignificant (P>0.05). The variation in phosphate-phosphorus due to changes in soil fauna was insignificant (P>0.05). Similarly, the phosphate-phosphorus contents in soil at sites of woodlice, termites and mites did not differ significantly (P>0.05) among themselves. But the changes in available phosphorus at control and experimental sites were significant (P<0.002). The interaction between fauna and sites was not significant (P>0.05).

Changes in soil respiration due to variation in soil fauna were highly significant (P<0.001). Similarly, the soil respiration varied significantly (P<0.05) with each other at sites harbouring woodlice, termite and mite. Soil respiration observed at experimental sites varied significantly (P<0.001). Further, the interaction between fauna and sites was statistically significant (P<0.001). Similarly, the variation in dehydrogenase activity due to changes in soil fauna was significant (P<0.001). However, changes

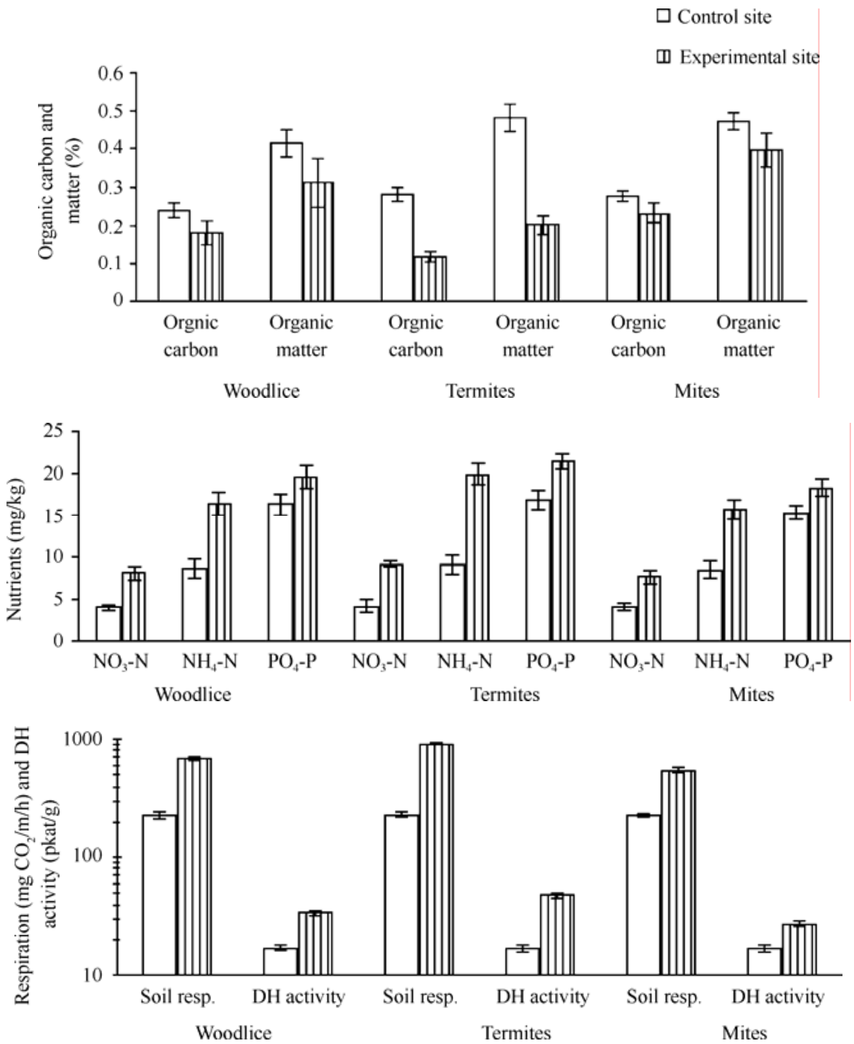

FIG. 1. Effects of woodlice, termite, and mite on organic carbon and matter, nitrate-nitrogen, ammonical-nitrogen, phosphate-phosphorus, and soil respiration and dehydrogenase activity of soil. Values are $\bar{x} \pm s$ of five replications.

in soil dehydrogenase activity at woodlice, termite and mite sites approached to being significant (*P*=0.068). Variation in soil dehydrogenase activity at control and experimental sites was highly significant (*P*<0.001). The interaction between soil fauna and sites was also significant (*P*<0.001).

Woodlouse showed 25% decrease in organic carbon and organic matter as compared to control site. Whereas termite and mite showed 58% and 16% decrease in organic carbon and organic matter at fauna rich sites than that of their controls, respectively. In contrast to organic carbon, nitrate-nitrogen exhibited 2-2.2- and 1.2-fold increase at experimental sites (fauna rich sites) than controls, respectively. Likewise, ammonical-nitrogen showed 1.9-2.2- and 1.8-fold increase at experimental sites (woodlice, termites, mites) than that of their controls, respectively. Similarly, the phosphate-phosphorus presented 1.2-1.3- and 1.2-fold increase, respectively as compared to controls. Soil respiration at experimental sites rich in woodlice, termites and mites produced 2.5-3.5- and 2-fold increase, respectively as compared to controls. Likewise, the soil dehydrogenase activity exhibited 2-2.9- and 1.6-fold increase, than that of their controls.

DISCUSSION

Decrease in organic carbon and organic matter, and increase in soil nutrients (available nitrogen and phosphorus) and microbial or biotic activity (soil respiration and dehydrogenase) at fauna rich sites compared to their controls indicate the role of woodlice, termites and mites in improving soil health by increasing availability of organic carbon and soil nutrients for plant growth. The gradation of efficiency of different groups of soil fauna in increasing organic carbon, soil nutrients as well as biotic activity was: termites> woodlice> mites (Fig. 1). However, the variations in degrees of effects of soil fauna were more or less similar as a result of ANOVA. But termite was of apparently maximum effect while differences between control and experimental sites were considered. Since termite is a voracious soil feeder and well adopted to desert environment, its higher efficiency as compared to woodlice and mite is obvious in improving functional aspects of soil. The castings of these soil fauna are rich in bacteria and fungi, hence the soil respiration and dehydrogenase activity is more at experimental site due to more biotic activity. Thus the improvement of soil biological properties is directly related to the availability of soil fauna at a particular site in arid environment. It means that termite is an efficient soil nutrient enricher and soil improver in desert area. Modification of soil material in epigeous termites is a consequence of the use of organic compounds of salivary and faecal origin in their construction[19]. Therefore, available nitrogen content is more abundant in termite nests than in surrounding soil, which is in agreement with the report of Lopez-Hernandez[20]. The earlier findings have also shown a substantial increase in available phosphorus at termite sites as compared to the surrounding soil[21-24].

There is evidence that nutrients accumulate at fauna rich soil sites. Thus soil fauna could play an important role in controlling nutrient cycling in fields, which are typically nutrient deficient in desert. Watson[25] showed that nutrients used are accumulated in mounds as fertilizer in nutrient-deficient African soils. It may be said that the dynamics of biogenic elements (carbon, nitrogen and phosphorus) at fauna rich sites compared with their associated soil act as sinks for these important elements. Fauna also help the conservation of water in desertic climate. The nutrient depleted conditions of desert environment together with the concentrations of carbon, nitrogen and phosphorus found at fauna concentrated sites corroborate the hypothesis that soil fauna can act as 'sinks' in the nutrient economy of hot desert with low productivity. Thus the improvement of soil biological properties is directly related to the availability of soil fauna at a particular site in arid region.

The increase in nutrient status along with soil respiration and dehydrogenase activity as a function of soil faunal population clearly demonstrate fauna-associated improvement in chemical and biological health of soil. Soil fauna has been found to reduce organic carbon with the concommitment increase in nutrient status (nitrate-nitrogen, ammonical-nitrogen, phosphate-phosphorus) and microbial activity (soil respiration and dehydrogenase activity) at selected sites. This indicates an active involvement of soil faunal bioresources in decomposition of leaf litter and improvement of functional aspects of soil in desert environment. Therefore, the soil fauna may also be inoculated or nurtured in degraded land as a part of the technical management practice for improvement of soil fertility in arid zone on a sustainable basis.

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