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Effects of vermincompost application on the population dynamics of Hypogastruradenticulata (Collembola) in an orchard habitat

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Abstract

Experiments were designed to evaluate the effects of vermicompost application on population abundance, vertical and spatial distribution, and the population age structure of *Hypogastrura denticulata* (Collembola). In field, experiment was designed on the base of completely randomize samples. Vermincompost treatments at doses of 0, 5, 10, 15 kg/plot were adopted and Collembola densities were estimated four times during 1 year after treatment. A significant effect on the abundance of Collembola in the 15 kg treated plot was observed, where its population abundance was obviously flourished. However, at a dose of 15 kg/plot, intensive vertical migration was recorded. In a vermin compost-free plot, and 5kg vermincompost treated plot *Hypogastrura denticulata*showed tendency of less frequent spatial aggregation. The application of vermincompostat the highest dose had a marked influence on the aggregation indices. A slight effect at the dose of 5 kg/plot, on the current reproductionstatuswas observed but no significant effect of that dose comparing with control could be detected. At the high dose of vermin compost (5 kg/plot) the pattern of the frequency distribution curve of different age classes could describe the general characteristic of the expanding population. It is concluded that the vermincompost treatment of 15 kg/plot has a positive effect on the abundance and the development of the test species. Moreover, that *Hypogastrura denticulata* may serve as bio indicators to evaluate the role of vermincompost application on the soil habitat.

Keywords: Vermicompost; Collembola; *Hypogastrura denticulata;*

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1. Introduction

Soil Collembola are one of the most important functional group among soil fauna. Al-Assiuty et al 2005 contribute to the breakdown of soil organic matter and to mineralisation of nutrients (Verhoef and Brussaard, 1990). Also, Collembola participate in the control of the microflora in soil as they feed on it (Khalil 2005) and, consequently, the decrease of their population densities will also reduce their contributions and vice versa. There is, therefore, reason to be concerned with the potential enhancedthe effects of useful organic fertilizer on theseorganisms.Vermicompostingisone of the most promising ways to recycle the wastes generated from power plants, as the process reduces the volume, and stabilizes the waste. The high organic matter content in vermicompost products also preserves soil fertility. (Hand et al., Atiyeh et al., 2000).Various studies have shown that vermicompost of organic waste accelerates organic matter stabilization (Lavelle and martin 1992, Brown et al. 2000) and gives chelating and phytohormonal elements which have a high content of microbial matter (Lavelle and Martin, 1992; Maboeta and Van Rensburg, 2003 and Arancon et. al. 2005) and stabilized humic substances.However, a general overview of the available data dealing with the role of vermicompost on the soil Collembola indicates that the experimental evidence on vermicompost is very limited.

The test species chosen is *Hypogastrura denticulata*. It appears that the species is mainly distributed in the soils of the Nile delta and the Northern Mediterranean coast of Egypt (Moen, 1970; Moursi et al., 1983; Al-Assiuty et al., 1993). In the present study, *Hypogastrura denticulat*a was selected because of its availability, and as far as the author is aware, there is no previous information on the effect of vermicompost treatment on the vital functions and population ecology of this species. The microbiological characterization of finished compost or vermicompost is still in its infancy, and a systematic microbiological analysis of products from composting facilities is still lacking (Hassen et al., 2001; Tang et al., 2003).

Accordingly, in this study attempts were made to determine how vermincomposttreatment affects field abundance, spatial and vertical distribution pattern as well as the current reproductive status under the effect of vermincompostamendment.

2. Materials and methods

An orchard field cultivated with citrus trees (*Citrus sinensis*) at Birket el saba region Menofia Governorate was selected for the present study. To minimize errors due to differences of soil factors and plant cover, a randomized block design was applied. Four separate quadrate blocks, each 400 m^2 with similar agronomic history were chosen. Each block was divided into four equal plots of about $100m^2$. Four doses of vermincompost (0, 5, 10, 15kg/plot) were applied. Each dose was applied to four plots in an alternative manner (Figure 1). The vermincompost treatments were applied four times to each plot, once every season (during2013). The chosen doses of vermincompost were based on a recommended dosess (e.g. 5, 10, 15 kg/plot) these doses are equivalent to 0.5, 1.0, 1.5 ton/hectar. The fourth plot, the vermincompost-free plot, served as control. Sampling was done 30 days after each vermincompost treatment, four times over a period of 1 year. The peripheral edges of each plot were excluded from the sampling scheme to minimize possible edge effects.

Ten soil samples were collected randomly from each plot each season. The sampler was a rectangular metal quadrate, 10×10 cm, which was driven into the soil to a depth of 15 cm. Each sample was divided into three equal subsamples (0-5, 5-10 and 10-15 cm depth). The test species, together with other soil fauna, were extracted from the soil samples using modified Berlese funnels (Bayoumi , 1978).

Preparation of Vermincompost

The farmyard manure and rice straw were obtained from the local farms. The rice straw was air dried and cut into small pieces about 4-15ml in length. Animal wastes were homogenized with rice straw. Urea as nitrogen source, phosphate and water were added to give C/N ratio 25 to 40 part carbon to 1part nitrogen as recommended by Mohamed (2011) and moisture content 60% which is considered optimum for composting (Keener et al., 2000). Empty gutted worms of an average weight of about 0.89 g were used. After 30 days (hyper thermal period up to 58 C) earthworms *Approctod eacaliginosa* were introduced into piles at a ratio of 30 g fresh weight worms /kg of homogenized piles. Vermincompost was left without turning for 5-6 months depending on the ability of worms in turning the pile materials and mixing it.

2.5. Statistical analysis

The population densities were converted to the number $/m^2$and expressed as log (x+1). The fluctuations in population density were evaluated using the coefficient of variation (c.v.), which expresses the variability among replicates (standard deviation) as a percentage of the mean. The aggregation index for the sampled population of the test species was calculated using the relative index $\lambda = S / \sqrt{x'}$(S=standard deviation,x'= arithmetic mean). Index λ was tested using x^2 with n –1 degrees of freedom: $x^2=(n-1)\ \lambda^2$ (Debauche, 1962) where the null hypothesis corresponds to a random distribution. The vertical distribution (mean depth M) and the intensity of vertical dispersion (depth deviation *D)* were statistically estimated according to Usher (1970). The Kruska l-Wallis test (Steel and Torrie , 1976) was applied to compare the data.

3. Results

3.1 Population density

The population densities in the 15 kg/plot vermincompost treated plots were increased by about 54%, in comparison with the control. The differences are statistically highly significant ($P<0.001$). The abundance did not, however, differ between 10 kg vermincompost treated plots and 15 kg vermicompost treated plots where the mean total were of $4750/m^2$ compared to 5325/ m^2respectively. In the vermincompost-free plot, seasonal changes in the relative population densities of the total individuals of *Hypogastrura denticulata*are shown in Fig. 2. It can be seen that the highest number of individuals was recorded during winter (4000 m^{-2}) followed by the spring season (3800 m^{-2}). The summer season showed the lowest abundance (800 m^{-2}). The fluctuation pattern of the populations in the other three treated plots was nearly the same. The degree of seasonal fluctuations in abundance was evaluated using the coefficient of variation. The fluctuation of abundance of the test species under vermincompost application was markedly lower at 10 and 15 kg/plot, in comparison with control, cv. % being 49.3% and 52.4%, respectively, and 68.7% for control. No effect of the 5 kg/plot verminompost dose could be seen on the coefficient of variation.

3.2 Vertical distribution

The vertical distribution of*Hypogastrura denticulata* is shown in Fig. 3 and Fig. 4. In vermincompost treatedplots, during sampling seasons, the relative abundance of *Hypogastrura denticulate* decreased with increasing soil depth. In the plot treated with 15 kg vermincompost treated plot, the total population density of *Hypogastrura denticulate* was relatively high (5325 ind/ / m^2 . The majority of them were concentrated in the uppermost soil stratum 5 cm (Fig. 3). In the vermicompost-free plot, it is clear that seasonal change had a marked effect on the vertical migration of *Hypogastrura denticulata,* where the uppermost stratum (0-5 cm) in summer and showed the lowest relative abundance of test species. However an obvious decreasing of about 60% of the total individuals could be seen during spring. The data on mean depths, shown in Fig. 3, revealed that in the vermincompost-free plot and plots treated with a low doseof vermicompost (5 kg/plot) no significant effect (P >0.05) of sampling time on the mean depths could be shown. In dry and relatively hot seasons (summer and autumn), *Hypogastrura denticulate* showed a low variability (depth deviation) of its depth distribution, in comparison with the wet and cold seasons (winter and spring). Plots treated with 10 and 15 kg/plot vermicompost showed no seasonal differences in calculated mean depth of *Hypogastrura denticulata* at these two plots showed a low vertical dispersion; depth deviation ranged between 2.11 and 2.7 in the 10 kg/plot vermincompost treated plot and 2.01 and 2.71 in the 15 kg/plot vermicompost treated plot. These values correspond to 2.88-4.06 in the case of the vermincompost-free plot.

3.3 Population age distribution

In organically managed system the adult forms represent about 25% of the total individual of *Hypogastrura denticulata.* However the pre reproductive forms (>0.5-<2mm) represent stages that were found to be more or less evenly distribution (fig. 5a.) thus the population structure represent a more stable population. In case of vermicompost-free plot under the low dose (5 kg/plot) no obvious change could be detected as compared with that of vermincompost-free plots (Fig. 5b). However at high dose of vermincompost(15 kg/plot) the pattern of the frequency distribution curve could describe the general characteristic of the expanding population (Fig. 5c).

3.4 Spatial distribution

Spatial distribution estimated for the population abundance of *Hypogastrura denticulate* showed that in vermincompost-free plot and 5 kg vermincompost treated plots individuals of this species had a clumped distribution during relatively cold seasons (winter and spring). However in summer and autumn it didn't show aggregation tendency. This is probably due to the low population abundance in these plots. Also the test species in 10, 15 kg vermincompost treated plots exhibited aggregation characteristic. However no apparent relationship exists between sampling dates and incidence of aggregation in the same plot (Fig. 6).

Pearson's correlation coefficient (Fig. 7) showed a strong positive correlation (r = 0.781, P <0.001) between the mean density of a sample and the degree of aggregation when the data from all four sampling plots during the four seasons were considered together.

4. Discussion

In field studies the assessment of any actual interaction between vermicompost addition and the number of collembolan species is difficult to quantify, and also identifying simple and predictable relationships between the population dynamics of species and its habitat. In general the effect of the vermincompost substance as bio product could be described indirectly and or directly (Sara nraj and Stella 2012). Due to richness in nutrient availability and microbial activity vermincomposts increase soil fertility, enhance plant growth and suppress the population of plant pathogens and pests, thereby enhancing soil health and minimizing the yield loss. Soil supplemented with vermincompost showed better plant growth compared with soil treated with inorganic fertilizers or cattle manure (Atiyeh et. al. 2002). several findings showed considerable increase in total viable counts of acrimony cetes and bacteria in the worm treated compost. (Partha sarathi and Ranga nathan 1998;Haritha Devi et al. 2009). Consequently, the increase of microbial population may be stand as important factor behind flourishing collembola.

The present study shows that the highest total individual numbers of *Hypogastrura denticulata*at the chosen are awere recorded during the relatively cold season; spring (5975ind./m^2) and winter (4640 ind./m^2) This could be due to the influence of temperature. Badejo and Van Straalen (1992) indicated that soil temperature accounts for a higher percentage of variation in springtail number.

Our results in the vermincompost-free plot and low dose vermicompst treated plots showed that *Hypogastrura denticulata*has a different seasonal tendency for aggregation, where no obvious aggregation patterns could be observed during relatively hot seasons, however a high tendency could be recorded during relatively cold seasons. In low dose vermincompost treated plots where no obvious changes in population density. A low aggregation tendency is strongly associated with the lowest population density this result in good agreement with Al-Assiuty and Khalil (1995) on the relationship between the relative population density and aggregation indices. Usher (1970) and Vegter (1983) referred to the same pattern of distribution among other collembolan taxa. Changes in Collembola abundance can be due to the direct enhancement of vermincompost to Collembola; the attractive action of vermincompost resulting in movement to uppermost layers, In low vermincompost treated plots, where no obvious changes in population density occurred, the attract induced activity of the test species towards the vermincompost source caused high aggregation intensity. This result is in good agreement with Al-Assiuty and Khalil (1995 and 1996) they indicated that a strong relationships between the relative population density and aggregation induces for adult *Entomoryamusatica*. The present results have shown a positive effect of vermicompost on *Hypogastrura denticulata.* It may be seen from the histograms of the age distribution that addition of vermicompost in high dose to soil caused marked changes in the age distribution pattern of collembolan communities. Moreover, the positive effect of vermincompost application on mature stages of collembolan led to a high biotic potential pattern for some species to overcome the negative effects. The increase of prereproductive formsin treated plots could be promising for collembolan population growth. However, the reverse may happen if the mortality rate for young individuals is taken into consideration. This factor has not been studied in our paper and could be undertaken in further research. It is also evident that effects of vermincompost need to be monitored over a longer time, due to significant temporal and species specific changes in response. It may be concluded that *Hypogastruradenticulata. M*ay serve as bio indicators to evaluate the role of vermicompost application on the soil habitat.

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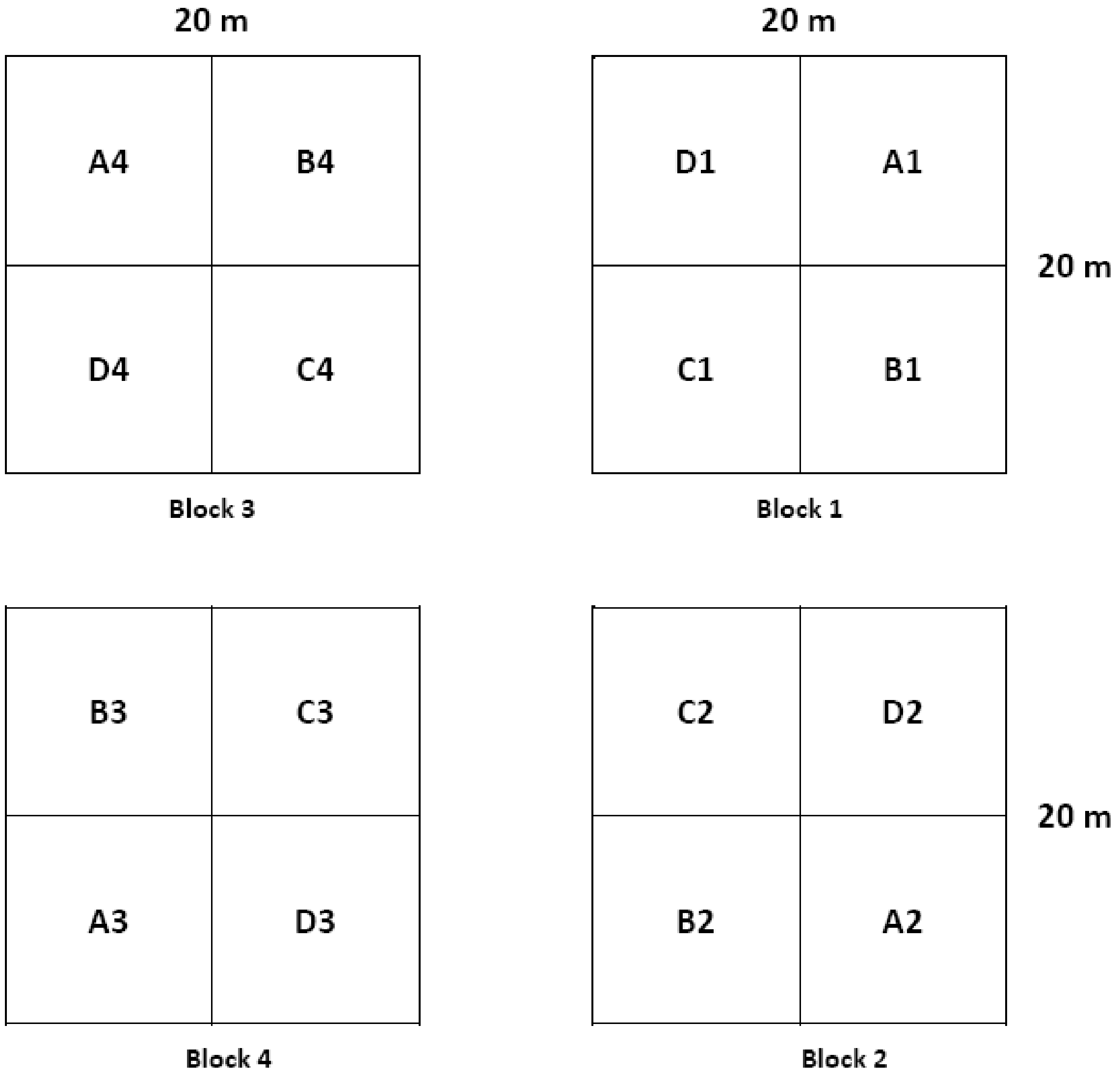


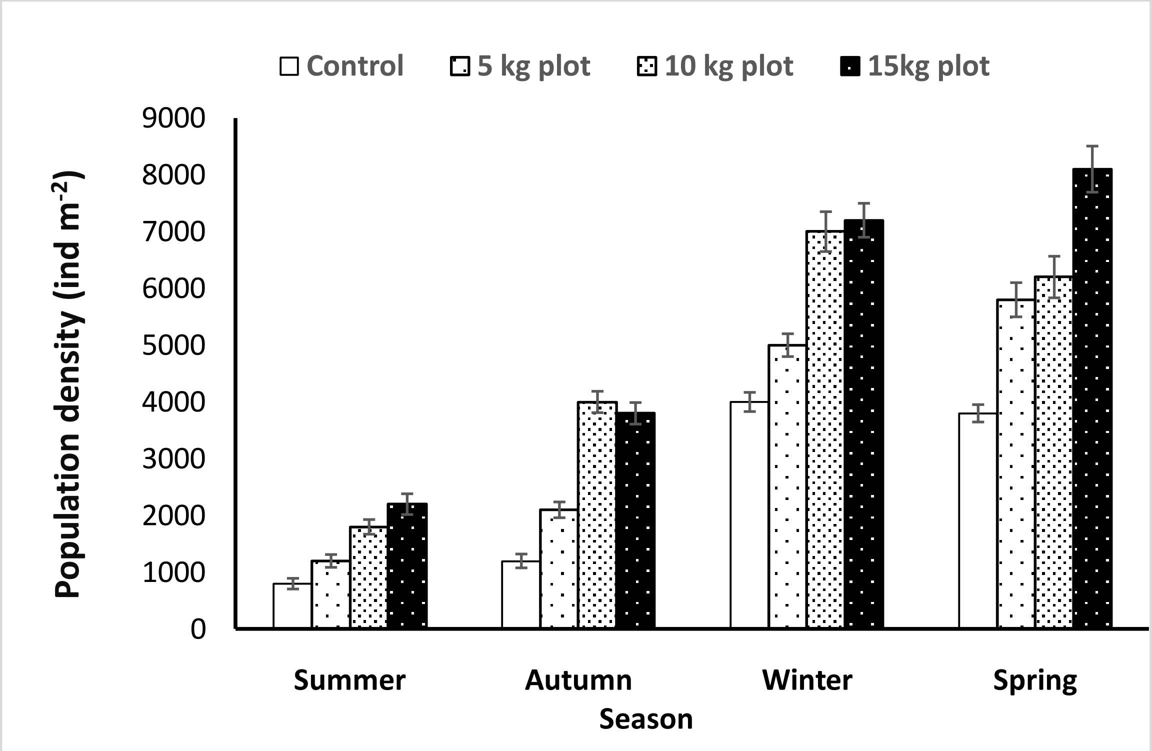
Plots A (A1 – A4) vermicompost free-plots.

Plots B (B1 – B4) 0.5 ton/ha vermicomposttreated-plots.

Plots C (C1 – C4) 1 ton/ha vermicomposttreated-plots.

Plots D (D1 – D4) 1.5 ton/ha vermicomposttreated-plots.

Figure 1. Diagram showing the layout of vermicompost applications according to randomized block design.



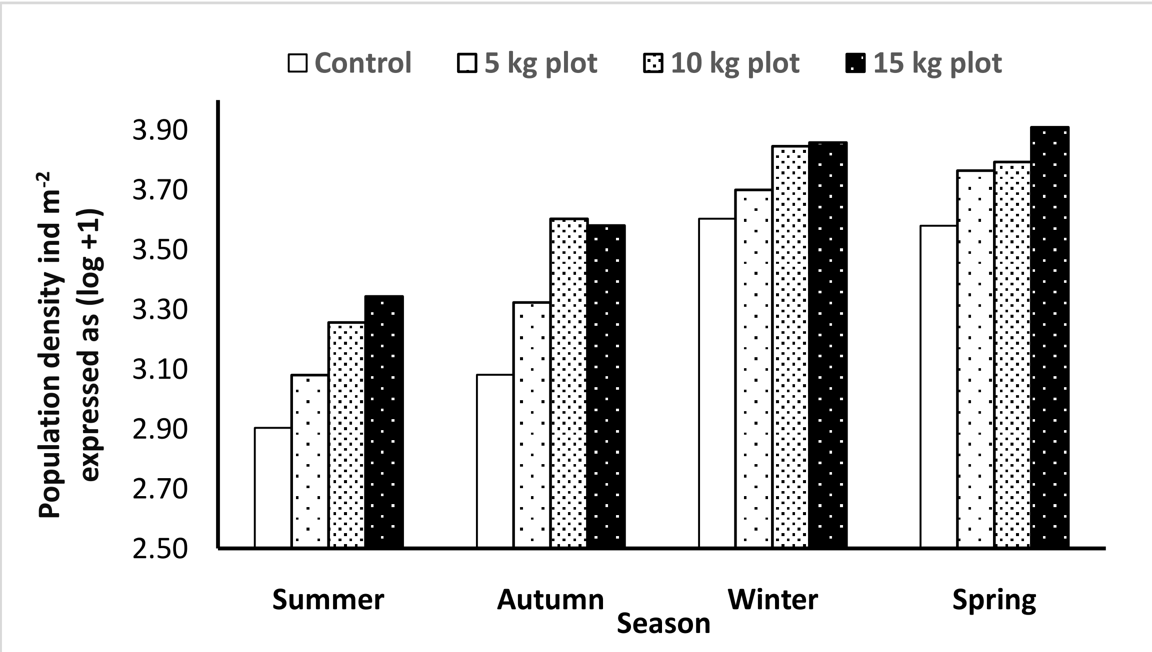


Figure 2. Seasonal relative density (mean ± SE) of adult *Hypogastrura denticulate* collected from four vermicompst treated plots.

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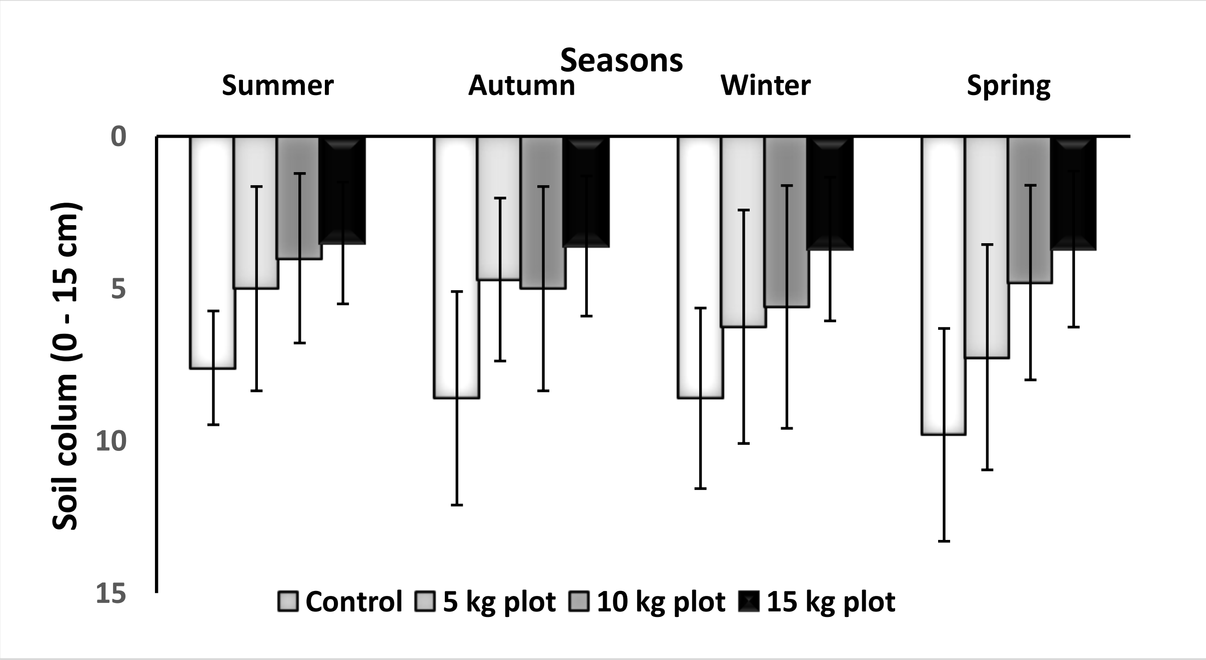

Figure 3. Seasonal mean depth (columns) and depth deviation (vertical arrows) of *Hypogastrura denticulata* in relative to the different vermincompost treatments.

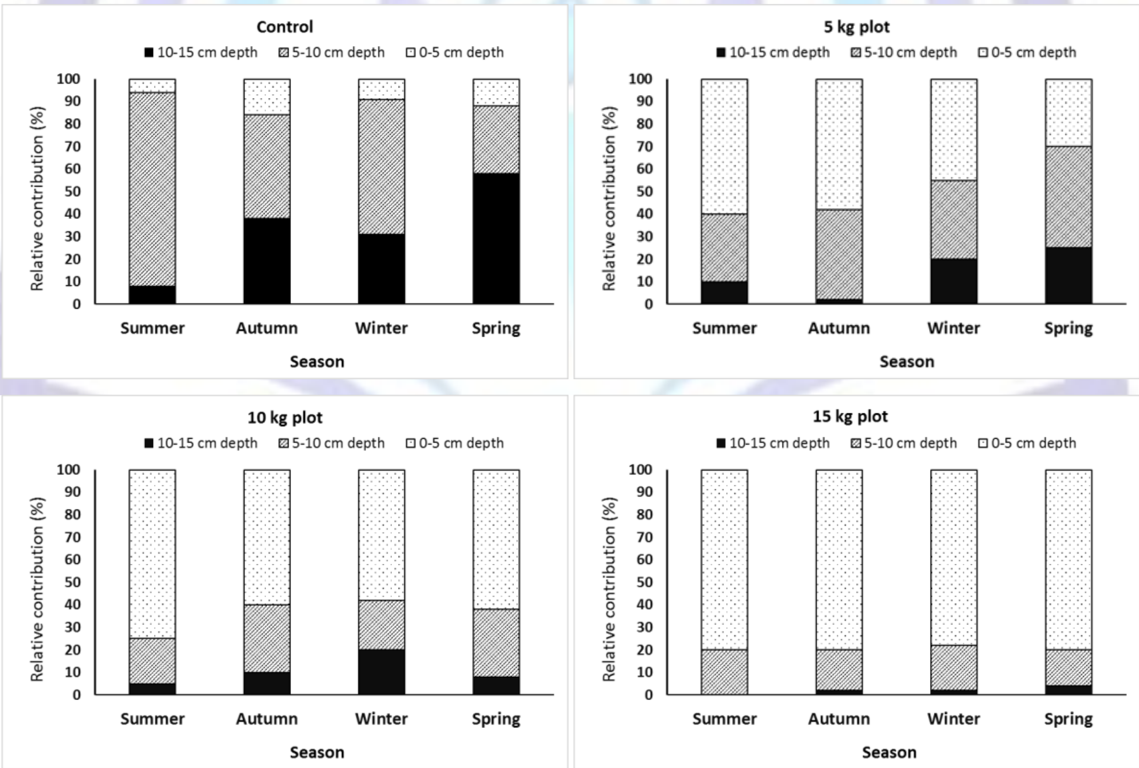

Figure 4. Seasonal vertical distribution of adult *Hypogastrura denticulate* (collembolan) in relation to the four different vermicompost treatments.

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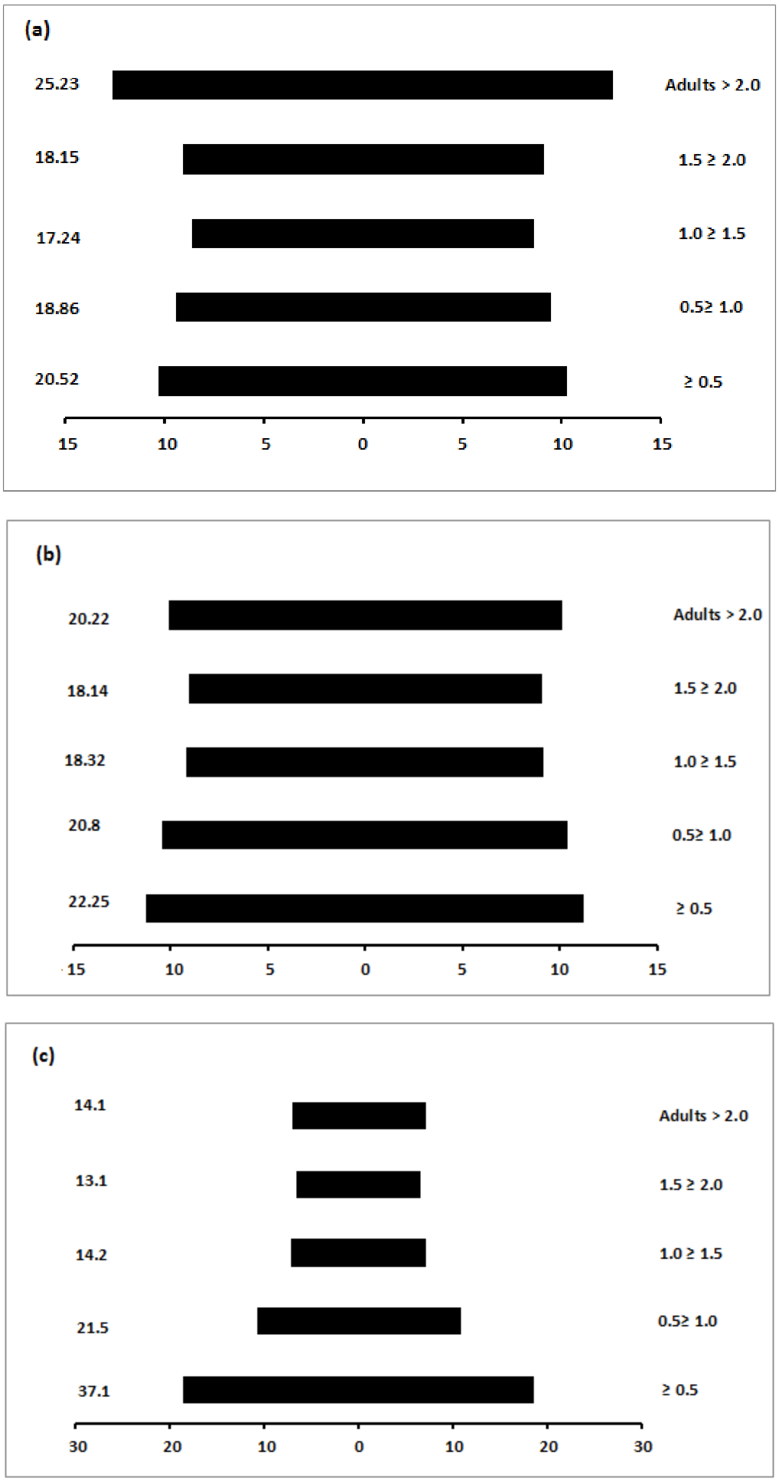

Figure 5. Population age distribution of five different size classes of*Hypogastrura denticulate* from (a) vermicompost free plots, (b) low vermicompost treated plots (5 kg/ plot) and (c) High vermicompost treated plots (15 kg/ plot).

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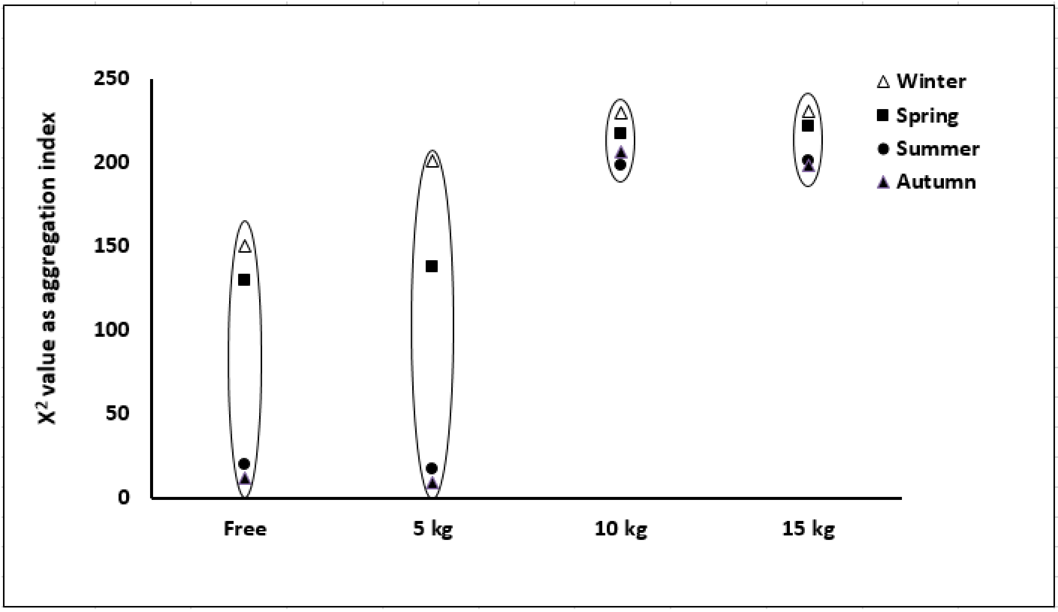

Figure 6. Seasonal fluctuation of spatial aggregation (standard deviation relative to mean) of *Hypogastrura denticulate* in relation to the four vermicompost treated plots.

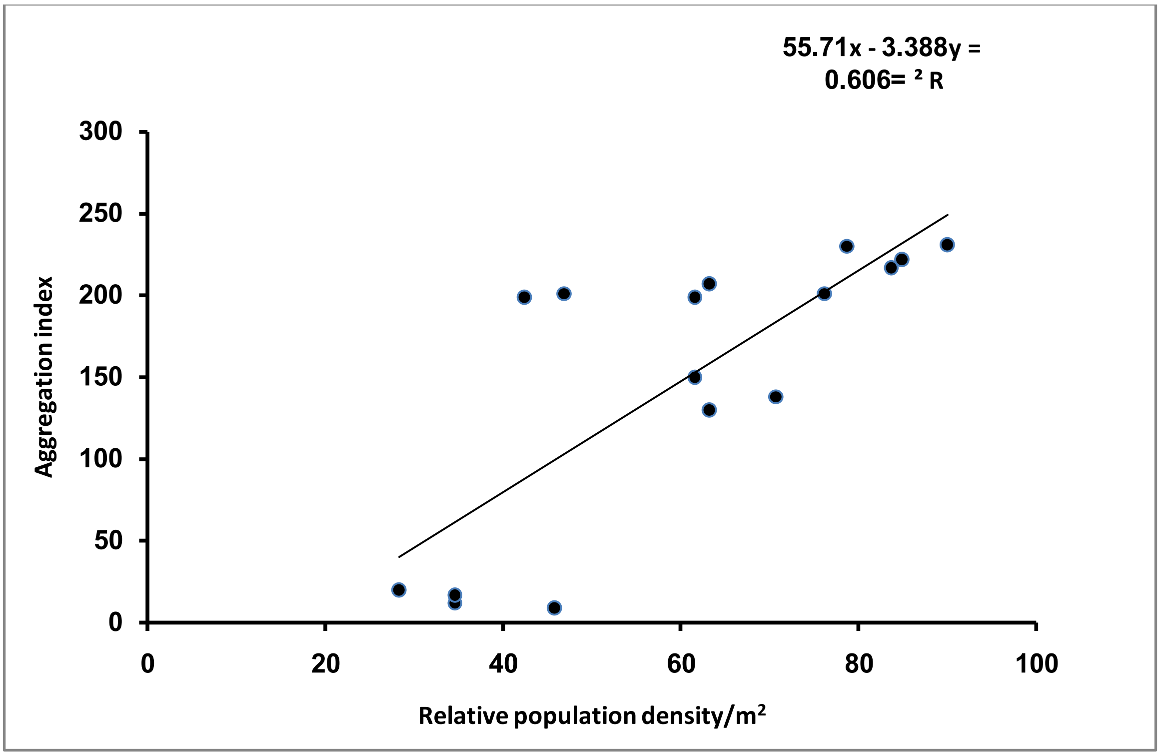

Figure7. Relationships between the relative population density/sample and aggregation indices for adult *Hypogastrura denticulate* sampled from experimental four vermicompost treated plots.