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Combined application of animal manure and straw benefit soil fauna community in dryland farming

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Abstract. Addition of organic waste~~s~~ such as animal manure~~s~~ and straw is a feasible practice to alleviate soil degradation, and the mitigation is closely related to the activities of soil-dwelling fauna. In this study, the community structure of soil fauna were compared under four treatment regimes: straw only, and straw combined with the use of chicken manure, ox manure and pig manure. A total of 12459 soil fauna were captured, belonging to 23 groups. Treatments animal manure combined with straw led to increased ~~the~~ number of soil fauna groups and individuals, diversity index, richness index and dominance index, while reduced the evenness index of soil fauna. Compared to the other treatments, maize straw plus chicken manure and maize straw plus pig manure treatments had the largest number of soil fauna groups. Among all the treatments, *Oribatida*, *Astigmata*, *Desoria* and *Folsomia* were the dominant ~~species~~, accounting for 69.94% of the total number of individuals. Maize straw plus pig manure treatment had the ~~largest~~ diversity ~~index~~ soil fauna community. The richness index of soil fauna community in maize straw plus chicken manure and maize straw plus pig manure treatments were higher compared to other treatments.

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The highest dominance index of soil fauna was recorded in maize straw plus ox manure treatment. In conclusion, our findings suggested that animal manure combined with straw, especially the application of maize straw plus pig manure was the most effective treatment for enhancing soil fauna community.

Keywords: animal manure; maize straw; soil fauna; community diversity

1 Introduction

Soil fauna is widely distributed in the farmland ecosystem and is involved in many important soil ecological processes and play key roles in maintenance of soil structure stability (Brussaard, 1998). The composition and diversity of functional traits of soil fauna can directly express their adaptability to soil environment and respond to soil fertility and pollution level (Pey et al., 2014). Different fauna groups have different sensitivity to soil environmental changes, so it is particularly important to study the abundance and community composition of soil fauna (Lakshmi et al., 2017). The diversity and community composition of soil fauna are affected by the quality and quantity of food, physical and chemical properties and biological characteristics of soil, and can reflect the health status of soil (Bian et al., 2019). Human activities such as agricultural cultivation, land use intensity and farmland restoration will change soil environment, which can directly affect the composition and nutrient structure of soil ecosystem (Morriën, 2016). The external environment and human activities can alter the quantity and quality of food resources as well as soil characteristics, thereby affecting the composition and diversity of soil fauna communities (Menta et al., 2020).

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Applying animal manure and straw can improve soil carbon (C) and nitrogen (N) contents, and enhance soil physical and chemical environment (Wei et al., 2016). Compared with traditional tillage, conservation tillage and combined application of organic materials were more likely to increase the density and diversity of soil fauna, and thus significantly improve soil fertility (Mbau et al., 2015). Zhu et al. (2015) found that the application of organic fertilizer can provide food sources for soil fauna, thus increasing the number and diversity of soil fauna. Returning organic materials to the field can increase the input of organic C and nutrients. On the one hand, soil fauna can promote the decomposition of organic materials, and on the other hand, they can change the composition of microbial community through predation, thus affecting the decomposition of organic matter and material circulation by microorganisms (Seppey et al., 2017).

Different soil fauna communities play different roles in the decomposition process of crop straw and animal manure, and also play an important role in the formation of soil nutrients. Soil fauna can affect refractory organic C through a variety of direct and indirect ways, and also improve the soil environment and have an important impact on the stabilization process of microbial organic C (Fox et al., 2006). Filser et al (2016) demonstrated a very strong impact of soil fauna on C turnover. Soil fauna can regulate the formation and decomposition of soil organic C, so it is of great significance to explore the changes of composition and diversity of different fauna communities and clarify the rational regulation of different organic materials on soil fauna.

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The goal of this research is to determine the combined effect of animal manure and straw (AM-S) on soil fauna communities in a dark brown soil. The research results will help to identify the most suitable animal manure and straw for improving soil fauna and providing a reference for agricultural residue management. We hypothesized that applying AM-S would affect the composition of fauna communities, while different animal manure might have different effects on soil fauna function and diversity.

2 Materials and methods

2.1 Study site

The study was set up in Liaoyuan County, Jilin Province, northeastern China (42°50′55″N, 125°20′31″E). This region is very cold during winter and hot during summer, having a temperate continental monsoon climate. The average annual temperature is 5.4 °C, and the mean annual precipitation is 666.5 mm. The soil is classified as dark-brown soil with a pH of 6.3. The total organic C, total N, alkali-hydrolyzable N, available phosphorus (P), and available potassium (K) in 0-20 cm soil are 12.3 g kg^{-1}, 1.3 g kg^{-1}, 100.4 mg kg^{-1}, 20.3 mg kg^{-1}, and 125.1 mg kg^{-1}, respectively. Artificial irrigation was not provided during the experiment although the area is dryland.

2.2 Field experiment

The field was arranged in a randomized block design consisting of twelve plots (50 m^2 each) with four treatments in three replicates. The treatments were maize straw only (S), maize straw plus ox manure (SO), maize straw plus chicken manure (SC),

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maize straw plus pig manure (SP). The chicken manure, ox manure, and pig manure were collected from chicken farms, ox farms, and pig farms in Liaoyuan County and they were composted a few months before application. Three replicate samples were analysed per mixture of composted manure that was collected from the livestock farms. The basic properties of the organic materials used in this study are shown in Table 1.

Table 1. Basic properties of the ~~initial organic materials~~.

Property	Maize straw	Ox manure	Chicken manure	Pig manure
Organic C (g kg^{-1})	423.05 ± 1.93a	308.15 ± 2.10c	238.61 ± 3.09d	313.54 ± 2.19b
Total N (g kg^{-1})	6.52 ± 0.46d	13.25 ± 0.64c	15.77 ± 0.58b	17.20 ± 1.01a
C/N	65.11 ± 4.47a	23.29 ± 0.97b	15.14 ± 0.37c	18.27 ± 0.95 c
Lignin (%)	6.32 ± 0.2b	7.23 ± 0.11a	3.21 ± 0.24d	5.09 ± 0.31c
Cellulose (%)	32.28 ± 0.64a	23.53 ± 1.4b	7.04 ± 0.18d	14.41 ± 0.24c
Hemicellulose (%)	22.37 ± 1.1a	15.38 ± 0.46b	4.26 ± 0.12d	13.24 ± 0.3c
Polyphenol (%)	0.87 ± 0.02a	0.73 ± 0.10b	0.68 ± 0.06b	0.69 ± 0.07b
Lignin/N	9.71 ± 0.38a	5.47 ± 0.35b	2.04 ± 0.21d	2.97 ± 0.35c
Soluble substance /%	32 ± 1.15d	42.24 ± 0.51b	40.24 ± 0.29c	47.56 ± 0.50a

Note: Data with the same lowercase letter within the same row do not differ significantly at the 5% level according to the least significant difference test. (Mean ± standard error, n = 3, C, carbon; N, nitrogen).

In this experiment, the same amount of maize straw was applied to each plot (7300 kg ha^{-1}). The application of the animal manure was adjusted so that equal amounts of C (7738 kg C ha^{-1}) can be applied in each plot. The application rate for the animal manure was 32,500 kg ha^{-1} for chicken manure, 25,123 kg ha^{-1} for ox manure, and 24,333 kg ha^{-1} for pig manure. The straw strip composting method was used for the returning of straws. In each plot, about 20 cm trenches were made whereby the same amount of maize straw was applied in all the treatment plots. Thus, different animal manures were evenly spread on the maize straw for the respective treatment plots. The incorporated organic materials were covered with the surrounding soil. However, the focus of this study was to sample the litterbags for the experiment.

An in situ soil burying test of a nylon net bag was conducted in May 2019. In October 2018, the maize straw from the test area was collected as the initial straw materials and brought back to the laboratory for air drying. The crushing length of the stems and leaves was about 8 cm, and the stalks and leaves were mixed evenly for use. Before straw bagging, 20.65 g of cow manure, 26.71 g of chicken manure, and 20 g of pig manure were used for SO, SC, and SP treatments (calculated according to the weight of straw in the straw bale, which was consistent with the application amount corresponding to the 7300 kg ha^{-1} straw returned to the field in the field test). There were 60 sample bags (4 treatments × 3 replicates × 5 samples), and the dimensions for the sample bag were 15 × 25 cm, 2 mm mesh size. The weight of straw in each bag was 6.00 ± 0.03 g, followed by adding the animal manure of each treatment, respectively, according to the equal C principle. The nylon bag was tied tightly and then buried in the corresponding plots of each treatment, respectively.

2.3 Soil Sampling and Measurement

Sample bags were destructively retrieved in May, June, July, August and September after the bags were buried. At each sampling date 12 (4 treatments × 3 replicates) nylon net bags were retrieved. On every sampling date, the litterbags were handled with great care during the removal process, and each litterbag was carefully

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transported in a separate plastic bag. Tullgren funnel was used to separate the soil fauna in the decomposing bag and store them in 75% alcohol solution after collection.

After fixation and preservation, the collected soil animals were classified, identified and counted with a stereomicroscope. Soil fauna were mainly classified according to Chinese Soil Fauna Retrieval Guide (Yin, 1998) and Insect classification and retrieval (Li et al., 1987)

In the analysis of soil fauna community, dominant group, common group and rare group were defined as more than 10%, 1-10% and less than 1% of the total number of captured individuals, respectively. For the diversity of soil fauna community, Shannon-Wiener diversity index (*H*), Simpson dominance index (*C*), Pielou evenness index (*E*) and Margalef richness index (*D*) were adopted, and the calculation formula was as follows (Zhang et al., 2018):

Shannon-wiener diversity index (*H*): $H = -\sum_{i=1}^{S} P_i In P_i$ (1)

Simpson dominance index (*C*): $C = \sum_{i=1}^{s} (Ni / N)^2$ (2)

Pielou evenness index (*E*): $E = H / InS$ (3)

Margalef richness index (*D*): $D = (S-1) / L_n N$ (4)

Where: S represents all groups of soil fauna, $P_i=N_i/N$ represents the abundance ratio of the ith group, N is the total number of individuals, and Ni is the number of individuals of the ith group.

Jaccard Similarity Index (*J*): $J = \frac{c}{a+b-c}$ (5)

Where: a and b respectively represent the number of groups of each treatment, and c

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represents the number of groups shared by the two treatments. Jaccard similarity index values greater than 0.75, between 0.5-0.75, between 0.25-0.5 and less than 0.25 indicate that two communities are very similar, medium similar, medium dissimilar and very dissimilar, respectively.

Motyka community similarity coefficient (*Sm*):

$$S_m = \frac{2\sum M_w}{M_A + M_B} \times 100 \qquad (6)$$

Where: *Mw* represents the smaller quantitative values of common species in two communities (A and B), M_A and M_B represent the sum of quantitative values of all species in community A and community B, respectively, where the quantitative values are expressed in the number of individuals. Motyka community similarity coefficient (*Sm*) greater than 75, 50-75, 25-50 and less than 25 indicated that the two communities were very similar, medium similar, medium dissimilar and very dissimilar, respectively.

The soil organic carbon (SOC) content was determined by $K_2Cr_2O_7$-H_2SO_4 oxidation (Ouyang et al., 2013) while the contents of easily oxidizable carbon (EOC) and dissolved organic carbon (DOC) were determined according to the method prescribed by Yeomans and Bremner (1998). The microbial biomass carbon (MBC) content was determined using the chloroform fumigation-extraction method, and $k_{EC} = 0.38$ (Vance et al., 1987). The particulate organic carbon (POC) was dispersed by sodium hexametaphosphate (Gong et al., 2008), and SOC content of the light fraction (LFOC) was determined by density separation method (Zhang et al., 2007).

The basic properties of the organic materials were analyzed as following: Organic C was determined by $K_2Cr_2O_7$-H_2SO_4 oxidation (Ouyang et al., 2013). Total N was

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measured by Kjeldahl method (Artiola, 1990). Cellulose, hemicellulose and lignin were measured using Van Soest acid detergent fiber (Van Soest, 1963). Polyphenol was determined by ferrous tartrate (Turkmen et al., 2006). The soluble substance was determined as described by Wu et al. (2004).

2.4 Statistical analysis

Statistical analyses were carried out using the SPSS 17.0 statistical software. Quantitative data are expressed as mean ± SD and analysed by one-way analysis of variance (ANOVA). Redundancy analysis (RDA) was used to detect the interrelationship fauna communities and the SOC fractions. Redundancy analysis was performed using CANOCO 4.5. Relevant data tables and graphs were obtained using Microsoft Excel.

3 Results

3.1 Composition of soil fauna community

A total of 12459 soil fauna specimens were identified during our study (Table 2), among which *Oribatida*, *Astigmata*, *Desoria* and *Folsomia* were the dominant ones across all treatments, accounting for 69.94% of the total number of individuals. The common taxa were 3 species (25.75% of the total number of individuals), including *Araneae*, *Actinedida* and *Entomobrya*. There were some differences in soil fauna communities under different treatments, among which, the number of soil animals under S treatment was the lowest (only 2153), accounting for 17.28% of the total number of individuals. Treatment SC had the largest number of soil animals, accounting for 32.43% of the total number of soil animals. The number of soil fauna groups in each treatment showed in order of SP=SC>SO>S.

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Table 2 Composition, individuals and dominance of soil fauna community after the application of animal manure combined with straw.

Name of soil animal	S		SO		SC		SP	
	Individuals	Dominance (%)	Individuals	Dominance (%)	Individuals	Dominance (%)	Individuals	Dominance (%)
Araneae	243	+++	382	+++	304	++	232	++
Astigmata	272	+++	244	++	582	+++	454	+++
Actinedida	215	++	133	++	277	++	262	++
Oribatida	638	+++	1013	+++	1421	+++	904	+++
Aphididae	0		2	+	15	+	7	+
Formicidae	1	+	6	+	18	+	45	++
Tipulidae	3	+	0	+	14	+	22	+
Scutigerellidae	0		4	+	6	+	5	+
Enchytraeidae	3	+	2	+	9	+	10	+
Carabidae	1	+	2	+	3	+	2	+
Staphilinidae	1	+	2	+	8	+	4	+
Staphylinidae	1	+	7	+	5	+	3	+
Sminthurus	0		0		3	+	26	+
Onychiurus	1	+	13	+	11	+	30	+
Protanura	5	+	3	+	4	+	3	+
Neanura	8	+	6	+	2	+	3	+
Hypogastrura	9	+	32	++	11	+	14	+
Proisotoma	0		4	+	11	+	8	+
Isotoma	17	+	33	++	25	+	10	+
Folsomia	278	+++	172	++	602	+++	757	+++
Desoria	301	+++	409	+++	391	++	309	++
Lepidocyrtus	0		17	+	25	+	14	+
Entomobrya	156	++	157	++	294	++	498	+++
Group number	18		21		23		23	
Total Individual	2153		2643		4041		3622	

Note: S, maize straw only; SO, maize straw plus ox manure; SC, maize straw plus chicken manure; SP, maize straw plus pig manure.

3.2 Monthly dynamic changes of individual and group number of soil fauna

The number of groups and individuals of soil fauna showed different changes in different sampling months (Figure 1). On the whole, the number of soil fauna groups increased first and then decreased with each month in all the treatments. The average group number of soil fauna among different treatments varied, following the order

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SC>SP>SO>S, and the average number of soil fauna groups was the highest in July. During the 5 months of the study, the individual number of soil fauna showed a trend of increasing in the first stages and then decreasing in the latter stages in all the treatments. The average individual number of soil fauna in all treatments was in the order of SC>SP>SO>S in each month, and the average number of individuals in all treatments was also the highest in July.

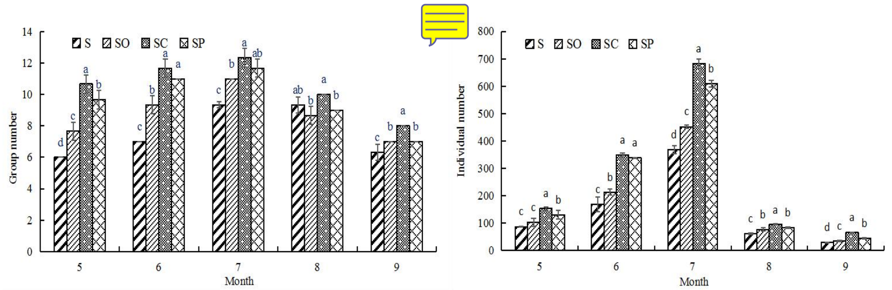

Figure. 1 Monthly dynamic changes of individual and group number of soil fauna

Note: The different lowercase letters above the bars among the different treatments indicate significance at *P*<0.05. (S, maize straw only; SO, maize straw plus ox manure; SC, maize straw plus chicken manure; SP, maize straw plus pig manure, n=3)

3.3 Monthly dynamic changes in the diversity of soil fauna community

Figure 2 shows that monthly dynamic changes in the diversity of soil fauna community. Compared with the S treatment, the Shannon-Wiener richness index of soil fauna in the AM-S-treated plots significantly fluctuated. The Shannon-Wiener index of soil fauna under SC treatment was the highest in June, and that of soil fauna under SP treatment was the highest in other experimental months. There was no significant difference in Pielou evenness index of soil fauna in all treatments at different sampling time. Margalef richness index of soil fauna increased first and then decreased with each month, and the Margalef richness index of all treatments was the highest in August. Compared with other months, the Simpson dominance index of soil fauna under SO treatment was the highest in July.

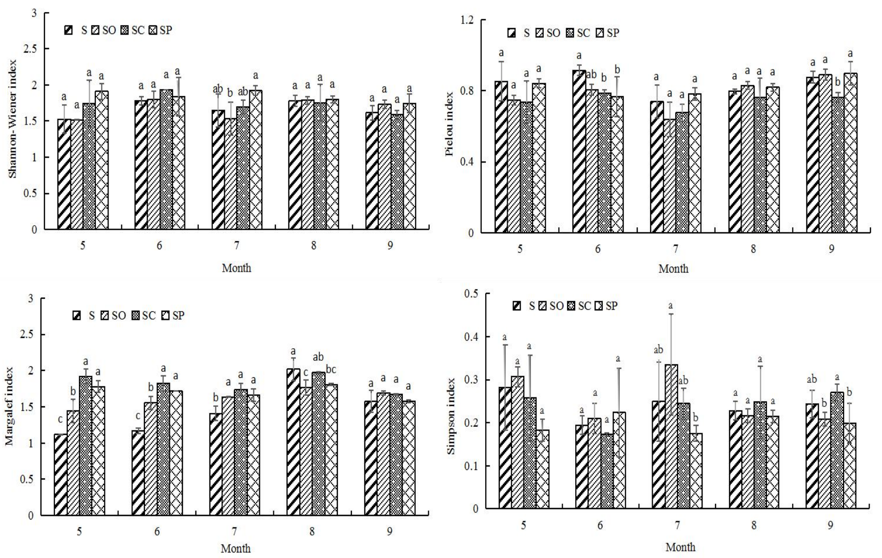

Figure. 2 Monthly dynamic changes in the diversity of soil fauna community

3.4 Diversity index of soil fauna community

The community characteristics of soil fauna under different treatments are shown in Table 3. The Shannon-Wiener diversity index of soil fauna under SP treatment was the highest, followed by SC treatment. Compared with S, AM-S treatments reduced the Pielou evenness index of soil fauna. The Margalef richness index of soil fauna followed the order SC>SP>SO>S. Compared with S treatment, SO treatment improved the Simpson dominance index of soil animal community. The results indicated that the number of individuals of some species accounted for a higher proportion of the total number in SO treatment, among which *Oribatida* accounted for

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the highest proportion (38.33%), while SC treatment did not change, and SP treatment reduced the Simpson dominance index.

Table. 3 Diversity index of soil fauna community

Treatment	Shannon-Wiener index	Pielou index	Margalef index	Simpson index
S	1.67±0.04b	0.84±0.03a	1.46±0.01d	0.24±0.02a
SO	1.67±0.07b	0.78±0.03ab	1.62±0.06c	0.26±0.03a
SC	1.74±0.04ab	0.74±0.01b	1.82±0.02a	0.24±0.01a
SP	1.84±0.10a	0.82±0.04a	1.71±0.04b	0.20±0.02b

3.5 Comparison of similarity of soil fauna communities

Jaccard similarity index and Motyka similarity coefficient of soil animal community are shown in Table 4. The Jaccard similarity index of any two communities under different treatments was between 0.78-1, which was greater than 0.75, indicating that the group composition of soil fauna communities under different treatments was at a very similar level. In terms of the similarity coefficient of Motyka community, the soil fauna communities between SP and S (73.70), SP and SO (71.28), SC and S (69.29) were at a moderate similarity level, while the *Sm* values of other fauna communities were between 75.10 and 100, which were at a very similar level.

Table. 4 The similarity indexes of soil fauna community

Index	Treatment	S	SO	SC	SP
Jaccard	S	1	0.82	0.78	0.78
	SO		1	0.96	0.96
	SC			1	1
	SP				1
Motyka	S	100	80.44	69.29	73.70
	SO		100	75.10	71.28
	SC			100	82.74
	SP				100

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3.6 Correlation analysis between soil fauna community and soil organic carbon fractions

The contents of SOC and SOC fractions under AM-S treatments were higher than that of S treatment (Table 5). Redundancy analysis showed the relationships among soil fauna (dominant and common groups) and the SOC fractions (Fig. 3). These SOC fractions explained 95% of the variation in animal communities, with the first axis (RDA1) explaining 81.2% of the variation, and the second axis (RDA2) explaining 13.8% of it. *Astigmata*、 *Folsomia*、 *Actinedida* and *Entomobrya* was positively correlated with DOC, SOC and EOC content. The content of MBC, LFOC, and POC was positively correlated with *Araneae*, while the content of DOC was negatively correlated with *Desoria.* All SOC fractions were positively correlated with *Oribatida*.

Table 5 The contents of soil organic carbon fractions after the application of animal manure combined with straw.

Treatment	SOC	DOC	MBC	EOC	LFOC	POC
S	15.82 ± 0.35cC	143.20 ± 6.12bB	92.55 ± 3.24dB	1.53± 0.06dD	0.62 ± 0.04cC	2.18 ± 0.07cB
SO	17.81 ± 0.34bB	154.644 ± 9.05bAB	136.25 ± 4.54aA	3.55 ± 0.09bB	0.82 ± 0.01aA	2.56 ± 0.05aA
SC	19.19 ± 0.50aA	157.16 ±11.01abAB	101.91 ± 1.35cB	3.30 ± 0.11cC	0.71 ± 0.02bB	2.46 ± 0.07abA
SP	18.23 ± 0.31bB	172.80 ± 6.71aA	127.14 ± 4.65aA	4.01 ±0.03aA	0.67 ±0.04bcBC	2.37 ± 0.09bA

Note: The different lowercase letters among the different treatments indicate significance at *P*<0.05. (SOC, Soil organic carbon; DOC, dissolved organic carbon; EOC, easily oxidizable carbon; MBC, microbial biomass carbon; POC, particulate organic carbon; LFOC, SOC content of the light fraction; S, maize straw only; SO, maize straw plus ox manure; SC, maize straw plus chicken manure; SP, maize straw plus pig manure, n=3)

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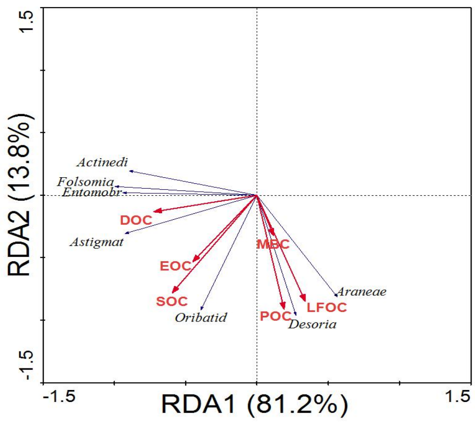

Figure. 3 A redundancy analysis (RDA) between soil organic carbon composition and dominant and common groups of soil fauna.

4 Discussion

4.1 Effects of the application of AM-S on soil fauna community

Soil fauna are an important part of the biogeochemical cycle, and play an important regulatory role in the decomposition of plant litter and soil nutrient mineralization (Birkhofer et al., 2011). Soil fauna are consumers and decomposers of farmland ecosystem, and the return of different organic materials to the field will change the soil environment, which will affect the community change of soil fauna and cause the recombination of various fauna groups. In our study, compared with S, the AM-S treatments greatly increased the groups and individual number of soil fauna. This may be because straw and animal manure as input of exogenous carbon supplement soil organic carbon, so as to enhance the activity of soil microorganisms, thereby promoting the degradation of straw and animal manure. The degradation products and soil microorganisms can provide food resources for soil animals, thus increasing the groups and individual number of soil fauna (Wang et al., 2019). Yang et

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al. (2013) argued that applied organic materials can be used as food sources for soil fauna, thus increasing the individual number, abundance and community composition of soil fauna in farmland. In addition, in this study, straw and animal manure were applied into the soil in strips, and then covered with soil, which effectively reduced the evaporation of soil water, slowed down the change of soil temperature, and provided a good habitat for soil fauna (Lian et al., 2017). The increasing number of soil fauna under the combined application of animal manure and straw was mainly due to the rapid increase of the dominant species in *Oribatida*, *Astigmata*, *Folsomia* and *Desoria*. *Folsomia* and *Desoria* belong to springtails in the phylum arthropoda. Springtails can promote the decomposition of residues and improve soil structure by using their own excreta (Eijsackers, 2001). Due to the different forms of exogenous carbon provided by different animal manure and straw returning to field, soil nutrients, physical and chemical properties and soil animal community composition were affected differently (Li et al., 2016). In the present study, SC and SP treatments had the largest number of soil fauna groups, indicating that compared with the soil environment formed by straw returning to the field, *Sminthurus*, *Aphididae*, *Scutigerellidae*, *Proisotoma*, *Lepidocyrtus* and other new species are more suitable for living in the environment formed by chicken manure and straw, pig manure and straw.

Generally, as long as the soil contains organic matter, there are nail mites inhabiting, they feed on plant debris, but the digestion and absorption capacity of organic matter is low, and most of them are excreted in feces. The accumulation of feces plays an important role in the improvement of soil fertility. In this study,

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compared with S treatment, the higher individual number of *Oribatida* was recorded under AM-S treatments. This may be because animal manure provided rich organic materials for *Oribatida*, promoted the growth and reproduction of *Oribatida*, and thus increased their number. The largest number of *Entomobrya* was found in SP treatment because pig manure promoted the growth of fungi and bacteria, which became a good food source for *Entomobrya*.

The average group number and individual number of soil fauna in all treatments were the highest in July, which might be because the soil hydrothermal environment in July was more suitable for the survival of soil fauna, enhanced the activity of soil fauna community, accelerated the decomposition of straw and animal manure, and then used by soil fauna and microorganisms (Wang et al., 2019). In our study, the number of groups and individuals of soil fauna increased first and then decreased with the months. This is because the easily decomposed organic matter (such as water-soluble substances and proteins, etc.) in straw and animal manure was first used by soil fauna and microorganisms, provided nutrients for the soil fauna breeding conditions, increased the content of organic matter in soil, soil environment created by suitable for soil fauna habitats, then increase the number of individuals and groups of soil fauna (Carrillo et al., 2011). Afterwards, the degradation of lignin and other substances remaining in the straw slowed down, and the release of nutrients was slow, which limited the nutrient sources of soil fauna, leading to a gradual decrease in the number of individuals and groups of soil fauna (Carrillo et al., 2011).

4.2 Effects of the application of AM-S on soil fauna diversity

As an important indicator of community composition, species diversity can reflect the number of species in the community, the complexity of nutrient structure in the ecosystem, and the stability of the community, thus indicating the difference and similarity among different communities. In this study, Shannon-Wiener index, Pielou index, Margalef index and Simpson index of soil fauna community were changed by straw and animal manure combined application. Zhu et al. (2013) found that long-term application of organic materials can significantly improve the diversity and richness of soil fauna community. Usually, the Simpson index can reflect the changes of the number of species in the community. The larger the Simpson index is, the more uneven the distribution of species in the community is, and the more prominent the dominant species are (Wang et al., 2001). In this study, compared with other treatments, the Simpson index of SO treatment was larger, and the Simpson index was higher in July, which was mainly caused by the higher number of *Oribatida*, indicating that the environment created by straw and ox manure, and more rain and proper temperature in July were more suitable for the survival of *Oribatida* (Liu et al., 2018). The Shannon-Wiener index of soil fauna community in SP treatment was the biggest, this may be because pig manure and straw not only provided nutrients for fauna, also affect their survival environment, such as maintain soil moisture, increase soil permeability, etc., these factors in favor of the survival of the soil fauna, so the application of straw and pig manure increased the soil fauna diversity (Li et al., 2014). Compared with S treatment, the combined application of AM-S reduced the Pielou index of soil fauna. It could be seen that the distribution of all species was the most

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even in the soil environment with straw alone, which may be because the application of animal manure increased the group of soil fauna and led to the decrease of evenness. Studies have shown that compared with communities with simple fauna composition and low number of species, communities with complex fauna composition and high number of species have lower evenness (Fu et al., 2002). The Margalef index of each treatment was the highest in August, which was consistent with the study of Wang et al. (2019). In this study, there was little difference in the similarity indexes of soil fauna communities under different treatments, which might be because the soil environment and nutrients provided by different animal manure and straw were relatively similar.

4.3 Correlation between soil fauna community and soil organic carbon fractions

In this study, *Oribatida* showed a positive correlation with all organic C fractions, which was consistent with the results of Lu et al (2013). *Oribatida* mainly feeds on humus and fungi and is sensitive to soil nutrients and pH (Wang et al., 2016). Bardgett et al. (2014) found that soil fauna cohabitating with microorganisms in the same habitat in soil, such as scavengers and microeaters, could mediate the organic C cycling process. *Folsomia*, *Desoria* and *Entomobrya* were positively correlated with organic carbon fractions, and their excreta and dead remains could provide available organic C resources for soil microorganisms.

5 Conclusion

Our results indicated that combining the animal manure with straw improved the number of soil fauna groups and individuals, and SC and SP treatments had the largest number of soil fauna groups. Treatment SP had the largest diversity index soil fauna community, while straw and animal manure combined treatments reduced the evenness of soil fauna. The richness index of soil fauna community in SC and SP were higher compared to other treatments. The highest dominance index of soil fauna was recorded in SO treatment. Therefore, we recommend the application of straw and pig manure as the most effective agronomic practice.

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