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1   **Combined application of animal manure and straw benefit soil fauna community**

2   **in dryland farming**

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9

10   **Abstract.** Addition of organic wastes such as animal manures and straw is a feasible

11   practice to alleviate soil degradation, and the mitigation is closely related to the

12   activities of soil-dwelling fauna. In this study, the community structure of soil fauna

13   were compared under four treatment regimes: straw only, and straw combined with

14   the use of chicken manure, ox manure and pig manure. A total of 12459 soil fauna

15   were captured, belonging to 23 groups. Treatments animal manure combined with

16   straw led to increased the number of soil fauna groups and individuals, diversity index,

17   richness index and dominance index, while reduced the evenness index of soil fauna.

18   Compared to the other treatments, maize straw plus chicken manure and maize straw

19   plus pig manure treatments had the largest number of soil fauna groups. Among all

20   the treatments, *Oribatida*, *Astigmata*, *Desoria* and *Folsomia* were the dominant

21   species, accounting for 69.94% of the total number of individuals. Maize straw plus

22   pig manure treatment had the largest diversity index soil fauna community. The

23   richness index of soil fauna community in maize straw plus chicken manure and

24   maize straw plus pig manure treatments were higher compared to other treatments.

25   The highest dominance index of soil fauna was recorded in maize straw plus ox

26   manure treatment. In conclusion, our findings suggested that animal manure

27   combined with straw, especially the application of maize straw plus pig manure was

28   the most effective treatment for enhancing soil fauna community.

29

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

31

32   **1 Introduction**

33   Soil fauna is widely distributed in the farmland ecosystem and is involved in

34   many important soil ecological processes and play key roles in maintenance of soil

35   structure stability (Brussaard, 1998). The composition and diversity of functional

36   traits of soil fauna can directly express their adaptability to soil environment and

37   respond to soil fertility and pollution level (Pey et al., 2014). Different fauna groups

38   have different sensitivity to soil environmental changes, so it is particularly important

39   to study the abundance and community composition of soil fauna (Lakshmi et al.,

40   2017). The diversity and community composition of soil fauna are affected by the

41   quality and quantity of food, physical and chemical properties and biological

42   characteristics of soil, and can reflect the health status of soil (Bian et al., 2019).

43   Human activities such as agricultural cultivation, land use intensity and farmland

44   restoration will change soil environment, which can directly affect the composition

45   and nutrient structure of soil ecosystem (Morriën, 2016). The external environment

46   and human activities can alter the quantity and quality of food resources as well as

47   soil characteristics, thereby affecting the composition and diversity of soil fauna

48   communities (Menta et al., 2020).

49   Applying animal manure and straw can improve soil carbon (C) and nitrogen (N)

50   contents, and enhance soil physical and chemical environment (Wei et al., 2016).

51   Compared with traditional tillage, conservation tillage and combined application of

52   organic materials were more likely to increase the density and diversity of soil fauna,

53   and thus significantly improve soil fertility (Mbau et al., 2015). Zhu et al. (2015)

54   found that the application of organic fertilizer can provide food sources for soil fauna,

55   thus increasing the number and diversity of soil fauna. Returning organic materials to

56   the field can increase the input of organic C and nutrients. On the one hand, soil fauna

57   can promote the decomposition of organic materials, and on the other hand, they can

58   change the composition of microbial community through predation, thus affecting the

59   decomposition of organic matter and material circulation by microorganisms (Seppey

60   et al., 2017).

61   Different soil fauna communities play different roles in the decomposition

62   process of crop straw and animal manure, and also play an important role in the

63   formation of soil nutrients. Soil fauna can affect refractory organic C through a

64   variety of direct and indirect ways, and also improve the soil environment and have an

65   important impact on the stabilization process of microbial organic C (Fox et al., 2006).

66   Filser et al (2016) demonstrated a very strong impact of soil fauna on C turnover. Soil

67   fauna can regulate the formation and decomposition of soil organic C, so it is of great

68   significance to explore the changes of composition and diversity of different fauna

69   communities and clarify the rational regulation of different organic materials on soil

70   fauna.

71   The goal of this research is to determine the combined effect of animal manure

72   and straw (AM-S) on soil fauna communities in a dark brown soil. The research

73   results will help to identify the most suitable animal manure and straw for improving

74   soil fauna and providing a reference for agricultural residue management. We

75   hypothesized that applying AM-S would affect the composition of fauna communities,

76   while different animal manure might have different effects on soil fauna function and

77   diversity.

78

79   **2 Materials and methods**

80   2.1 Study site

81   The study was set up in Liaoyuan County, Jilin Province, northeastern China

82   (42°50′55″N, 125°20′31″E). This region is very cold during winter and hot during

83   summer, having a temperate continental monsoon climate. The average annual

84   temperature is 5.4 °C, and the mean annual precipitation is 666.5 mm. The soil is

85   classified as dark-brown soil with a pH of 6.3. The total organic C, total N,

86   alkali-hydrolyzable N, available phosphorus (P), and available potassium (K) in 0-20

87   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},

88   respectively. Artificial irrigation was not provided during the experiment although the

89   area is dryland.

90   2.2 Field experiment

91   The field was arranged in a randomized block design consisting of twelve plots

92   (50 m^2 each) with four treatments in three replicates. The treatments were maize straw

93   only (S), maize straw plus ox manure (SO), maize straw plus chicken manure (SC),

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94 maize straw plus pig manure (SP). The chicken manure, ox manure, and pig manure

95 were collected from chicken farms, ox farms, and pig farms in Liaoyuan County and

96 they were composted a few months before application. Three replicate samples were

97 analysed per mixture of composted manure that was collected from the livestock

98 farms. The basic properties of the organic materials used in this study are shown in

99 Table 1.

100   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

101 Note: Data with the same lowercase letter within the same row do not differ significantly at the
102 5% level according to the least significant difference test. (Mean ± standard error, n = 3, C, carbon;
103 N, nitrogen).

104   In this experiment, the same amount of maize straw was applied to each plot

105 (7300 kg ha^{-1}). The application of the animal manure was adjusted so that equal

106 amounts of C (7738 kg C ha^{-1}) can be applied in each plot. The application rate for

107 the animal manure was 32,500 kg ha^{-1} for chicken manure, 25,123 kg ha^{-1} for ox

108 manure, and 24,333 kg ha^{-1} for pig manure. The straw strip composting method was

109 used for the returning of straws. In each plot, about 20 cm trenches were made

110 whereby the same amount of maize straw was applied in all the treatment plots. Thus,

111 different animal manures were evenly spread on the maize straw for the respective

112 treatment plots. The incorporated organic materials were covered with the

113 surrounding soil. However, the focus of this study was to sample the litterbags for the

114 experiment.

115 An in situ soil burying test of a nylon net bag was conducted in May 2019. In

116 October 2018, the maize straw from the test area was collected as the initial straw

117 materials and brought back to the laboratory for air drying. The crushing length of the

118 stems and leaves was about 8 cm, and the stalks and leaves were mixed evenly for use.

119 Before straw bagging, 20.65 g of cow manure, 26.71 g of chicken manure, and 20 g of

120 pig manure were used for SO, SC, and SP treatments (calculated according to the

121 weight of straw in the straw bale, which was consistent with the application amount

122 corresponding to the 7300 kg ha^{-1} straw returned to the field in the field test). There

123 were 60 sample bags (4 treatments × 3 replicates × 5 samples), and the dimensions for

124 the sample bag were 15 × 25 cm, 2 mm mesh size. The weight of straw in each bag

125 was 6.00 ± 0.03 g, followed by adding the animal manure of each treatment,

126 respectively, according to the equal C principle. The nylon bag was tied tightly and

127 then buried in the corresponding plots of each treatment, respectively.

128 2.3 Soil Sampling and Measurement

129 Sample bags were destructively retrieved in May, June, July, August and

130 September after the bags were buried. At each sampling date 12 (4 treatments × 3

131 replicates) nylon net bags were retrieved. On every sampling date, the litterbags were

132 handled with great care during the removal process, and each litterbag was carefully

133   transported in a separate plastic bag. Tullgren funnel was used to separate the soil

134   fauna in the decomposing bag and store them in 75% alcohol solution after collection.

135   After fixation and preservation, the collected soil animals were classified,

136   identified and counted with a stereomicroscope. Soil fauna were mainly classified

137   according to Chinese Soil Fauna Retrieval Guide (Yin, 1998) and Insect classification

138   and retrieval (Li et al., 1987)

139   In the analysis of soil fauna community, dominant group, common group and

140   rare group were defined as more than 10%, 1-10% and less than 1% of the total

141   number of captured individuals, respectively. For the diversity of soil fauna

142   community, Shannon-Wiener diversity index (*H*), Simpson dominance index (*C*),

143   Pielou evenness index (*E*) and Margalef richness index (*D*) were adopted, and the

144   calculation formula was as follows (Zhang et al., 2018):

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

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

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

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

149   Where: *S* represents all groups of soil fauna, $P_i = N_i/N$ represents the abundance ratio of

150   the ith group, *N* is the total number of individuals, and *Ni* is the number of individuals

151   of the ith group.

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

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

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154   represents the number of groups shared by the two treatments. Jaccard similarity

155   index values greater than 0.75, between 0.5-0.75, between 0.25-0.5 and less than 0.25

156   indicate that two communities are very similar, medium similar, medium dissimilar

157   and very dissimilar, respectively.

158   Motyka community similarity coefficient (*Sm*): $S_m = \dfrac{2\sum M_w}{M_A + M_B} \times 100$

(6)

159   Where: *Mw* represents the smaller quantitative values of common species in two

160   communities (A and B), M_A and M_B represent the sum of quantitative values of all

161   species in community A and community B, respectively, where the quantitative values

162   are expressed in the number of individuals. Motyka community similarity coefficient

163   (*Sm*) greater than 75, 50-75, 25-50 and less than 25 indicated that the two

164   communities were very similar, medium similar, medium dissimilar and very

165   dissimilar, respectively.

166   The soil organic carbon (SOC) content was determined by $K_2Cr_2O_7$-H_2SO_4

167   oxidation (Ouyang et al., 2013) while the contents of easily oxidizable carbon (EOC)

168   and dissolved organic carbon (DOC) were determined according to the method

169   prescribed by Yeomans and Bremner (1998). The microbial biomass carbon (MBC)

170   content was determined using the chloroform fumigation-extraction method, and k_{EC}

171   = 0.38 (Vance et al., 1987). The particulate organic carbon (POC) was dispersed by

172   sodium hexametaphosphate (Gong et al., 2008), and SOC content of the light fraction

173   (LFOC) was determined by density separation method (Zhang et al., 2007).

174   The basic properties of the organic materials were analyzed as following: Organic

175   C was determined by $K_2Cr_2O_7$-H_2SO_4 oxidation (Ouyang et al., 2013). Total N was

176 measured by Kjeldahl method (Artiola, 1990). Cellulose, hemicellulose and lignin

177 were measured using Van Soest acid detergent fiber (Van Soest, 1963). Polyphenol

178 was determined by ferrous tartrate (Turkmen et al., 2006). The soluble substance was

179 determined as described by Wu et al. (2004).

180 2.4 Statistical analysis

181 Statistical analyses were carried out using the SPSS 17.0 statistical software.

182 Quantitative data are expressed as mean ± SD and analysed by one-way analysis of

183 variance (ANOVA). Redundancy analysis (RDA) was used to detect the

184 interrelationship fauna communities and the SOC fractions. Redundancy analysis was

185 performed using CANOCO 4.5. Relevant data tables and graphs were obtained using

186 Microsoft Excel.

187 **3 Results**

188 3.1 Composition of soil fauna community

189 A total of 12459 soil fauna specimens were identified during our study (Table 2),

190 among which *Oribatida*, *Astigmata*, *Desoria* and *Folsomia* were the dominant ones

191 across all treatments, accounting for 69.94% of the total number of individuals. The

192 common taxa were 3 species (25.75% of the total number of individuals), including

193 *Araneae*, *Actinedida* and *Entomobrya*. There were some differences in soil fauna

194 communities under different treatments, among which, the number of soil animals

195 under S treatment was the lowest (only 2153), accounting for 17.28% of the total

196 number of individuals. Treatment SC had the largest number of soil animals,

197 accounting for 32.43% of the total number of soil animals. The number of soil fauna

198 groups in each treatment showed in order of SP=SC>SO>S.

199

200 Table 2 Composition, individuals and dominance of soil fauna community after the application of
201 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	

202 Note: S, maize straw only; SO, maize straw plus ox manure; SC, maize straw plus chicken manure;
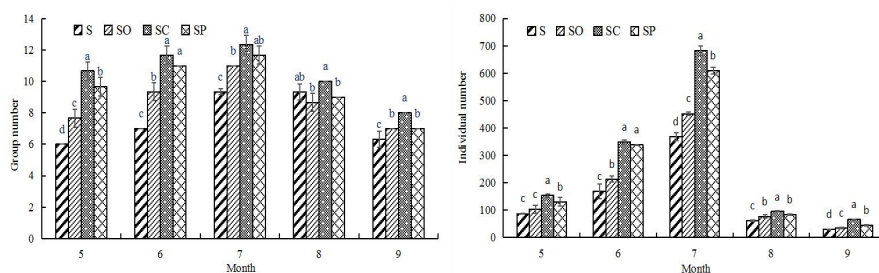203 SP, maize straw plus pig manure.
204

205 3.2 Monthly dynamic changes of individual and group number of soil fauna

206 The number of groups and individuals of soil fauna showed different changes in

207 different sampling months (Figure 1). On the whole, the number of soil fauna groups

208 increased first and then decreased with each month in all the treatments. The average

209 group number of soil fauna among different treatments varied, following the order

210 SC>SP>SO>S, and the average number of soil fauna groups was the highest in July.

211 During the 5 months of the study, the individual number of soil fauna showed a trend

212 of increasing in the first stages and then decreasing in the latter stages in all the

213 treatments. The average individual number of soil fauna in all treatments was in the

214 order of SC>SP>SO>S in each month, and the average number of individuals in all

215 treatments was also the highest in July.

216

217

218 Figure. 1 Monthly dynamic changes of individual and group number of soil fauna
219 Note: The different lowercase letters above the bars among the different treatments indicate
220 significance at *P*<0.05. (S, maize straw only; SO, maize straw plus ox manure; SC, maize straw
221 plus chicken manure; SP, maize straw plus pig manure, n=3)

222

223 3.3 Monthly dynamic changes in the diversity of soil fauna community

224 Figure 2 shows that monthly dynamic changes in the diversity of soil fauna

225 community. Compared with the S treatment, the Shannon-Wiener richness index of

226 soil fauna in the AM-S-treated plots significantly fluctuated. The Shannon-Wiener

227 index of soil fauna under SC treatment was the highest in June, and that of soil fauna

228 under SP treatment was the highest in other experimental months. There was no

229 significant difference in Pielou evenness index of soil fauna in all treatments at

230 different sampling time. Margalef richness index of soil fauna increased first and then

231 decreased with each month, and the Margalef richness index of all treatments was the

232 highest in August. Compared with other months, the Simpson dominance index of soil

233 fauna under SO treatment was the highest in July.

234
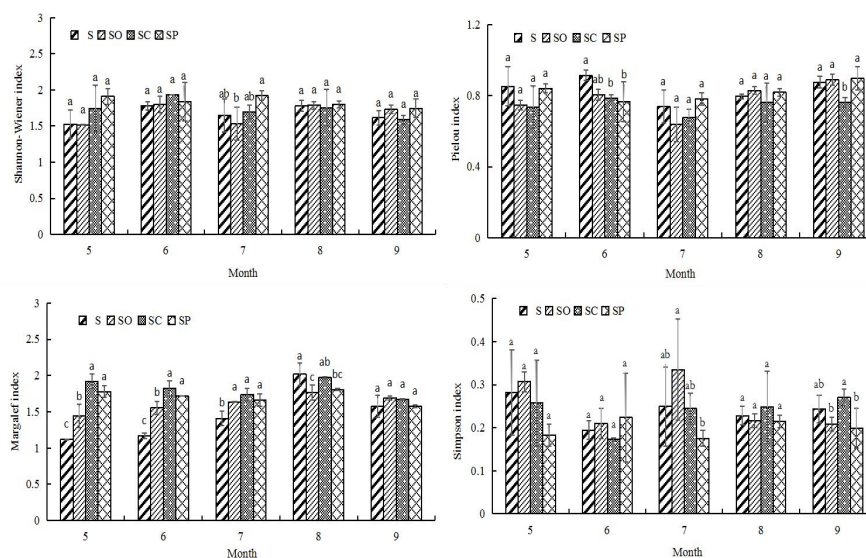
236 Figure. 2 Monthly dynamic changes in the diversity of soil fauna community

237

238 3.4 Diversity index of soil fauna community

239 The community characteristics of soil fauna under different treatments are shown in

240 Table 3. The Shannon-Wiener diversity index of soil fauna under SP treatment was the

241 highest, followed by SC treatment. Compared with S, AM-S treatments reduced the

242 Pielou evenness index of soil fauna. The Margalef richness index of soil fauna

243 followed the order SC>SP>SO>S. Compared with S treatment, SO treatment

244 improved the Simpson dominance index of soil animal community. The results

245 indicated that the number of individuals of some species accounted for a higher

246 proportion of the total number in SO treatment, among which *Oribatida* accounted for

247 the highest proportion (38.33%), while SC treatment did not change, and SP treatment

248 reduced the Simpson dominance index.

249 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

250

251 3.5 Comparison of similarity of soil fauna communities

252 Jaccard similarity index and Motyka similarity coefficient of soil animal

253 community are shown in Table 4. The Jaccard similarity index of any two

254 communities under different treatments was between 0.78-1, which was greater than

255 0.75, indicating that the group composition of soil fauna communities under different

256 treatments was at a very similar level. In terms of the similarity coefficient of Motyka

257 community, the soil fauna communities between SP and S (73.70), SP and SO (71.28),

258 SC and S (69.29) were at a moderate similarity level, while the Sm values of other

259 fauna communities were between 75.10 and 100, which were at a very similar level.

260 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

261

262 3.6 Correlation analysis between soil fauna community and soil organic carbon
263 fractions

264 The contents of SOC and SOC fractions under AM-S treatments were higher than

265 that of S treatment (Table 5). Redundancy analysis showed the relationships among

266 soil fauna (dominant and common groups) and the SOC fractions (Fig. 3). These SOC

267 fractions explained 95% of the variation in animal communities, with the first axis

268 (RDA1) explaining 81.2% of the variation, and the second axis (RDA2) explaining

269 13.8% of it. *Astigmata*、*Folsomia*、*Actinedida* and *Entomobrya* was positively

270 correlated with DOC, SOC and EOC content. The content of MBC, LFOC, and POC

271 was positively correlated with *Araneae*, while the content of DOC was negatively

272 correlated with *Desoria*. All SOC fractions were positively correlated with *Oribatida*.

273

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

276

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

277

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

283
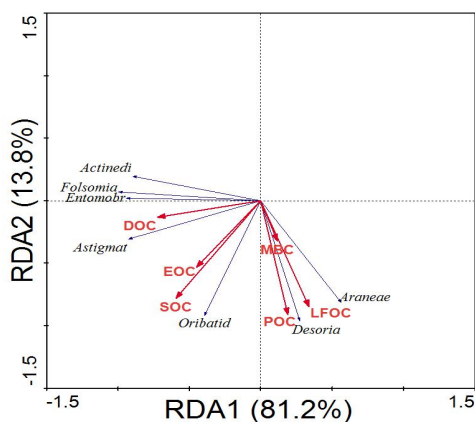
Figure. 3 A redundancy analysis (RDA) between soil organic carbon composition and dominant and common groups of soil fauna.

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

302   al. (2013) argued that applied organic materials can be used as food sources for soil

303   fauna, thus increasing the individual number, abundance and community composition

304   of soil fauna in farmland. In addition, in this study, straw and animal manure were

305   applied into the soil in strips, and then covered with soil, which effectively reduced

306   the evaporation of soil water, slowed down the change of soil temperature, and

307   provided a good habitat for soil fauna (Lian et al., 2017). The increasing number of

308   soil fauna under the combined application of animal manure and straw was mainly

309   due to the rapid increase of the dominant species in *Oribatida*, *Astigmata*, *Folsomia*

310   and *Desoria*. *Folsomia* and *Desoria* belong to springtails in the phylum arthropoda.

311   Springtails can promote the decomposition of residues and improve soil structure by

312   using their own excreta (Eijsackers, 2001). Due to the different forms of exogenous

313   carbon provided by different animal manure and straw returning to field, soil nutrients,

314   physical and chemical properties and soil animal community composition were

315   affected differently (Li et al., 2016). In the present study, SC and SP treatments had

316   the largest number of soil fauna groups, indicating that compared with the soil

317   environment formed by straw returning to the field, *Sminthurus*, *Aphididae*,

318   *Scutigerellidae*, *Proisotoma*, *Lepidocyrtus* and other new species are more suitable for

319   living in the environment formed by chicken manure and straw, pig manure and straw.

320   Generally, as long as the soil contains organic matter, there are nail mites

321   inhabiting, they feed on plant debris, but the digestion and absorption capacity of

322   organic matter is low, and most of them are excreted in feces. The accumulation of

323   feces plays an important role in the improvement of soil fertility. In this study,

324   compared with S treatment, the higher individual number of *Oribatida* was recorded

325   under AM-S treatments. This may be because animal manure provided rich organic

326   materials for *Oribatida*, promoted the growth and reproduction of *Oribatida*, and thus

327   increased their number. The largest number of *Entomobrya* was found in SP treatment

328   because pig manure promoted the growth of fungi and bacteria, which became a good

329   food source for *Entomobrya*.

330   The average group number and individual number of soil fauna in all treatments

331   were the highest in July, which might be because the soil hydrothermal environment

332   in July was more suitable for the survival of soil fauna, enhanced the activity of soil

333   fauna community, accelerated the decomposition of straw and animal manure, and

334   then used by soil fauna and microorganisms (Wang et al., 2019). In our study, the

335   number of groups and individuals of soil fauna increased first and then decreased with

336   the months. This is because the easily decomposed organic matter (such as

337   water-soluble substances and proteins, etc.) in straw and animal manure was first used

338   by soil fauna and microorganisms, provided nutrients for the soil fauna breeding

339   conditions, increased the content of organic matter in soil, soil environment created by

340   suitable for soil fauna habitats, then increase the number of individuals and groups of

341   soil fauna (Carrillo et al., 2011). Afterwards, the degradation of lignin and other

342   substances remaining in the straw slowed down, and the release of nutrients was slow,

343   which limited the nutrient sources of soil fauna, leading to a gradual decrease in the

344   number of individuals and groups of soil fauna (Carrillo et al., 2011).

345

346   4.2 Effects of the application of AM-S on soil fauna diversity

347   As an important indicator of community composition, species diversity can

348   reflect the number of species in the community, the complexity of nutrient structure in

349   the ecosystem, and the stability of the community, thus indicating the difference and

350   similarity among different communities. In this study, Shannon-Wiener index, Pielou

351   index, Margalef index and Simpson index of soil fauna community were changed by

352   straw and animal manure combined application. Zhu et al. (2013) found that

353   long-term application of organic materials can significantly improve the diversity and

354   richness of soil fauna community. Usually, the Simpson index can reflect the changes

355   of the number of species in the community. The larger the Simpson index is, the more

356   uneven the distribution of species in the community is, and the more prominent the

357   dominant species are (Wang et al., 2001). In this study, compared with other

358   treatments, the Simpson index of SO treatment was larger, and the Simpson index was

359   higher in July, which was mainly caused by the higher number of *Oribatida*,

360   indicating that the environment created by straw and ox manure, and more rain and

361   proper temperature in July were more suitable for the survival of *Oribatida* (Liu et al.,

362   2018). The Shannon-Wiener index of soil fauna community in SP treatment was the

363   biggest, this may be because pig manure and straw not only provided nutrients for

364   fauna, also affect their survival environment, such as maintain soil moisture, increase

365   soil permeability, etc., these factors in favor of the survival of the soil fauna, so the

366   application of straw and pig manure increased the soil fauna diversity (Li et al., 2014).

367   Compared with S treatment, the combined application of AM-S reduced the Pielou

368   index of soil fauna. It could be seen that the distribution of all species was the most

369 even in the soil environment with straw alone, which may be because the application

370 of animal manure increased the group of soil fauna and led to the decrease of

371 evenness. Studies have shown that compared with communities with simple fauna

372 composition and low number of species, communities with complex fauna

373 composition and high number of species have lower evenness (Fu et al., 2002). The

374 Margalef index of each treatment was the highest in August, which was consistent

375 with the study of Wang et al. (2019). In this study, there was little difference in the

376 similarity indexes of soil fauna communities under different treatments, which might

377 be because the soil environment and nutrients provided by different animal manure

378 and straw were relatively similar.

379

380 4.3 Correlation between soil fauna community and soil organic carbon fractions

381   In this study, *Oribatida* showed a positive correlation with all organic C fractions,

382 which was consistent with the results of Lu et al (2013). *Oribatida* mainly feeds on

383 humus and fungi and is sensitive to soil nutrients and pH (Wang et al., 2016). Bardgett

384 et al. (2014) found that soil fauna cohabitating with microorganisms in the same

385 habitat in soil, such as scavengers and microeaters, could mediate the organic C

386 cycling process. *Folsomia*, *Desoria* and *Entomobrya* were positively correlated with

387 organic carbon fractions, and their excreta and dead remains could provide available

388 organic C resources for soil microorganisms.

389

390 **5 Conclusion**

391   Our results indicated that combining the animal manure with straw improved the

392 number of soil fauna groups and individuals, and SC and SP treatments had the largest

393 number of soil fauna groups. Treatment SP had the largest diversity index soil fauna

394 community, while straw and animal manure combined treatments reduced the

395 evenness of soil fauna. The richness index of soil fauna community in SC and SP

396 were higher compared to other treatments. The highest dominance index of soil fauna

397 was recorded in SO treatment. Therefore, we recommend the application of straw and

398 pig manure as the most effective agronomic practice.

403 **Conflicts of Interest:** The authors declare no conflict of interest.

404

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