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► **To cite this version:**

Cheng Hu, Yingchun Qi. Effective microorganisms and compost favor nematodes in wheat crops. *Agronomy for Sustainable Development*, 2013, 33 (3), pp.573-579. 10.1007/s13593-012-0130-9 . hal-01201373

**HAL Id: hal-01201373**

**<https://hal.science/hal-01201373>**

Submitted on 17 Sep 2015

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# Effective microorganisms and compost favor nematodes in wheat crops

Cheng Hu · Yingchun Qi

Accepted: 21 December 2012 / Published online: 16 January 2013  
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**Abstract** Excessive application of mineral fertilizers wastes resources and contaminates the environment. Alternative natural substitutes could solve those issues. Here, we hypothesize that organic compost may increase soil biological fertility more effectively than mineral fertilizers, and that effective microorganisms could improve the effects of traditional compost. So far, few investigations have analyzed the effects of the effective microorganisms on soil fauna such as nematodes. A 1997–2004 field experiment of soil fertility and crop yield has been carried out at China Agricultural University's Qu-Zhou experimental station. A randomized block experiment comprised effective microorganisms, compost, traditional compost, N and P fertilizer treatment, and untreated controls. Soil nematode community structure and wheat yields were analyzed during wheat growth stages. Results show that in May the total nematode number is 43.21 % higher for effective microorganisms compost plots compared with traditional compost plots. Soil free-living nematodes are 29.32 % more abundant and bacteria-feeding nematodes are 63.23 % more abundant for effective microorganisms compost plots compared with traditional compost plots in June. Wheat grain yield is correlated with soil free-living nematodes during the jointing stage of wheat growth, with a correlation coefficient  $R^2$  of 0.88.

**Keywords** Effective microorganisms · Compost · Soil nematodes · Community structure · Long-term fertilization experiment · *Triticum aestivum*

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## 1 Introduction

Mineral fertilizers have been excessively and unreasonably applied, not only wasting resources but also contaminating environment. The substitution of agro-chemicals with natural substances has been advocated as a means of meeting the demands of sustainable agriculture (Diacono and Montemurro 2010; Singh et al. 2011). In recent years, some successful efforts have been made to at least partially substitute agro-chemicals with natural substances and so minimize the adverse effects of the synthetic agro-chemicals (Javaid 2006). One successful effort was made by Higa (1991), who isolated some beneficial microorganisms from the soil, calling them “effective microorganisms.” According to Higa and Parr (1994), effective microorganisms include about 80 species, such as photosynthetic bacteria, lactic acid bacteria, yeasts, actinomycetes, and fermenting fungi such as *Aspergillus* and *Penicillium*. Some studies reported that effective microorganisms improved crop growth and yield by increasing photosynthesis, producing bioactive substances, such as hormones and enzymes, controlling soil diseases, and accelerating decomposition of lignin materials in the soil (Daly and Stewart 1999; Formowitz et al. 2007; Javaid et al. 2008). Khaliq et al. (2006) and Javaid and Bajwa (2011) reported that the application of effective microorganisms increased the efficiency with which organic nutrients were used.

Soil nematodes are critical participants in fundamental ecological processes in the soil, such as soil matter decomposition and nutrient cycling (Neher 2001). Fiscus and Neher (2002) observed significant relationships between soil characteristics and nematode abundance in different functional guilds. In agricultural ecosystems, nematode abundance and diversity are used to infer soil ecosystem processes, soil ecological functions, and response to disturbance on soil fauna (Porazinskaa et al. 1999; Yeates 2003; Hu et al. 2011). In this way, the soil nematode community

structure has been used as a bioindicator of soil health in many different environments (Bongers and Bongers 1998) (Fig. 1).

Previous studies have mainly focused on crop growth, yield, and soil properties affected by the application of EM (Daly and Stewart 1999; Khaliq et al. 2006). However, there have been no reports of the effects of the application of effective microorganisms on soil fauna, such as soil nematodes. These investigations show the effects of effective microorganisms on the soil nematode community and may facilitate the selection of the optimal fertilization strategy for maintaining soil fertility and high crop yields.

The objectives of this study were as follows: (1) to determine the effects of long-term application of effective microorganisms on the soil nematode community and (2) to evaluate the differences in soil nematode community structure attributable to long-term application of organic and mineral fertilizers in a wheat and corn crop system.

## 2 Materials and methods

### 2.1 Experimental site and design

The experimental sites were located at Qu-Zhou experimental station of China Agricultural University in Hebei Province, North China Plain (36°52' N and 115°01' E). The climate in this experimental station is warm, semi-humid, and has rainy summers and dry, cold winters. The mean annual temperature is 13.2 °C and ranges from a minimum of -2.9 °C in January to a maximum of 26.8 °C in July. The mean annual precipitation is 542.7 mm, of which 60 % occurs from July to September. The annual non-frost period is 201 days. The soil at experimental site is an Aquic Cambisol, which has developed on alluvial plain.



**Fig. 1** Soil nematodes are widely spread, tremendous abundant and highly diverse, occupying multiple trophic positions in the soil food web, including bacterivores, fungivores, plant-parasites, as well as omnivores and predators. So, soil nematodes were used as indicators of biodiversity and ecological stability and for assessing change of soil environments

The long-term fertilizer experiment was designed with four treatments and three replications, laid out in a randomized complete block design with 12 plots, each 4×8 m in size. All plots were planted with wheat (*Triticum aestivum* L.) in winter and with maize (*Zea mays* L.) in summer on an annual rotation starting in 1997, which is the typical cropping system in this region. The wheat was planted in October and harvested in June, followed by maize which was planted in June and harvested in October.

The four treatments consisted of applied effective microorganisms compost treatment (EM; 15 t ha<sup>-1</sup>; 1 ml of effective microorganisms concentrate containing a minimum of 10<sup>5</sup> viable organisms of *Streptomyces albus*, *Propionibacterium freudenreichii*, *Streptococcus lactis*, *Aspergillus oryzae*, *Mucor hiemalis*, *Saccharomyces cerevisiae*, and *Candida utilis*, in addition to an unspecified number of *Lactobacillus* sp., *Rhodopseudomonas* sp., and *Streptomyces griseus*), applied traditional compost treatment (TC; 15 t ha<sup>-1</sup>), applied NP fertilizer treatment (NP; N 265.5 kg ha<sup>-1</sup> and P<sub>2</sub>O<sub>5</sub> 90 kg ha<sup>-1</sup>), and a control (CT; no soil amendment). The traditional compost was 60 % straw, 30 % livestock dung, 5 % cottonseed-pressed trash, and 5 % bran (with a mean nutrient content of N 100.5 kg ha<sup>-1</sup>, P<sub>2</sub>O<sub>5</sub> 36 kg ha<sup>-1</sup>, and K<sub>2</sub>O 196.2 kg ha<sup>-1</sup>). Every 50 kg of effective microorganisms compost consisted of traditional compost to which 200 ml of effective microorganisms concentrate had been added.

Fertilizers were applied twice every year, just before the planting of wheat in the winter and maize in the summer, and the amount of fertilizer was consistent across treatments and seasons. Neither compost nor chemical fertilizer was applied during crop growth stages. The amount of fertilizers applied and rates and times of application were typical for this region. The fertilized and unfertilized plots were the same type of tillage. The aboveground crop was mowed and removed, and no straw was returned to the soil. Besides the three fertilizer treatments, all other agronomic management was identical.

### 2.2 Soil sampling

A total of 72 soil samples were collected from October 2004 to June 2005 (October and November 2004 and March, April, May, and June 2005) and stored in tied and insulated plastic bags to prevent moisture loss. They were transferred to 4 °C storage as soon as possible until they could be used to analyze soil nematode community structure. Every soil sample consisted of 15 core soils.

### 2.3 Extraction and identification of soil nematodes

Field moist subsamples (100 g) of each sample were used to extract nematodes with the sugar flotation and centrifugation method (Barker et al. 1985). The nematode populations were

expressed as 100 g<sup>-1</sup> dry soil. All extracted nematodes in each sample were counted and then preserved in formalin. One hundred nematodes per sample were randomly selected and identified to genus (Mal and Lyon 1975; Ying 1998).

## 2.4 Nematode community

The characteristics of the nematode communities were described using the following approaches: (1) total number of nematodes per 100 g dry soil; (2) number of soil free-living nematodes per 100 g dry soil; and (3) trophic structure: (a) bacterial feeders, (b) fungal feeders, (c) plant feeders, and (d) omnivore–predators (Yeates et al. 1993).

## 2.5 Statistical analysis

One-way analysis of variance was used to detect differences between different treatments. Differences at the  $p < 0.05$  level were considered statistically significant under the least significant difference test. All statistical analyses and stepwise regression were performed using SPSS 11.5 version software package (SPSS, Chicago, IL).

## 3 Results and discussion

### 3.1 Effect of different soil amendments on nematode population

The total number of nematodes was 24.59, 79.27, and 173.23 % higher in effective microorganisms compost plots than in NP fertilizer plots in March, May, and June, respectively. It was 142.61, 86.15, and 204.77 % higher in effective microorganisms compost plots than in control plots. The total number of nematodes was 56.48 and 110.58 % higher in traditional compost plots than in NP fertilizer plots in November and June, respectively. It was 52.25 and 134.89 % higher in traditional compost plots than in control plots. The total number of nematodes was 43.21 and 29.75 % higher in effective microorganisms compost plots than in traditional compost plots in May and June, respectively. The total number of nematodes was higher 94.73 % in NP fertilizer plots than in control plots in March (Table 1). Increased nematode abundance after application of organic manure was also reported by Villenave et al. (2003). The increase in nematode populations may be directly linked to the greater abundance of food associated with the introduction of compost. In March, soil free-living nematodes were 72.55, 97.07, and 128.77 % more abundant in effective microorganisms compost plots than in traditional compost, NP fertilizer, and control plots, respectively. In June, they were 29.32, 293.82, and 227.36 %, more abundant, in EM plots than in traditional compost, NP fertilizer, and control

plots, respectively. In June, soil free-living nematodes were 204.54 and 153.15 % more abundant in TC plots than in the NP fertilizer and control plots, respectively (Table 1). Villenave et al. (2010) observed that soil free-living nematodes were significantly more abundant in manure plots than in unamended control plots.

In March, bacteria-feeding nematodes were 119.93, 142.98, and 180.52 % more abundant in effective microorganisms compost plots than in traditional compost, NP fertilizer, and control plots, respectively. In June, they were 63.23, 464.18, and 273.82 % more abundant in the effective microorganisms compost plots than in traditional compost, NP fertilizer, and control plots, respectively. In June, bacteria-feeding nematodes were 245.64, and 129.02 % more abundant in traditional compost plots than in NP fertilizer and control plots, respectively. In the present study, fungus-feeding nematodes were less trophic than other groups of nematodes. In November, fungus-feeding nematodes were 130.74 and 104.22 % more abundant in control plots than in NP fertilizer compost or effective microorganisms plots, respectively (Table 1). Bacterial feeders of the Ba<sub>1</sub> and Ba<sub>2</sub> guilds, which contain enrichment opportunists, were most responsive to increases in their food supply. In particular, *Cephalobus*, *Rhabditis*, and *Protorhabditis* dominated the bacteria-feeding nematode community. Those results were consistent with observations reported by Briar et al. (2007). Villenave et al. (2010) reported that long-term addition of straw and manure significantly promoted the abundance of both bacterial and fungal feeders.

Plant parasitic nematodes were the most dominant trophic groups in the present study. In May, plant parasitic nematodes were 73.39, 60.64, and 123.18 % more abundant in effective microorganisms compost plots than in traditional compost plots, NP fertilizer plots, and control plots respectively. In June, they were 30.03, 128.65, and 191.96 % more abundant effective microorganisms compost plots than in traditional compost plots, NP fertilizer plots, and control plots, respectively. In June, the omnivore-predators were 261.61 % more abundant in traditional compost plots than in control plots (Table 1). Similarly, Ou et al. (2005) found that plant parasitic nematodes were predominant trophic group in maize fields. However, DuPont et al. (2009) found that bacteria-feeding nematodes were dominant trophic group in organic agriculture systems and Leroy et al. (2009) reported that bacteria-feeding nematodes were dominant trophic group in farmyard manure treatment. Villenave et al. (2010) found that the number of plant parasitic nematodes (mainly *Pratylenchus* and *Tylenchorhynchus*) was significantly higher in plots fertilized with manure than in unmodified or straw-amended plots. On average, in the present study, the number of plant parasitic

**Table 1** The number of soil nematodes (individuals/100 g dry soil) in different treatments and on different sampling dates

Date	Treatment	TN	FN	BF	FF	PP	OP
October 2004	CT	291.51 b	114.52 a	76.09 a	14.00 a	176.99 b	24.43 a
	NP	407.39 a, b	157.12 a	101.14 a	29.02 a	250.27 a, b	26.96 a
	TC	425.80 a, b	153.21 a	107.63 a	28.50 a	272.59 a	17.08 a
	EM	475.19 a	186.65 a	138.84 a	17.46 a	288.54 a	30.35 a
November 2004	CT	448.45 b	185.27 a, b	128.61 a	40.68 a	263.18 b	15.98 a, b
	NP	436.33 b	111.60 b	74.63 a	17.63 b	324.73 a, b	19.34 a, b
	TC	682.76 a	210.54 a	147.69 a	32.77 a, b	472.21 a	30.08 a
	EM	472.41 b	137.55 a, b	104.41 a	19.92 b	334.86 a, b	13.22 b
March 2005	CT	347.99 c	71.66 b	39.74 b	14.48 a	276.33 b	17.44 a
	NP	677.64 b	83.19 b	45.88 b	15.70 a	594.45 a	21.61 a
	TC	810.24 a, b	95.01 b	50.69 b	19.36 a	715.23 a	24.96 a
	EM	844.27 a	163.94 a	111.48 a	23.15 a	680.32 a	29.31 a
April 2005	CT	236.20 b	83.93 a	55.92 a	11.93 a	152.26 a	16.08 a
	NP	255.01 a, b	88.94 a	51.67 a	19.87 a	166.07 a	17.39 a
	TC	351.97 a	111.58 a	74.07 a	16.37 a	240.38 a	21.15 a
	EM	337.99 a, b	125.56 a	108.46 a	8.68 a	212.43 a	8.43 a
May 2005	CT	391.74 b	194.26 a, b	147.90 a, b	15.82 a	197.48 b	30.54 a
	NP	406.79 b	132.42 b	77.00 a	29.03 a	274.37 b	26.38 a
	TC	509.22 b	255.03 a, b	174.46 a, b	34.15 a	254.19 b	46.42 a
	EM	729.24 a	288.50 a	250.09 a	22.44 a	440.74 a	15.96 a
June 2005	CT	267.70 c	96.95 c	66.24 c	13.65 a	170.74 c	17.06 c
	NP	298.60 c	80.59 c	43.89 c	16.12 a	218.01 c	20.58 b, c
	TC	628.80 b	245.43 b	151.70 b	32.04 a	383.38 b	61.69 a
	EM	815.87 a	317.38 a	247.62 a	22.34 a	498.49 a	47.42 a, b
Average	CT	330.60 c	124.43 b	85.75 b, c	18.43 a	206.16 c	20.26 a
	NP	413.63 b	108.98 b	65.70 c	21.23 a	304.65 b	22.04 a
	TC	568.13 a	178.47 a	117.70 a, b	27.20 a	389.66 a	33.56 a
	EM	612.49 a	203.26 a	160.15 a	19.00 a	409.23 a	24.12 a

Different letters (a–c) in the same column indicate significant differences ( $p < 0.05$ ) between treatments on the same sampling dates according to least significant difference multiple comparison

*TN* total number of nematodes, *FN* the number of free-living nematodes in the soil, *BF* bacterial feeders, *FF* fungal feeders, *PP* plant parasites, *OP* omnivores and predators, *CT* control, *NP* NP fertilizer treatment, *TC* traditional compost treatment, *EM* effective microorganisms compost treatment

nematodes was 34.33 and 27.90 % higher in effective microorganisms and traditional compost plots than in NP fertilizer plots, respectively. This was because there was more food available for the plant parasitic nematodes in compost plots, causing wheat biomasses to be 57.93 and 47.64 % higher in effective microorganisms and traditional compost plots than in NP fertilizer plots, respectively (Table 3).

### 3.2 Effects of different soil amendments on nematode community

A total of 49 nematode taxa were identified in the present study. There were 15 bacterial feeders, 5 fungal feeders, 19 plant feeders, 5 omnivores, and 5 predators (Table 2). A

total of 43 nematode genera were observed in effective microorganisms compost plots, 39 in traditional compost plots, 38 in NP fertilizer plots, and 40 in CT plots. *Tylenchorhynchus*, *Pratylenchus*, and *Rotylenchus* were the dominant genera. They showed mean relative abundances of 11.26, 10.95, and 10.09 %, respectively. More nematode genera were found in effective microorganisms compost plots than in NP fertilizer plots, reflecting a greater biodiversity of soil habitat in these plots (Ekschmitt et al. 2001). The negative effect of chemical fertilizer on the soil ecosystem was attributed to decreases in soil biodiversity. The use of chemical fertilizer decreased the number of bacteria-feeding genera. This number was tightly correlated with soil nutrient cycling. While 49 nematode taxa were identified in the present study, only 38 were identified in a continuous

**Table 2** Mean relative abundance (in percent) of soil nematode taxa for each treatment in all sampling dates

Genus	Guild	CT	NP	TC	EM
<i>Cephalobus</i>	Ba2	4.32	5.57	5.74	7.49
<i>Eucephalobus</i>	Ba2	3.20	2.69	2.98	3.83
<i>Acrobeloides</i>	Ba2	1.11	0.69	1.31	1.40
<i>Chiloplacus</i>	Ba2	0.06	0.06	0.00	0.10
<i>Cervidellus</i>	Ba2	0.05	0.00	0.20	0.08
<i>Acrobeles</i>	Ba2	0.73	2.38	1.21	1.33
<i>Panagrolaimus</i>	Ba1	1.87	0.00	0.45	0.44
<i>Protorhabditis</i>	Ba1	5.99	2.47	5.05	5.79
<i>Mesorhabditis</i>	Ba1	0.00	0.00	0.00	0.05
<i>Odontorhabditis</i>	Ba1	0.04	0.00	0.16	0.30
<i>Caenorhabditis</i>	Ba1	0.00	0.00	0.00	0.15
<i>Poikilolaimus</i>	Ba1	0.00	0.06	0.31	0.69
<i>Rhabditis</i>	Ba1	7.29	3.06	4.67	5.41
<i>Chambersiella</i>	Ba2	0.11	0.05	0.00	0.03
<i>Monhystera</i>	Ba2	0.00	0.00	0.00	0.03
Total bacterivores		24.77	17.04	22.10	27.12
<i>Ditylenchus</i>	Fu2	0.06	0.46	0.17	0.00
<i>Nothotylenchus</i>	Fu2	0.00	0.14	0.28	0.08
<i>Aphelenchus</i>	Fu2	0.89	0.41	0.87	0.45
<i>Aphelenchoides</i>	Fu2	2.46	3.73	2.60	1.71
<i>Tylencholaimus</i>	Fu4	1.86	1.00	1.03	0.91
Total fungivores		5.27	5.73	4.96	3.15
<i>Tylenchus</i>	H2	6.80	1.65	1.95	2.28
<i>Filenchus</i>	H2	6.76	6.71	9.50	9.25
<i>Psilenchus</i>	H2	0.16	0.04	0.07	0.29
<i>Tetylenchus</i>	H2	4.50	9.76	7.88	7.29
<i>Dolichodoros</i>	H3	0.10	0.00	0.05	0.08
<i>Brachydoros</i>	H3	0.28	0.19	1.89	2.02
<i>Belonolaimus</i>	H2	0.59	0.36	0.35	0.43
<i>Tylenchorhynchus</i>	H2	9.47	16.68	9.47	9.41
<i>Pratylenchus</i>	H3	9.16	13.89	9.97	10.79
<i>Hoplolaimus</i>	H3	0.61	0.12	0.06	0.00
<i>Helicotylenchus</i>	H3	9.52	8.78	10.50	9.86
<i>Rotylenchus</i>	H3	10.23	9.07	10.30	10.77
<i>Rotylenchulus</i>	H3	0.13	0.00	0.00	0.00
<i>Paratylenchus</i>	H2	0.10	0.58	0.23	0.39
<i>Oxydirus</i>	H5	0.93	0.90	0.99	1.29
<i>Longidorus</i>	H5	1.19	0.75	1.95	0.66
<i>Longidorella</i>	H5	0.63	0.33	0.20	0.09
<i>Xiphinema</i>	H5	2.58	1.69	1.39	0.96
<i>Trichodoros</i>	H4	0.00	0.05	0.00	0.00
Total plant-parasites		63.74	71.55	66.74	65.85
<i>Dorylaimus</i>	Om4	2.51	2.28	2.57	1.21
<i>Mesodorylaimus</i>	Om4	1.04	0.87	0.50	0.45
<i>Enchodelus</i>	Om4	0.15	0.09	0.49	0.03
<i>Eudorylaimus</i>	Om4	0.92	1.36	1.13	0.79
<i>Aporcelaimus</i>	Om5	1.32	0.83	1.33	1.17
Total omnivores		5.94	5.43	6.01	3.65

**Table 2** (continued)

Genus	Guild	CT	NP	TC	EM
<i>Nygolaimus</i>	Ca5	0.20	0.00	0.11	0.00
<i>Sectonema</i>	Ca5	0.00	0.14	0.00	0.00
<i>Labronema</i>	Ca4	0.08	0.11	0.08	0.15
<i>Mononchus</i>	Ca4	0.00	0.00	0.00	0.03
<i>Ironus</i>	Ca4	0.00	0.00	0.00	0.05
Total predators		0.28	0.25	0.18	0.22

CT control, NP NP fertilizer treatment, TC traditional compost treatment, EM effective microorganisms compost treatment, Ba bacterivores, Fu fungivores, Ca predators (carnivores), Om omnivores, H plant feeders (herbivores)

Functional guild classifications are made based on feeding habits and life-cycle characteristics (Ba, Fu, Ca, Om, and H) (Yeates et al. 1993). Suffix numbers are *c-p* values for the taxon (Bongers and Bongers 1998)

sorghum cropping system, and only 35 were identified in a soybean–wheat–corn rotation system (Pan et al. 2010; Villenave et al. 2010).

### 3.3 Effect of different soil amendments on wheat biomass and yield

Wheat biomass and yield are shown in Table 3. Wheat biomass was 57.93 and 190.93 % higher in plots treated with effective microorganisms compost than in NP fertilizer plots and control plots, respectively. It was 47.64 and 171.98 % higher in traditional compost plots than in NP fertilizer and control plots, respectively. Javaid and Bajwa (2011) reported that the shoot biomass of mungbeans was 70.89 and 50 % during the flowering and maturity stages, respectively, after the use of effective microorganisms on farmyard manure. Wheat yields were 3.92, 14.04, and 264.67 % higher in plots treated with effective microorganisms than in plots treated with traditional compost, NP fertilizer plots, and control plots, respectively. Khaliq et al. (2006) reported that the use of effective microorganisms in combination with organic

**Table 3** Wheat biomass and yield in soils under different treatments

Treatment	Wheat biomass (g/10 plants)	Wheat yields (t h <sup>-1</sup> m <sup>-2</sup> )
CT	13.56 c	1.67 d
NP	24.98 b	5.34 c
TC	36.88 a	5.86 b
EM	39.45 a	6.09 a

Different letters (a–d) in the same column indicate significant differences ( $p < 0.05$ ) between treatments according to least significant difference multiple comparison

CT control, NP NP fertilizer treatment, TC traditional compost treatment, EM effective microorganism compost treatment

manure enhanced cotton yields by 23 % over organic manure alone.

Stepwise regression equations were conducted to assess soil nematode community parameters during different stages. These parameters were significantly associated with wheat grain yield. Plant feeders were found to be significant predictors of wheat grain yields in October 2004 and June 2005 (Table 4). Fungal feeders were found to be significant predictors of wheat grain yield in October 2004 and June 2005. Soil free-living nematodes were found to be significant predictors of wheat grain yield in March and April 2005. Mandal et al. (2007) found that grain yield of wheat was significantly associated with alkaline phosphatase activity at the dough stages of wheat growth.

#### 4 Conclusions

Based on these results, we concluded that the long-term application of effective microorganisms compost could affect soil nematode community structure, wheat biomass, and grain yield. The total number of nematodes was 43.21 and 29.75 % higher in compost plots treated with effective microorganisms compost than in traditional compost plot in May and June, respectively. Soil free-living nematodes and bacteria-feeding nematodes were 29.32 and 63.23 % more plentiful, respectively, in treated compost plots than in traditional compost plots in June. Wheat biomass was 57.93 and 190.93 % higher in plots treated with effective microorganisms compost than in those treated with NP fertilizer and in control plots, respectively. Wheat yields were 3.92, 14.04, and 264.67 % higher in plots treated with effective microorganisms compost plot than in traditional compost plots, NP fertilizer plots, and control plots. Stepwise regressions revealed that wheat grain yields were significantly associated with soil free-living nematodes ( $R^2=0.88$ ) during

**Table 4** Stepwise regression of grain yields of wheat with soil nematode community on different sampling dates

Date	Predictor variable	Constant	Coefficient	$R^2$	$F$	$p$
04 Oct	PP	-1.535	0.025	0.60	14.341	0.004
04 Nov	FF	7.331	-0.093	0.37	5.819	0.037
05 Mar	FN	-0.728	0.008	0.88	71.963	0.000
05 Apr	FN	0.232	0.013	0.33	4.970	0.049
05 May	PP	1.951	0.01	0.33	4.896	0.051
05 Jun	PP	1.721	0.009	0.52	10.948	0.008

FN number of soil free-living nematodes, FF fungal feeders, PP plant parasites

The values are fitted in the equation:  $y=a+bx_1+cx_2$ ;  $y$ =grain yield;  $x_1$  and  $x_2$  are the independent variables; and  $a$ ,  $b$ , and  $c$  are coefficients

the jointing stage of wheat growth. Long-term application of effective microorganisms was found to increase the biological fertility of soil.

**Acknowledgments** We would like to thank Aiming Shi of Qu-Zhou Experimental Station of China Agricultural University for her valuable assistance with our field study.

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