INTERNATIONAL JOURNAL OF AGRICULTURE & BIOLOGY
ISSN Print: 1560–8530; ISSN Online: 1814–9596
18F–102/2018/20–10–2265–2270
DOI: 10.17957/IJAB/15.0776
http://www.fspublishers.org

Full Length Article

Effects of Altitude and Growth Stage on *Amorphophallus konjac* Microecosystem in Mount Emei

Peng Yin[1], Qinlan Guan[1], Xia Hu[1] and Mingfu Gong[1,2*]
[1]*College of Life Sciences, Leshan Normal University, Leshan 614000, China*
[2]*Institute of Biodiversity Conservation and Utilization in Mount Emer, University of Leshan Normal, Leshan 614000, China*
[*]For correspondence: gongmingfu98@163.com

Abstract

Konjac soft rot is one of the main diseases that affect negatively the production of konjac. In this study, we used through control experiments to investigate the effects of altitude (551 m, 750 m, 1029 m, 1380 m and 1575 m) and growth period stages (seedling, corm changing, tuber-swelling, tuber-maturating) on the number of rhizosphere microbes and the incidence of konjac soft rot. The altitude and growth stage of konjac had a significant influence on the number of rhizosphere microbes and the incidence of soft rot disease. The number of rhizobacteria and actinomycetes tended to increase with the elevation of altitude, whereas the number of rhizosphere fungi and the incidence of konjac soft rot were gradually reduced. The rise in konjac levels augmented the numbers of rhizobacteria and actinomycetes, which reached its highest values in tuber infancy. Therefore, an appropriate increase in the altitude can effectively control the incidence of konjac soft rot.

Keywords: Altitude; *Amorphophallus konjac*; Growth stage; Mount emei; Rhizosphere

Introduction

Mount Emei is located at Mount Emei City, Sichuan Province, China. The area of Mount Emei is approximately 154 km^2 (Liao *et al*., 2013). Due to the higher elevation and the larger slope, the climate zone of the Mount Emei is distributed vertically. Altitudes from 1,500 m to 2,100 m have warm temperate climate; from 2,100 m to 2,500 m temperate climate; and above 2,500 m sub-frigid climate. Different altitudes in Mount Emei have various climatic characteristics. The areas at an altitude below that of the Qingyin pavilion belong to the low-mountain area characterized by lush vegetation, cool winds, and clear springs. The temperature of low mountain area does not differ from that of the plain area. The regions from the Qingyin Pavilion to the Elephant Bathing Pool are middle-mountain, with a temperature that is 4°C - 5°C lower than that of the low-mountain area, (*e.g.*, at the Baoguo Temple). The area spanning from the Elephant Bathing Pool to the Golden Peak Temple is a high-mountain featured by a temperature that is 12°C lower than the one measured at the low-mountain area, (*e.g.*, at Baoguo Temple). This complex set of specific climatic conditions has inevitably affected the ecological distribution of soil microorganisms in Mount Emei (Li, 1984).

Amorphophallus konjac is cultivated on large areas in Mount Emei because of its rich content of Konjac glucomannan (KGM). However, konjac soft rot disease, caused by *Erwinia carotovora* subsp *carotovora* (Ecc), is the main disease in the representatives of the *Amorphophallus* genus that causes substantial losses of production (Toth *et al*., 2003). Konjac soft rot disease has had a significant holdback on konjac industry development. For decades, extensive research aimed at the prevention from and treatment of bacterial konjac soft rot has been conducted on approaches, including biological control, microbial pesticides, natural extracts pesticides, disease-resistant gene cloning, and bio-pesticides (Marois *et al*., 1982; Zhou *et al*., 2007; Cui and Li, 2009; Zhang *et al*., 2011; Ding *et al*., 2014). Nevertheless, no effective methods to combat konjac soft rot have been discovered so far.

Soil microorganisms are of crucial importance to disease control, carbon (C) and nitrogen (N) cycling (Lucas *et al*., 2007; Liang *et al*., 2011), ecosystem functioning (Stroud *et al*., 2007), and global climate change (Singh *et al*., 2010). A number of biotic and abiotic factors are well documented to influence soil microbial communities, which in turn may affect the tunover and accumulation of soil microbial residues. Such factors include the vegetation type (Bach *et al*., 2010; Liang *et al*., 2012), water content (Brockett *et al*., 2012), temperature (Pettersson and Baath, 2003), soil depth (Fierer *et al*., 2003), pH (Baath and Anderson, 2003), growth periods (Lv *et al*., 2011; Wu *et al*., 2012), soil type (Rousk *et al*., 2010), planting years (Wang *et al*., 2012) and chemical material decomposed (Ding, 2011). The effects of diverse climatic regimes on soil

To cite this paper: Yin, P., Q. Guan, X. Hu and M. Gong, 2018. Effects of altitude and growth stage on *Amorphophallus konjac* microecosystem in mount emei. *Int. J. Agric. Biol*., 20: 2265–2270

microbial communities and residues are still insufficiently investigated, although earlier studies have been performed on the impact of the latitude (Yergeau *et al.*, 2007; Wu *et al.*, 2009), and altitude (He and Zhu, 2011; Yu and Shi, 2011; Cai *et al.*, 2016). The altitude-induced environmental conditions have been reported to influence soil microbial communities in mountains (Schinner and Gstrauntthaler, 1981; Diaz *et al.*, 2003; Ma *et al.*, 2004; Giri *et al.*, 2007; Margesin *et al.*, 2009). For example, altitude-varied changes in microbial community composition were controlled by pH rather than temperature fluctuations in the Arctic fields of Finnish Lapland (Mannisto *et al.*, 2007). Shen *et al.* (2013) also discovered that soil pH drives the spatial distribution of bacterial communities along with the elevation of Changbai Mountain. These studies suggest that soil simple prediction of the distribution of microbial communities cannot be done as it is associated with a wide range of factors than the mere altitude.

In the present study, we conducted control experiments to examine the effects of altitude (551 m, 750 m, 1029 m, 1380 m, and 1575 m) and growth period stages of konjac (seedling, corm changing, tuber-swelling, tuber-maturating stages) on the number of rhizosphere microbes involved in the production of konjac and the incidence of konjac soft rot.

Materials and Methods

Test Site Characteristics

The trial was conducted in Mt. Emei in 2016. Five experimental plots were randomly selected and established in soils of different altitudes of Mount Emei, including Baoguo Temple (H1, altitude 551 m), Qingyin pavilion (H2, altitude 750 m), Wannian Temple (H3, altitude 1029 m), Zero kilometer (H4, altitude 1380 m), and Xixinsuo Temple (H5, altitude 1575 m). Each experimental plot was divided into three 20-m^2 sample areas that we used for konjac planting.

Soil Samples

The rhizosphere soil samples were collected from experimental plots at five different altitudes at four different seedling stages of konjac growth (seedling, corm changing, tuber-swelling and tuber-maturating stages). The rhizospheric soil samples obtained in the field were immediately put into an ice box for storage, and the frozen soil samples were promptly transferred to the laboratory for analysis.

Incidence Rate of Konjac Soft Rot

The incidence rates of konjac soft rot were investigated in experimental plots located at five different altitudes in four different seedling stages: seedling, corm changing, tuber-swelling and tuber-maturating stages. The incidence rate was calculated using the following formula:

Incidence rate (%) = (number of diseased plants/total number of survey plants) × 100.

Influence of the Altitude on Rhizosphere Microbes of Konjac

The dilution coating plate method was used for rhizosphere microbiological analysis. Beef extract peptone medium was utilized for bacteria culture, Martin's medium was used for fungi culture, and Gaogan No. 1 medium was used for actinomycetes culture.

Results

Effects of Altitude and Growth Period on Incidence Rate of Konjac Soft Rot

As can be seen in Fig. 1, the altitude had a significant effect on the incidence of soft rot disease which was gradually reduced with the elevation of altitude. Furthermore, the four growth stages of konjac studied also had a significant influence on the incidence of soft rot disease which rose with the growth of konjac, reaching its highest values during the tuber-swelling stage, whereas it rapidly decreased at the tuber-maturating stage (Fig. 1).

Influence of the Altitude and the Growth Period on the Numbers of Rhizosphere Bacteria Involved in Konjac Production

As can be seen in Fig. 2, the altitude and growth period stage of konjac exerted a significant inpact on the number of rhizosphere bacteria associated with konjac formation. We found that the number of these rhizosphere bacteria gradually increased with the elevation of altitude but gradually decreased with the progression of the growth period. The lowest number of bacteria was established at the tuber-swelling stage, but it rapidly increased at the tuber-maturating stage (Fig. 2).

Influence of the Altitude and the Growth Period on Konjac-Producing Rhizosphere Actinomycetes

The number of konjac-forming rhizosphere actinomycetes gradually increased with the elevation of altitude. However, the opposite trend was observed concerning the phase of development. The number of rhizosphere actinomycetes decreased with advancing the stages of the growth of konjac, reaching the lowest values at the tuber-swelling stage. This number rapidly increased at the tuber-maturating stage (Fig. 3).

Influence of Altitude and Growth Period on Rhizosphere Fungi of Konjac

As can be seen in Fig. 4, the altitude and growth period of

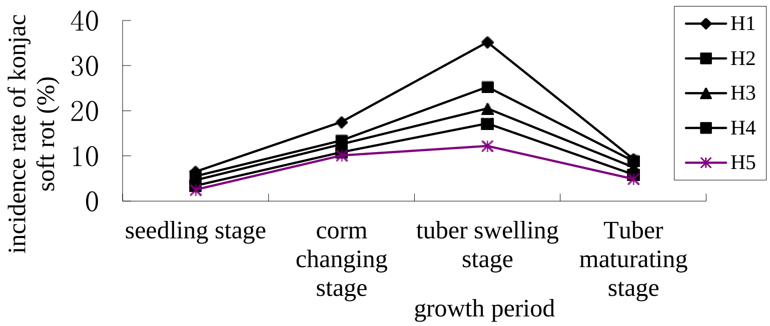

Fig. 1: Effects of altitude and growth period on incidence rate of konjac soft rot

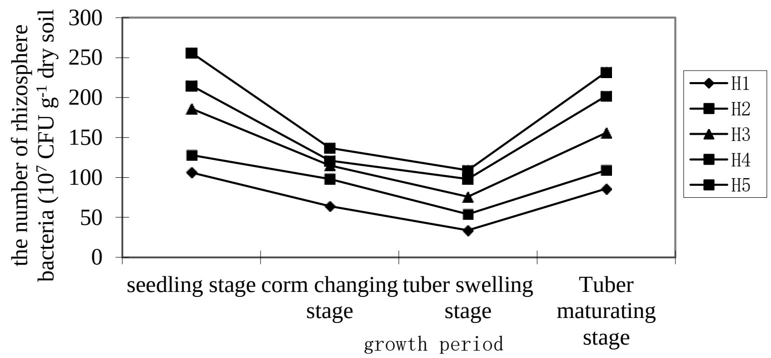

Fig. 2: Effects of altitude and growth period on the number of rhizosphere bacteria of konjac

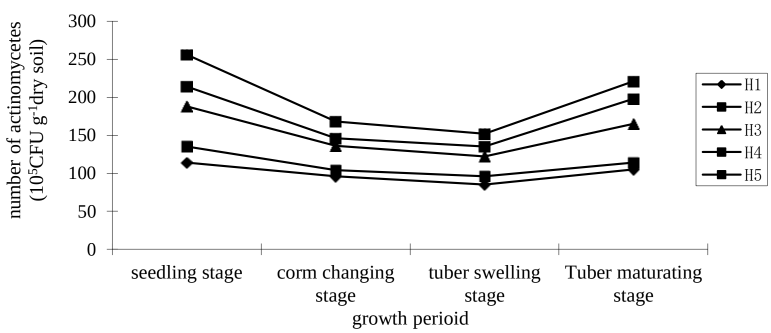

Fig. 3: Effects of altitude and growth period on the number of rhizosphere actinomycetes of konjac

konjac had a significant influence on the number of rhizosphere fungi of konjac (Table 1), which was gradually reduced with the increase of altitude.

In addition, this number steadily rose with the advancement of the growth stages of konjac, reaching the highest value at tuber-swelling stage and rapidly decreasing at the tuber-maturating stage (Fig. 4).

Discussion

The change in the altitude gradient leads to the changes in many environmental factors such as temperature, light and water, which causes the gradient effects in an environment system, such as those associated with the microclimate, soil physical and chemical characteristics, which deeply affects the soil microbial biomass, community structure, and the number of soil-transmitted pathogenic microorganisms (Gaston, 2000; Fierer *et al.*, 2011; Xue *et al.*, 2011; Xu *et al.*, 2012; Wu *et al.*, 2013; Cao *et al.*, 2016).

The research on the characteristics of soil microbial biomass and the occurrence of plant-borne diseases in association with altitude changes has been of substantial significance for exploring the impact of environmental factors on the ecological processes in konjac soil (such as konjac soft rot disease). Soil microbial biomass was found to be an important biological indicator of soil quality (Hu and Wu, 2002). Our experimental results showed that altitude had a significant effect on the number of

Table 1: Effects of altitude and growth period on the number of rhizosphere fungi of konjac (10^4 CFUg^{-1} dry soil)

experimental plots	Growth period				
	seedling stage	corm changing stage	tuber swelling stage	Tuber maturating stage	average value
Baoguo Temple	85	106	138	98	106.8aA
Qingyin pavilion	82	98	115	85	95.0bAB
Wannian Temple	75	89	106	79	87.3bB
Zero kilometer	41	74	85	58	64.5cC
Xixinsuo Temple	35	58	63	46	50.5dD
average value	63.6 dC	85bB	101.4 aA	73.2 cC	

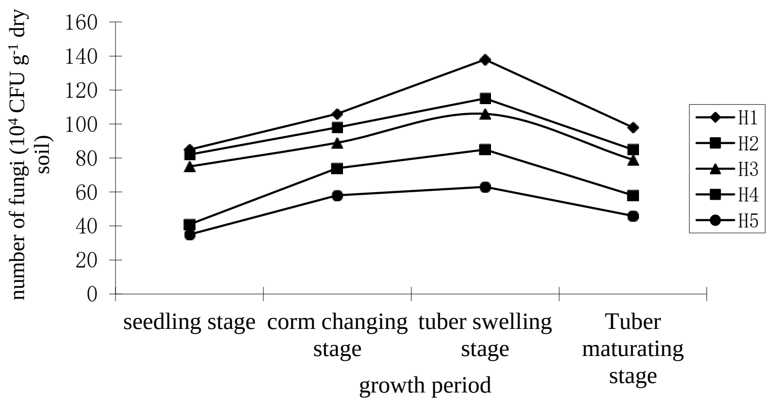

Fig. 4: Effects of altitude and growth period on the number of rhizosphere fungi of konjac

rhizosphere microbes and the incidence of soft rot disease. The number of rhizobacteria and actinomycetes tended to increase with the elevation of altitude, while the number of rhizosphere fungi and the incidence of konjac soft rot gradually reduced. Nevertheless, the results of this study are different from those obtained in earlier examinations on the quantity of microorganisms in a forest soil of Mount Emei (Hu *et al.*, 2015; Cai *et al.*, 2016). The authors found that the increase in the altitude caused a decline in the proportion of bacteria in soil.

Previous research established that the plant growth stage had significant effects on the number and type of rhizosphere soil microbes (Lv *et al.*, 2011; Wu *et al.*, 2012; Fu *et al.*, 2014; Yang *et al.*, 2016). Additionally, Fu *et al.* (2014) discovered that the numbers of microbes in the rhizophere soil of Dongxiang Wild Rice (*Oryza rufipogon*) were diverse at different stages; bacteria were dominant, followed by actinomycetes, and fungi. The abundance of the microbial flora at the different growth stages showed an initial trend of increase, followed by a decrease (Fu *et al.*, 2014). Significant difference was found in Aconitum rhizosphere soil microorganism of different stages and different conditions and the soil microorganism showed a gradual downward trend in diseased plant of different trophophase, and enhance trend following decrease in healthy plants (Wu *et al.*, 2012). The results of our study evidenced that the growth stage of konjac exerted a significant effect on the number of rhizosphere microbes and the incidence of soft rot disease. We discovered that the number of rhizobacteria and actinomycetes increased along with the growth of konjac, reaching the highest values during tuberization and rapidly decreasing at maturity. The number of rhizosphere fungi and the incidence of soft rot, however, had the opposite trend, reaching the lowest values at the earliest stages of tuber formation.

Soil microorganisms antagonized each other had harmful and beneficial effects on plants and established a homeostasis under normal conditions. Once this balance was broken, soil-borne disease can be triggered. Some rhizosphere microbes secreted some organic matter to the rhizosphere soil to cause toxic effects on crops (Han *et al.*, 2000; Wu *et al.*, 2002), or to cause the decline of microbial diversity and the number of pathogens antagonistic bacteria (Yang *et al.*, 2001; Mithofer, 2002). In this study, the trend of the number of bacteria and actinomycetes in the rhizosphere soil of *A. konjac* was negatively correlated with the incidence of konjac soft rot disease. However, the number of fungi in the rhizosphere soil was positively associated with the incidence of konjac soft rot disease. These findings indicate that rhizobacteria and actinomycetes contribute to the control of the growth of konjac soft rot bacteria.

Conclusion

The altitude and growth stage of konjac had a significant effect on the number of rhizosphere microbes and the incidence of soft rot disease. The number of rhizobacteria and actinomycetes tended to increase with the elevation of altitude, whereas the number of rhizosphere fungi and the incidence of konjac soft rot were gradually reduced. The number of rhizosphere fungi and the incidence of soft rot displayed the opposite trend, reaching the lowest values at the earliest phases of tuber development. Therefore, an increase in the altitude can effectively control konjac soft rot disease.

Acknowledgements

We acknowledge the financial supports of the project of the Science and Technology Department in Sichuan province (2018NFP0107), the scientific research fund of Sichuan Provincial Education Department (15TD0026, 18ZA0245, 16ZA0306), and the scientific research fund of bamboo diseases and pests control and resources development key laboratory of Sichuan Province (17ZZ004, 17ZZ005).

References

Baath, E. and T.H. Andersonk, 2003. Comparison of soil fungal/bacterial ratios in a pH gradient using physiological and PLFA-based techniques. *Soil Biol. Biochem.*, 35: 955–963

Bach, L.H., J.A. Grytnes, R. Halvorsen and M. Ohlson, 2010. Tree influence on soil microbial community structure. *Soil Biol. Biochem.*, 42: 1934–1943

Brockett, B.F.T., C.E. Prescott and S.J. Grayston, 2012. Soil moisture is the major factor influencing microbial community structure and enzyme activities across seven biogeoclimatic zones in western Canada. *Soil Biol. Biochem.*, 44: 9–20

Cai, S., X. Hu and Z.Y. Wang, 2016. Response of Soil Microbial Biomass to Elevation Gradient in Mount Emei. *South Chin. Agric.*, 10: 248–250

Cao, R., F.Z. Wu, W.Q. Yang, Z.F. Xu, B. Tani, B. Wang, J. Li and C.H. Chang, 2016. Effects of altitudes on soil microbial biomass and enzyme activity in alpine-gorge regions. *Yin Yong Sheng J. Appl. Ecol.*, 27: 1257–1264

Cui, M. and C. Li, 2009. Advances in Occurrence and control techniques of konjac soft rot. *Chin. Plant Prot*., 29: 33–35

Diaz, H.F., M. Grosjean and L. Graumlich, 2003. Climate variability and change in high elevation regions: past, present and future. *Clim. Change*, 59: 1–4

Ding, Z.L., 2011. Effect of Glucomannan on Growth Curve of Pathogen of Soft Rot Disease in *Amorphophalms konjac*. *Acta Agric. Jiangxi*, 23: 111–112

Ding, Z.L., Z.Y. Wan, Z.B. Jiao, R. Zhou, X.H. Tan, K.K. Zhang and J.P. Wu, 2014. Progress and Countermeasures for Soft Rot Disease of *Amorphophallus konjac*. *Chin. Agric. Sci. Bull.*, 30: 238–241

Fierer, N., C.M. McCain, P. Meir, M. Zimmermann, J.M. Rapp, M.R. Silman and R. Knight, 2011. Microbes do not follow the elevational diversity patterns of plants and animals. *Ecology*, 92: 797–804

Fierer, N., J.P. Schimel and P.A. Holden, 2003. Variations in microbial community composition through two soil depth profiles. *Soil Biol. Biochem.*, 35: 167–176

Fu, X.Q., J.E. Liu and W.X. Huang, 2014. Studies on Rhizosphere Soil Microbial Quantity and Enzyme Acticity of Dongxiang Wild Rice in Different Growth Stages. *Acta. Agric. Univ. Jiangxiensis*, 36: 1191–1195

Gaston, K.J., 2000. Global patterns in biodiversity. *Nature*, 405: 220–227

Giri, D.D., P.N. Shukla, S. Kashyap, P. Singh and A.K. Kashyap, 2007. Variation in methanotrophic bacterial population along an altitude gradient at two slopes in tropical dry deciduous forest. *Soil Biol. Biochem.*, 39: 2424–2426

Han, L.M., F. Yan, S.Q. Wang, H.Y. Ju, Z.M. Yang and J.C. Yan, 2000. Primary identification of organic compounds in soybean rhizospheric soil on continuous and altermate cropping and their allelopathy on soybean seed germination. *Chin. J. Appl. Ecol.*, 11: 582–586

He, Z.X. and F. Zhu, 2011. Spatial Distribution of Soil Nutrient and Soil Microbes Along Altitude Gradient in the Xuefeng Mountain. *Chin. Agric. Sci. Bull.*, 27: 73–78

Hu, X., S. Cai, J.H. Liao, J. Huang and P. Yin, 2015. Responses of soil microbial and enzyme activity features of different altitudes of Mt. Emei. *J. Chongqing Normal Univ. (Nat. Sci.)*, 33: 109–114

Hu, Y.L. and X.F. Wu, 2002. Discussion soil microbial biomass a bio-indicator of soil quality for latosol earth. *J. Centr. South For. Univ.*, 22: 51–53

Li, X.G., 1984. The preliminarily investigation on the vertical distribution of the forest vegetation on Emei Mountain, Sichuan Province. *Acta Phytoecol. Geobot. Sin.*, 1: 52–66

Liang, C., E.C. Jesus, D.S. Duncan, R.D. Jackson and J.M. Tiedje, 2012. Soil microbial communities under model biofuel cropping systems in southern Wisconsin, USA: Impact of crop species and soil properties. *Appl. Soil Ecol.*, 54: 24–31

Liang, C., G. Cheng, D.L. Wixon and T.C. Balser, 2011. An Absorbing Markov Chain approach to understanding the microbial role in soil carbon stabilization. *Biogeochemistry*, 106: 303–309

Liao, Z.Y., Z.J. Zhang, M. Xie, L.G. Xie and X.J. Fu, 2013.Study on the Effect of Temple Health and Wellness in Temple Mount in Emei Mount. *Chin. J. Hlth. Med.*, 15: 85

Lucas, R.W., B.B. Casper, J.K. Jackson and T.C. Balser, 2007. Soil microbial communities and extracellular enzyme activity in the New Jersey Pinelands. *Soil Biol. Biochem.*, 39: 2508–2519

Lv, S., X. Zhang, Y. Tan, H.L. Liu, Z.P. Tian and G.P. Zeng, 2011. Dynamics between soil microorganism and soil character actors during carthamus tinctorius growth periods. *Pratacult. Sci.*, 28: 2084–2091

Ma, X., T. Chen, G. Zhang and R. Wang, 2004. Microbial community structure along an altitude gradient in three different localities. *Fol. Microbiol.*, 49: 105–111

Mannisto, M.K., M. Tiirola and M.M. Haggblom, 2007. Bacterial communities in Arctic fjelds of Finnish Lapland are stable but highly pH-dependent. *FEMS Microbiol. Ecol.*, 59: 452–465

Margesin, R., M. Jud, D. Tscherko and F. Schinner, 2009. Microbial communities and activities in alpine and subalpine soils. *FEMS Microbiol. Ecol.*, 67: 208–218

Marois, J.J., S.A. Johnston, M.T. Dunn and G.C. Papavizas, 1982. Biological control of *Verticillium wilt* of eggplant in the field. *Plant Dis.*, 66: 1166–1168

Mithofer, A., 2002. Suppression of plant defence in rhizobia-legume symbiosis Trends in Plant. *Science*, 7: 440–444

Pettersson, M. and E. Baath, 2003. Temperature-dependent changes in the soil bacterial community in limed and unlimed soil. *FEMS Microbiol. Ecol.*, 45: 13–21

Rousk, J., P.C. Brookes and E. Baath, 2010. The microbial PLFA composition as affected by pH in an arable soil. *Soil Biol. Biochem.*, 42: 516–520

Schinner, F. and G. Gstraunthaler, 1981. Adaptation of microbial activities to the environmental conditions in alpine soils. *Oecologia*, 50: 113–116

Shen, C., J. Xiong, H. Zhang, Y. Feng and X. Lin, 2013. Soil pH drives the spatial distribution of bacterial communities along elevation on Changbai Mountain. *Soil Biol. Biochem.*, 57: 204–211

Singh, B.K., R.D. Bardgett, P. Smith and D.S. Reay, 2010. Microorganisms and climate change: Terrestrial feedbacks and mitigation options. *Nat. Rev. Microbiol.*, 8: 779–790

Stroud, J.L., G.I. Paton and K.T. Semple, 2007. Microbe-aliphatic hydrocarbon interactions in soil: Implications for biodegradation and bioremediation. *J. Appl. Microbiol.*, 102: 1239–1253

Toth, I.K., K.S. Bell, M.C. Holeva and P.R. Birch, 2003. Soft rot erwiniae: from genes to genomes, *Mol. Plant Pathol.*, 4: 17–30

Wang, X.S., B.H. Du, L.T. Yao, S.L. Wang, Z. Xu and Y.Q. Ding, 2012. Effects of planting years on microbial communities structure in Peony rhizosphere soil. *J. Shandong Agric. Univ. (Nat. Sci.)*. 43: 501–507

Wu, F.Z., L.Z. Men and J.Z. Wen, 2002. Effect of root exudates on mycelium growth of cucumber *Fusarium* wilt. *Chin. Veg.*, 5: 26–27

Wu, Q.H., Y.T. Ma, G.Z. Wang, Q. Ma and R.C. Xu, 2012. Study of dynamic characteristics of soil microorganism in rhizosphere soils of *Aconitum carmichaeli* of different trophophase. *Pharm. Clin. Chin. Mater. Med.*, 3: 1–3

Wu, Y., B. Ma, L. Zhou, H. Wang and J. Xu, 2009. Changes in the soil microbial community structure with latitude in eastern China, based on phospholipid fatty acid analysis. *Appl. Soil Ecol.*, 43: 234–240

Wu, Z.Y., W.X. Lin, Z.F. Chen, C.X. Fang, Z.X. Zhang, L.K. Wu, M.M. Zhou and T. Chen, 2013. Variations of soil microbial community diversity along an elevational gradient in mid-subtropical forest. *Chin. J. Plant Ecol.*, 37: 397–406

Xu, R.B., J.P. Li, W. Kong, Z.G. Chen, C.Y. Li, J. Guo, L. Guo, X.L. Cao and X.H. Li, 2012. Effect of Elevation on the Soil Microbe Quantity in Tobacco-Growing Region of Baokang in Hubei Province. *Hubei Agric. Sci.*, 51: 5625–5627

Xue, S., P. Li, Z.B. Li, G.B. Liu and Y. Zheng, 2011. Soil microbial biomass and activity along an altitudinal gradient in dry-hot valley. *Chin. Environ. Sci.*, 31: 1888–1895

Yang, C.H., D.E. Crowley and J.A. Menge, 2001. 16S rDNA fingerprinting of rhizosphere bacterial communities associated with healthy and phytophora infected avocadotoots. FEMS *Microbiol. Ecol.*, 35: 129–136

Yang, Q., R. Wang, Y. Xu, C. Kang, Y. Miao and M. Li, 2016. Dynamic change of the rhizosphere microbial community in response to growth stages of consecutively monocultured *Rehmanniae glutinosa*. *Biologia*, 71: 1320–1329

Yergeau, E., S. Bokhorst, A.H.L. Huiskes, H.T.S. Boschker and R. Aerts, 2007. Size and structure of bacterial, fungal and nematode communities along an Antarctic environmental gradient. *FEMS Microbiol. Ecol.*, 59: 436–451

Yu, J.L. and H.X. Shi, 2011. Quantity of soil microbe in felty soil in different elevations in Yushu of Qinghai Province and affecting factors. *Chin. J. Grassl.* 33: 46–50

Zhang, L.H., Y.J. Wang, L. Liao and G.H. Ji, 2011. Biocontrol effect of *Lysobacter antibioticus* 06-4 on soft rot pathogen of *Amorphoph allus konjac* its mechanism. *J. Hunan Agric. Univ. (Nat. Sci.)*, 37: 286–289

Zhou, Y., L. Chen, X.L. Chai, Z.N. Yu and M. Sun, 2007. Isolation of endophytic antagonistic bacterium from *Amorphophallus konjac* and research on its antibacterial metabolite. *Acta Microbiol. Sin.*, 47: 1076–1079

(Received 18 May 2018; Accepted 31 May 2018)