Pak. J. Bot., 55(6): 2091-2099, 2023. DOI: http://dx.doi.org/10.30848/PJB2023-6(5)

SOIL INTRINSIC PROPERTIES CHANGES AND YIELD LOSS OF LANZHOU LILY (*LILIUM DAVIDII* VAR. *UNICOLOR*) UNDER CONTINUOUS CROPPING IN THE ARID AREA OF WESTERN CHINA

HONGYU YANG[1], LI HUI[1], HONGQIANG SUN[1], MOHAMMED MUJITABA DAWUDA[1,2], MOUQIANG LI[1,3] AND GUIYING SHI[1]*

[1]*College of Horticulture, Gansu Agricultural University, Lanzhou, China*
[2]*Department of Horticulture, FoA., University for Development Studies P. O. Box TL 1882, Tamale, Ghana*
[3]*Agricultural Technology Extension Center of Lintao, China*
[*]*Corresponding author's email: shigy@gsau.edu.cn*

Abstract

Lanzhou lily (*Lilium davidii* var. *unicolor*) is the only edible lily in China and it is a kind of narrow distribution endemic species and cultivated under monoculture and continuous system, which result in soil degradation and severe consecutive replant problems (CRPs). In this experiment, we investigated the soil physicchemical properties, microbial numbers, soil enzyme activities and yield in 20 sample fields with 0,3,6 and 9 years of replanting. The result showed that Continuous cropping significantly changed soil physiochemical properties and enzyme activities at the harvesting stage. By extending the period for replanting, the soil pH, salt content and organic matter increased significantly ($p<0.05$), while soil water content decreased significantly. The soil nutrient indexes such as Alkali-hydrolyzable nitrogen and available phosphorus also increased significantly while available potassium decreased. Moreover, the soil urease activities and phosphatase activities greatly improved, while hydrogen peroxidase and sucrase activities decreased with the continuous cropping. Generally, soil bacteria number decreased significantly, while soil fungi increased significantly, and the highest fungi/bacteria were recorded in the 9-year treatment. However, the highest actinomycetes numbers was recorded in 3-year and 9-year treatments. Continuous cropping also changed bulb yield and the yield components significantly, as well as deteriorated the bulb quality and storability. With prolonged replanting years, mother bulb weight and baby bulb numbers decreased, and the yield in 9-year treatment decreased significantly by 18.03% compared to 0-year treatment. These results demonstrated that soil transformation from a bacterial type to a fungal type, soil water-holding capacity decrease, soil salinization, especially excessive accumulation of available phosphorus played important role in soil degradation and yield decline under long-term continuous cropping. These results also suggest that some management practice such as soil disinfection, beneficial microorganism or bio-organic fertilizers usage, as well as decreasing phosphorus fertilizer input could help in maintain the soil quality and improve the yield and quality of Lanzhou lily in fields with more than 6 years of replanting.

Key words: Replant; Lily; Fungi/bacteria; Soil property; Enzyme activity; Yield.

Introduction

Lanzhou lily (*Lilium davidii* var. *unicolor*) is the only edible lily in China and it is commonly cultivated in the hilly region (2000-2600m above sea level) of the central Gansu Province, which belonged to the arid area in western China. The unique climate in the region gives the lily a special sweet taste and quality; hence, it is popular in southern China, Korea and Japan. As a result of the high economic value of the crop and limited land for crop cultivation, the crop is commonly put under long term continuous cropping system which result in soil degradation and severe consecutive replant problems (CRPs). The very obvious adverse effect of this system on the crop is declining yield and poor quality of the harvested produce. In order to overcome this problems, local famers usually apply high amounts of organic fertilizers yearly to maintain the fertility of the soil. This, however, has not been able to improve the situation as farmers continuously obtain lower yields with poor quality produce.

Soil microbial activities are important to sustainable agriculture because microbes can mediate many biochemical processes that support agricultural production. These processes include recycling of plant nutrients, maintenance of soil structure and degradation of agrochemicals (Lanzen *et al*., 2013). Consequently, its abundance, diversity, and composition are sensitive to the changes in land use and management. Therefore, these can be been considered as early indicators of change in the quality of soil ecosystems (Castellanos *et al*., 2009; Trivedi *et al*., 2016). The activities of soil microbes are also closely related to plant species, as well as the soil type and soil management practices (Berg & Smalla, 2009). Replanting is reported to influence root physiology and the quality and quantity of root exudates; consequently, these changes exert a selection on root-associated microorganisms (Wu *et al*., 2015; Zhang *et al*., 2016). Many reports revealed the negative effects of soil microbes on plant growth and yield and discussed some important bacterium and fungi communities related to crop CRPs (Franke-Whittle *et al*., 2015; Xiong *et al*., 2015; She *et al*., 2017). For instance, with increased years of replanting wheat, soybean, potato, peanut and leek, populations of beneficial bacteria and actinomycetes in plant rizosphere decreased significantly, while harmful soil fungi increased significantly (Sun *et al*., 2001; Li *et al*., 2006; Li, 2006; Wang *et al*., 2010; Qin *et al*., 2017). Consequently, the microbial population structure becomes unbalanced with harmful microorganisms such as *Fusaria* and *Mortierella*, providing negative effect on plant root growth (Wang *et al*., 2012). For Lanzhou Lily, we identified five pathogenic fungi (including *Fusarium oxysporium*) which caused the lily wilt (a kind of soil-borne disease) in field sunder long term continuous cropping (Bian *et al*., 2016). In addition, soil enzymes play very important role in material cycle and energy conversion in the soil ecosystem (Qiu *et al*., 2011), and they can serve as important indicators for measuring the movement and strength of various soil biochemical processes (Rasool *et al*., 2014). However, some reports revealed that enzyme activities can be restricted with continuous cropping, but the case was complex (Zhang *et al*., 2008; Liu *et al*., 2010; Miao *et al*., 2016).

Being a narrow distribution crop, there are only fewer reports related to Lanzhou lily CRP (Bian *et al*., 2016; Chen *et al*., 2016), and these reports mainly focused on the lily soil-borne disease and autotoxin city problems (Wu *et al*., 2015; Bian *et al*., 2016). The objectives of this research were: (1) to determine the effect of length of continuous cropping of Lanzhou lily on soil microbial community characteristics, soil physical and chemical properties and enzyme activity; (2) to determine the factors that influences the rate of changes that occur in the soil under long term continuous cropping of Lanzhou lily.

Materials and Methods

Field description and soil sampling: The experiment was conducted at BaoJiashan village, Lintao county, Gansu province (western China, 103°53′12″～103°53′14″E, 35°49′11″～35°49′13″N, 2330m elevation). The soil is locally known as Huangmian soil and it has a deep soil layer, high water–storage capacity, pH 7.8 and organic matter, 13g.kg-1. The site has been utilized for the cultivation of Lanzhou lily for over 140 years.

Because Lanzhou lily is grown for 3 years before harvest, we designed the experiment with 4 treatments as follows: 0-year (never crop lily), 3-year (crop lily for3 year), 6-year (monocrop lily for 6 year), 9-year (monocrop lily for 9 year). After investigation focused on its planting history and soil properties and spatial variation, four types of 20 sampling sites were chosen (five sampling sites for each treatment) and 66 ㎡ (11m×6m) was chosen as one plot in each sampling site. The lily was planted with density of 0.30m×0.15m per plan let in March 28, 2016 (the bulblet seed was about 17±2g) and managed by traditional agricultural practices in this region with high organic fertilizer (composed sheep or chicken manure 30m3/ha each year) and without irrigation.

Soil sample collection: Within each plot, soil samples were obtained from within the root zone of the sampled plants. Then, the rhizosphere soils were gently mixed together in each plot. All the samples were transferred to the lab for further measurements.

Microbial community assay: This was conducted at four stages: seedling stage (June 10, 2016), flowering stage (July-18, 2016), capsule formation stage (September-1, 2016) and harvesting stage (Octbor-15, 2016). The bacteria were cultured in a beef extract peptone medium, the fungi were cultured in a Rose Bengal medium Bangladesh red medium, and actinomycetes were cultured in a Gauze medium high-growth medium. The plate counting method was used to determine the amount of soil microorganisms.

Soil physical and chemical properties and soil enzyme assay: This was done at the harvesting stage (Octbor-15, 2016). Soil physiochemical property assay was based on the following methods: soil pH value was measured by portable pH meter (Model: HANNA HI8314) according to V soil: V water = 1: 5; EC value was measured by Shanghai Ray magnetic conductivity meter DDS-307A; Bulk density was measured by the cutting ring method; Salt content was measured by drugs drying-Quality method, Water content was measured by oven-drying method; Organic matter was measured by potassium dichromate method; Alkali-hydrolyzable nitrogen was measured byalkali-diffusion method, Available phosphorus was measured by Mo-Sb colorimetric method, Available potassium was measured by flame photometry method. Partially data were described in our published work (Shi et al., 2020).

Soil enzyme assay was based on the following methods: Hydrogen peroxidase activity was determined using KMnO4 titration method; Urease activity was measured using phenol sodium hypochlorite colorimetric method; Alka line phosphatase activity was measured using disodium phenyl phosphate colorimetric method, and Sucrase activity determined using Dinitrosalicylic acid colorimetric (DNS) method.

Yield determination: The yield was measured in October 15th, 2016. Twenty (20) plants were randomly selected and the yield was estimated by the planting density. Yield components were also assessed using these twenty tagged plants for each treatment plot.

Data analysis: Microsoft Excel 2010 software was used for raw data processing and charting. Analysis of variance was performed using SPSS 19.0 statistical software. Significant difference was detected using Duncan's multiple comparison method (p<0.05).

Results

Continuous cropping effects on soil physical and chemical properties in Lanzhou lily: Continuous cropping years affected soil physical and chemical properties (Table 1). Comparison of the 9-year treatment with 0-year treatment, soil pH significantly (p<0.05) increased to 7.99±0.06, an increase of 2.96%. By comparing the 6-year and 9-year treatments with 0-year treatment, the soil salt content increased significantly by 66.67% and 108.33%, respectively, while the soil water content decreased significantly by 9.66% and 17.19%, respectively. However, no significant difference in soil bulk density was recorded among all the treatments.

Continuous cropping years also affected soil nutrient content (Table 1). The results showed that in the6-yearand 9-year treatments, the soil organic matter increased significantly by 11.58% and 25.28%, over the 0-year treatment, respectively. In addition, the soil alkali-hydrolyzable nitrogen increased significantly by 26.72% and 27.76%, over the 0-year treatment, respectively. Moreover, soil available phosphorus increased significantly by 105.68% and 122.22%, over the 0-year treatment, respectively. However, soil available potassium decreased significantly by 13.38% and 27.69%, respectively, when compared with the 0-year treatment.

Continuous cropping of Lanzhou lily affects soil enzymes activities: Continuous cropping years affected soil enzyme activities (Fig. 1). Soil hydrogenate peroxidase and sucrase activities decreased gradually with replanting years, while urease and alkaline phosphatase activities increased gradually. The 6-yearand 9-year treatments decreased soil hydrogenate peroxidase activity significantly by 32.82% and 47.10%, respectively compared with the 0-year treatment. By comparing the 3, 6and 9-year treatment with the 0-year treatment, soil sucrase activity decreased significantly by 10.26%, 16.77% and 30.97%, respectively. In addition, soil alkaline phosphatase increased significantly by 12.12%, 19.70% and 36.36%, respectively. However, soil urease activity those treatments increased significantly by 11.44%, 17.30% and 24.93%, compared with the 0-year treatment.

Continuous cropping effects on soil bacteria and fungi in Lanzhou lily: The soil bacteria populations were affected by long term continuous cropping of Lanzhou lily (Fig. 2): From seedling stage to harvesting stage, bacterial numbers decreased with increase in the years of continuous cropping. At the four growth stages, compared with o-year treatment, bacterial numbers in the 6-yeart treatment decreased significantly (p<0.05) by 19.09%, 26.55%, 31.77% and 26.83%, respectively. Similarly, bacterial numbers in the 9-year treatment also reduced significantly by 33.06%, 46.51%, 31.77% and 40.73%, respectively. However, no significant difference was observed between the 6-year treatment and 9-year treatment. Moreover, in every treatment, the maximum bacterial numbers were observed during the flowering stage.

The soil fungi populations were affected by long term continuous cropping of Lanzhou lily (Fig. 3). From the seedling stage to harvesting stage, fungi numbers increased with increase in number of years of continuous cropping. At the four growth stages, compared with 0-year treatment, fungi numbers increased in the 6-year treatment significantly (p<0.05) by 39.29%, 135.71%, 106.06%, and 123.18%, respectively. Similarly, fungi numbers in 9-year treatment also increased significantly by 157.14%, 224.11%, 158.33% and 167.55%, respectively. Moreover, significant difference was observed between the 6-year treatment and 9-year treatment. And the maximum fungal numbers were observed in the flowering stage in every treatment.

The actinomycetes populations were affected by long term continuous cropping of Lanzhou lily (Fig. 4): From the seedling stage to harvesting stage, compared with the 0-year treatment, actinomycete numbers in the 3-year treatment significantly (p<0.05) increased firstly, then decreased in the 6-yeartreatment, and increased again in the 9-year treatment. Moreover, in every treatment, the maximum actinomycetes numbers were observed during the flower stage.

Continuous cropping effects on yield and yield components of Lanzhou lily: Long term continuous cropping affected the yield and yield components of Lanzhou lily (Table 2). After one year of growth, mother seed grew bigger into big mother bulb and produced several baby bulb son its side (the mass <1 g/baby bulb). With the increase of continuous cropping years, mother bulb weight, baby bulb numbers and yield gradually decreased. In comparison of the 3-year treatment with 0-year treatment, these three indexes did not decrease significantly. However, by comparing the 6-year and the 9-year treatments with the 0-year treatment, mother bulb weight decreased significantly (p<0.05) by 15.54% and 18.02%, respectively, and the baby bulb numbers also decreased significantly by 37.71% and 44.92%, respectively. Thus, the yield decreased significantly the yield in 9-year treatment decreased significantly by 18.03% compared to 0-year treatment. Moreover, dry matter of mother bulb also decreased with increasing years of replanting.

Meanwhile, continuous cropping also affected bulb diameter. By comparingthe3 and 9-year treatments with 0-year treatment, the horizontal diameter of mother bulbs decreased significantly by 5.07% and 10.89%, respectively (p<0.05), while the vertical diameter did not change significantly. Thus, the spherical index decreased with replanting years.

Correlation analysis on the soil microbe, enzyme activity and physicochemical properties: Some soil physicochemical properties indexes dynamics related to the change of microbial numbers and soil enzyme activities (Table 3). Bulk density significantly (p<0.05) and negatively correlated with fungi numbers urease activity and alkaline phosphatase activity, but positively correlated with hydrogenate peroxidase activity and sucrose activity. Water content so significantly and negatively correlated with fungi numbers, fungi/bacteria, urease activity, alkaline phosphatase activity. It, however, correlated positively with bacteria numbers, hydrogenate peroxidase activity and sucrose activity. The pH significantly and negatively correlated with sucrose activity, but positively correlated with urease activity, alkaline phosphatase activity. However, there was no significant correlation with fungi numbers and bacteria numbers. Salt content significantly and positively correlated with fungal numbers fungi/bacteria, alkaline phosphatase activity, but negatively correlated with bacteria numbers, hydrogenate peroxidase activity and sucrose activity.

Moreover, some soil nutrition indexes dynamics also related to the shift of some microbe and enzyme activity indexes (Table 2): Organic matter content significantly and negatively correlated with hydrogenate peroxidase activity and sucrose activity, but positively correlated with fungal numbers, fungi/bacteria and alkaline phosphatase activity. Alkali-hydrolysable nitrogen significantly and negatively relevant to hydrogenate peroxidase activity; Available phosphorus significantly and negatively correlated with hydrogenate peroxidase activity but positively correlated with urease activity. Available potassium significantly and negatively correlated with fungal numbers, fungi/bacteria, urease activity, alkaline phosphatase activity and positively correlated with hydrogenate peroxidase activity and sucrase activity.

Table 1. Changes in soils physicochemical properties under long term continuous cropping of Lanzhou lily.

Treatments	Bulk density ($g\ cm^{-3}$)	Water content (%)	pH	Salt content ($g\ kg^{-1}$)	Organic matter ($g\ kg^{-1}$)	Alkali-hydrolyzable nitrogen ($mg\ kg^{-1}$)	Available phosphorus ($mg\ kg^{-1}$)	Available potassium ($mg\ kg^{-1}$)
0-year	1.33 ± 0.01a	14.63 ± 0.20a	7.76 ± 0.07b	0.48 ± 0.03c	13.21 ± 0.21c	65.16 ± 2.25b	94.48 ± 2.08c	236.55 ± 6.25a
3-year	1.32 ± 0.01a	14.20 ± 0.36a	7.87 ± 0.05ab	0.58 ± 0.02c	13.96 ± 0.23bc	71.32 ± 1.50b	146.18 ± 10.36b	219.73 ± 6.14ab
6-year	1.31 ± 0.01a	13.19 ± 0.24b	7.90 ± 0.07ab	0.80 ± 0.02b	14.74 ± 0.28b	82.57 ± 2.23a	194.33 ± 5.79a	204.89 ± 8.24b
9-year	1.30 ± 0.01a	12.09 ± 0.16c	7.99 ± 0.06a	1.08 ± 0.08a	16.55 ± 0.34a	83.25 ± 1.79a	209.95 ± 7.50a	171.04 ± 7.27c

Table 2. Yield components and yield of Lanzhou lily under long term continuous cropping.

Treatment	Weight /g	dry matter	Mother bulb			The number of baby bulb	weight of baby bulb /g	Yield /(Kg·hm-2)
			horizontal diameter /mm	vertical diameter /mm	Spherical index			
0-year	31.08 ± 1.40a	93.14%	42.42 ± 1.53a	36.87 ± 0.86a	1.1505	11.80 ± 0.16a	0.82 ± 0.15a	6837.63a
3-year	30.26 ± 0.89a	92.76%	40.43 ± 0.38a	35.50 ± 0.95a	1.1780	10.43 ± 0.38a	0.85 ± 0.09a	6657.23a
6-year	26.25 ± 1.38b	92.48%	40.27 ± 1.37ab	35.04 ± 1.48a	1.1493	7.35 ± 0.20b	0.76 ± 0.22a	5775.03b
9-year	25.48 ± 1.69b	92.31%	37.80 ± 1.81b	34.37 ± 1.42a	1.0998	6.50 ± 0.28c	0.78 ± 0.18a	5605.63b

Note: The yield determination is not included in baby bulbs. Spherical index=horizontal diameter/vertical diameter

Table 3. Correlations between soil physicochemical properties, enzyme activities and microbial communities under long term continuous cropping of Lanzhou lily.

	Fungal	Bacteria	Fungi/Bacteria	Actinomycetes	hydrogenate peroxidase	Urease	Alkaline phosphatase	Sucrase
Bulk density	-0.968*	0.903	-0.942	-0.687	0.990**	-0.990**	-0.990*	0.990*
water content	-0.994**	0.959*	-0.987*	-0.607	0.991**	-0.951*	-0.982*	0.982*
PH	0.907	-0.811	0.89	0.818	-0.942	0.994**	0.986*	-0.986*
Salt content	0.992**	-0.956*	0.990*	0.62	-0.986*	0.948	0.984*	-0.984*
organic matter	0.969*	-0.921	0.980*	0.696	-0.964*	0.949	0.991**	-0.992**
Alkali-hydrolysable nitrogen	0.928	-0.873	0.859	0.527	-0.966*	0.946	0.905	-0.905
Available phosphorus	0.919	-0.84	0.86	0.655	-0.965*	0.982*	0.941	-0.941
Available potassium	-.967*	0.913	-0.974*	-0.712	0.967*	-0.960*	-0.996**	0.996**

Note: The microbial numbers, enzyme activities, and physicochemical properties data were measured at harvesting stage (2016. 2016-10-15)

* Means relevance is significant at the 0.05 level; ** Means relevance is significant at the 0.01 level

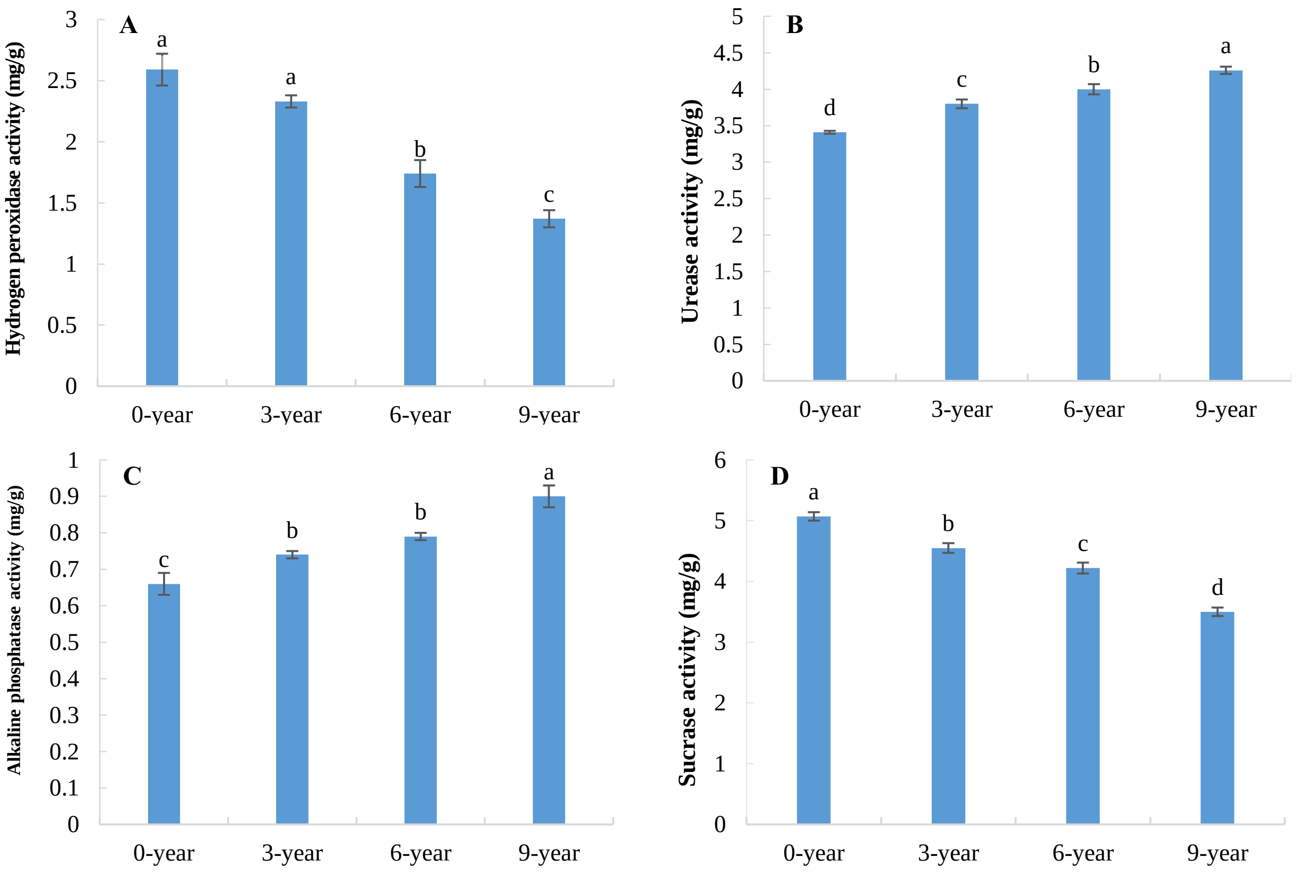

Fig. 1. Soil enzyme activities under long term continuous cropping of Lanzhou lily at harvesting stage.

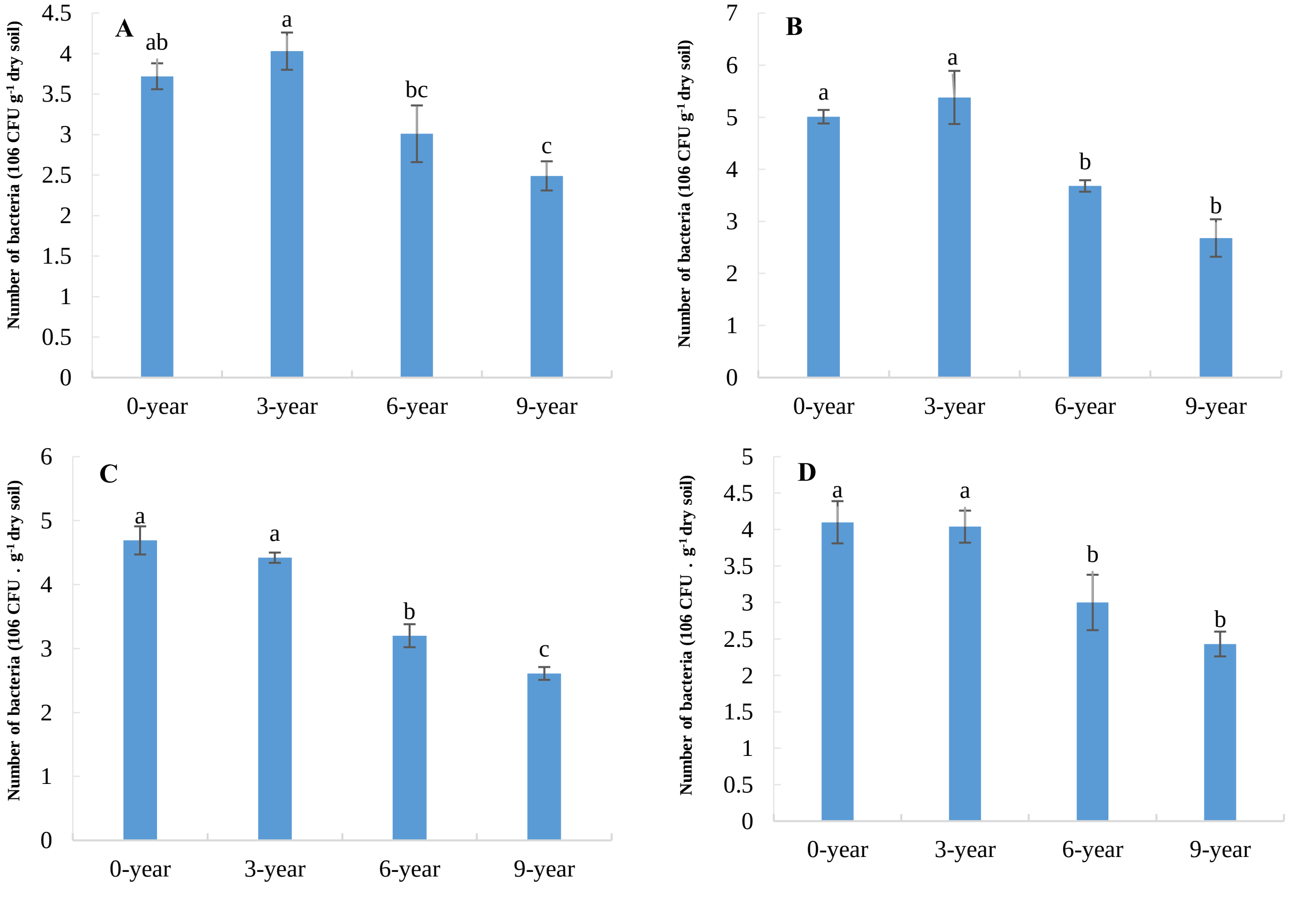

Fig. 2. Soil bacteria population dynamics under long term continuous cropping of Lanzhou lily at seedling stage: Jun-10 (A), Flowering stage: Jul-18 (B), Capsule formation stage: Sep-1 (C), Harvesting stage: Oct-15 (D).

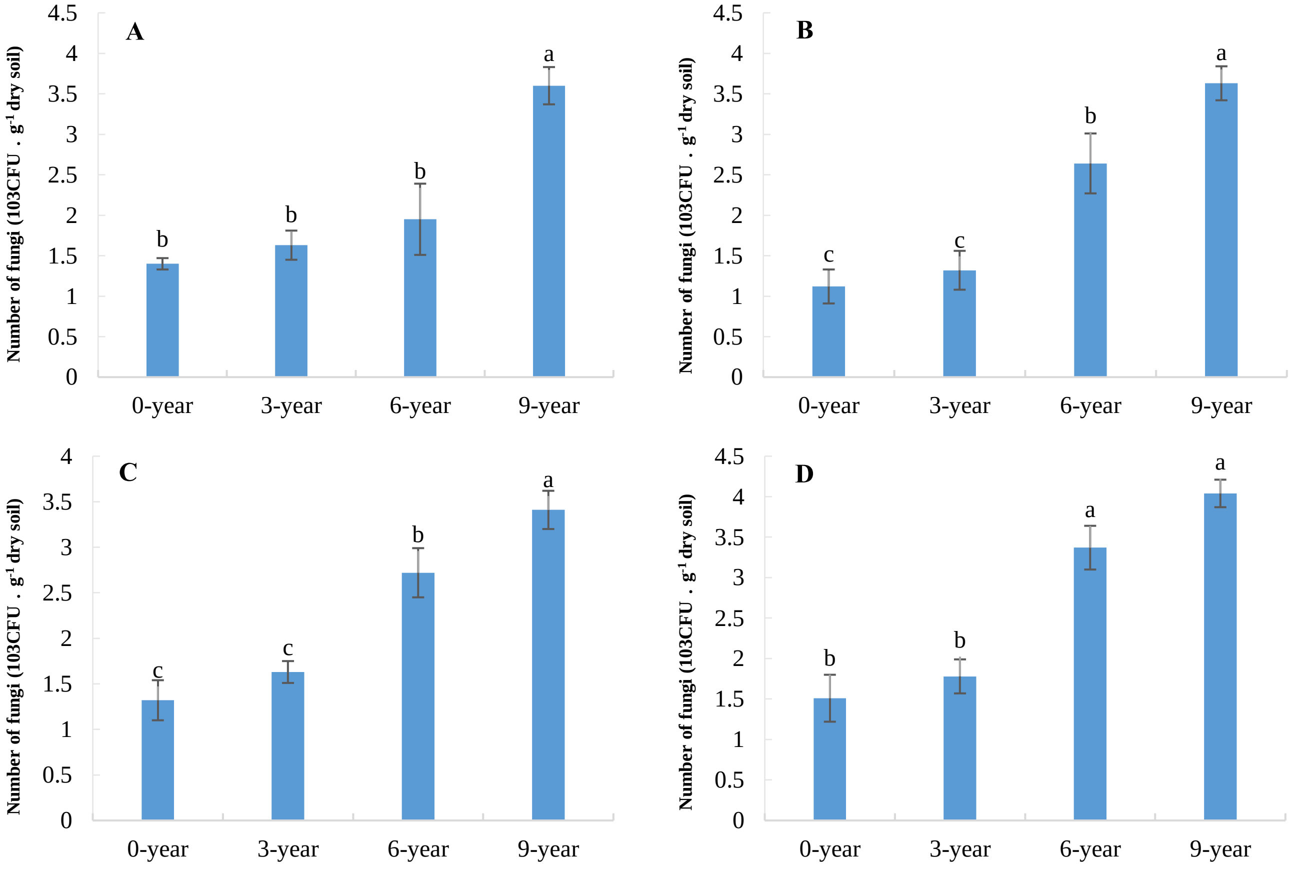

Fig. 3. Soil fungi population dynamics under long term continuous cropping of Lanzhou lily at seedling stage: Jun-10(A), Flowering stage: Jul-18(B), Capsule formation stage: Sep-1(C), Harvesting stage: Oct-15(D)

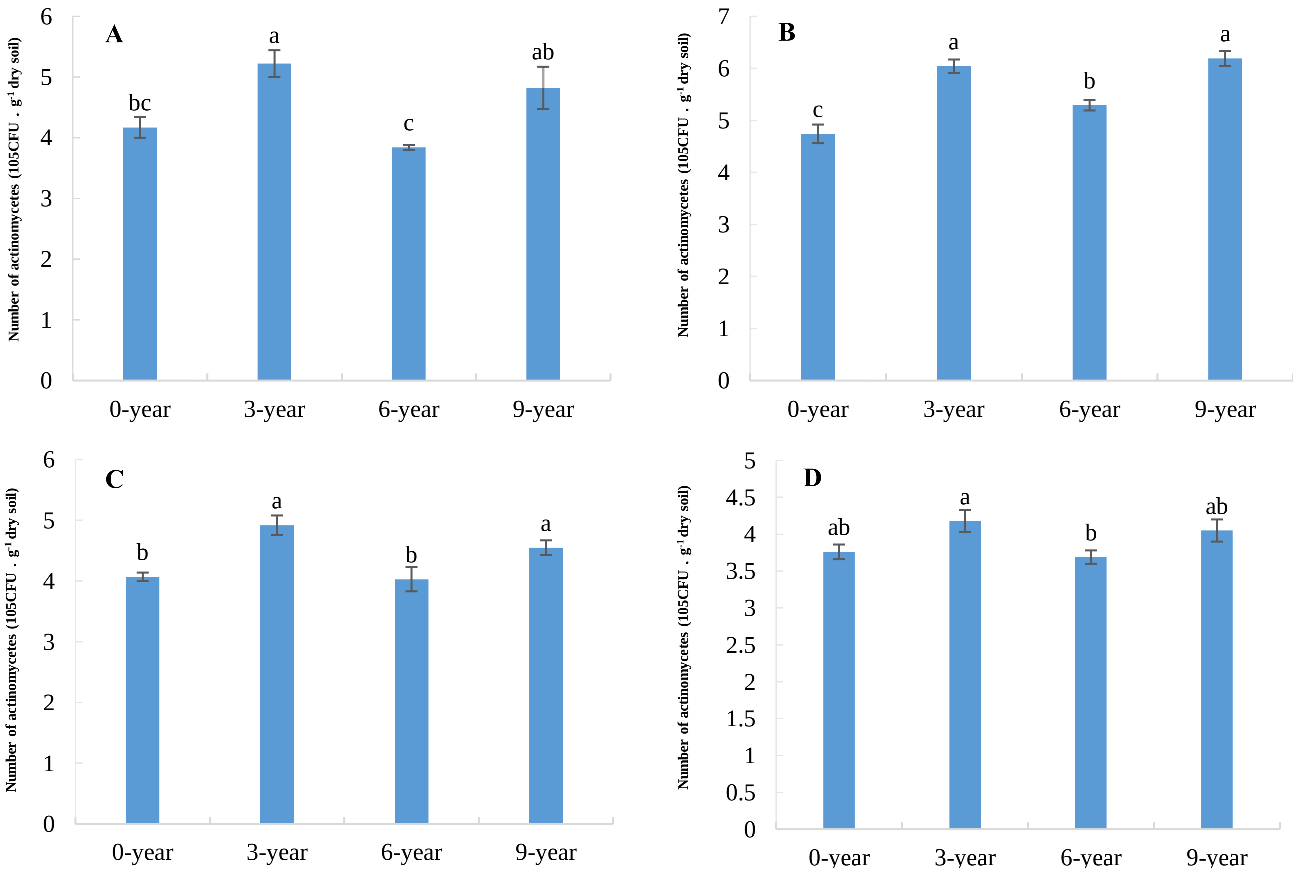

Fig. 4. Soil actinomycetes population dynamics under long term continuous cropping of Lanzhou lily at seedling stage: Jun-10 (A), Flowering stage: Jul-18 (B), Capsule formation stage: Sep-1 (C), Harvesting stage: Oct-15 (D).

Discussion

It is reported that the change in soil microbial community is regarded as one of the main factors of CRP (Larkin 2008).This experiment showed that with extension of replanting period of Lanzhou Lily, the root rhizosphere fungi numbers increased and the bacteria numbers decreased significantly (Figs. 2, 3.). This finding agreed with some previous reports (Alvey *et al*., 2001; Sun *et al*., 2001; Ma *et al*., 2004; Li *et al*., 2006; Li 2006; Wang *et al*., 2010; Qin *et al*., 2017), which also detected the microorganism numbers on medium and the results revealed that with cereal, wheat and vegetables long-term continuous cropping, the soil fungi harmful to root rhizosphere increased, while bacteria and actinomycetes beneficial to plant roots decreased significantly. Thus, the soil microbe shifted from bacteria type to fungi type. However, our experiments showed that the dynamics of soil actinomycetes has not the similarity as it is demonstrated in cereal and potato continuous cropping (Alvey *et al*., 2001; Qin *et al*., 2017) (Fig. 4.).

Crop cultivation is known to generally reduce the amount of soil organic matter and replanting reduce it sharply, thus reducing nutrient availability (Sun *et al*., 2015; Trivedi *et al*., 2016), but for Lanzhou lily, the case was different, because from 0 years to 9 years replanting, the soil organic matter increased from 13.96 to 16.55 g · kg-1 (Table 1). This crop is cultivated perennial, and before harvest, its leaf and stem died at winter and stayed in the field without any cleaning practice. On the other side, being the lily is very sensitive to chemical fertilizer input, the soil was managed by in putting organic fertilizer to maintain its productivity (composed sheep or chicken manure 30m3/ha each year). Thus, the soil organic matter increased under long term replanting years. Some reports mentioned that under long-term monocropping, organic fertilizer treatment causes a shift in bacterial community structure and increase in bacterial diversity and abundance in comparison to long-term use of chemical fertilizer by high-throughput sequencing (Chaudhry *et al*., 2012; Kelderer *et al*., 2012). There are lots of bacterium in the soil, we only detected the culturable bacterium on beef extract peptone medium, but in the soil, there are much more bacteria which cannot be cultured on medium. So, it is necessary to make further study on the microorganism dynamics in this replanting system.

Soil moisture holding capacity decrease is another important factor related to the lily replant soil degradation. It is very interesting that although the soil organic matters significant increased and buck density in significant decreased with replanting years, water content in significantly decreased (Table 1). However, Pearson correlation analysis demonstrated that it significantly negative relevant to fungi numbers and positive relevant to bacteria numbers (Table 3). Thus, we believe that water content is a one of the main factors to drive the soil microbe shifted from bacteria type to fungi type. This result agreed with recently published report which demonstrated that soil moisture was one of important factors for explaining bacterium and fungi community structure variations by comparing the microbial communities in conventional tillage with reduced tillage (Degrune *et al*., 2017). Soil pH has also been reported as a predictor of bacterial community structure (Lauber *et al*., 2009; Trivedi *et al*., 2016). Our team identified five *Fusarium* sp. As Lanzhou Lily wilt pathogens and proved that the medium pH 8 was optimum for the fungi hypha growth and spore germination (our research result, not published). In this study, the soil pH value increased from 7.76 in0-year treatment to 7.99 in9-year treatment (Table 1). Thus, it is speculated that with the lily replanting, the increase value of soil pH enhanced the pathogenic propagation and affection, therefore aggravates the occurrence of wilt disease. However, because suitable pH for Lanzhou lily is lower than 8.2, the soil pH is still optimum for the Lily growth after nine years of replanting. Lily replanting also resulted in the soil salt content accumulation, which agree with the previous reports of replanting problems related to many vegetables cultivated with plastic film mulching (Chen *et al*., 2014; Yu *et al*., 2015). It is generally considered that the soil secondary salinization occurs when the soluble salt content is 1.0-3.0 g/kg, and Lanzhou Lily is very sensitive to salt stress (Zhao *et al*., 2008).The salt content reached 1.08±0.08 g/kg after nine years of replanting (Table 1). So we conclude that lily soil might be salinized for long-term replanting.

These results also showed that the impact of crop replanting on soil enzymes activities is complex and the their responses might be caused by differences among plant species, monoculture time span and cropping practice. It is generally regarded that soil alkaline phosphatase, sucrose, urease and hydrogenate peroxidase reduced when the crop (potato, peanut and foxtail millet) replanting years is long enough and the continuous cropping problems were observed (Sun *et al*., 2001; Wang *et al*., 2010; Miao *et al*., 2016; Qin *et al*., 2017). But our results indicated that with continuous cropping, both hydrogenate peroxidase and sucrase activities decreased, while soil urease and alkaline phosphatase activities were greatly improved (Fig. 1). It is reported that in garlic replanting system, 5-10 years of replanting increased the rhizosphere soil urease and phosphatase activities, but in a long period of time (from 15 to 20 years), these two enzyme activities decreased significantly (Liu *et al*., 2010). Moreover, another report about Chinese Chives demonstrated that with 5-20 years replanting , these two enzyme activities decreased (Wang *et al*., 2010). Lanzhou Lily, garlic and Chinese chives are classification as allium vegetables with fleshy root and was perennial cultured. So our result may be explained that for Lanzhou lily, 9 years replanting is not long enough to result in the decrease of these two soil enzymes activities.

Based on the data of soil basic fertility and the fertilization scheme demonstrated in the reference about Lanzhou Lily fertilization scheme in this main production region (Huang 2007; Lin *et al*., 2011; Lin & Luo, 2011), we calculated the suitable soil nutrient requirements following: available nitrogen 90-100 mg/kg, available phosphorus 37 mg/kg and available potassium 200 mg/kg. Our experiments indicated that during 9 years of continuous cropping, the Lily soil alkalized nitrogen was still lower than its nutrient requirement, and the soil available potassium began to fall and below the nutrient requirement. But the soil available phosphorus greatly accumulated, which was 2 times morein 0-year treatment and 6 times more in 9-year treatment compared to the suitable nutrient requirement. Both the insufficient nitrogen and potassium can be supplemented by fertilizing, while much more abundant phosphorus in replanting soil hardlydecrease. In this area, farmers often mix phosphorus fertilizer and organic fertilizer together (50-75 calcium superphosphate (P_2O_5 content: 12%)/ perM3 sheep or chicken manure) without any microbial inoculum, this may be the reason of high available phosphorus accumulation in this replant system. Therefore, we believe that phosphorus accumulation is another important factor on the lily soil nutrition degradation after long-term replanting.

Conclusion

Long-term continuous cropping of Lanzhou lily decreases the yield by decreasing mother bulbs weight, as well as the baby bulbs numbers. It also decreases the quality of the produce by decreasing the dry matter content, increasing the water content, and thus, deteriorates the food quality of the produce. These results demonstrated that soil transformation from a bacterial type to a fungal type, soil water-holding capacity decrease, soil salinization, especially excessive accumulation of available phosphorus played important role in soil degradation and yield decline under long-term continuous cropping. These results also suggest that some management practice such as soil disinfection, beneficial microorganism or bio-organic fertilizers usage, as well as decreasing phosphorus fertilizer input could help in maintain the soil quality and improve the yield and quality of Lanzhou lily in fields with more than 6 years of replanting.

Acknowledgment: This research was funded by the National Natural Science Foundation of China, grant number 31860549; the Key research project of Gansu province of China, grant number 22YF7NA108

Funding: This research was funded by the National Natural Science Foundation of China, grant number 31860549; the Key research project of Gansu province of China, grant number 22YF7NA108.

References

Alvey, S., M. Bagayoko, G. Neumann and A. Buerkert. 2001. Cereal/legume rotations affect chemical properties and biological activities in two West African soils. *J. Plant Soil*, 231(1): 45-54.

Berg, G. and K. Smalla. 2009. Plant species and soil type cooperatively shape the structure and function of microbial communities in the rhizosphere. *J.* FEMS *Microbiol. Ecol.*, 68(1): 1-13.

Bian, X.R., G.Y. Shi, Q.L. Liang, H.Q. Sun, S.F. Fan and J.I. Chen. 2016. Lanzhou lily blight pathogen isolation and identification of pathogenic measurement. *J. Gansu Agri. Uni*., 4: 58-64.

Castellanos, T., A.B. Dohrmann, G. Imfeld, S. Baumgarte and C.C. Tebbe. 2009. Search of environmental descriptors to explain the variability of the bacterial diversity from maize rhizospheres across a regional scale. *Europ. J. Soil Biol.*, 45(5): 383-393.

Chen, J.L., H.Q. Sun, S.F. Fan, L. Li, G.Y. Shi, X. Qu and H.Y. Yang. 2016. Of lily seedlings from lanzhou lily root secretion study. *J. Gansu Agri. Uni.*, 6: 64-69.

Chen, Y.H., J.Q. Guo and X.D. Zhang. 2014. Climatic regionalization of 100 suitable crops in Lanzhou based on GIS. *J. Arid Meteorol.*, 32(01): 157-161.

Degrune, F., N. Theodorakopoulos, G. Colinet, M.P. Hiel, B. Bodson, B. Taminiau, G. Daube, M. Vandenbol and M. Hartmann. 2017. Temporal dynamics of soil microbial communities below the seedbed under two contrasting tillage regimes. *Front. Microbiol.*, 8: 1127**.**

Franke-Whittle, I.H., L.M. Manici, H. Insam and B. Stres. 2015. Rhizosphere bacteria and fungi associated with plant growth in soils of three replanted apple orchards. *Plant Soil*, 395(1/2): 317-333.

Huang, P. 2007. Effects of fertilization on plant growth and bulb yield of Lanzhou lily. *Plant Nutr. Fert. Sci.*, (04): 753-756.

Kelderer, M., L.M. Manici, F. Caputo and M. Thalheimer. 2012. Planting in the 'inter-row' to overcome replant disease in apple orchards: A study on the effectiveness of the practice based on microbial indicators. *Plant Soil*, 357: 381-393.

Lanzén, A., A. Simachew, A. Gessesse, D. Chmolowska, I. Jonassen and L. Ovreas. 2017. Surprising prokaryotic and eukaryotic diversity, community structure and biogeography of Ethiopian soda lakes. *PLoS One*, 8(8): e72577.

Larkin, R.P. 2008. Relative effects of biological amendments and crop rotations on soil microbial communities and soilborne diseases of potato. *Soil Biol. Biochem.*, 40(6): 1341-1351.

Lauber, C.L., M. Hamady, R. Knight and N. Fierer. 2009. Pyrosequencing-based assessment of soil pH as a predictor of soil bacterial community structure at the continental scale.[J]. *Appl. Environ. Microbiol.*, 75(15): 5111-20.

Li, C.G., X.M. L.I. and J.G. Wang. 2006. Effects of soybean continuous cropping on soil and rhizosphere microbial community function. *Acta Ecol. Sinica*, 4: 1144-1150.

Li, Q.F. 2006. Dynamics of the *Microbia* L florain the liriope rhizosphere and out rhizosphere during continuous cropping years. *Chinese J. Soil Sci.*, 37(3): 563-565.

Lin, Y.H. and J.J. Luo. 2011. Effects of Nitrogen on yield, nutrient accumulation and quality of lily in Lanzhou [J]. *Acta Prataculturae Sinica*, 20(05): 223-230.

Lin, Y.H., F.X. Guo, J.J. Luo, J.H. Sun and Y.H. Zhang. 2011. Effects of different nitrogen application levels on nutrient accumulation and nitrogen utilization of lily in arid land [J]. *Acta Prataculturae Sinica*, 20(2): 101-108.

Liu, S.H., S.Q. Liu, Z.K. Zhang, H. Wei, J.J. Qi, and J.F. Duan. 2010. Effects of continuous cropping of garlic on rhizosphere soil microbial and enzyme activities [J]. *Scientia Agri. Sinica*, 43(5): 1000-1006.

Ma, Y.H., M. Wei and X.F. Wang. 2004. Changes of root microbial flora and enzyme activities of cucumber in solar greenhouse. *Chinese J. Appl. Ecol.*, (6): 1005-1008.

Miao, J.Y., X. LI, D. Zhou, Y., Gao, X.L. Gao, P.K. Wang, J.F. Gao, P. Yang and B.L. Feng. 2016. Effects of continuous cropping on enzyme activities and nutrients in millet soil. *Agric. Res. Arid Areas*, 34(03): 123-126-152.

Qin, S.H., S. Yeboah, L. Cao, J. Zhang, S.L. Shi and Y.H. Liu. 2017. Breaking continuous potato cropping with legumes improves soil microbial communities, enzyme activities and tuber yield. *Plos One*, 12(5): e0175934.

Qiu, Y., Y.J. Wang, Z.K. Xie and Y.J. Zhang. 2011. Effects of gravel mulch on soil organic carbon, microorganism and soil enzyme activities in farmland [J]. *Acta Agri. Northwest China*, 20(10): 176-180.

Rasool, N., Z.A. Reshi, M.A. Shah. 2014. Effect of butachlor (G) on soil enzyme activity. *Europ. J. Soil Biol.*, 61: 94-100.

She, S., J.J. Niu, C. Zhang, Y.H. Xiao, W. Chen, L.J. Dai, X.D. Liu and H.Q. Yin. 2017. Significant relationship between soil bacterial community structure and incidence of bacterial wilt disease under continuous cropping system. A*rch. Microbiol.*, 99(2): 267-275.

Shi, G.Y., H.Q. Sun, A. Calderón-Urrea, X.X. Jia, H.Y. Yang and G.L. Su. 2020. Soil fungal diversity loss and appearance of specific fungal pathogenic communities associated with the consecutive replant problem (CRP) in Lily. *Front. Microbiol.*, 11: 1649.

Sun, X.S, H.S. Feng, S.B. Wan and X.Q. Zuo. 2001. Changes of main microbial groups and soil enzyme activities in continuous cropping peanut field and their interactions. *Acta Agronomica Sinica*, (05): 617-621.

Sun, X.T., G.Q. Long, G.H. Zhang, B. Meng, Z.J. Chen, S.C. Yang and J.W. Chen. 2015 Notoginseng based continuous cropping obstacle of soil physical and chemical properties and enzyme activity research. *J. Ecol. Environ.*, 24(3): 409-417.

Trivedi, P., M. Delgado-Baquerizo, L. Anderson and B. Singh. 2016. Brajesh Singh. Response of soil properties and microbial communities to agriculture: Implications for primary productivity and soil health indicators. *Fronti. Plant Sci.*, 7: 990.

Wang, H.W., X.X. Wang, L.X. Lv, Y. Xiao and C.C. Dai. 2012. Effects of endophytic fungi on soil microbial and enzyme activities of peanut continuous cropping. *Chinese J. App. Ecol.*, 23(10): 2693-2700.

Wang, Z.G., W.H. Xu, T.W. Guo. 2010. Leek continuous cropping soil microorganism and enzyme activity of greenhouses. *The Influe. Soil Bull.*, 9(5): 1048-1052.

Wu, Z.J., Z.K. Xie, L. Yang, R.Y. Wang, Z.H. Guo, Y.B. Zhang, L. Wang and R. Kh. 2015. Identification of autotoxins from root exudates of Lanzhou lily (*Lilium davidii* var. *unicolor*). *Allelopath. J.*, 35(1): 35-48.

Xiong, W., Q. Zhao, J. Zhao, W. Xun, R. Li, R. Zhang, H. Wu and Q. Shen. 2015. Different continuous cropping spans significantly affect microbial community membership and structure in a vanilla-grown soil as revealed by deep pyrosequencing. *Microb. Ecol.*,70(1):

Yu, S.P., J.S. Yang, S.Y. Cui, G.M. Liu, R.J. Yao and X. Zhang. 2015. Soil quality characteristics of vegetable greenhouses in different years of continuous cropping in beach reclamation area. *Soil Fertil.*, (04): 8-14.

Zhang, B., X.Z. Li, F.Q. Wang, M.J. Li, J.Y. Zhang, L. Gu, L.J. Zhang, W.Q. Tu and Z.Y. Zhang. 2016. Assaying the potential autotoxins and microbial community associated with Rehmannia glutinosa replant problems based on its 'autotoxic circle. *Plant Soil*, 407(1/2): 307-322.

Zhang, L., Z.H. Cheng, Y.L. Zhou, X.Y. Dong and W. Ling. 2008. Lily growth period of rhizosphere microorganisms and enzyme activities change. *J. Garden.*, (7): 1031-1038.

Zhao, X.M., T. Dong, F. Liu, H.X. Li and Y. Hao. 2008. Effects of NaCl stress on seedling growth and development of Lily in Lanzhou. *Agri. Res. Arid Areas*, (02): 85-89.

(Received for publication 18 February 2022)