Study on different potato continuous cropping ways on rhizosphere soil nutrients and enzyme activities

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***Abstract*— *To address the problem of food security, China produced potatoes as a staple food in 2015.However, there are increasing problems with continuous cropping production methods, potato continuous cropping has been inevitable.So it is necessary to research under the different potato continuous cropping ways, potato rhizosphere soil nutrients and enzyme activities which can direct potato fertilizer and ease potato continuous cropping obstacle. A two-growing season investigation was carried out during the spring and autumn of 2014 and 2015 to determine the different ways of potato continuous cropping on the overall growth of potatoes, soil nutrients, and enzyme activities. During continuous cropping nitrogen (N) content of rhizosphere soil was reduced; available potassium (Kav) was significantly reduced($p \leq 5\%$), especially in spring and autumn continuous cropping; and total phosphorus (P_{tot}) was reduced during the growth stage. However, the total potassium (K_{tot}), available phosphorus(P_{av}), and organic carbon (C_{tot}) increased before they decreased. For rhizosphere soil enzyme activities, urease initially increased and then decreased, and was lower in continuous cropping than multiple continuous cropping; in spring of 2015, invertase was the highest with continuous cropping. Catalase and polyphenol oxidase decreased initially before increasing. Continuous cropping in spring and autumn consumed more nutrients, especially potassium (K) than in spring. Therefore, potatoes planted in both spring and autumn enhanced the problems of continuous cropping. However, multiple continuous cropping that eased rhizosphere soil nutrient absorption and effectively improves soil nutrients and enzyme activities could provide an effective method for managing the negative impacts associated with continuous cropping.*

***Keywords*— potato continuous cropping, rhizosphere, soil nutrients, soil enzyme activities, polyphenol oxidase.**

I. INTRODUCTION

Follow the rice, wheat and maize, potato (*Solanum tuberosum L.*) is the fourth-most important food crop worldwide. It is one of the major crops in China as well. To date, the planting acreage and production of potato in China ranked as top one worldwide. In 2015, the potato staple strategy are put forward in our country, by advancing the potato food development, adjusting measures to local conditions enlarges planting area, from the current $5.3*10^4hm^2$ to expand to $1.0*10^6$ hm^2(Schirring, 2015). However, due to the limitations of different crops in different ecological conditions and authentic, and optional rotation crop limitations such as low efficiency and the urgency of the economic demand, makes the potato continuous cropping pattern is inevitable.

In Gansu, Sichuan and Inner Mongolia, due to rapid development of potato industry, its planted area extended to more than 65% of the country (Long et al., 2013), the potato continuous cropping patterns have been inevitable under the condition of limited arable land. under the condition of several years of planting potato model continuously has inevitable. Especially with the comparative benefits the improvement of potato industry, potato planting area in the northwest China increases year by year. Indingxi area, Gansu province, the potato continuous cropping has amounted to more than five years in some part of arable land, the potato continuous cropping is common, thus resulting in increasing problems for effective agricultural management in China. These problems include an increase of pests and diseases (Jeffrey et al., 2015), and a negative impact on soil physiochemical properties, soil microbes, and allelopathy(Rice,1985; Zhang et al., 2015). Previous researchers reported that continuous cropping decreases yield, quality, and causes diseases and imbalances of soil ecology (Wu at al., 2009; Zhang et al., 2010); thus, seriously affecting the production and economic benefits of potatoes.

It is worth mentioning that with development of China, the potato continuous cropping is inevitable. So explore the different ways of continuous cropping patterns, research rhizosphere soil nutrient and enzyme activity is significant.

The negative impacts of continuous cropping have become a major constraint in potato cultivation (Meng et al., 2012). The negative impacts of continuous cropping were mainly caused by an increase of soil-borne diseases (Robert et al., 2014; Lai et al., 2011), the degradation of soil physical and chemical properties (Liu et al., 2009; Zhang et al., 2007), and root secretion and residue decomposition resulting in autotoxicity (Cheng et al., 2013; Wang et al., 2005). The negative impacts from continuous cropping of different crops are considerably different, but mainly affect the soil.Most studies have focused on vegetables (Wu et al., 2007; Xiao et al., 2012), melons and fruit (Zhao et al., 2008), soybeans (Miao et al., 2007), and Chinese medicinal herbs (Zhang et al., 2010; Hao et al., 2008). In continuous cropping systems, previous research reported that soil nutrients and enzyme activities were affected, and this effect was sustained in later growing seasons (Zhou et al., 2011). However, how the rhizosphere soil nutrients and soil enzyme activities at different growing stages are affected by continuous cropping needs to be determined. There has been limited research on overcoming the negative impact of continuous cropping and other production practices.

Although at present there have been lots of research about the potato continuous cropping obstacle, but the potato production practice of continuous cropping is not practically solved. This study based on the potato continuous cropping, under the different modes of the potato continuous cropping research onrhizosphere soil nutrient and enzyme activity of comparative analysis, aimed at the production of continuous cropping potatoes offer ideas and solutions.The objectives of this study were 1) to evaluate the effect of the continuous potato cropping on rhizosphere soil nutrients and enzyme activities on the growth characteristics of potatoes; and 2) to show the negative impacts of potato continuous cropping, direct the potato production. The results from the present study should provide a greater understanding of the negative impacts of continuous cropping and contribute to the improved management of potato cultivation.

II. MATERIALS AND METHODS

2.1 Site descriptions

The experiment was conducted in 2014 and 2015 in the field at the experimental station in the college farm, southwest Sichuan Agricultural University, Chengdu, Sichuan Province (southwest China, N 30° 67 ', E 104° 06'). The soil chemical characteristics were: pH (1:1 water) 5.08, organic carbon (C_{tot}) 18.72 mg/kg, total nitrogen(N_{tot}) 2.68 g/kg, total phosphorus (P_{tot})0.58 g/kg, total potassium(K_{tot}) 13.00 g/kg, available nitrogen(N_{av}) 138.68 mg/kg, available phosphorus(P_{av}) 18.72 mg/kg, available potassium(K_{av}) 126.31mg/kg. The plant site before the experiment had been previously planted with a potato crop in 2013. The present study included A (multiple continuous cropping), B (potato continuous cropping in spring), and C (potato continuous cropping in spring and autumn) cultivation.All three cropping were conducted in a randomized block design of three repetitions in two years and two growing seasons. About 30 g whole potato tubers, cultivar Chuanyu 117, were planted at a depth of 8 cm.Six potatoes were planted into the compartment with control soil from each pot (60 × 40 × 35 cm). Before potato planting, experimental plots were uniformly tilled and a compound fertilizer 750 kg·ha^{-1} (N-P2O5-K_2O 15-15-15) was initially used as a base fertilizer. Fertilizer was not added again. Standard agronomic practices were equally performed in all treatments. The sampling periods were before seeding, flowering, tuber bulking, and maturity. In autumn 2014 and 2015, the land of A and B was idle, and C was planted with potatoes (its index was not measured because planting in autumn was for enhancing the negative impacts of continuous cropping).

2.2Rhizosphere soil nutrients

The initial soil samples were ground by mortar and pestle to pass a 0.15 mm sieve to remove plant residues and stones prior to chemical analysis. Total nitrogen(N_{tot}), phosphorus (P_{tot}), and potassium(K_{tot}) were measured using the method described by Bao (2005).Soil organic carbon (C_{tot}) was determined using the Walkley-Black method; total nitrogen(N_{tot}) was assayed using the Kjeldahl method;total phosphorus(P_{tot}) was measured by phosphomolybdate-blue spectrophotometry; total potassium(K_{tot}) was measured by NaOH molten-flame photometry; organic matter was measured by heat dilution using potassium dichromate volumetry; alkali-hydrolyzablenitrogen(N_{av}) was measured by alkali-hydrolyzed reduction diffusion; available phosphorus(P_{av}) was measured using 0.5 mol/L $NaCO_3$; and available potassium(K_{av}) was measured by NH_4OAc leaching and flame spectrophotometry.

2.3Rhizosphere soil enzyme activities

Soil enzyme analysis was performed on the same samples that were air-dried,ground, passed through a 1-mm mesh, and maintained at room temperature (Guan, 1989). Invertase activity was determined using 3,5-dinitrosalicylic acid colorimetry; urease activity was measured using phenol-sodium hypochlorite sodium colorimetry; polyphenol oxidase was measured using phenol colorimetry; and catalase was assayed using a titration method described by Guan (1989).

2.4Statistics analysis

The analysis were carried out using Microsoft Office Excel 2007, variance for the data was performed by DPS. Means were separated by LSD at the 0.05 probability level.

III. RESULTS AND DISCUSSION

3.1 Nitrogen contents of rhizosphere soils

In 2014, compared with before seeding, in maturity stage, the content of totalnitrogen(N_{tot}) in rhizosphere soil was reduced by 4.41, 14.55, and 14.71%, for A1, B1, and C1, respectively. However, except for C2, the content of totalnitrogen(N_{tot}) varied smoothly in spring of 2015, the A2 was reduced by 1.01%, and B2 and C2 increased by 0.51 and 16.16%, respectively. The C content decreased with continuous cropping years. In maturity stage of 2014, the alkali-hydrolyzablenitrogen(N_{av}) content reduced by 22.74, 26.10, and 20.26%, for A1, B1, and C1, respectively; and in A2 and B2 increased by 28.89, and 18.46%, however, C2 decreased by 9.15%. In tuber bulking stage, the content of alkali-hydrolyzablenitrogen(N_{av}) changed rapidly. Alkali-hydrolyzablenitrogen(N_{av}) content showed little difference in different continuous cropping ways in the spring of 2014, and were reduced in 2015. The variation of totalnitrogen(N_{tot}) showed the opposite trend.

Table.1: Nitrogen contents of rhizosphere soils

		Before seeding	Flowering	Tuber bulking	Maturity
Total Nitrogen (g/kg)	A1	2.72 ± 0.09a	2.67 ± 0.11c	2.81 ± 0.23a	2.60 ± 0.05ab
	B1	2.68 ± 0.03a	2.75 ± 0.26a	2.42 ± 0.21bc	2.29 ± 0.13c
	C1	2.72 ± 0.13a	2.72 ± 0.05a	2.42 ± 0.03bc	2.32 ± 0.04c
	A2	1.99 ± 0.02a	1.94 ± 0.23ab	1.78 ± 0.23ab	1.97 ± 0.16a
	B2	1.97 ± 0.04a	1.95 ± 0.32a	1.87 ± 0.20ab	1.98 ± 0.32a
	C2	1.66 ± 0.00b	1.96 ± 0.04a	1.76 ± 0.12ab	1.98 ± 0.06a
Alkali-hydrolyzable nitrogen (mg/kg)	A1	168.63 ± 1.52a	166.43 ± 1.92ab	132.77 ± 2.83cde	129.97 ± 1.65de
	B1	170.97 ± 2.72a	167.93 ± 1.30ab	136.73 ± 2.14cd	126.35 ± 0.93e
	C1	160.39 ± 8.55b	164.27 ± 5.76ab	137.89 ± 2.88c	127.89 ± 7.23e
	A2	105.00 ± 0.00h	121.33 ± 8.08cde	135.33 ± 4.04a	135.33 ± 4.04a
	B2	108.33 ± 5.77fgh	123.67 ± 4.04bcd	115.50 ± 9.26def	128.33 ± 4.04abc
	C2	116.67 ± 4.04def	130.67 ± 4.04ab	114.33 ± 8.08efg	106.00 ± 1.73gh

A1, B1, C1 stand for A, B, C in 2014, A2, B2, C2 stand for A, B, C in 2015; In the same year, values within a column followed by different lowercase letters are significantly different at the 0.05 probability level, as determined by Fisher's least significant difference test; n = 3.

3.2Phosphorus contents of rhizosphere soils

From table 2, total phosphorus(P_{tot}) was decreased with growth as the continuous cropping years increased. These three treatments showed the significant effects on the total phosphorus(P_{tot}) . A1 increased by 3.32%, and B1 and C2 were reduced by 15.49 and 14.53%, respectively. In 2015, the content of total phosphorus(P_{tot}) was reduced by 13.11, 23.07 and 15.71% for A2, B2, and C2, respectively. Throughout the growth stages, there was a considerable change in total phosphorus(P_{tot}) content. In maturity stage, the total phosphorus(P_{tot}) content ranged from 0.500 to 0.600 g/kg. The variation of available phosphorus(P_{av}) content is different from total phosphorus(P_{tot}). In spring of 2014, available phosphorus(P_{av}) was reduced by 46.99, 39.56, and 39.42% for A1, B1, and C1, respectively. In contrast to that in 2015, it increased by 28.35, 25.03, and11.96% for A2, B2, and C2, respectively. Even though the total phosphorus(P_{tot}) in the whole growth period fluctuated largely, its content did not significantly reduce. In the spring of 2014, phosphorus content increased, total phosphorus(P_{tot}) was insignificantly different from multiple continuous cropping, and the available phosphorus(P_{av}) content was more reduced than multiple continuous cropping in the spring of 2015.

Table.2: Phosphorus contents of rhizosphere soils

		Before seeding	Flowering	Tuber bulking	Maturity
Total phosphorus (g/kg)	A1	0.572 ± 0.007abc	0.571 ± 0.020abc	0.547 ± 0.003bcd	0.591 ± 0.010a
	B1	0.594 ± 0.009a	0.549 ± 0.058bcd	0.510 ± 0.051de	0.502 ± 0.022e
	C1	0.585 ± 0.007ab	0.542 ± 0.004cde	0.517 ± 0.003de	0.500 ± 0.007e

http://dx.doi.org/10.22161/ijeab/3.5.29 ISSN: 2456-1878

	A2	0.610 ± 0.010c	0.580 ± 0.010d	0.527 ± 0.006e	0.530 ± 0.0170e
	B2	0.659 ± 0.005a	0.638 ± 0.025ab	0.576 ± 0.009d	0.507 ± 0.004e
	C2	0.630 ± 0.006bc	0.579 ± 0.034d	0.566 ± 0.008d	0.531 ± 0.011e
Available-phosphorus (mg/kg)	A1	18.92 ± 0.26bc	16.80 ± 0.24d	16.77 ± 0.15d	10.03 ± 0.11f
	B1	20.35 ± 0.76a	19.23 ± 0.12b	17.06 ± 0.03d	12.30 ± 0.54e
	C1	20.09 ± 0.11a	18.35 ± 0.42c	17.01 ± 0.43d	12.17 ± 0.18e
	A2	16.86 ± 1.59cd	17.37 ± 0.17cd	24.14 ± 6.15a	21.64 ± 1.19ab
	B2	14.86 ± 0.77d	18.90 ± 0.32bc	21.43 ± 0.86ab	18.58 ± 0.65bc
	C2	18.90 ± 0.61bc	19.22 ± 0.22bc	20.39 ± 0.37ab	21.16 ± 2.79ab

A1, B1, C1 stand for A, B, C in 2014, A2, B2, C2 stand for A, B, C in 2015; In the same year, values within a column followed by different lowercase letters are significantly different at the 0.05 probability level, as determined by Fisher's least significant difference test; n = 3.

3.3Potassium contents of rhizosphere soils

As for total potassium(K_{tot}), in maturity stage, there was minimal difference between each treatment. Total potassium(K_{tot}) increased before it decreased. Eventually, the contents were reduced by 5.39, 1.85, 1.57%, for A1, B1, and C1, respectively, and then increased by 4.00, 4.37, and 0.00% for A2, B2, and C2, respectively. Available potassium(K_{av}) was reduced by 5.54, 23.92, and 24.46% for A1, B1, and C1, respectively, but thereafter increased by 30.55, 126.47, and 21.02% for A2, B2, and C2, respectively. From Table 3, total potassium(K_{tot}) content in rhizosphere soil was relatively stable, but the available potassium(K_{av})content varied greatly.potato continuous cropping in spring and autumn was lower than multiple continuous cropping year by year. Potatoes, as a high potassium crop, required more potassium for self-growth. In present study, potato continuous cropping consumed a small amount of total potassium(K_{tot}), but large amounts of available potassium(K_{av}). This can directly affect the application of fertilizer in production.

Table.3: Potassium contents of rhizosphere soils

		Before seeding	Flowering	Tuber bulking	Maturity
Total potassium (g/kg)	A1	13.55 ± 0.05ab	14.41 ± 1.53a	13.42 ± 0.09b	12.82 ± 0.55b
	B1	13.51 ± 0.04ab	13.52 ± 0.16ab	12.95 ± 0.74b	13.26 ± 0.20b
	C1	13.36 ± 0.22b	13.21 ± 0.04b	12.81 ± 0.23b	13.15 ± 0.14b
	A2	13.00 ± 0.74cd	11.47 ± 0.37e	12.54 ± 0.28d	13.52 ± 0.16bc
	B2	12.60 ± 1.15d	15.05 ± 0.46a	14.25 ± 0.97ab	13.15 ± 0.19cd
	C2	13.06 ± 0.19cd	11.40 ± 0.11e	13.03 ± 0.21cd	13.06 ± 0.05cd
Available-potassium (mg/kg)	A1	99.59 ± 0.95c	131.03 ± 6.13b	75.38 ± 2.94f	94.07 ± 4.78cd
	B1	103.03 ± 7.55c	141.88 ± 14.38a	88.54 ± 3.99de	78.39 ± 2.36ef
	C1	103.77 ± 6.44c	140.95 ± 5.82ab	93.78 ± 2.05cd	80.91 ± 4.21ef
	A2	137.88 ± 14.97c	149.22 ± 9.93c	166.76 ± 6.45b	180.00 ± 5.99a
	B2	50.20 ± 1.56h	122.75 ± 3.77d	104.11 ± 5.44e	113.69 ± 2.89de
	C2	56.10 ± 4.27h	90.95 ± 3.59f	84.95 ± 2.90f	67.89 ± 2.74g

3.4 Organic carbon contents of rhizosphere soils

The annual organic carbon (C_{tot}) content of rhizosphere soils decreased before increasing. In spring of 2014, the organiccarbon (C_{tot})content in maturity stage was reduced by 36.25, 25.26 and 24.84% for A1, B1, and C1, respectively, than before seeding. In 2015, it increased by 17.10, 31.13 and 67.27% for A2, B2, and C2, respectively. This implies that the higher the initial organic carbon (C_{tot}) content of soil, the faster it decreased. Organic carbon (C_{tot}) is the main source of soil nutrients; however,in this experiment, the

http://dx.doi.org/10.22161/ijeab/3.5.29 ISSN: 2456-1878

organic carbon (C_{tot}) content of potato continuous cropping in spring and autumn was higher, decreased lower, and increased faster than multiple continuous cropping and continuous cropping in autumn.

Table.4: Organic carbon contents of rhizosphere soils

		Before seeding	Flowering	Tuber bulking	Maturity
Organic matter (g/kg)	A1	19.17 ± 1.26bc	19.99 ± 0.97abc	21.65 ± 2.82a	12.22 ± 0.05e
	B1	20.55 ± 1.94abc	20.86 ± 2.30ab	18.42 ± 0.47c	15.36 ± 1.83d
	C1	20.29 ± 0.35abc	20.78 ± 0.57ab	19.24 ± 0.65bc	15.25 ± 0.55d
	A2	15.56 ± 2.40def	15.96 ± 0.96cde	12.10 ± 0.61g	18.22 ± 2.20bc
	B2	14.10 ± 1.66efg	14.50 ± 0.61defg	13.57 ± 2.11efg	18.49 ± 0.83b
	C2	13.44 ± 0.61fg	18.75 ± 1.05b	16.89 ± 0.23bcd	22.48 ± 2.05a

3.5 Enzyme activities of rhizosphere soils

Table 5 showed that urease steadily increased in t 2014, with the maximum level in flowering stage. In maturity stage, it increased by 34.00, 22.37, 21.71%, for A1, B1, and C1, respectively. and it increased by 20.33, 9.24, and 5.83%, for A2, B2, and C2, respectively. Although over both years urease increased, it was lower in 2015 than that in 2014.The rhizosphere soil invertase activity in maturity stage increased by 52.07, 7.65, 11.24%, for A1, B1, and C1, respectively.In spring of 2015, A2, and B2 in maturity stage decreased by 52.92 and 19.39%, respectively, whereas C2 increased by 25.47%. For catalase, B1 and C1 were reduced by 13.68 and 8.62%, whereas A1 increased by 13.86%. In 2015, catalase increased by 9.88, 6.13 and 11.88%, for A2, B2, and C2, respectively. In present study, there was little difference between the treatments in 2014, with only small variations. In maturity stage, A1 increased by 3.67%, and B1 and B2 were reduced by 10.05 and 1.66%, respectively. However, in 2015, polyphenol oxidase activity changed considerably, especially in tuber bulking stage. Eventually, the activity of polyphenol oxidase increased by 27.97, 25.28, 5.24%, for A2, B2, and C2, respectively.

Table.5: Enzyme activities of rhizosphere soils

		Before seeding	Flowering	Tuber bulking	Maturity
Urease (mg/g)	A1	1.50 ± 0.02e	1.52 ± 0.04e	1.77 ± 0.04c	2.01 ± 0.02a
	B1	1.52 ± 0.00e	1.51 ± 0.00e	1.58 ± 0.00d	1.86 ± 0.03b
	C1	1.52 ± 0.01e	1.51 ± 0.00e	1.58 ± 0.00d	1.85 ± 0.00b
	A2	1.23 ± 0.19cde	1.50 ± 0.08a	1.33 ± 0.11bcd	1.48 ± 0.03ab
	B2	1.19 ± 0.04de	1.41 ± 0.11abc	1.23 ± 0.03cde	1.30 ± 0.11bcd
	C2	1.23 ± 0.19de	1.32 ± 0.07bcd	1.10 ± 0.07e	1.30 ± 0.11bcd
Invertase(mg/g)	A1	19.07 ± 0.25ef	18.60 ± 0.36f	27.03 ± 1.10b	29.00 ± 1.11a
	B1	18.70 ± 0.70f	18.57 ± 0.15f	22.93 ± 1.47c	20.13 ± 1.34de
	C1	18.32 ± 0.29f	20.36 ± 1.17d	22.92 ± 0.30c	20.38 ± 0.43c
	A2	31.97 ± 2.24b	15.18 ± 1.25f	20.27 ± 0.90d	15.05 ± 1.26f
	B2	24.09 ± 1.37c	29.43 ± 1.87b	17.68 ± 0.09def	19.42 ± 4.02de
	C2	24.89 ± 2.23c	36.35 ± 1.11a	16.94 ± 0.74ef	30.57 ± 1.84b
Hydrogen peroxidase (mg/g)	A1	1.01 ± 0.01ef	1.09 ± 0.02bcd	0.98 ± 0.02f	1.15 ± 0.03ab
	B1	1.17 ± 0.07a	1.08 ± 0.03cd	1.09 ± 0.04bcd	1.01 ± 0.04ef
	C1	1.16 ± 0.03a	1.08 ± 0.02cd	1.12 ± 0.02abc	1.06 ± 0.04de
	A2	1.62 ± 0.04cd	1.58 ± 0.01de	1.64 ± 0.02c	1.78 ± 0.03ab
	B2	1.63 ± 0.02cd	1.57 ± 0.03e	1.81 ± 0.01a	1.73 ± 0.05b

	C2	1.60 ± 0.07cde	1.60 ± 0.03cde	1.73 ± 0.02b	1.79 ± 0.01a
Polyphenol oxidase (mg/g)	A1	1.91 ± 0.13ab	2.00 ± 0.22a	1.88 ± 0.32ab	1.98 ± 0.22a
	B1	1.89 ± 0.09ab	1.88 ± 0.04ab	1.76 ± 0.04ab	1.70 ± 0.11b
	C1	1.81 ± 0.09ab	1.80 ± 0.15ab	1.82 ± 0.03ab	1.78 ± 0.11ab
	A2	2.36 ± 0.61bcde	2.03 ± 0.48de	3.98 ± 0.67a	3.02 ± 0.45b
	B2	1.78 ± 0.15e	2.24 ± 0.27cde	2.30 ± 0.08cde	2.23 ± 0.15cde
	C2	2.48 ± 0.38bcd	2.80 ± 0.52bc	2.30 ± 0.21cde	2.61 ± 0.27bcd

Table.6: The tuber yield of all three A, B, C variants (kg·ha^{-1})

	A	B	C
2014	--	6985	7019
2015	7190	6215	6343

IV. DISCUSSION

It is generally hypothesized that the soil nutrients decreased annually with continuous cropping (Xiao et al., 2012). But in this research, the available phosphorus(P_{av}),the available potassium(K_{av}) contentand organic carbon (C_{tot}) content were different. This illustrated that the different crops, the difference of continuous cropping ways and seasons, the content of potato root nutrients, and root secretions from the toxic effect and residues, had different effects on soil nutrients. When plant roots and soil are in close contact, a large variability of soil area is formed, and the micro-ecological environment of the potato rhizosphere soil changes. Therefore, under the condition of constant continuous cropping, this inevitably affects plant growth and development.

Soil enzyme activities play an important role in the soil ecosystem, and can reflect the changes in soil quality. Soil enzyme activities are the key to overcome the problems associated with continuous cropping and other agricultural practices that destroy the soil health (Yim et al., 2013). In the present study, compared with potato multiple continuous cropping, the activities of urease, polyphenol oxidase, and invertase were lower in the spring of 2014 but higher in 2015. Catalase activity was lower and then little different. Simultaneously, as for continuous cropping years, urease enzyme activity was reduced, and invertase,catalase, and polyphenol oxidase activities increased. In tuber bulking and maturity stage, rhizosphere soil enzyme activities increased significantly. During the tuber-bulking and maturity stage, the potato root system shows high activity, utilizing excessive rhizosphere soil nutrients, which increases the rhizosphere soil enzyme activity.

Polyphenol oxidase (PPO) is secreted by the plant roots, increasing soil microbial activity and the decomposition of plant and animal residues, releasing compound enzymes (Claus et al. 2010; Yoruk et al., 2003). These are biodegradable soil phenolics that slow down the allelopathy between plants, thereby creating advantageous conditions for plants to expand their habitats. In the present study, rhizosphere soil polyphenol oxidase activity increased with increasing years of planting. The research results are similar to the research on *Caraganakorshinskii* (Cao et al., 2008), where polyphenol oxidase activity of continuous cropping in spring and autumn is higher than that in spring. The soil enzyme activity of sucrase, urease, and catalase has been related to soil fertility, butonly less data is available on the activity of polyphenol oxidase. In the present study, there were significant differences in polyphenol oxidase activity under continuous cropping. Therefore, soil polyphenol oxidase can be considered as an indicator of the negative impact of continuous potato cropping, but requires further verification.

As for the result of the tuber yield, there is a certain relationship between the tuber yield and continuous cropping years, the method of cultivation pattern. But a small difference soil change between multiple continuous cropping(A) and potato continuous cropping in spring (B) andcontinuous cropping in spring and autumn (C) in the short term of continuous cropping for two years, there is a significant difference between them for continuous cropping over three years. Potato continuous cropping consumed more nutrients, especially available nutrients. We think potato continuous cropping for two years is possibly the threshold for the local ecological environmental conditions and cultivation. For potato growing, to meet production requirements and the economic benefits of continuous cropping, the most efficient cultivation period for the process would be two years, and plans to extend it would require a reasonable arrangement to provide a practical basis. Meanwhile, continuous cropping in spring and autumn increased the negative impact. Multiple continuous cropping reduced the rhizosphere soil nutrient absorption, but negated the negative impacts of continuous cropping.

ACKNOWLEDGMENTS

This work was jointly supported by theNationalScience-Technology SupportPlanProjects (2012BAD06B0407) and Sichuan Breeding Research Project (2011N0098-15-5). We express our gratitude to Huang Qiang and ZhaLi for assistance in soil sampling and testing.

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