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EVALUATION AND SCREENING OF RESISTANCE TO REPLANT IN GERMPLASM OF GRAPE AND PHYSIOLOGICAL MECHANISMS OF ITS RESISTANCE

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Abstract

The aim of the present work was to screen out grape germplasms resisting to replant obstacle, and to analyze their resistant mechanism. Here we used 94 grape resources as the testing materials. The cuttings of each resource were planted in pot filled with control (normal) soil as well as replanting soil. After 2 years investigation, '101-14', '8612'were screened for replant-susceptible resources, and 'Mcadams', 'Dawuhezi' were screened for replant-resisting resource. Under replanting stress, resources with resistance exhibited an increase in maximum photochemical efficiency of PS□, and net photosynthetic rate improved. The MDA content of 'Mcadams' planted in normal soil was 25.62% lower than that planted in replant soil, and showed a strong resistance. For 'Dawuhezi', the protected enzyme SOD and PPO could be activated under replanting stress, which effectively avoided the harm of active oxygen to the seedling, presenting a more vigorous plant growth.

Key words: Grape, Replant disease, Photosynthetic characteristics, Defense enzyme.

Introduction

Replant disease in fruits often occurs when trees are grown in a soil that had previously supported the same or similar plant species leading to reductions in plant growth, crop yields and shortening of the productive life of the orchard (Bent *et al*., 2009; Reighard *et al*., 2008). In China, grapes are widely cultivated. However, with the increasing of replanting years, severe problems appeared when people reused the old vineyards, presenting an obvious suppression for the young seedling.

At present, there have been many studies about the control of replant obstacle, focusing on crop rotation, soil fallow and disinfection (Yu *et al*., 2004). However, to overcome replant obstacle, the breeding of resistant cultivar must be the most efficient way. At present, the research on the evaluation of germplasm resisting to replant obstacle is still blank in grapevine. The present study was carried out with 94 grapevine germplasm (including table grape and rootstock). The objective was to evaluate the performance of resources in replant conditions, and screen replant-resisting resource.

Material and Methods

Material: Ninety four grapevine germplasms, introduced from Zhengzhou Fruit Research Insititute, Chinese Academy of Agriculture Sciences, are listed in Tables 1 & 2. The control soil was the soil on which grapevines have never been planted, and the replant soil was collected from the replant vineyard of Shenyang Agricultural University. The replant vineyard was established in 1978, and renew twice in-situ since 1978, the soil of which was aquic brown soil. The soil physicochemical properties are provided in Table 3.

Pot experiment: This test was conducted in rain-shelter greenhouse at a field of vineyard, Shenyang Agriculture University, from May 2012 to August 2013. In May 2012, cuttings of 94 grapevine germplasms were planted in nutrition bags after root induction, 10 cutting seedlings for each germplasm, among them, 5 cutting were planted in replant soil and 5 in control soil. After one month, seedlings were then transplanted into circular-section pots with a diameter of 32cm for further cultivation. Thirty days later, the physiological parameters of the seedlings were measured. In August 1st, seedlings were taken out from the pot, and plant fresh mass was measured after washed by water. Repeated experiment was done in 2013.

Measuring methods: Plant fresh mass was measured by conventional method. Net photosynthetic rate was measured with a portable photosynthesis system CIRAS-1 on a sunny day. Chlorophyll fluorescence parameters were measured using a plant efficiency analyzer (PEA-MK2, Hansatech Instruments Ltd., UK). Before each measure, sample was dark-adapted for 30min. Then minimal and maximal fluorescence of dark-adapted Fo and Fm, respectively, were recorded with the PEA-MK2. The variable fluorescence (Fv) was calculated as Fv = Fm - Fo (Lan *et al*., 2010).

The relative content of chlorophyll was measured by Unispec-SC spectrum analyzer. Leaf SOD activity was determined by nitroblue tetrazolium(NBT) photoreduction and MDA was measured by spectrophotomet using the thiobarbituric acid method. PPO activity was measured by catechol method.

Data analysis: Data was analyzed by software Excel 2011 and DPS 7.05.

Increasing (decreasing) range =[(data from replant soil - data from control soil) / data from control soil] ×100%.

Table 1. List of studied rootstocks, description and origin.

Code	Rootstock	Species	Origin
1	Gloire A	*V. riparia* michaux	France
2	SaltGreek	*V. labrusca L*	-
3	Hybride France	*V. vinifera*×*V.rupestris*	-
4	*Vitis rupestris*	*V. rupestris* Scheele	United States
5	Labruse	-	-
6	101-14	*V. riparia* × *V. rupestris*	France
7	S04	*V. berlandieri resseguier*×*V. riparia*	Germany
8	Fercal	berlandieri colombard 1 B × richter 31	France
9	5BB	*V. berlandieri*×*V. riparia*	Austria
10	*Vitis riparia* 580	*V. riparia 580*	United States
11	Dog Ridge	*V. rupestris*×*V. candicans*	United States
12	Riparia Gloire	*V. riparia*	United States
13	3309Couderc	*V. riparia* ×*V. rupestris*	France
14	775	Hybrid of *V. labrusca L*	-
15	520A	*V. berlandieri*×*V. riparia*	Italy
16	110R	*V. berlandieri*×*V. rupestris*	France
17	Flourish	*Vitis riparia*	United States
18	Eldorado	Concord ×Allen	United States
19	Barrett 50	*V. riparia* michaux	United States
20	Freedom♀	1613C×Dog Ridge	United States
21	LN33	*V. rupestris*	United States
22	Mcadams♀	*V. riparia*	-
23	*V. riparia* pulliat 6403	*V. riparia*	United States
24	101♀	-	-
25	Meissner	*V. riparia* michaux	United States
26	*V. rupestris* du Lot	*V. rupestris* scheele	France
27	188-08	*V. berlandieri*×*V. riparia*	-
28	Beaumout	*V. riparia*	United States
29	1613Couderc	*V. labrusca*×*V. riparia*×*V. Vinifera,*	France
30	420A	*V. berlandieri* × *V. riparia*	France
31	Kangzhen No.6	*V. berlandieri*×*V. riparia*×*V. labrusca cv.*	China
32	Champini	*V. champinii* planchon	United States
33	*V. riparia* Grand glaber A	*V.riparia* michaux	France
34	Kangzhen No.5	*V.berlandieri* × *V. riparia*×*V. labrusca cv.*	China
35	Kangzhen No.3	*V. berlandieri*×*V. riparia cv.*	China
36	Kangzhen No.1	*V. berlandieri*×*V. riparia cv.*	China
37	*Vitis rupestris Scheele(A),*	*V. rupestris* scheele	United States
38	225Ru	*V. berlandieri*×*V. rupestris*	Italy
39	*V. cinera* engel	*V. cinera engel*	-
40	140 Ru	*V. berlandieri* ×*V. rupestris*	Italy
41	Mcadams	Interspecific crossing	United States
42	*V. wecase*	*V. wecase*	-
43	*V. riparia* pulliat 6402	*V. riparia*	United States

"-"means not quite clear

Table 2. List of studied table grapes, description and origin.

Code	Table grapes	Species	Origin
44	Guifeimeigui	*V. viniferas L*	China
45	8612	*V. viniferas L* ×*V. labrusca L*	China
46	Bolgar	*V. viniferas L*	Turkey
47	Red Fuji,	*V. viniferas L* ×*V. labrusca L*	Japan
48	Bixiangwuhe	*V. viniferas L*	China
49	Delaware	*(V. labrusca X aestivalis)* ×*V. vinifera*	United States
50	Champion	*V. labrusca L*	United States
51	Cardinal	*V. viniferas L*	United States
52	Rommel	*V. viniferas L* ×*V. labrusca L*	United States
53	Campbell	*V. labrusca L*×*V. viniferas L*	United States
54	Ryuho	*V. labrusca L*×*V. viniferas L*	Japan
55	Yipingxiang	*V. viniferas L*×*V. labrusca L*	-
56	Kaiotome	*V. viniferas L*	Japan
57	Emerald Seedless,	*V. viniferas L*	United States
58	79-05-6,	*V. vinifera*×*V. labrusca L*	China
59	Heihuxiang	*V. labrusca L*	United States
60	Mars Seedless	*V. vinifera*×*V. labrusca L*	United States
61	Alexander	*V. viniferas L*	Egypt
62	Benizuiho(Ikawa 665)	*V. vinifera*×*V. labrusca L.*	Japan
63	Ikawa 666	*V. vinifera*×*V. labrusca L.*	Japan
64	Triumph	*V. vinifera*×*V. labrusca L.*	United States
65	Khani	*V. viniferas L*	Afghan
66	Beijiagan	*V. viniferas L*	China
67	Honey Red	*V. vinifera*×*V. labrusca L.*	Japan
68	Meizhoubai	*V. vinifera*×*V. labrusca L.*	-
69	Summer Black	*V. vinifera*×*V. labrusca L.*	Japan
70	Horizon	*V. vinifera*×*V. labrusca L.*	United States
71	Bailey	*V. vinifera*×*V. labrusca L.*	Japan
72	Luoyang No.2	-	China
73	Victoria	*V. viniferas L*	Romania
74	Huangguan	*V. vinifera*×*V. labrusca L.*	Japan
75	Pinger	*V. viniferas L*	-
76	Hongmulage	*V. viniferas L*	China
77	Black seedless	*V. viniferas L*	State of Israel
78	Aogusite	*V. viniferas L*	Romania
79	Takasumi	*V. vinifera*×*V .labrusca L.*	Japan
80	Tamina	*V. viniferas L*	Romania
81	Golden Muscat	*V. vinifera*×*V. labrusca L.*	United States
82	Zaomanao	*V. viniferas L*	China
83	Baikeshikeer	*V. viniferas L*	China
84	Amilia	*V. viniferas L*	-
85	Yatomi Rosa	*V. viniferas L*	Japan
86	Meiguiyi	*V. vinifera*×*V. labrusca L.*	China
87	Afghanistan	*V. viniferas L*	-
88	Manai	*V. viniferas L*	China
89	Heimeixiang	*V. vinifera*×*V .labrusca L.*	China
90	Moerduowa	Guzalikala×SV12375	Moldova
91	Djoura Ousioum	-	Uzbekistan
92	Longyan	*V. viniferas L*	China
93	Feicuimeigui	*V. vinifera*×*V. labrusca L.*	China
94	Dawuhezi	*V. viniferas L*	China

"-"means not quite clear

Table 3. The basic nutrient status of test soil.

Experimental soil	Total N ($g \cdot kg^{-1}$)	Total P ($g \cdot kg^{-1}$)	Total K ($g \cdot kg^{-1}$)	Available N ($mg \cdot kg^{-1}$)	Available P ($mg \cdot kg^{-1}$)	Available K ($mg \cdot kg^{-1}$)	Organic matter ($g \cdot kg^{-1}$)	pH
Replant soil	1.3011	1.5847	5.5170	144.07	136.72	135.44	17.7365	6.89
Control soil	1.0712	1.1027	5.3462	105.60	127.49	134.32	15.9706	6.65

Table 4. Typical grape resources.

No resistance to replanting		Strong resistance to replanting	
Rootstock resources	Table resource	Rootstock resources	Table resource
101-14	8612	Mcadams	Dawuhezi

Results

Effect of replant soil on plant fresh mass: The data of replant soil on seedling fresh mass were measured in 2012 as Figs. 1, 2 shows. Compared with seedlings in control soil, rootstock 101-14(6) and table grape 8612(45) exhibited a weaker growth vigor in replant soil, and had a decreasing range of 61.00% and 70.70% respectively. While rootstock Mcadams (41) and table grape Dawuhezi (94) present a more vigorous growth in replant soil than in control soil, which had increased by 44.73% and 70.58% respectively in fresh mass.

The germplasm which plant fresh mass decreasing amplitude were over 60% and increasing range were more than 40% were used for repeated experiment in 2013. Fig. 3 shows the effect of replant soil on fresh mass in 2013. The trends of 101-14, 8612, Mcadams and Dawuhezi were similar to that in 2012. The decreasing amplitudes of 101-14 and 8612 were 30.42% and 23.62% respectively. Their decrease were over 20% in both years. While the increasing amplitudes of Mcadams and Dawuhezi were 48.56% and 170.72% respectively. Their increase were more than 40% in both years.

Based on 2 years' data of plant fresh mass, we got 4 typical grapevine germplasm (Table 4), among which 101-14 (rootstock) and 8612 (table grape) had weaker growth in replant soil than in control soil, indicating no resistance to replant; while Mcadams and Dawuhezi exhibited a strong vigor in replant soil than in control soil, representing strong resistance to replant.

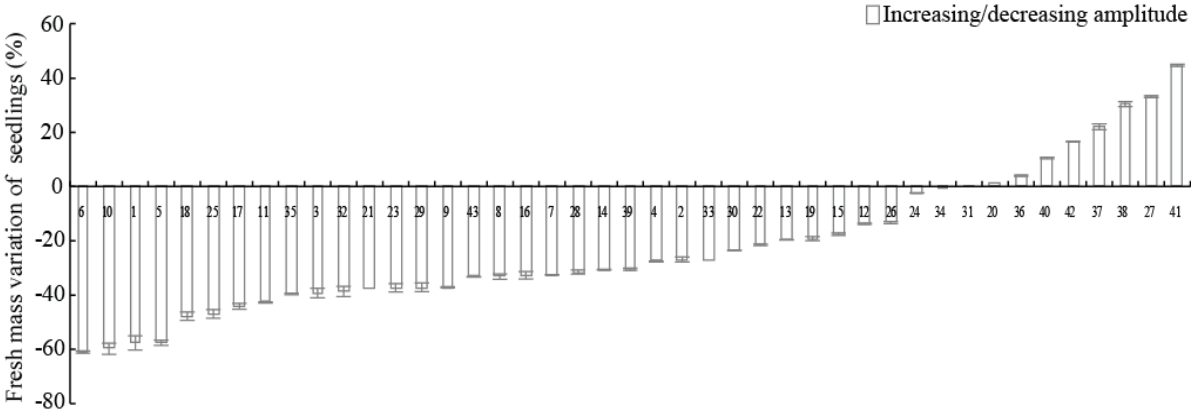

Fig. 1. Effect of replant soil on fresh mass of rootstocks in the first year (The code was shown in Table 1).

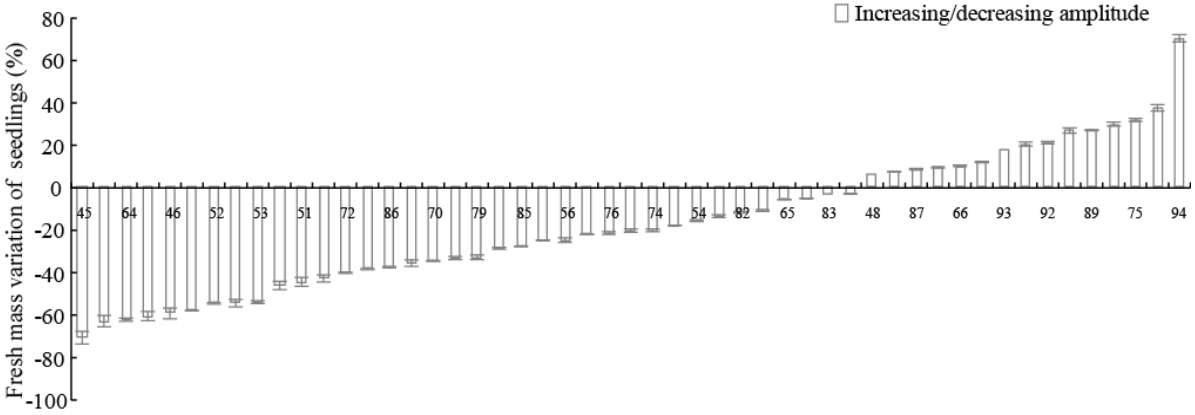

Fig. 2. Effect of replant soil on fresh mass of table grapes in the first year (The code was shown in Table 2).

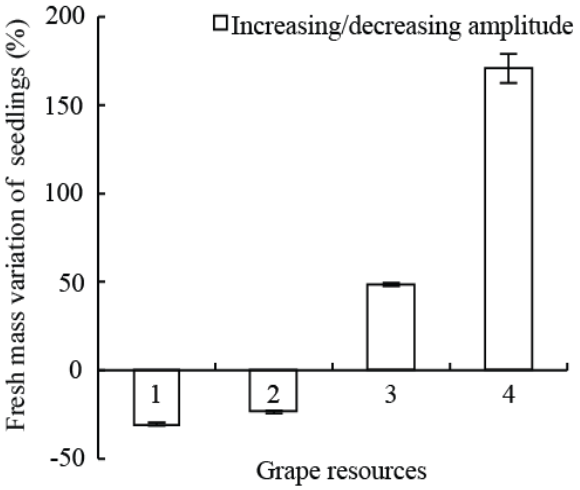

Fig. 3. Effect of replant soil on fresh mass of seedlings in the second year. (1: 101-14, 2: 8612, 3: Mcadams, 4: Dawuhezi) The same below.

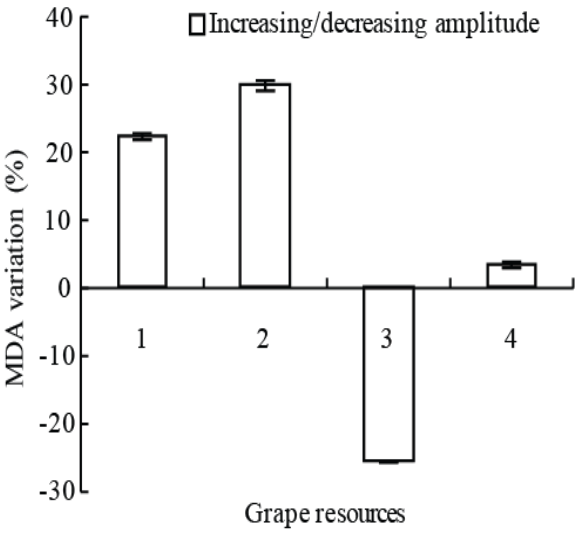

Fig. 4. Effect of replant soil on MDA content of grape leaves.

Effect of replant soil on plant photosynthesis: The effect of replant soil on photosynthesis parameter of leaf was shown in Table 5. Replant-susceptible germplasm showed a decrease in net photosynthesis rate, transpiration rate, stomatal conductance and intercellular CO_2 concentration, while the stomatal limitation value increased. The net photosynthesis rate of 101-14 and 8612 had a reduction of 18.97% and 15.44%, and transpiration rate had a reduction of 27.66% and 7.62% respectively, which indicated that replant soil reduced the leaf transpiration rate and efficiency of light energy transform, and the absorbed and assimilated ability of seedlings was weakened by replant soil. Under the treatment of replant soil, leaf Gs and Ci value decreased, while Ls value increased, indicating that the reduction of net photosynthesis rate was caused by stomatal factors. Plant water use efficiency depends on CO_2 net assimilation rate and transpiration efficiency. As shown from Table 5, the WUE value of 8612 in replant soil was lower than that in control soil, which indicated that water consumption of seedling grown in replant soil was increased.

Dawuhezi had strong resistance to replanting. No changes of net photosynthesis rate of seedlings were found between replant soil and control soil, and the increasing amplitude of transpiration rate was very small (0.40%) under replant treatment. An increase of 2.24% in net photosynthesis rate and a decrease of 10.09% in transpiration rate of Mcadams were observed under replant treatment.

Effect of replant soil on chlorophyll content: Table 6 showed the effect of replant soil on chlorophyll content. Among 4 grape germplasm, 101-14 and 8612 (Both them were replant-susceptible resources) showed a large decrease by 17.16% and 18.35% respectively in chlorophyll content. For germplasm of replanting resistance, the chlorophyll content of Dawuhezi seedling in replant soil was also lower than that in control soil, with a decrease by 8.87%, while Mcadams represented an opposite trend, increased by 1.73%.

Effect of replant soil on chlorophyll fluorescence parameters: The effect of replant soil on chlorophyll fluorescence was shown in Table 7. The Fo is the fluorescent when the reaction center of photosystem II (PSII) are all open, and the increase in Fo indicates the injury of PSII (Kitajima & Butler, 1975; Xu *et al*., 2002; Meng *et al*.,2012). For replant-susceptible resources, Fo value in replant soil was higher than that in control soil. While for germplasm with high replanting resistance, the value in replant soil was lower. Fm was the fluorescence yield when PS□ reaction center was in a closed state. Fm could reflect the state of electron transport in PS□center (Liu *et al*., 2009). For replant-susceptible germplasm, Fm value in replant soil was lower than that in control soil, and vice versa. That implies, in replant soil, PS□ reaction center was destroyed and electron delivering was restricted in PS□.

It was obvious that Fv/Fm of 8612 (replant-susceptible germplasm) surviving in replant soil presented a relative low level, meaning that, under replant stress, primary conversion of light energy of PS□ decreased and potential active center was harmed so as to restrain the initial reaction of photosynthesis. However, the PS□ of Mcadams & Dawuhezi (Germplasm of resisting to replant) presented a higher level in replant soil than that in control soil.

Effect of replant soil on MDA content: The effect of replant soil on MDA content was shown in Fig. 4. Leaf MDA content in 101-14 and 8612 (replant-susceptible resources) increased under replant treatment, showing an obvious increasing range of over 20%. The increasing range of Dawuhezi was within 5%, and Mcadams has an obvious decreasing range of 25.62% under replant treatment.

Table 5. Effects of replant soil on photosynthetic parameters in grape leaves.

Grape resources	Treatment	Photosynthesis (Pn) ($\mu mol.m^{-2}.s^{-1}$)	Transpiration rate (Tr) ($mmol.m^{-2}.s^{-1}$)	Stomatal conductance (Gs) ($mmol.m^{-2}.s^{-1}$)	Intercellular CO_2 concentration (Ci) ($\mu mol.mol^{-1}$)	Stomatal limitation value (Ls)	Water use efficiency (WUE) ($\mu mol.mmol^{-1}$)
101-14	Control soil	16.2 ± 0.2	4.35 ± 0.16	644 ± 1	279 ± 13	0.229 ± 0.011	3.77±0.03
	Replant soil	13.1 ± 0.3	3.15 ± 0.07	268 ± 6	246 ± 11	0.323 ± 0.007	4.17±0.18
	Amplitude of variation	-18.97% ± 0.34%	-27.66% ± 1.02%	-58.44% ± 2.49%	-11.83% ± 0.36%	41.25% ± 0.56%	10.53% ± 0.24%
8612	Control soil	14.9 ± 0.4	4.07 ± 0.18	639 ± 21	279 ± 12	0.226 ± 0.006	3.66±0.11
	Replant soil	12.6 ± 0.1	3.76 ± 0.13	522 ± 11	266 ± 7	0.253 ± 0.008	3.35±0.14
	Amplitude of variation	-15.44% ± 0.58%	-7.62% ± 0.06%	-18.31% ± 0.26%	-4.66% ± 0.14%	11.97% ± 0.39%	-8.46% ± 0.27%
Mcadams	Control soil	16.4 ± 0.4	4.23 ± 0.03	624 ± 19	302 ± 6	0.221 ± 0.006	3.87±0.16
	Replant soil	16.7 ± 0.2	3.8 ± 0.10	571 ± 22	299 ± 14	0.238 ± 0.008	4.42±0.10
	Amplitude of variation	2.24% ± 0.11%	-10.09% ± 0.11%	-8.39% ± 0.37%	-0.77% ± 0.01%	8.28% ± 0.37%	14.22% ± 0.08%
Dawuhezi	Control soil	16.2 ± 0.1	4.14 ± 0.07	646 ± 12	298 ± 4	0.220 ± 0.007	3.92±0.10
	Replant soil	16.2 ± 0.4	4.16 ± 0.06	549 ± 14	287 ± 5	0.244 ± 0.004	3.94±0.08
	Amplitude of variation	0.00% ± 0.32%	0.40% ± 0.01%	-14.97% ± 0.22%	-3.70% ± 0.11%	11.01% ± 0.32%	0.56% ± 0.02%

Table 6. Effect of replant soil on chlorophyll content in grape leaves.

Grape resources	Control soil	Replant soil	Amplitude of variation
101-14	0.5353 ± 0.0159	0.4435 ± 0.0139	-17.16% ± 0.56%
8612	0.5297 ± 0.0251	0.4325 ± 0.0154	-18.35% ± 0.45%
Mcadams	0.5203 ± 0.0167	0.5293 ± 0.0256	1.73% ± 0.08%
Dawuhezi	0.4931 ± 0.0154	0.4493 ± 0.0011	-8.87% ± 0.25%

Table 7. Effect of replant soil on chlorophyll fluorescence in grape leaves.

Grape resources	Treatment	Initial Fluorescence (Fo)	Maximum fluorescence (Fm)	Variable fluorescence (Fv)	Maximum photochemical efficiency of PS□((Fv/Fm)
101-14	Control soil	437.6 ± 8.1	2323.5 ± 22.9	1872.6 ± 38.2	0.806 ± 0.026
	Replant soil	450.9 ± 17.9	2298.1 ± 30.8	1860.5 ± 21.2	0.810 ± 0.016
	Amplitude of variation	3.05% ± 0.01%	-1.09% ± 0.04%	-0.64% ± 0.03%	0.45% ± 0.02%
8612	Control soil	605.9 ± 4.0	3137.0 ± 62.6	2522.0 ± 73.5	0.804 ± 0.014
	Replant soil	615.0 ± 20.1	3002.6 ± 66.1	2396.7 ± 31.8	0.798 ± 0.013
	Amplitude of variation	1.50% ± 0.05%	-4.28% ± 0.18%	-4.97% ± 0.05%	-0.71% ± 0.01%
Mcadams	Control soil	576.3 ± 16.9	2593.7 ± 96.4	2020.5 ± 26.6	0.779 ± 0.017
	Replant soil	573.2 ± 3.3	2893.0 ± 81.7	2316.6 ± 102.5	0.801 ± 0.036
	Amplitude of variation	-0.55% ± 0.01%	11.54% ± 0.01%	14.66% ± 0.27%	2.79% ± 0.05%
Dawuhezi	Control soil	567.2 ± 6.7	2715.9 ± 73.3	2148.7 ± 100.7	0.791 ± 0.036
	Replant soil	558.0 ± 19.2	2817.7 ± 105.0	2259.6 ± 88.9	0.802 ± 0.011
	Amplitude of variation	-1.62% ± 0.07%	3.75% ± 0.01%	5.16% ± 0.20%	1.37% ± 0.01%

Effect of replant soil on SOD activity: The effect of replant soil on SOD activity is shown in Fig. 5. For the treated germplasm, leaf SOD activity was higher than control. Among them, 101-14 expressed the maximum increasing range of 31.59%. The increasing range of Mcadams and Dawuhezi was only 1.91% and 1.00% respectively.

Effect of replant soil on PPO activity: The effect of replant soil on PPO activity was shown in Fig. 6. For the typical germplasm, leaf PPO activity in replant soil was higher than that in control soil. The increasing range of Mcadams & Dawuhezi was small (less than 8%). 101-14 and 8612 had a large increasing range (both over 40%), especially for 8612 (141.18%).

Discussion

Replant obstacle is a difficult problem at present. The breeding of resistant cultivars could fundamentally overcome the problem. Germplasm of resisting to replant disease had been successfully selected in soybean (Chen *et al*., 2008), apple (Wang *et al*., 2009), peach (Jiménez *et al*., 2011)and strawberry (Ma *et al*., 2012). The present study indicated that most of grape germplasm could be suppressed by replanting, and two germplasm (Mcadams & Dawuhezi) were screened for strong replant resistance.

Plant photosynthetic organ was very sensitive to adversity stress, and was often the primary position of suffers (Zhang *et al*., 2009). Chlorophyll fluorescence analysis technique was based on photosynthesis, and was an ideal

probe to study photosynthetic physiology and detect the relationship between plant and adversity stress (Sayed, 2003). The fixed fluorescence (Fo) was the yield of the (PSI) reaction center fully opened, which relating to chlorophyll concentration. The maximum fluorescence (Fm) was the yield of the PS□ reaction center fully closed, which reflecting the electron transfer situation of PS□ (Lichtenthaler & Rinderle, 1988; Schreiber *et al*., 1994; Govindjee *et al*., 1981). As an important parameter of chlorophyll fluorescence, Fv/Fm was well used as a sensitive indicator of plant photosynthetic performance (Baker *et al*., 2008; Maxwell & Johnsen, 2000). It was actually the maximum quantum efficiency of PSII photochemistry, reflecting the largest solar energy conversion efficiency in PSII reaction center. Fv/Fm normally remained at a relative constant level under unstressed conditions, however decreased to varying degrees under stress conditions (Baker *et al*., 2008; Campbell *et al*., 1998). Replant obstacle was one of the adversity stress. In this study, replant soil could result in the increase of Fo and the decrease of Fm in replant-susceptible resources, which indicated that the maximal photochemical efficiency decreased and photoinhibition was intensified in seedling, at the same time, their relative chlorophyll content in replant soil was also lower than that in control soil, and led to photosynthesis decreased, affecting matter synthesis and transport, and led to dramatic decline of plant growth. For Mcadams with high replant resistance, the increase of net photosynthesis rate might be caused by the increase of relative chlorophyll content and the enhancement of maximal photochemical efficiency of PS□. For Dawuhezi, relative chlorophyll content dropped, but the PS□ maximum photochemical efficiency enhanced, leading photosynthetic rate not influenced by replanting.

Recently, the role of the antioxidant system in the plant in response to environmental stress has received wide attention (Prasad *et al*., 1999; Scebba *et al*., 1998; Wu *et al*., 2003).

Malonaldehyde (MDA) was an important product of membrane lipid peroxidation. The content of MDA reflects the level of membrane lipid peroxidation (Chai *et al*., 1997). During the period of evolution, stablization of plant structure and function could be sustained by dynamic balance of active oxygen through its automatically generation and elimination (Wu *et al*., 2007). Superoxide dismutase (SOD) is a primary enzymatic defence system, which catalyses dismutation of superoxide radicals to hydrogen peroxide and protects plant against the potential damage from superoxide radicals. The increase of PPO activity could enhance the content of phenoxide, and inhibit the cell-wall-degrading enzyme activity from the secretion of pathogens, and played a critical role in plant defense system. In apple, replanting led to the increase of SOD and PPO activity in roots, and the increase range could be used to signify the resistance to stress. The less increase was, the stronger resistant ability was (Wang *et al*., 2009). For most germplasm in the study, MDA, SOD and PPO activity in replant soil was higher than that in control soil. Among them, germplasm with high replanting resistance had a small increase of defence enzyme activity, and vice versa, indicating a stronger resistance to adversity for germplasm with high replanting resistance.

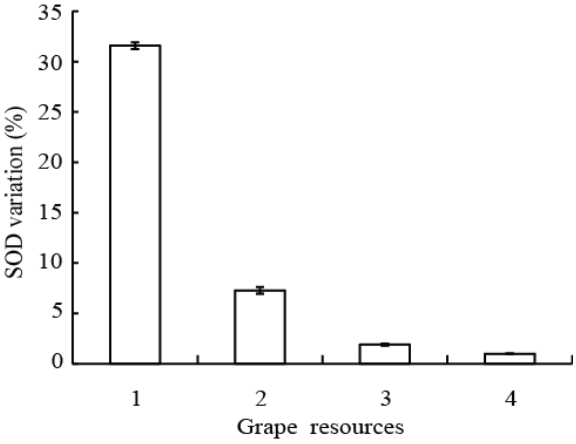

Fig. 5. Effect of replant soil on SOD activity of grape leaves.

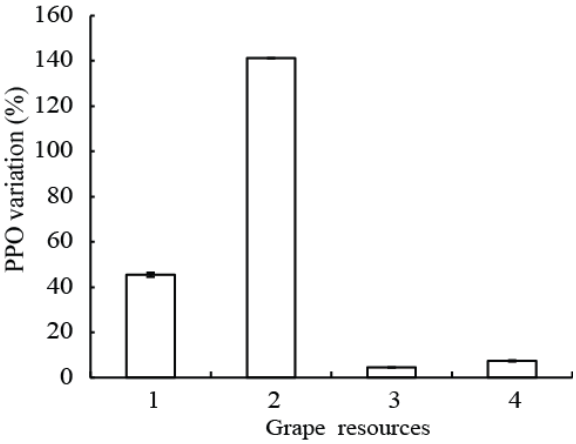

Fig. 6. Effect of replant soil on PPO activity of grape leaves.

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