西北林学院学报 2015，30(5)：79～85
Journal of Northwest Forestry University

doi:10.3969/j.issn.1001-7461.2015.05.13

Photosynthetic Responses of A New Grapevine Variety ‘Xinyu’ in Turpan

JI Wei[1], SUN Feng[2], LUO Qiang-wei[2], ZHANG Zong-qin[1*]

(1. *Key Laboratory of Biology and Genetic Improvement of Horticultural Crops (Northwest Region), Ministry of Agriculture, P. R. China, State Key Laboratory of Crop Stress Biology in Arid Areas, Northwest A&F University, Yangling, Shaanxi* 712100 *China*; 2. *Institute of Grape and Melon of Xinjiang Uygur Autonomous Region, Shanshan, Xinjiang* 838200, *China*)

Abstract: Turpan is one of the major high-quality grape production bases in the world for years because its climate is so special (hot, dry, and windy). The grape market needs the varieties with high yield, quality, and environmental adaptability. ‘Xinyu’ is a new variety bred by crossing selection of E42-6 (a self-pollinated inbred of *Vitis vinifera* cv. ‘Red Globe’) as female and *Vitis vinifera* cv. ‘Rizamat’ as male parents and registered in the Crop Varieties Registered Commission of Xinjiang Uygur Autonomous Region in 2005. In this study, we determined the impacts of environmental factors on its photosynthesis. The results showed the climate in Turpan was characterized by long-time intensive sunshine, high temperature and relatively low humidity. The peak value of photosynthetic available radiation (*PARi*) was 1 454 $\mu mol \cdot m^{-2} \cdot s^{-1}$, and the minimum and average values were 111 $\mu mol \cdot m^{-2} \cdot s^{-1}$ and 938.889 6 $\mu mol \cdot m^{-2} \cdot s^{-1}$, respectively. Air temperature and sunlight intensity reached the highest values during 1 p.m. to 4 p.m. Net photosynthetic rate (*Pn*) of Xinyu increased stably before 11 a.m. and there was a midday depression during 11 a.m. to 2 p.m. The minimum value of *Pn* appeared at noon (2.77 $\mu mol \cdot m^{-2} \cdot s^{-1}$). It was concluded that as a new grape cultivar, “Xinyu” could withstand extreme climate conditions in Turpan.

Key words: *vitis*; grapevine; photosynthesis; new variety; Turpan

中图分类号:S663.1　　**文献标志码**:A　　**文章编号**:1001-7461(2015)05-0079-07

葡萄新品种“新郁”在新疆吐鲁番地区的光合效应研究

纪　薇[1]，孙　峰[2]，骆强伟[2]，张宗勤[1*]

（1.西北农林科技大学，旱区作物逆境生物学国家重点实验室，农业部西北地区园艺作物生物学与种质创制重点实验室，陕西 杨陵 712100；2.新疆维吾尔自治区葡萄瓜果研究所，新疆 鄯善 838200）

摘　要：新疆吐鲁番地区多年来作为世界上优质葡萄的主产地之一，气候条件极其特殊（高温、干燥、多风）。高产、优质、环境适应性强的葡萄新品种一直是市场的需求方向。“新郁”是由E42-6（“红地球”实生优系）为母本，“里扎马特”为父本杂交育成的新品种，于2005年在新疆维吾尔自治区农作物品种登记委员会登记。研究测定了环境因子对葡萄品种“新郁”光合效应的影响。结果表明，吐鲁番地区强光照持续时间长，高温低湿；光合有效辐射（*PARi*）最高为1 454 $\mu mol \cdot m^{-2} \cdot s^{-1}$，谷值为111 $\mu mol \cdot m^{-2} \cdot s^{-1}$，平均为938.889 6 $\mu mol \cdot m^{-2} \cdot s^{-1}$；大气温度和光照强度在13:00—16:00稳定增长至最高值，净光合速率（*Pn*）在11:00之前保持稳定增长，在11:00—14:00有“午休”现象，在正午时达最低值，为2.77 $\mu mol \cdot m^{-2} \cdot s^{-1}$。可见，葡萄新品种“新郁”在新疆的极端天气下生长适应性良好。

收稿日期：2014-12-04　**修回日期**：2015-03-19

基金项目：国家“十一五”科技支撑计划项目（2007BAD36B08）。

作者简介：纪薇，女，讲师，博士，研究方向：园艺植物育种学。E-mail：jiweiputao@163.com

* **通信作者**：张宗勤，男，副教授，博士，研究方向：园艺植物种质资源学。E-mail：zhangzongqin@nwsuaf.edu.cn

关键词:葡萄属;葡萄;光合作用;新品种;吐鲁番

Grapes are the most popular and widely grown fruit in the world and grow successfully in almost every climate. Breeding objectives vary by region and market necessity, but many programs seek to combine high quality fruit with environmental adaptation and improved disease resistance. Breeding resistant rootstock has long been considered to be an effective approach to controlling *Xiphinema index*[1-2].

Grapevine is cultivated nearly 2 300 years old in Turpan District in Xinjiang, China[3]. Turpan is one of the major high-quality grape production bases in the world for years because of its hot, dry, and windy climate[4]. These growing conditions are significantly different from those in much of Europe. It is essential to provide supplementary water by irrigation for grapevines to both survive and to make satisfactory growth over the hot summer months. The size of viticulture here is over 27 000 hm^2 for years. 80% of grapevine cultured in the area is 'Thompson Seedless' (*Vitis vinifera*) for raisin and table grape production. Growers want high yielding grapes with good shelf life and suitability for Xinjiang′s diverse growing regions. Therefore, new varieties of the great necessity need to be introduced or bred in Xinjiang. Some new varieties had been bred in the similar dry region[5] and been bred or studied via traditional and transgenic methodology[6]. 'Xinyu' is a new variety we bred in 2005, but it has not been studied extensively.

Fruit breeding requires testing of many characteristics to increase the probability of electing superior genotypes. These characters include physiology and molecular background as well as basically commercial important traits of grapes, such as berry ripening time, berry weight, soluble solids concentration, titratable acidity, and berry flesh texture[7-14]. However, many characteristics that are used to describe responses physiologically of the variety "Xinyu" are not known.

The objectives of this study were to evaluate the productivity, and to illustrate its physiological adaptation mechanism by determining the responsibility to climate factors of the new variety 'Xinyu' on photosynthesis in local vineyard, and to estimate the feasibility of the methodology of grapevine breeding via hybridization based on the photosynthetic responses in the arid desert region.

1 Materials and methods

1.1 Plant material and experimental site

'Xinyu' was bred and selected at the experimental vineyard in Institute of Grape and Melon of Xinjiang Uygur Autonomous Region(Turpan, Xinjiang, China, 90°17′30″E, 42°54′32″N, altitude 435 m). The site is in a typical continental temperate climate zone. It is rich in sunlight resource with a mean annual sunshine duration over 3 056 h, mean annual temperature of 14.4℃, annual accumulated temperature (>0℃) of 5 956℃ and (≥10℃) of 5 372.5℃, frost-free days of 224 days. The highest temperature could reach 48.3℃ historically. The average duration of the temperature over 40℃ is around 40 days, Temperature difference between day and night could reach 20℃. However, the regions is limited in water resources with a mean annual precipitation of 16.6 mm, and mean annual evaporation from a free water surface is 2 844.9 mm, and relative air humidity is as low as 30%.

The 5-year-old grapevines were planted with row spacing of 5 m and plant spacing of 1 m. The trellis for grapevine is shed at 1.5 m in height.

1.2 Gas exchanges

The net photosynthesis rate (*Pn*), the stomatal conductance (*Gs*), the transpiration rate (*Tr*), photosynthetic available radiation (*PARi*), and vapor deficit at the leaf surface (*Vpdl*) were measured simultaneously in fully developed leaves using a portable infrared gas analyser (Li-Cor 6400 Photosynthetic Meter, Lincoln, NE, USA). The infrared gas analysis system was equipped with a clamp-on leaf cuvette that exposed 6 cm^2 of leaf area. Measurements were replicated at seven leaves for each time from morning till evening.

1.3 Environmental condition determination

Air temperature and humidity were determined by using three automatic hygrothermographs (ZDR-20, Zhejiang University of Electrical

Equipment Factory, China) and two automatic thermographs (ZDR-21, Zhejiang University of Electrical Equipment Factory, China) placed on the grape leaf canopy. Three data of humidity and seven data of temperature were recorded automatically in every 30 s. Sunlight intensity was determined by using a Dual Radiation Meter (Apogee Instruments Inc., China).

1.4 Chlorophyll measurements

Chlorophyll readings were taken with a hand-held dual-wavelength meter (SPAD 502, Chlorophyll meter, Minolta Camera Co., Ltd., Japan). For each time, the 11 fully expanded leaves per plot were used.

1.5 Data analysis

Graphics and curve fitting were performed using Microsoft Excel 2003 software (Microsoft Corporation). All data analyzed using software DPS 3.01 (Data Processing System, Refine Information Tech. Co., LtD., China). Data regarding the interactions were reported when the interactions were statistically significant at Duncan's multiple range test at $p<0.05$ or $p<0.01$.

2 Results and analysis

2.1 Diurnal variation of *Pn*, sunlight intensity, air temperature, relative humidity and *PARi*

In Turpan, Xinjiang, the time of sunrise in August was about 7.30 a.m. (Beijing Time). Air temperature and sunlight intensity kept at high levels from 10 a.m. to 6 p.m., however the relative humidity dropped to a relative lower value. Air temperature and sunlight intensity reached the intraday highest value during 1 p.m. to 4 p.m., while *Pn* was at a relative high value. *PARi* reached peak at 1 454 μmol · m^{-2} · s^{-1}, reached valley at 111 μmol · m^{-2} · s^{-1}. The average *PARi* was at 938.889 6 μmol · m^{-2} · s^{-1} which was 340.956 5 μmol · m^{-2} · s^{-1} lower than intraday average canopy sunlight intensity. A steady increase in *Pn* was measured before 11 a.m. and there was 'midday depression' during 11 a.m. to 2 p.m. and the valley value was at 2.77 μmol · m^{-2} · s^{-1} at noon, which respectively accounted for 49% and 38% of the peak value of *Pn* before midday depression and after midday depression (Fig. 1). It was obvious that the climate in Turpan provided an extremely hot and relatively dry condition for growing of grapevine. It is characterized by long-time simultaneous high sunlight intensity, high temperature and relatively low humidity here. 'Xinyu', as a new fruitful variety, could adapt to this local environmental conditions well.

2.2 Relationship between *Pn* and the environmental factors

The changes of *Pn* of the leaves has no obvious regularity, but the trend line showed that the overall *Pn* was increasing as the rising of air temperature and sunlight intensity and decreasing as the rising of relative humidity (Fig. 2 A—C). Even though the high-temperature up to 39℃ was not the major restriction factor on *Pn* (Fig. 2A). And

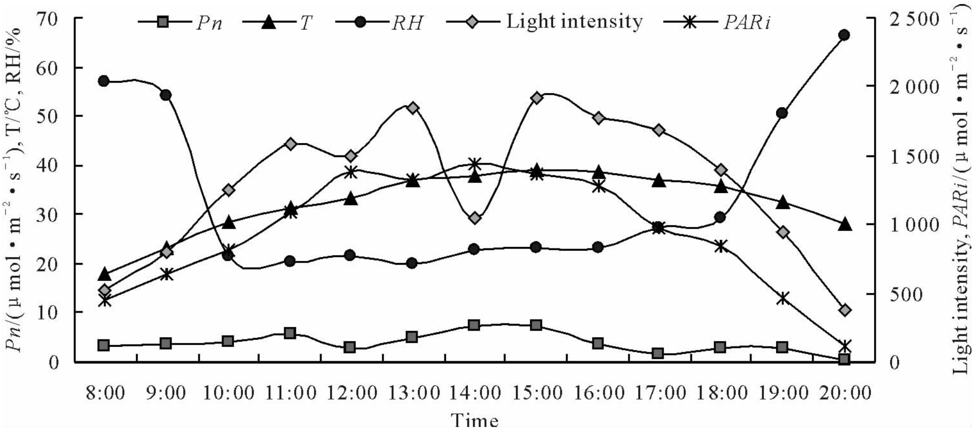

Fig. 1 Diurnal variation of the net photosynthesis rate (*Pn*), sunlight intensity, air temperature (*T*), relative humidity (*RH*) and photosynthetic available radiation (*PARi*) (Turpan, Aug. 12th, 2008)

图 1　净光合速率(*Pn*),日照强度,大气温度(*T*),相对湿度(*RH*)和光合有效辐射(*PARi*)的日变化(吐鲁番,2008 年 8 月 12 号)

the *Pn* reached peak at 2.78 μmol · m^{-2} · s^{-1} when the relative humidity was 25.27%. The relative humidity neither was too high nor too low is conducive to photosynthesis (Fig. 2B). The sunlight intensity over 1 000 μmol · m^{-2} · s^{-1} was from 9 a. m. to 7 p. m., peaking at 1 920 μmol · m^{-2} · s^{-1} at 3 p. m. Solar radiation in this area is quite well (Fig. 2C).

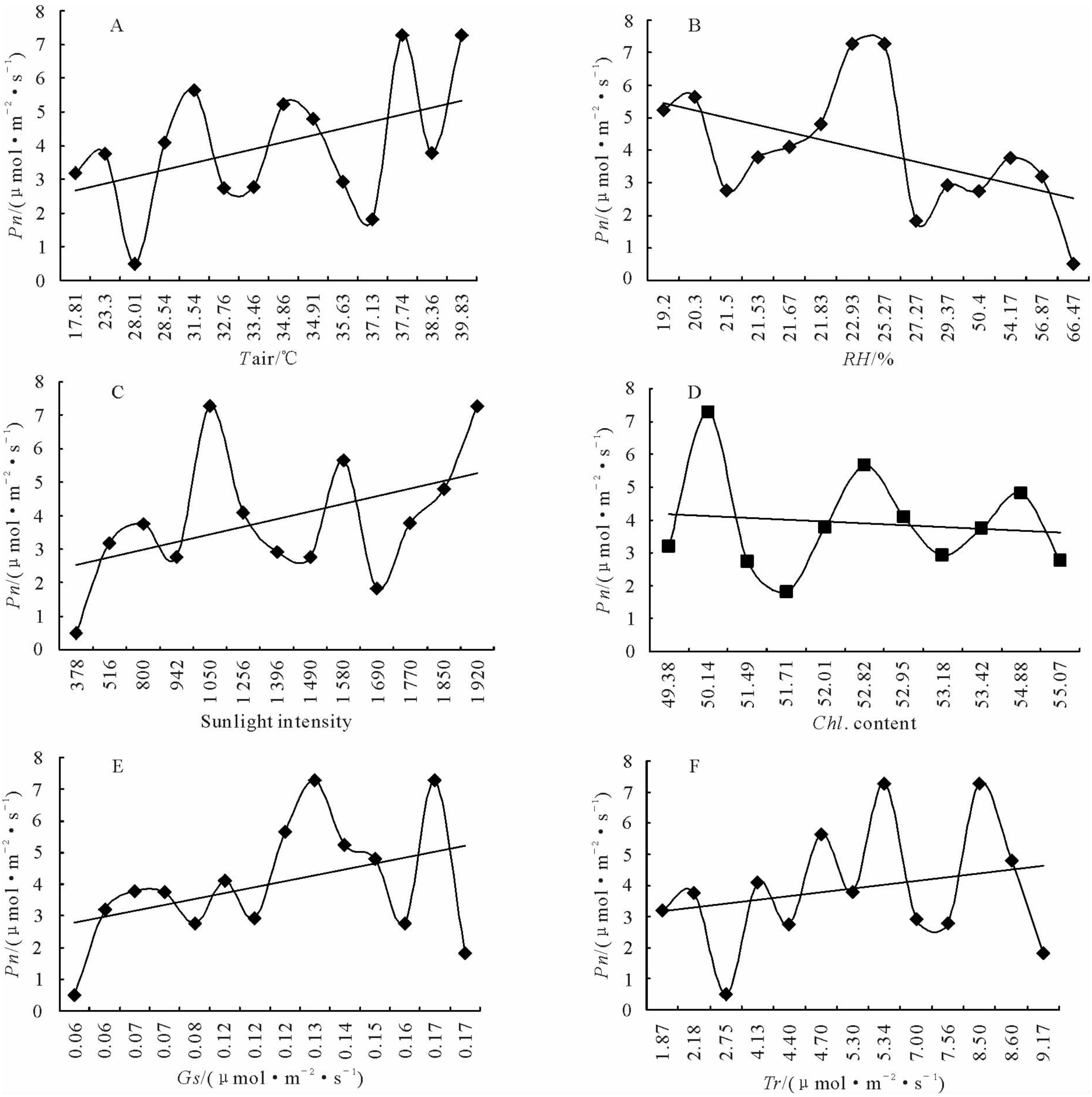

Fig. 2 A: relationship between the net photosynthesis rate (*Pn*) of the leaves and air temperature (*Tair*), B: relationship between *Pn* and Relative Humidity(*RH*) of canopy leaves, C: relationship between *Pn* and sunlight intensity of canopy leaves, D: relationship between *Pn* and chlorophyll content(*Chl* con.), E: relationship between *Pn* and stomatal conductance (*Gs*), F: relationship between *Pn* and transpiration rate (*Tr*)

图 2 A：叶片净光合速率(*Pn*) 和大气温度(*T*air)之间的关系，B:净光合速率(*Pn*)和叶幕层相对湿度(*RH*)之间的关系，C:净光合速率(*Pn*)和叶幕层光照强度之间的关系，D:净光合速率(*Pn*)和叶绿素含量(*Chl* con.)之间的关系，E:净光合速率(*Pn*)和气孔导度(*Gs*)之间的关系，F:净光合速率(*Pn*)和蒸腾速率(*Tr*)之间的关系

2.3 Diurnal variation of *Pn*, chlorophyll content, *Tr* and *Vpdl*

Statistical analysis showed that chlorophyll contents were significant difference in the different time periods ($F_{cal}=2.462\ 988>F_{crit}=1.911\ 141$, $p_{-value(0.05)}=0.010\ 3$). It showed that chlorophyll content affected by environmental conditions, but the changes of *Pn* was no correlation with leaf chlorophyll content (Fig. 2D).

Gs had significant difference in the different time periods ($F_{cal}=14.710\ 4\gg F_{crit}=2.343\ 1$) based on statistical analysis. The peak value was at

0.174 429 μmol · m^{-2} · s^{-1} at 5 p.m. and the valley value was at 0.059 2 μmol · m^{-2} · s^{-1} at 8 p.m. The changes of *Pn* of the leaves had no apparent regularity, but the trend line showed that the overall *Pn* was increasing as the rising of *Gs*, that was to say, *Pn* was increasing with the increasing degree of stomatal opening (Fig. 2E). *Tr* was significant difference in the different time periods ($F_{cal}=37.041\,0 \gg F_{crit}=2.343\,1$). *Tr* reached peak at 9.171 4 μmol · m^{-2} · s^{-1} at 5 p.m., valley at 1.874 3 at 8 p.m. and average at 5.499 8 (Fig. 2F).

2.4 Relationship between diurnal variation of *Pn* and other indexes of photosynthesis

The chlorophyll content was increasing before 1 p.m., and reached the lowest value at 2 p.m. *Pn* Significantly dropped when the chlorophyll content reached the highest value. It showed that chlorophyll content was not the determinant of *Pn* (Fig. 3).

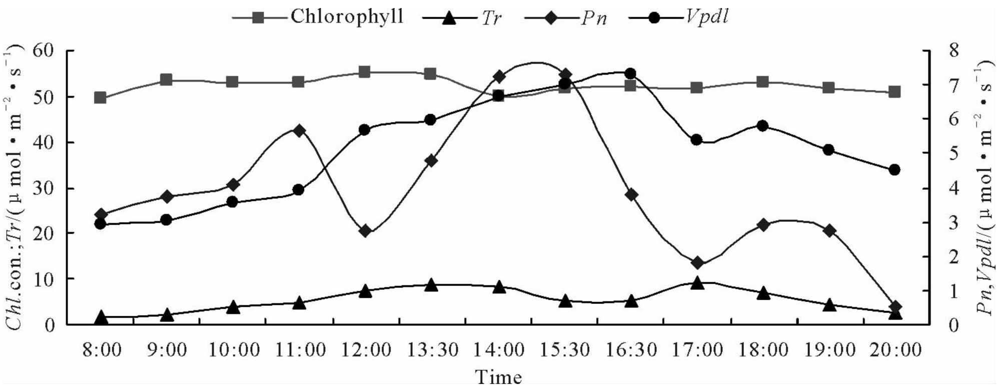

Fig. 3 Diurnal variation of the net photosynthesis rate (*Pn*), chlorophyll content (*Chl* con.), transpiration rate (*Tr*) and vapor deficit at the leaf surface (*Vpdl*)

图 3 净光合速率(*Pn*),叶绿素含量 (*Chl* con.),叶面蒸腾速率(*Tr*)和叶面饱和蒸汽压亏缺(*Vpdl*)的日变化

2.5 Correlation analysis of *Pn* and other indexes of photosynthesis

The correlation analysis showed that there were significant positive correlations between *Pn* and *PARi*, sunlight intensity, T_{air}, *Vpdl*, *Tr* and *Gs* respectively. And the order of correlation was *PARi* > sunlight intensity > T_{air} > *Vpdl* > *Tr* > *Gs*. But *Pn* has no correlation with chlorophyll content and *RH*. The chlorophyll content has significant correlations with sunlight intensity, *Tr* and *Vpdl* has significant correlations with *Tair* (Table 1).

Table 1 Correlation analysis of net photosynthesis rate (*Pn*) and other indexes of photosynthesis*

表 1 净光合速率(*Pn*)和光合作用其他指标的相关性分析*

	Pn	*Chl* con.	*Tr*	*Vpdl*	Light intensity	*PARi*	*Gs*	Tair	*RH*
Pn	1.00								
Chl con.	−0.02	1.00							
Tr	0.22	0.33	1.00						
Vpdl	0.34	0.10	0.68	1.00					
Light intensity	0.44	0.52	0.66	0.64	1.00				
PARi	0.69	0.38	0.71	0.67	0.81	1.00			
Gs	0.16	0.46	0.87	0.28	0.60	0.58	1.00		
Tair	0.35	0.27	0.80	0.92	0.78	0.71	0.53	1.00	
RH	−0.58	−0.45	−0.72	−0.55	−0.88	−0.90	−0.72	−0.71	1.00

注: * the net photosynthesis rate(*Pn*), chlorophyll content(*Chl* con.), transpiration rate (*Tr*) and vapor deficit at the leaf surface (*Vpdl*), photosynthetic available radiation (*PARi*), stomatal conductance (*Gs*), air temperature(*Tair*), relative humidity of air (*RH*).

3 Conclusion and discussion

3.1 The influences of environmental factors

The grape and wine consumption concerns at least 40 countries in the world. The climate of the different grape-growing regions worldwide accounts for a large part of the diversity of varieties cultivated, and viticulture products[15]. Generally, in a given area, the soil type and viticultural practices do not change significantly from year to year and, therefore, climate is the most dominant factor in determining grape quality[16]. Exposure to sublethal high temperature can increase the thermotolerance of plants. Potential mechanisms of response include synthesis of heat-shock proteins and isoprene and antioxidant production to protect the photosynthetic apparatus and cellular metabolism[17]. The highest temperature in Turpan is about 40℃. Not only the temperature, but the low air humidity (15－25 mm rainfall yearly) and strong radiation (solar radiation beyond 10℃ is 3 250－3 770 mJ · m^{-2}), make the region a rough but excellent place for organic viticulture. So the appropriate variety must be bred for viticulture that adapting the climate. 'Xinyu' is a new variety we released 2005[18]. For the reasons mentioned *supra*, it is not surprising to note that the number of papers in literature which have dealt with the variety 'Xinyu' is quite small. This is the purpose of the study we performed. The physiology of photosynthetic properties of the variety was studied and reported here. Further studies are essential to determine other physiological and molecular basis of the variety in different regions.

The available evidence indicates that exposure of plants to environmental stresses can cause damage to compensated leaf photosynthesis; reducing CO_2 assimilation rates[19]. Increased temperatures curtail photosynthesis and increase CO_2 transfer conductance between intercellular spaces and carboxylation sites[20]. Stomatal conductance and net photosynthesis are inhibited by moderate heat stress in many plant species due to decreases in the activation state of rubisco[13,21]. In maize the *Pn* was inhibited at leaf temperatures above 38℃ and inhibition was much more severe when temperature was increased abruptly rather than gradually. However, high temperatures inhibition was independent of stomatal response to high temperature[13]. We got the similar results that *Pn* was not inhibited at temperature even above 39℃, but weak midday depression when temperature increased abruptly during 11 a. m. to 2 p. m. Despite negative effects of high temperature was observed, the optimum temperature for leaf photosynthesis is likely to increase with elevated levels of atmospheric CO_2. Several studies have concluded that CO_2-induced increases in crop yields are much more plausible[20]. Our results indicated that there were significant positive correlations between *Pn* and *PARi*, sunlight intensity, *Tair*, *Vpdl*, *Tr* and *Gs* respectively. *Pn* was at a relative high value even the air temperature and sunlight intensity reached the intraday highest value during 1 p. m. to 4 p. m., and the trend line showed that the overall *Pn* was increasing as the rising of air temperature, sunlight intensity, stomatal conductance and the transpiration rate. We could induced that 'Xinyu' could adapt to the environment in Turpan.

Heat shock reduces the amount of photosynthetic pigments[20]. We found that chlorophyll content had significant difference in the different time periods and chlorophyll content was affected by environmental conditions. However, the changes of *Pn* had no correlation with leaf chlorophyll content in this study. More researches may be needed to explain this mechanism.

3.2 The economic characters of fructification

A successful new fruit variety must be superior for yield and quality characteristics. Yield depends on the quantity of product whereas quality often decides the market price. Fruit quality is of paramount importance in marketing table grapes, no matter how superior is its yield performance[22]. It would be unwise to select a vine based only on a few characteristics because they may have unfavorable impacts on other characteristics.

Progenies characteristics could be predicted by its parents and evaluated objectively by the responsibility to the environment factors. 'Xinyu' is a variety with acceptable quality and productivity of its parents and with the good performances to the specific climate. The bunch of 'Xinyu' is conical and compact, and the weight of a single bunch is over 800 g. The berry is oblong and the pericarp is fuchsia. The average berry weight of 'Xinyu', E42-6 and 'Rizamat' is 11.6 g, 8.6 g and 9.1 g, respectively. It is obvious that 'Xinyu', as a new cultivar, has better economic characters than its parents. The multiple spot regional trials showed that the cultivar were excellent of its strong vigorous growth, high yield and good quality[18]. The results of the economic characters of fructification and the photosynthetic responses demonstrated that it is feasible of the methodology of grapevine breeding via hybridization in the arid desert region of northwest China. The results of this study could be used to instruct the variety extension, suitable cultivating technology development of the variety, and to be a reference for new variety breeding work especially in the similar climate region.

Therefore, we could conclude that the climate in Turpan District in Xinjiang, China, provides an extremely hot and relatively dry condition for growing of grapevine. It is characterized by long-time simultaneous high sunlight intensity, high temperature and relatively low humidity here. Xinyu, a new variety, can adapt to these special local environmental conditions and has a better economic character than its parents, and with great potential for extending to the region of climate similarity.

Reference:

[1] CHLOUPEKA O, HRSTKOVA P, SCHWEIGERT P. Yield and its stability, crop diversity, adaptability and response to climate change, weather and fertilisation over 75 years in the Czech Republic in comparison to some European countries[J]. Field Crops Research, 2004, 85(2): 167-190.

[2] XU K, RIAZ S, RORONCORONI N C, *et al*. Genetic and QTL analysis of resistance to *Xiphinema index* in a grapevine cross [J]. Theoretic and Application Genetics, 2008, 116(2): 305-311.

[3] JIANG H E, ZHANG Y B, LI X, *et al*. Evidence for early viticulture in China: proof of a grapevine (*Vitis vinifera* L., Vitaceae) in the Yanghai Tombs, Xinjiang[J]. J. of Archaeological Sci, 2009, 36(7): 1458-1465.

[4] HE P C. Ampeliology[M]. Beijing: China Agriculture Press, 1999.

[5] POSSINGHAM J V. Breeding grapes for warm climates-the Australia experimence[J]. Acta Horticulturae, 1995, 3: 88.

[6] BORNHOFF B A, HARST M, ZYPRIAN E, *et al*. Transgenic plants of *Vitis vinifera* cv. *seyval* blanc[J]. Plant Cell Rep, 2005, 24(7): 433-438.

[7] WRIERI C, ZERBIB G, MARCHIOL L, *et al*. Physiological response of grapevine leaves to lightflecks[J]. Scientia Horticulturae, 1995(6): 147-159.

[8] SATO A, YAMADA M, IWANAMI H, *et al*. Optimal spatial and temporal measurement repetition for reducing environmental variation of berry traits in grape breeding[J]. Scientia Horticulturae, 2000, 85(1): 75-83.

[9] AMANDA R. WALKER, ELIZABETH LEE, *et al*. Two new grape cultivars, bud sports of Cabernet Sauvignon bearing pale-coloured berries, are the result of deletion of two regulatory genes of the berry colour locus[J]. Plant Mol. Biol., 2006, 62(4/5): 623-635.

[10] RAMOS M C, MARTíNEZ-CASASNOVAS J A. Impact of land levelling on soil moisture and runoff variability in vineyards under different rainfall distributions in a mediterranean climate and its influence on crop productivity[J]. J. of Hydrology, 2006, 321(1): 131-146.

[11] HOOD A, CECHET B, HOSSAIN H, *et al*. Options for Victorian agriculture in a "new" climate: pilot study linking climate change and land suitability modeling[J]. Environmental Modelling & Software, 2006, 21(9): 1280-1289.

[12] CHRISTOS A, DORDAS, CHRISTOS SIOULAS. Safflower yield, chlorophyll content, photosynthesis, and water use efficiency response to nitrogen fertilization under rainfed conditions[J]. Ind. Crops and Pro., 2088, 27: 75-85.

[13] PONI S, BERNIZZONI F, CIVARDI S. Response of "Sangiovese" grapevines to partial root-zone drying: gas-exchange, growth and grape composition[J]. Scientia Horticulturae, 2007, 114(2): 96-103.

[14] PONI S, CIVARDI S. The effect of early leaf removal on whole-canopy gas exchange and vine performance of "*Vitis vinifera*" L. "Sangiovese"[J]. Vitis, 2008, 47(1): 1-6.

[15] TONIETTO J, CARBONNEAU A. A multicriteria climatic classification system for grape-growing regions worldwide [J]. Agricultural and Forest Meteorology, 2004, 124: 81-97.

[16] ZSÓFI ZS, GÁL L, SZILÁGYI Z, *et al*. Use of stomatal conductance and pre-dawn water potential to classify terroir for the grape variety[J]. Australian J. of Grape and Wine Research, 2009, 15(1): 36-47.

[17] KOZLOWSKI T T, PALLARDY S G. Acclimation and adaptive responses of woody plants to environmental stresses [J]. The Botanical Review, 2002, 68(2): 270-334.

[18] LUO Q W, SUN F, CAI J S, *et al*. A new grape cultivar 'Xinyu'[J]. Acta Horticulturae Sinica, 2007, 34 (3): 797. 骆强伟，孙锋，蔡军社，等. 葡萄新品种-新郁[J]. 园艺学报，2007, 34 (3): 797.

[19] ANTHONY E. HALL. Breeding for adaptation to drought and heat in cowpea[J]. European J. of Agronomy, 2004, 21 (4): 447-454.

[20] WAHID A, GELANI S, ASHRAF M, *et al*. Heat tolerance in plants: an overview[J]. Environmental and Experimental Botany, 2007, 61: 199-223.

[21] GALBÁCS Z, MOLNÁR S, HALÁSZ G, *et al*. Identification of grapevine cultivars using microsatelite-based DNA barcodes[J]. Vitis, 2009, 48(1): 17-24.

[22] SISTRUNK W A, J N MOORE. Quality[M]. MOORE J N, JANICK J, eds., Methods in Fruit Breeding. West Lafayette: Purdue University Press, Indiana, 1983: 274-293.