Journal of the Saudi Society of Agricultural Sciences (2015) xxx, xxx–xxx

King Saud University

Journal of the Saudi Society of Agricultural Sciences

www.ksu.edu.sa
www.sciencedirect.com

FULL LENGTH ARTICLE

Influence of drought stress on photosynthetic characteristics and protective enzymes of potato at seedling stage

Jianhui Li, Zhenming Cang, Feng Jiao, Xuejing Bai, Ding Zhang, Ruichang Zhai *

Heilongjiang Bayi Agricultural University, Daqing 163319, Helongjian Province, China

Received 14 January 2015; revised 3 March 2015; accepted 5 March 2015

KEYWORDS

Photosynthesis rate;
Light-response curve;
Chlorophyll fluorescence parameters;
Drought stress;
Activity of protective enzymes

Abstract The influences of drought stress on the photosynthesis rate, the chlorophyll fluorescence parameters, the activity of protective enzymes of potato, and the biomass fresh weights of potato leaves at seedling stage were investigated, using two different varieties of potato with significant difference in drought resistance to carry out potted plant experiment with water control. Under mild and medium drought stresses, the two potato varieties stabilized the photosynthetic organ functions by light capture reduction, heat dissipation and the regulation of enzyme activity. The damage of photosystem II and antioxidant enzyme system was the non-stomatal limitation factors for the decrease of the photosynthesis rate under serious drought stress. The influence on the physiological parameters of potato Kexin No. 1 was weaker than that of potato Kexin No. 12 under drought stresses. The higher photosynthesis rate and stronger activity of protective enzymes were the important physiological reasons for the drought resistance of Kexin No. 1.

1. Introduction

Water deficiency is a common adverse factor for the growth of plants in the field conditions. It has substantial influence on the growth condition, morphological structure and physiology and biochemistry of plants (Bosabalidis and Kofidis, 2002; Jill et al., 2012; Wu et al., 2008). Under the drought stress, plants usually respond via stomata regulation, osmotic adjustment and anti-oxidative defense, in order to relieve the damage caused by the drought stress. However, long period of high intensity of drought stress could retard the growth of plants, causing the changes of the morphological structure and the distribution pattern of biomass, or even death (Christina and Gisela, 2013; Dias et al., 2007). Therefore, the response of crops to the drought stress and the drought resistance mechanism has drawn an increasing attention. Studies (Efeoglu et al., 2009) indicated that drought is an important factor responsible for the inhibited growth of plants and reduced photosynthesis. Drought could prevent the entering of CO_2 into the leaves, influence the absorption of CO_2 by the carboxylation center and result in the decrease of net photosynthetic rate (P_n) (Zhang, 1999). In recent years, there have been studies on

* Corresponding author. Tel./fax: +86 459 6819186.
E-mail address: ruichangzhai@163.com (R. Zhai).
Peer review under responsibility of King Saud University.

ELSEVIER Production and hosting by Elsevier

http://dx.doi.org/10.1016/j.jssas.2015.03.001
1658-077X © 2015 Production and hosting by Elsevier B.V. on behalf of King Saud University.

the relationship between the fluorescence characteristics of leaves and the membrane lipid peroxidation during the photo-oxidation process. The results indicate that the PS II light energy conversion and the metabolism of reactive oxygen species are closely related to stress (Massacci et al., 1990; Wang et al., 2006). Therefore, the comprehensive study on photosynthesis, activity of protective enzymes and the relationship between the two can help explain the mechanism of the light energy conversion and utilization as well as the mechanism of drought resistance and yield increase.

Potato is one of the four major cereal crops in the world. It is planted in 156 countries and regions worldwide (Breezy, 2013). Potato is also an important agricultural and economic crop in northern China, with a large planting area. Potato is a typical crop of temperate climate, sensitive to water deficiency (Xu et al., 2008). However, most of the potato planting area in China is in shortage of water resources and the water deficiency influences greatly the growth and yield of potato (Lin et al., 2010). But up till now, there have been no systematic and profound studies on the drought resistance physiology and regulation in potato. This research selected different varieties of potato with significant difference in drought resistance to carry out potted plant experiment with water control. The purpose was to study the influence of drought stress on the photosynthesis rate, the chlorophyll fluorescence parameters and the activity of protective enzymes. The work will deepen the understanding of the mechanism of light energy utilization and dissipation in potatoes under drought stress. A theoretical reference is provided for water saving in the planting of potatoes.

2. Materials and methods

2.1. Experiment location and materials

The potted plant experiment was conducted in the mobile canopy in the science park of Farm 858 in Heilongjiang Province in 2012. The experiment location is situated in the eastern part of the Yunshan depression zone of Hulin Basin, with cold temperate continental monsoon climate. The annual average precipitation is 566.2 mm and the frost free period is 141 days. The test soil is the 0–20 cm surface layer of albic bleached meadow soil. The measurement results of the traits of soil are as follows: Organic matter, 19.82 g kg^{-1}, alkali-hydrolysable nitrogen, 103.41 mg kg^{-1}, available phosphorus (Olsen-P), 23.83 mg kg^{-1}, available potassium (1 mol L^{-1} NH_4OAC-AAS method), 121.61 mg kg^{-1}, pH (electrode method), 7.21. The varieties of potato used for the experiment were Kexin No. 1 with strong drought resistance and Kexin No. 12 with weak drought resistance. Kexin No. 1 has erect form, with medium number of shoots and sturdy stems. The growth season is approximately 95 days, and the stress resistance is strong. Kexin No. 12 has erect form, with medium growth vigor and medium number of shoots. The growth season is approximately 95 days, with resistance to virus diseases and susceptibility to late blight.

2.2. Experiment design

The air dried soil of 15 kg was placed into a plastic barrel with the mouth 36 cm in diameter, the bottom diameter of 28 cm and a height of 38 cm. On the bottom of the barrel were drilled 5–6 holes with the diameter of 1 cm each. The rigid plastic tube inserted into the bottom of the barrel was used for the watering. The completely randomized design was adopted for the potted plant experiment. The degree of drought stress was determined according to the soil moisture content. The watering treatment had 4 levels, i.e. normal watering for each variety (CK), with soil moisture content being the maximum water holding capacity in field, 70–80%; mild drought (T1), with the soil moisture content being 60–70% of the maximum water holding capacity in field; medium drought (T2), with the soil moisture content being 50–60% of the maximum water holding capacity in field; serious drought (T3), with the soil moisture content being 35–45% of the maximum water holding capacity in field. The stress treatment was applied 10 days after the seedling. Every treatment had 10 pots and 3 duplicates. There were 120 pots of each species in total. During the growth of potato, the canopy was shut down in the rainfall, and it would be opened in other times to let potato grow in the open. Soil moisture content was determined by TZS-IIW soil moisture analyzer equipped with FDR soil moisture sensor (Tuopu Co., China).

On May 10, the seed potato with uniform growth status and one terminal bud was planted in the plastic barrel. Every pot had 1 plant until the natural drought reached the defined range of soil moisture content. Every day at 8:00 am and 18:00 pm, the water was supplemented and controlled with weighing method and the record was made. When the soil relative moisture content indicated drought stress, the third compound leaf under the terminal leaf (fully expanded leaf) of the sample plants was obtained for the measurement of parameters for 7 consecutive days at 9:00.

2.3. Measurement parameters and methods

2.3.1. Measurement of light-response curve of the leaf

The Li-6400 portable photosynthesis system produced by the American company Li-cor was used to measure the P_n-PAR response curve during 9:00–12:00 using Li-6400-02B red and blue light source. The measurement was conducted for 2 consecutive sunny days and 3 duplicates were set. The average value was taken as the measurement value. via the open air channel, the temperature was set at 25 °C, the atmosphere CO_2 concentration (C_a), 400 μmol mol^{-1}, the atmosphere relative humidity, 50–70%, the light intensity scale, 1800, 1600, 1400, 1200, 1000, 800, 600, 400, 350, 300, 200, 150, 100, 50, 20, 0 μmol m^{-2} s^{-1}, respectively. The net photosynthetic rate (P_n, μmol m^{-2} s^{-1}), stomatal conductance (G_s, mmol m^{-2} s^{-1}) and intercellular CO_2 concentration (C_i, cmol mol^{-1}) of the leaves at each light intensity were measured. The stoma limit value was calculated according to $(L_s) = 1 - C_i/C_a$ (Larocque, 2002).

2.3.2. Measurement of light-response curves of chlorophyll fluorescence parameters

The PAM-2100 fluorescence analyzer produced by German company WALZ was used to measure the light-response curve of chlorophyll fluorescence parameters at the symmetric points with the leaf vein as the axis. After the dark adaptation for 30 min, the initial fluorescence (F_0) and maximum fluorescence (F_m) in dark adaptation were measured. The 11 light intensities

Please cite this article in press as: Li, J. et al., Influence of drought stress on photosynthetic characteristics and protective enzymes of potato at seedling stage. Journal of the Saudi Society of Agricultural Sciences (2015), http://dx.doi.org/10.1016/j.jssas.2015.03.001