

Influence of Surface Waterlogging on Cotton Seedlings under High Temperature Synoptic Conditions

^{1,2}Qiao-yan Qin, ^{1,2}Jian-qiang Zhu, ^{1,3}Chen-zhong Jia and ²Hong-yun Ma

¹Engineering Research Center of Wetland Agriculture in the Middle Reaches, Ministry of Education,

²Department of Agriculture, Yangtze University, Jingzhou 434025, P.R China

³Department of Chemical and Environmental Engineering, Yangtze University,
Jingzhou 434023, P.R. China

Abstract: Surface waterlogging is an agro-meteorological disaster caused by excessive precipitation, when field water is too deep, too long, to detriment crop growth. Soil waterlogging caused by flooding has become a major natural disasters affecting cotton (*Gossypium hirsutum* L.) production in the middle and lower reaches of the Yangtze River. Pot experiment was conducted at the cotton seedlings stage and in the greenhouse to simulate the waterlogged field combined with high temperature synoptic condition after the rain. Results indicated that: surface waterlogging significantly inhibits plant growth and there was a very significant negative correlation between plant height and stress time; the root shoot ratio had a increasing tendency with coercion time extension; Chlorophyll SPAD value in cotton leaves of 6 and 9 days treatment increased in the early adversity; when the waterlogging stresses relieves, the chlorophyll SPAD value reduced significantly; red-green ratio responses to waterlogging stress is relatively lagging; red-green ratio of cotton main stalk decreased and then increased; Malondial Dehyde (MDA) content increased rapidly and lasted to a certain time; when the waterlogging stresses relieves, MDA content of 6 and 9 days treatment still maintained a higher level and there was no remarkable difference between them; at the initial period, mostly seedlings were at the wilting conditions, the activity of Superoxide Dismutase (SOD) was low; but as the flooding time extending, SOD activity increased; SOD activity change tendency of 6 and 9 days treatment was consistent; Peroxide enzyme (POD) activity had no significant difference between different treatment in the early adversity, as the prolonged waterlogging stresses, which of 3 and 9 days treatment increased gradually; after being transferred to outside the greenhouse, POD activity of 6 days treatment was low abnormally.

Keywords: Cotton seedlings, high temperature synoptic conditions, surface waterlogging

INTRODUCTION

Waterlogging disaster is the general term of surface waterlogging and subsurface waterlogging. Surface waterlogging is an agro-meteorological disaster caused by excessive precipitation, when field water is too deep, too long, to detriment crop growth. Subsurface waterlogging is a natural disaster due to the long-term high groundwater level or perched water in the soil surface which has led to the crop root zone excessive moisture and produce the imbalance of water vapor, deteriorate soil environment, dipping crop roots, influence the normal growth of crops (Liu *et al.*, 2011; Zhu *et al.*, 2011). Jianghan plain is one of the well-known commodity cotton base in China, because of the impact of the subtropical monsoon climate, there is usually more than one strong precipitation process accompanied waterlogging disaster in spring and summer (Zhu *et al.*, 2011). Cotton is known to be poorly adapted to waterlogged conditions (Stephen

et al., 2009). Soil waterlogging caused by flooding has become a major natural disasters affecting cotton production (Li *et al.*, 1999). Seedling waterlogging stress mainly affects the cotton normal growth and development and stress tolerance (Wang *et al.*, 2001; Li *et al.*, 2005). Cotton would produce a certain adaptability to soil waterlogging stress and restore growth, but prolonged as waterlogging, restoring growth slows down (Liang *et al.*, 2008). In the middle-lower reaches of Yangtze River, rain-induced waterlogging farmland is common in the summer. Usually there are two typical situations: the crops suffering the waterlogging stresses under non-high temperature weather and high temperature weather after rain. In view of the above two cases, research has important practical significance for scientific management of farmland water. But as yet there are few related reports of composite conditions of high temperature and waterlogging on cotton growth and development. Therefore, on the basis of the previous isolated studies

about waterlogging and high temperature, influence of surface waterlogging on cotton seedlings under high temperature synoptic conditions was studied in this study, with a view to provide theoretical basis for the cultivation of cotton resistant to adverse circumstance and increase production.

MATERIALS AND METHODS

Pot culture experiment was conducted in greenhouse at Yangtze University Agricultural College experiment bases in 2011. Experimental crop was Jing hybrid cotton-88, cultivated seedlings in the nutrition bowl in mid-April, transplanted one plant at 3 leaf stage to each plastic bucket with 45 cm high and 20 cm diameter which had a flooding hole at the bottom. The plastic buckets were filled with 2 kg of soil which was sieved to 2 mm on an oven dry basis. The soil is loam, pH value is 7.6, contains 15.4 g/kg organic matter and 56.7 mg/kg available phosphorus and 185.6 mg/kg available potassium. Conventional crop management was applied during the recovery period. When the main stem red and green ratio is 6/4 or 7/3, placed the plastic buckets into the 10×1 m pool and kept 10 cm thick layer of water above the soil (June 8), to simulate surface waterlogging stress situations, with the management of normal soil moisture (the relative water content is 60-70%) as a comparison (control treatment, ck). Stayed 9 days in the greenhouse to analog high temperatures synoptic conditions, where the average temperature was 30°C and higher than the natural environment around 3°C. The experiment was arranged for three levels of 3, 6, 9 days and laid out in a randomized complete block design with 8 replications in each case.

Using ice box, fully expanded leaves of each treatment was selected every 5 days on morning 6:00-8:00. All analyses were performed on the main stem down 3 or 4 fully expanded functional leaves, each treatment took 3 plants and parallel determination 2 times every time.

The main stalk red green ratio surveyed with tape measure. Chlorophyll SPAD value of function leaf was determined by SPAD-502 Chlorophyll meter. Fluorescence parameter was determined by OS-30P Fluorescence analyzer. The activity of POD was determined by the more invasive wood phenol method, the activity of SOD with NBT method, MDA content with thiobarbituric acid color method (Chen and Wang, 2002).

All data presented are the mean value of the replications. Excel 2003 and the DPS v7.05 are used for data processing and statistical analysis.

RESULTS AND DISCUSSION

Analysis of plant height and root shoot ratio: Surface waterlogging significantly inhibits plant growth and there was a very significant negative correlation

Table 1: Effect of plant height and root shoot ratio by surface waterlogging combined with high temperature

Item	Stress time (days)			
	0	3	6	9
Height (cm)	31.30 a	25.70 b	22.90 c	21.30 c
Root shoot ratio	0.639 b	0.667 b	0.754 a	0.776 a

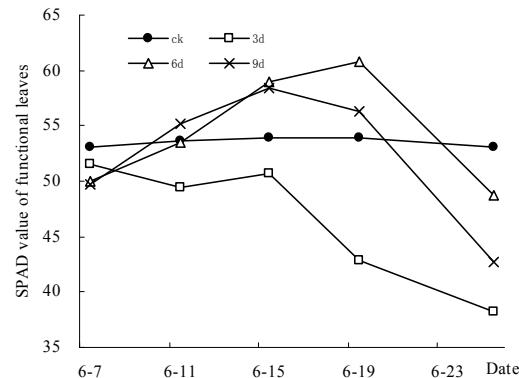


Fig. 1: Characteristic feature of the SPAD value

between plant height and stress time (Table 1), the correlation coefficients is -0.9401** ($p<0.01$, $n = 32$). Plant height had no significant difference between surface waterlogging stresses 6 and 9 days treatment, which indicated that cotton could produce a certain adaptability to surface waterlogging stress along with stress time extension. Surface waterlogging significantly inhibited above-ground organs growth and the root shoot ratio had an increasing tendency with stress time extension.

The characteristic feature of leaves chlorophyll SPAD values: Surface waterlogging stress significantly influenced functional leaves photosynthesis of cotton under high temperature synoptic conditions. Chlorophyll SPAD value in cotton leaves of 6 and 9 days treatment increased in the early adversity. Nine days later, the visual damaged symptom was found in the plants exposed to subsurface waterlogging treatment, being characterized by leaf chlorosis. When the waterlogging stresses relieves, the chlorophyll SPAD value reduced significantly (Fig. 1). Results indicated that chlorophyll SPAD value response to surface waterlogging injury needed certain time.

The characteristic feature of red-green ratio of cotton main stalk: Red-green ratio is the ratio of cotton main stalk red section and the green section. To a certain extent, it is often as a form of seedlings diagnostics indicator in field which reflecting the growth of cotton plants (Zhu and Li, 2006). The red and green section of seedlings stage main stalk respectively takes accounts for 50%, when red section is too long indicating the weak growth, on the contrary, green section is too long indicating the exuberant growth.

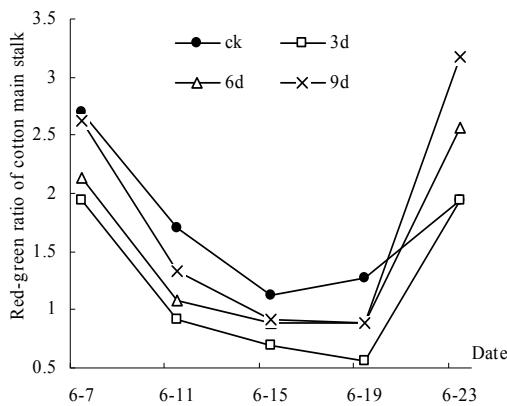


Fig. 2: Characteristic feature of red-green ratio of cotton main stalk

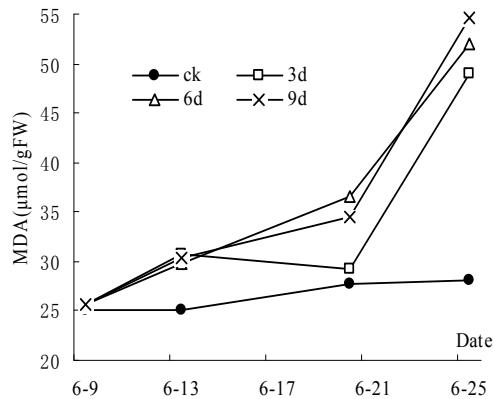


Fig. 3: Characteristic feature of MDA

Red-green ratio responses to waterlogging stress are relatively lagging. At beginning of waterlogging, plants are growing rapidly red-green ratio decreased gradually. With the prolonged of waterlogging stress, red-green ratio increased (Fig. 2).

The characteristic feature of MDA content: Malondial Dehyde (MDA) content is the membrane lipid per oxidation of most direct indicators. When cotton seedlings were subjected to surface waterlogging stress conditions, MDA content increased rapidly and lasted to a certain time (Fig. 3). When the waterlogging stresses relieves, MDA content of 6 and 9 days treatment still maintained higher level, which indicated the seedlings suffered injury seriously and there was no remarkable difference between them.

The characteristic feature of SOD activity: Been subjected to surface waterlogging stress conditions, the activity of SOD was far below the control treatment at the initial period (Fig. 4), perhaps because that the cotton plant suffered injury seriously and most

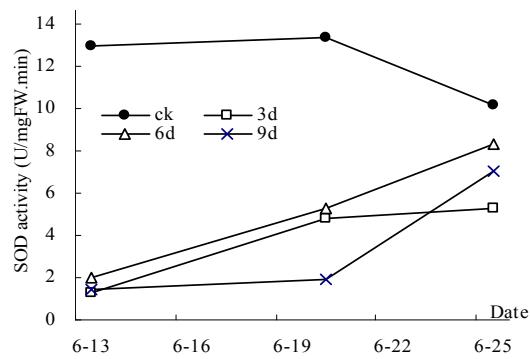


Fig. 4: Characteristic feature of SOD activity

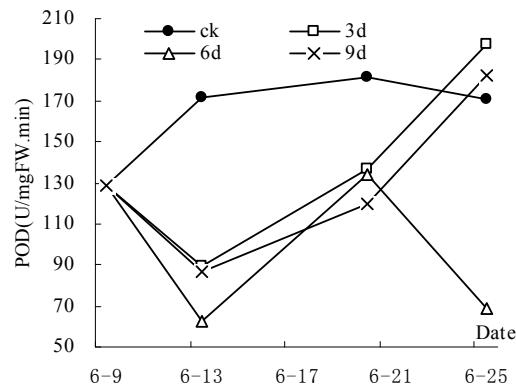


Fig. 5: Characteristic feature of POD activity

seedlings were at the wilting conditions (Each process ranging from 3-5 strain). But as the stress time extending, cotton seedlings produce certain adaptability to surface waterlogging environment, cotton seedlings growth gradually recovered and SOD activity increased to cope with excessive free radicals in the plants body. SOD activity change tendency of 6 and 9 days treatment was consistent. After being transferred to outside the greenhouse, along with the arrival of new turn precipitation (on June 19), the SOD activity of 6 and 9 days treatment showed an increasing tendency.

The characteristic feature of POD activity: Peroxide enzyme (POD) widely exists in the plant different organization as higher activity adaptive enzyme. It can reflect the characteristic of plant growth, metabolism condition as well as the compatibility to external environment. POD had the dual function and the expression time of different waterlogging processing was distinct (Zhang and Kirkham, 1994). POD activity had no significant difference between different treatment in the early adversity, as the prolonged waterlogging stresses, which of 3 and 9 days treatment increased gradually (Fig. 5). After being transferred to outside the greenhouse, POD activity of 6 days

treatment was abnormally low, but this result was consistent with that of subsurface waterlogging experimental results (9 days treatment) for the same period. The influence mechanism of POD to prevent waterlogging needs to be studied further.

CONCLUSION

Through experimental study and analysis, the following conclusions can be gained: impact of surface waterlogging combined with high temperature synoptic conditions on crops is usually due to the different length of time. In the early adversity, most cotton seedlings were at the wilting conditions. But cotton seedlings would produce certain adaptability to resistance adverse circumstances and restore growth through the self-adjustment as the stress time extending. Surface waterlogging stress influenced the photosynthetic performance of cotton and lead to the chlorophyll SPAD value and red-green ratio of cotton main stalk reducing significantly. But they responses to surface waterlogging stress are relatively lagging. When cotton seedlings are subjected to surface waterlogging stress conditions, the capacity of leaves for active oxygen generation is increased, often resulting in oxidative damages. MDA content is the most direct indicators of membrane lipid per-oxidation. In this experiment, MDA content increased rapidly and lasted to a certain time. Specific activities of some antioxidant enzymatic almost changes significantly during prolonged waterlogging treatment. The activity of SOD was far below the control treatment and POD activity had different change tendency between the different treatments. The influence mechanism of POD to prevent waterlogging needs to be studied further.

Therefore, it is very necessary for us to select proper regulative measures to resist the damage of cotton seedlings by the surface waterlogging.

ACKNOWLEDGMENT

This study has been partly supported by National Scientific Fund (51079007) and Special Fund for Agro-scientific Research in the Public Interest (201203032).

REFERENCES

- Chen, J.X. and X.F. Wang, 2002. The Guidance of Plant Physiology Experiments. South China University of Technology Press, Guangzhou, pp: 119-124.
- Li, L.N., K.Q. Peng, F.Z. Sun and B.J. Quo, 1999. Effects of flooding on yield and quality of cotton. *Acta Agron. Sin.*, 25(1): 109-114.
- Li, H.L., X.G. Wang, L.G. Cheng, D.F. Liu, X.P. Guo and W. Liu, 2005. Research on the criteria of farmland drainage under the influence of combined controlling of surface and subsurface waterlogging in several phases of cotton. *J. Irrig. Drain.*, 24(4): 1-4.
- Liang, Z.J., H.B. Tao, H.Z. Zhao, H.M. Liu and P. Wang, 2008. Recovery growth and photosynthesis of cotton at seedling stage with waterlogging stress. *Act. Botan. Boreali Occidentalia Sinica*, 28(9): 1830-1836.
- Liu, K.W., J. Fu and J.Q. Zhu, 2011. Effect of waterlogged stress on growth and development of upland crops and nutrient loss in farmland. *Hubei Agric. Sci.*, 50(1): 49-52.
- Stephen, P.M., P.B. Michael and T. Pongmanee, 2009. Cotton leaf nutrient concentrations in response to waterlogging under field conditions. *Field Crop. Res.*, 113: 246-255.
- Wang, L.M., J.B. Wang, F.F. Shen, X.K. Zhang and R.Z. Liu, 2001. Influences of waterlogging and drought on different transgenic BT cotton cultivars. *Cotton Sci.*, 13(2): 87-90.
- Zhang, J.X. and M.B. Kirkham, 1994. Drought-stress-induced changes in activities of superoxide dismutase, catalase and peroxidase in wheat species. *Plant Cell Physiol.*, 35: 785-791.
- Zhu, J.Q. and J. Li, 2006. Influence of continuous stress from multiple processes of surface and subsurface water logging on cotton. *J. Irrig. Drain.*, 25(3): 70-74.
- Zhu, J.Q., G.H. Ou, W.Y. Zhang and D.F. Liu, 2011. Experimental research on effect of surface and subsurface waterlogging in stage of cotton flowering and boll set on yield. *Trans. Chinese Soc. Agric. Eng.*, 19(4): 80-83.