

## Physiological Response of Cotton in Flowering Stage to Waterlogging Coupling with High Temperature

<sup>1</sup>Wei Yang, <sup>1</sup>Qi-xia Wu and <sup>1,2</sup>Jian-qiang Zhu

<sup>1</sup>Agricultural Department,

<sup>2</sup>Engineering Research Center of Wetland Agriculture in the Middle Reaches, Ministry of Education, Yangtze University, Jingzhou 434025, Hubei, P.R. China

**Abstract:** In midsummer, southern plain of China often has plenty of precipitation meanwhile encounters hot damage and a phenomena may occur that a synoptic process with the maximum temperature more than 35 for more than 3 days befalls within a week or 10 days after farmland suffering from waterlogging caused by heavy rainfall, this phenomena can be defined as concomitance of hot and waterlogging (abbreviated as CHW). The stage of cotton flowering stage in southern plain of China is just in midsummer, so cotton often meets comprehensive stress from CHW stress, CHW stress during this stage inhibits cotton development and reduces final yield significantly. In order to study the stress reaction and subsequent response under the artificial simulated high temperature and waterlogging after rained coupling effects, used E Hybrid Cotton 88 which widely cultivated in the Middle-Lower of Yangtze River in China, analyzed the effects of waterlogging on SOD and POD activities and MDA contents and chlorophyll contents of cotton under high temperature stress during flowering stage. The results showed that high temperature and waterlogging effects apparently decreased SOD activities, chlorophyll of a, b and a/b, declined significantly comparison of CK. During the beginning stage in upon double stresses, they had slow changes and no significant differences among those treatments. However, the 5 days of the end of the high temperature days in later period, its value gradually increased and the decomposition rate of chlorophyll a was faster than chlorophyll b, ranges from 0.70 to 1.68 and from 0.10 to 0.50, respectively; Oppositely, waterlogging and high temperature double stresses significantly increased the POD activity and MDA contents, which declined significantly compared with CK. Generally, as the intensity of high temperature and waterlogging double stresses increased (decreased), the upper indexes added (reduced) obviously, of that surface waterlogging 6 days > subsurface waterlogging 10 days > surface waterlogging 3 days > subsurface waterlogging 5 days, high temperature duration time 7 > 5 > 3 days, daily high temperature duration time 6 > 3 h. The test is not a good proxy for growing cotton under high temperature and waterlogging stresses, but promoted the theoretical innovation and development of farmland drainage, improving agricultural production level.

**Keywords:** Cotton, growth indexes, high temperature, waterlogging stress

### INTRODUCTION

Waterlogging is considered as a usual natural disaster in the middle and lower reaches of the Yangtze River in China and cotton is very sensitive to its effect, which produced the most severe influence on cotton during from the flowering stage to boll opening stage (Zhu *et al.*, 2000). Cotton production with an extreme and unpredicted variability was attributed to management practices and unfavorable weather conditions (Chen and Ni, 1987). Heat becomes an important environmental factors influencing cotton production and physiological indexes with the greenhouse effect strengthening and the global temperature continue to rise (Deng *et al.*, 1998; Rishi *et al.*, 2007). It is reported that the maximum

temperature increasing 1°C/day may result in lint yield reduction of 110 kg/hm<sup>2</sup> with high temperature stress. From the last ten-day of June to July and August in this district, the high frequency in high temperature and high humidity, the long waterlogging duration time, waterlogging and high temperature double stresses often affect interactively cotton physiological and chemical indexes (Zhu *et al.*, 2000). Additionally, climate warming may generate atypical condition in south plum rains, frequency enhancement in farmland met by accident rainstorm and high temperature, while it is not quite clear views to conduct that the active response of cotton physiological and chemical indexes and its subsequent rules when after rains appears high temperature stress. This study adopted pot experiments to create the CHW stress and observe changes of

physiological responses of cotton in the process of CHW stress, the aims to find out the physiological response of cotton in flowering stage to CHW stress and promote the theoretical innovation development of farmland drainage and provide the theoretical basis to explore effective remedial measures of cotton after the CHW stress.

## MATERIALS AND METHODS

The pot experiment was carried out in 2011 in tested field of Agricultural Department of Yangtze University. The potted soil was loam, PH 7.4, organic matter 15.4 g/kg, available P was 14 mg/kg and available K was 84.7 mg/kg. The tested pot diameters was 40 cm, high 70 cm and have a flooding hole in its bottom, built-in mixing uniform loam 20 kg, according to planning density bury to soil and one plant each pot. The tested materials was Hybrid Cotton Jing-88F<sub>1</sub>, grew strong seeding on 15 April 2011, selected uniform seeding transplanting at 3 leaves stage, applied 20 g compound fertilizer each pot, until used 20 g compound fertilizer and 5 g caramide at budding stage.

Experiment adopted completely randomized block design, arranged two conditions with surface waterlogging and subsurface waterlogging, each condition set high temperature continual days and daily high temperature continual time. The surface waterlogging arranged two levels with 5 and 10 days, the subsurface waterlogging arranged 2 levels with 3 and 6 days, the high temperature continual days arranged 3 levels with 3, 5 and 7 days, daily high temperature continual time arranged 2 levels with 3 and 6 h. surface and subsurface waterlogging was treated at the flowering stage on 18 July, until the end of treatments drained water off, selected normal management as ck, Experiment conducted 24 treatments except ck, repeated 5 times each treatment, selected 20 pot as a sub-district, total was 6, area was 7.5×2.5 m. L (T<sub>w</sub>, T<sub>h</sub>, T<sub>w-35</sub>) was selected as high temperature and surface waterlogging treatment, T<sub>w</sub> represented for surface waterlogging days (d), T<sub>h</sub> represented for high temperature continual days (d), T<sub>w-35</sub> represented for daily high temperature continual time (h); identically, Z(T<sub>w</sub>, T<sub>h</sub>, T<sub>w-35</sub>) was selected as high temperature and subsurface waterlogging treatment, T<sub>w</sub> represented for subsurface waterlogging days, T<sub>h</sub> represented for high temperature continual days, T<sub>w-35</sub> represented for daily high temperature continual time.

In order to simulate field natural heat stress, directly warming shed which was made by 1 mm polyethylene plastic film was designed to conduct high temperature treatment every sub-district in flowering stage, which was identical to sub-district., high about 2 m, the next day of waterlogged cotton beginning

conducted in heat treatment at 10:00 am every day, until the end of high temperature moved it from the experimental field.

**Sampling and indexes determination:** At the end of each treatment after the second day morning 6:00-8:00 sampling, whichever three plants consistently grew of functional leaves down 4 of main stem, every processing took 3 plants, parallel determination 2 times every time.

Enzyme activities determination is NBT method for the determination of SOD activities, the more invasive wood phenol method for the determination of POD activities and thiobarbituric acid ratio determination of MDA contents (Liu, 1983).

Chlorophyll was determined by the following operation: weigh 0.2 g leaves placed in a test tube, added 25 mL extraction solution (Acetone: ethanol = 2:1) and then to a test tube, placed in the dark for 24 h until leaves completely white, UV use UV-5300 pc visible spectrophotometer to determinate 645 and 663 nm absorbance and according to the following formula (1), (2) and (3) to calculate the chlorophyll concentration and contents of a and b:

$$C_a = 12.7 \times OD_{663} - 2.59 \times OD_{645} \quad (1)$$

$$C_b = 22.9 \times OD_{645} - 4.68 \times OD_{663} \quad (2)$$

$$\text{Chlorophyll contents} = (\text{chlorophyll concentration} \times 25 \text{ mL}) / \text{sample weight (mg/g)} \quad (3)$$

**Statistical analysis:** EXCEL 2003 and the DPS v7.05 for data processing and statistical analysis

## RESULTS AND DISCUSSION

**The effects of waterlogging on leaves SOD activities under high temperature stress:** SOD activity was significantly declined by the high temperature and waterlogging double stresses through multiple analyses. The same waterlogged level, with the increasing in the intensity of high temperature stress, the SOD gradually decreased, as the high temperature stress exceeded 5 days, the SOD activity dropped faster; the same days of high temperature stress, SOD activity along with the extension of the duration of the daily high temperature reduced. Overall, the impact of surface waterlogging on SOD activity was greater than the subsurface waterlogging, but the subsurface waterlogging processing time exceeded a certain value, its impact would be greater than the surface waterlogging, the activity under surface waterlogging for 6 day > subsurface waterlogging for 10 days > surface waterlogging for 3 days > subsurface waterlogging for 5

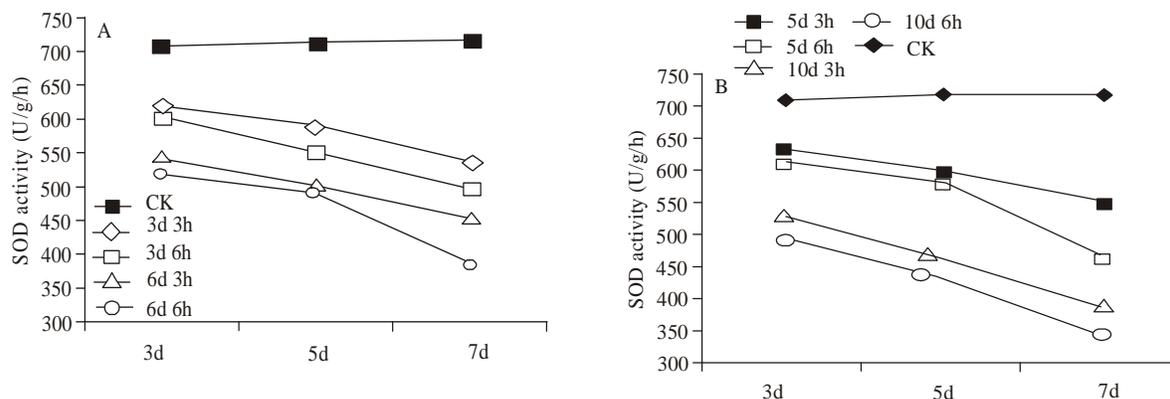


Fig. 1: Effect of surface waterlogging (A) and subsurface waterlogging (B) on leaves SOD activities

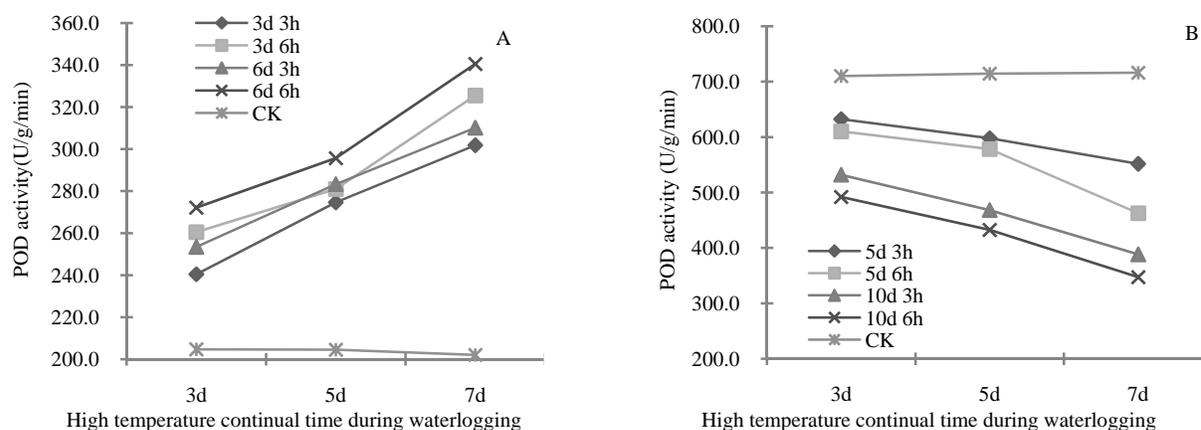


Fig. 2: The effect of surface waterlogging (A) and subsurface waterlogging (B) on leaves POD activity with high temperature

days, while the impact of high temperature time is 7>5>3 days, the impact of daily high temperature time is 6>3 h, SOD content of treatment L (6, 7, 6) was the lowest, but CK oppositely. The influences of different treatments on SOD activity as shown in Fig. 1A and B

**The effect of waterlogging on leaves POD activities under high temperature stress:** POD activity was obviously declined by the high temperature and waterlogging double stresses through multiple analyses. In the same waterlogged level, with the increase in the intensity of high temperature stress, the POD gradually added, as the high temperature stress exceeded 5 days, the POD activity augment faster; the same days of high temperature stress, POD activity along with the extension of the duration of the daily high temperature increased. In word, the impact of surface waterlogging on POD activity was greater than the subsurface waterlogging, but the subsurface waterlogging processing time exceeded a certain edge, its impact would be greater than the surface waterlogging, its activity of surface waterlogging 6 days> subsurface waterlogging 10 days> surface waterlogging 3 days> subsurface waterlogging 5 days, high temperature continued days was 7>5>3 days, high temperature time was 6>3 h, of treatment L (6, 7, 6) contents was the

highest and CK oppositely. Some results had been shown in Fig. 2A and B.

**The effect of waterlogging on leaves MDA contents under high temperature stress:** MDA contents significantly increase under the high temperature and waterlogging double stress through multiple analyses. The same waterlogged level, with the increase in the intensity of high temperature stress, the contents gradually added, as the high temperature stress exceeded 5 days, the activities of MDA augment faster; the same days of high temperature stress, MDA contents along with the extension of the duration of the daily high temperature time increased. In conclusion, the impact of surface waterlogging on MDA contents was greater than the subsurface waterlogging, but the subsurface waterlogging exceeded a certain boundary, its impact would be greater than that of surface waterlogging, the sequence from big to small is: the adverse impact of 6 days of surface waterlogging >10 days of subsurface waterlogging >3 days of surface waterlogging >5 days of subsurface waterlogging; of high temperature for 7>5>3 days, of high temperature for 6>3 h, treatment L (6, 7, 6) contents was the highest and CK oppositely. The experimental results had been shown in Fig. 3A and B.

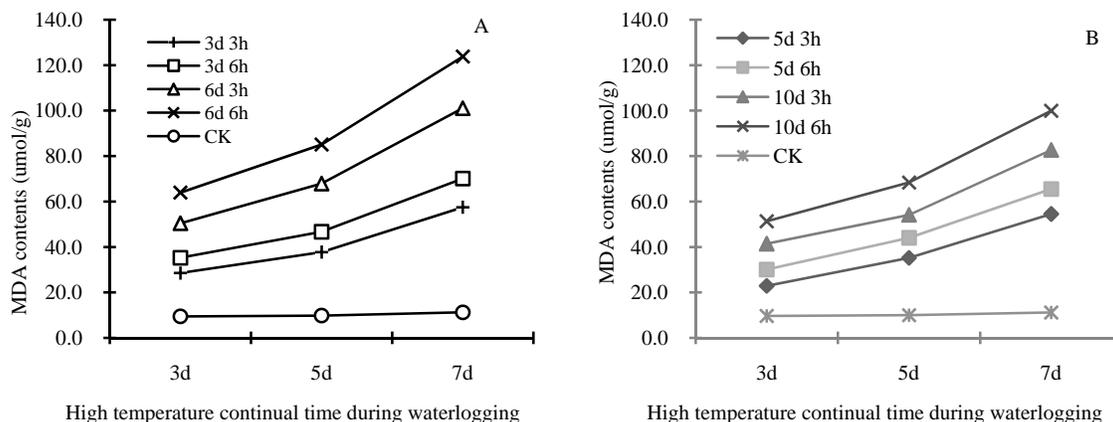


Fig. 3: The effect of surface waterlogging (A) and subsurface waterlogging (B) on leaves MDA contents with high temperature

Table 1: The effects of different treatments on chlorophyll contents under high temperature stress

Treatments	Chl a	Chl b	Chl (a+b)	Chl a/chl b	Treatments	Chl a	Chl b	Chl (a+b)	Chl a/Chl b
CK	1.75 a	0.55 a	2.27 a	3.18 h	CK	1.74 a	0.55 a	2.29 a	3.16 h
L (3, 0, 0)	1.65 b	0.50 b	2.15 b	3.30 g	Z (5, 0, 0)	1.68 b	0.50 b	2.18 b	3.36 g
L (3, 3, 3)	1.60 c	0.43 c	2.04 c	3.72 f	Z (5, 3, 3)	1.66 c	0.44 c	2.10 c	3.77 f
L (3, 3, 6)	1.56 d	0.39 d	1.95 d	4.00 e	Z (5, 3, 6)	1.62 d	0.40 d	2.02 d	4.02 e
L (3, 5, 3)	1.42 e	0.34 e	1.77 e	4.17 d	Z (5, 5, 3)	1.59 e	0.34 e	1.93 e	4.68 d
L (3, 5, 6)	1.32 f	0.31 f	1.63 f	4.26 c	Z (5, 5, 6)	1.53 f	0.27 f	1.80 f	5.67 c
L (3, 7, 3)	1.22 g	0.24 g	1.46 g	5.13 b	Z (5, 7, 3)	1.40 g	0.20 g	1.60 g	7.00 b
L (3, 7, 6)	1.13 h	0.20 h	1.34 h	5.65 a	Z (5, 7, 6)	1.33 h	0.15 h	1.48 h	8.87 a
L (6, 0, 0)	1.54 b	0.42 b	1.97 b	3.66 g	Z (10, 0, 0)	1.59 b	0.48 b	2.08 b	3.32 g
L (6, 3, 3)	1.45 c	0.37 c	1.83 c	3.92 f	Z (10, 3, 3)	1.50 c	0.38 c	1.88 c	3.95 f
L (6, 3, 6)	1.39 d	0.30 d	1.69 d	4.63 e	Z (10, 3, 6)	1.43 d	0.34 d	1.77 d	4.17 e
L (6, 5, 3)	1.20 e	0.23 e	1.46 e	5.21 d	Z (10, 5, 3)	1.37 e	0.28 e	1.65 e	4.89 d
L (6, 5, 6)	1.04 f	0.21 f	1.25 f	5.31 c	Z (10, 5, 6)	1.26 f	0.25 f	1.51 f	5.04 c
L (6, 7, 3)	0.96 g	0.15 g	1.12 g	6.39 b	Z (10, 7, 3)	1.16 g	0.21 g	1.37 g	5.52 b
L (6, 7, 6)	0.70 h	0.10 h	0.80 h	7.00 a	Z (10, 7, 6)	1.10 h	0.14 h	1.24 h	7.86 a

**The effect of waterlogging on leaves chlorophyll contents under high temperature stress:** As can be seen from the Table 1, High temperature obviously affected chlorophyll (was shorted for chl) contents of a, b, a/b and its total contents, chlorophyll a and b significantly reduced compared with CK, L (6, 7, 6) was the lowest, but CK oppositely. The same waterlogged level, with the increasing of intensity of high temperature stress, the chlorophyll contents gradually reduced and a/b value oppositely. When the high temperature stress exceeded 5 days, the distance of a and b contents become further, chlorophyll b was faster in reduction than chlorophyll a, maybe accumulated temperature time exacerbated its decomposition, finally resulted in chlorophyll a and b rapid decomposition. Nevertheless, the value of chlorophyll a and b generally kept the range from 0.70 to 1.68 and from 0.10 to 0.50, respectively. The effects of surface waterlogging on chlorophyll was greater than subsurface waterlogging and the high temperature continual time 7>5>3 days.

### CONCLUSION

Under the normal circumstances, the free radicals and enzyme system of plant had a dynamic equilibrium between ascorbic acid and glutathione, which not

damaged plant (Deng *et al.*, 2010). Plants SOD was plant major physiological enzyme, which could clear free radical scavenging, delay aging plants (Jiang *et al.*, 2002). Commonly, SOD activity and MDA contents was used as physiological and biochemical indices indicates that the aging process (Liu, 1983). Flowering was strong period cotton was very sensitive to water and too much water will affect the growth of cotton. Research has shown that the early waterlogged duration time, the initial value of SOD and POD activity and MDA contents would increase, but with the extension of waterlogging time, SOD activity decreased, POD activity and MDA contents increased. Chlorophyll is one of the important conditions of plant photosynthesis and crop by stress level could be reflected to some degree.

High temperature and waterlogging double stresses significantly reduced cotton SOD activity, an increase of POD activity and MDA contents. In early period of waterlogged and high temperature, the changed rate of their contents become slowing, as high-temperature continuous days more than 5 days, their contents changes faster. Generally, the more serious waterlogged, the longer duration in high temperature, the speed of its contents become more faster, of surface waterlogging for 6 day> subsurface waterlogging for 10

days> surface waterlogging for 3 days> subsurface waterlogging for 5 days, the influence according to the order from big to small is under high temperature for 7>5>3 days, of high temperature for 6>3 h and other treatments got to significant differences; the coupling of high temperature and waterlogging significantly reduced chlorophyll a, b and (a + b) contents, also. In the early period of treatments, a obvious reducing with the cumulative increase of chlorophyll contents with the waterlogged strength and high temperature duration, when it reached a certain stage, the ratio of chlorophyll a to chlorophyll b had a little change in the early period to some degree because of the declined speed of chlorophyll b was more faster than chlorophyll a.

It is an objective reality that waterlogging and high temperature occur concomitantly. Coupled action of them is adverse to crop, which influence on crop is different than that caused by any one of the both. With regard to the coupling of waterlogging and high temperature, a reasonable experimental design is very important, we only gained one year of the relevant experimental data at a testing point and further verification is needed to do multi-point experiment for many years.

#### **ACKNOWLEDGMENT**

The authors thank the National Natural Science Foundation of China (grant number: 51079007). During the experiment, undergraduate students Zhen-hui Jiang and Ming-feng Li gave assistance in experimental observation, thanks for their help.

#### **REFERENCES**

- Chen, B.S. and J.Z. Ni, 1987. Cotton Cultivation Physiology. Agriculture Press, Beijing, pp: 169-190, (In Chinese).
- Deng , T.H., Z.X. Zhu, W.S. Fang, G.Q. Zhao and X.J. Fu, 1998. The effect of soil moisture on abscission rate of squares and bolls and fiber quality of cotton. Chinese J. Agrometeorology, 19(3): 8-13, (In Chinese).
- Deng, J.M., G.S. Xiong, X.L. Yuan, F. Jia and Z. Liu, 2010. Differences in SOD, POD, CAT activities and MDA contents and their responses to high temperature stress at peak flowering stage in cotton lines with different tolerance to high temperature. Cotton Sci., 22(3): 242-247, (In Chinese).
- Jiang, D., Q.N. Tao and G.P. Zhang, 2002. Effect of Waterlogging on senescence of flag leaves and root of wheat Yangmai5. Chinese J. Appl. Ecol., 3(11): 1519-1521, (In Chinese).
- Liu, D.H., 1983. Plant leaves senescence. Plan. Physiol. Comm., (1): 4-19.
- Rishi, P.S., P.V. Vara Prasad, K. Sunita and S.N. Giri, K.R. Reddy, 2007. Influence of high temperature and breeding for heat tolerance in cotton: A review. Adv. Agron., 93: 313-385.
- Zhu, J.Q., W.Y. Zhang, C.B. Pan, L.G. Chen, G.H. Ou, X.Q. Chen and L. Cheng, 2000. Experimental research upon sensibility of several crops to water logging. J. Irrig. Drain., 19(3): 42-46, (In Chinese).