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EFFECTS OF POTASSIUM SILICATE FERTILIZER ON PHOTOSYNTHETIC CHARACTERISTICS AND YIELD IN WINTER WHEAT (*TRITICUM AESTIVUM* L.)

WUBO LI, MENG LI, YUNSHUO XU AND YAN SHI*

Dryland-technology Key Laboratory of Shandong Province, College of Agronomy,
Qingdao Agricultural University, Qingdao City, China

Keyword: Potassium silicate, Winter wheat, Photosynthetic characteristics, Yield

Abstract

Effects of different dosages of potassium silicate fertilizer on photosynthetic characteristics and yield of winter wheat under field conditions were studied. Four different dosages: 0, 45, 90 and 135kg/ha were applied. Results showed that the chlorophyll content, net photosynthetic rate of wheat flag leaf firstly increased and then decreased with the increase of levels of potassium silicate fertilizer. By the change of SPAD values after flowering, when the application of potassium silicate fertilizer was 90 kg/ha, the existence time of chlorophyll in flag leaf was significantly long, and the net photosynthetic rate was significantly increased. The 1000-grain weight of winter wheat significantly increased and the yield the highest. Overall, when the applied amount of potassium silicate fertilizer was 90 kg/ha, the performances of winter wheat were best.

Introduction

The content of Silicon (Si) on the earth is second only to nitrogen. Controversies of Si in plant growth are large, because Si has not been classified as an essential nutrient for higher plants. Si only works under certain conditions (Coskun *et al.* 2019). In some special conditions, the Si will enhance the yield by affecting physiological processes (Korndörfer and Lepsch. 2001). Only silicic acid in the form of molecules dissolved in water, can be absorbed by plants, such as the grower decisions on optimal N rate will have more impact than cultivar selection (Liang *et al.* 2014). The silicon fertilizer application increased leaf area, specific leaf area, and pigment concentration (chlorophyll a and carotenoids) as well as photosynthesis and transpiration rates of well-watered potato plants (Pilon *et al.* 2013). The slag-type silicate fertilizer could be the soil amendment for reducing CH_4 emissions in rice paddy soil (Ali *et al.* 2008). When adding potassium silicate to the strawberry solutions, the growth and yield of strawberry can be maintained under salinity (Yaghubi *et al.* 2016). The silicate can increase the strawberry's resistance against powdery mildew and improve the hardness of leaves (Kanto *et al.* 2004). Si is the most important component of wheat ash (Terzioğlu *et al.* 2013). The research showed that the reasonable proportion of fertilizer can not only effectively inhibit leaf senescence, but it increased the photosynthetic capacity and yield of wheat, and also effectively improved the utilization rate of fertilizer nutrients (Wang and Shi 2020).

In the whole period of wheat, the demand for silicon is relatively large. However, there are few reports of the application of silicon fertilizer in winter wheat production. Potassium silicate fertilizer is a common mineral fertilizer. Whereas, there is poorly research on the effect of potassium silicate fertilizer on the photosynthetic characteristics and yield of winter wheat. Thus the present study aimed to investigate effects of potassium silicate fertilizer on the photosynthetic characteristics and yield of winter wheat after flowering and also to find out the most appropriate amount of potassium silicate fertilizer and provide relatively reliable theoretical basis for the potassium silicate fertilizer.

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*Author for correspondence: <1150028572@qq.com>.

Materials and Methods

The field experiments were carried out from October 2013 to June 2015 in the experimental base of Qingdao Agricultural University where a warm temperate monsoon continental climate with an annual average temperature of 12.6°C prevails and the annual average precipitation of about 700 mm. The variety of winter wheat is Jimai 22 The potassium silicate fertilizer was produced by Sinopharm Chemical Reagent Co., Ltd, its K_2O content is 47.0~51.0%, the ratio of K_2O: SiO_2 is about 1.49~1.65, and the compound fertilizer is potassium sulfate compound fertilizer (N-P_2O_5-K_2O: 17-17-17).

There were 4 different treatments in this experiment (Table 1): Control (CK), Treatment 1, Treatment 2 and Treatment 3. Compound fertilizer and potassium silicate fertilizer were mixed evenly according to the corresponding quality, and they were applied to the land by furrow fertilization. The ditch depth was about 20 cm. The winter wheat was sown in the middle of October, and the sowing of winter wheat was at the rate of 112.5 kg/ha. All treatments were randomly selected the block area, each block area was 2.5 m × 50 m. Each treatment was repeated 3 times. In addition, all fertilizers were used as the base fertilizer. The water needed for winter wheat growth only came from the natural precipitation. Table 1 shows the fertilization dosages of each treatments.

Table 1. Details of fertilizer of each treatment.

Treatment	Compound fertilizer (kg/ha)	Potassium silicate fertilizer (kg/ha)
CK (Control)	750	0
T1	750	45
T2	750	90
T3	750	135

The data needed to be measured included the relative chlorophyll content (SPAD values) and the indexes of photosynthetic characteristics of flag leaf. The present data were recorded at flowering of winter wheat (0d), and measured every 7 days. SPAD values were measured using a chlorophyll meter (SPAD 502, Konica Minolta, Japan). The indexes of photosynthetic characteristics were determined by LI-6400 (LI-COR, America) and measured 3 times in flag leaf.

Data processing and chart drawing were performed in Origin 2019, and statistical analysis of data and significant test of differences were performed with DPS v7.05.

Results and Discussion

Results of the effects of Potassium Silicate Fertilizer on SPAD Value of flag leaf showed that SPAD values of the treatments with potassium silicate fertilizer were higher or significantly higher than CK at 7, 14, 21 and 28 days after flowering (Fig. 1). At 28 d after flowering, the differences in the SAPD values of T1, T2 and T3 increased by 23.82, 41.53 and 25.33%, resapectively than CK (Fig. 1). The differences of SPAD values among T1, T2 T3 and CK were significant at 14, 21 and 28d after flowering. Above all, with the longer of the number of days after flowering, treatments and CK became more different. Especially, the SPAD value was higher than others when the application amount of potassium silicate fertilizer was 90 kg/ha (T2), even significantly different.

Effects of potassium silicate fertilizer on net photosynthetic rate (NPR) of flag leaf showed that each treatment was different in different periods (Fig. 2). Net photosynthetic rates of T1, T2 and T3 were higher than CK as the days after flowering. At 14, 21 and 28d after flowering, the treatments and CK showed significant differences. Specially, the NPR was significantly higher than the other treatments when the application amount of potassium silicate fertilizer was 90 kg/ha (T2).

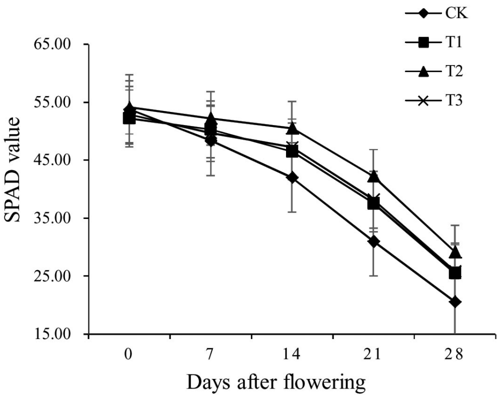

Fig 1. SPAD values of different treatments.

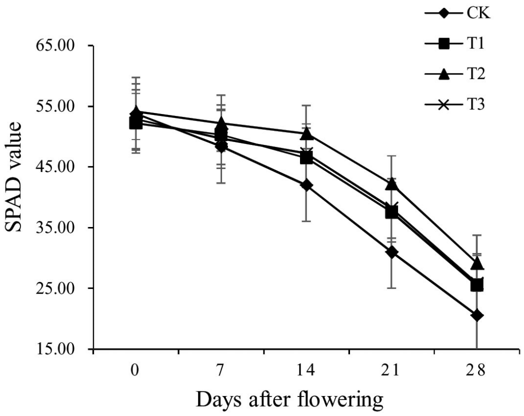

Fig. 2. Net photosynthetic rate of different treatments.

As shown in Fig. 3, with the day after flowering was increasing, the change of stomatal conductance among the treatments were generally of the same trend. The stomatal conductance of T2 was higher than CK at 7, 21 and 28d after flowering, though the differences were only significant at 14 and 21d. The stomatal conductance of T2 was higher than the others. The highest value of stomatal conductance was found in T2.

The intercellular CO_2 concentration of different treatments were different after application of potassium silicate fertilizer (Fig. 4). At 28 days, the highest values were at T2 and compared with others, the difference was significant. Intercellular CO_2 concentrations of T1 and T3 decreased significantly.

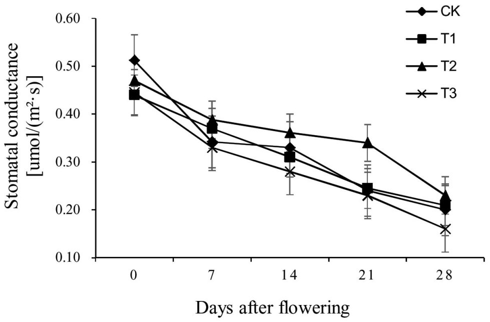

Fig. 3. Stomatal conductance of different treatments.

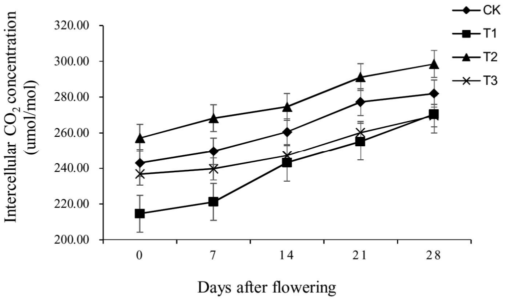

Fig. 4. Intercellular CO_2 concentration of different treatments.

The transpiration rate of potassium silicate fertilizer treatment was significantly higher than CK after application of potassium silicate fertilizer (Fig. 5). However, the transpiration rate of T1 was not significantly lower than CK at 21d after flowering. At 7d after flowering, T1 was not significantly higher than T2. In general, the transpiration rate increased with the increase of potassium silicate fertilizer application. Nevertheless, the transpiration rate decreased when the potassium silicate fertilizer was over 90 kg/ha.

Table 2 showed the yield and its components of different treatments. The number of spikes between treatments was T2 > T3 > T1 > CK; the grains number per spike of was T2 = CK > T1 > T3; the 1000-grain weight showed T2 > T1 > T3 > CK. 1000-grains weight was the key reason for increasing yield.

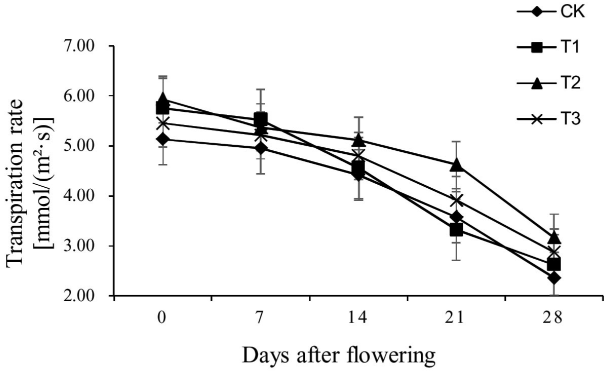

Fig. 5. Transpiration rate of different treatments.

Table 2. Yield and its components of different treatments.

Treatment	Spike number （10^6/ha）	Grains number per spike	1000-grains weight(g)	Grains yield （kg/ha)
CK	5.60a	26.00a	36.95c	5214.00c
T1	5.62a	24.76a	39.11b	5279.55b
T2	5.63a	26.00a	40.39a	5685.45a
T3	5.62a	22.67b	37.46c	5197.95c

a,b and c represent significant correlations at the 0.05 level.

Results showed that the number of spikes and grains did not increase effectively after applying potassium silicate fertilizer. Among the components of winter wheat yield, there was no significant difference in the number of spikes among the treatments. However, the difference of 1000-grain weight among the 4 treatments was significant, and the yield among 4 treatments was significant. The maximum value was reached at the fertilization rate of 90 kg/ha. T3 yield was not significantly lower than CK. The results of this study showed that the application of potassium silicate fertilizer can increase the 1000-grain weight of winter wheat, thereby increasing the total yield of winter wheat. The present investigation revealed that chlorophyll content in the 28d experimental group was still significantly higher than CK, which indicated that potassium silicate fertilizer could effectively prolong the existence time of chlorophyll in winter wheat. In the early stage of flowering, the chlorophyll content and net photosynthetic rate of flag leaves have shown differences, T2 was the highest level, but it had not reached the significant level. At 28d after flowering, the net photosynthetic rate of the experimental group is higher than CK, almost at the same time, the transpiration rate of flag leaf was higher. This may be related to the larger stomatal conductance. It was worth mentioning that the increase of intercellular CO_2 was an important condition to increase the photosynthetic rate of flag leaf. The experiments had shown that the overall photosynthetic characteristics of winter wheat reached the highest level when 90 kg/ha potassium silicate fertilizer was applied.

Silicon can moderately affect the net C assimilation and transpiration rates (FÉLix *et al.* 2018). Si is known to effectively mitigate various environmental stresses and enhance plant resistance against both fungal and bacterial pathogens (Wang *et al.* 2017). Si application decreased transpiration, specific leaf area, petiole length, and promoted the flowering, fruit firmness, leaf/crown number, fresh and dry weight of shoot and root and water use efficiency (Dehghanipoodeh *et al.* 2016). The added Ca-silicate increased photosynthesis, transpiration and stomatal conductance significantly over the non-amended treatment (Bokhtiar *et al.* 2012). The proper application of silicon fertilizer can improve the net photosynthetic rate of crops. With the growth of winter wheat, there was a significant difference in chlorophyll content between the experimental group and the control group, which indicated that potassium silicate fertilizer could effectively improve the chlorophyll content. The reason might be that potassium silicate can promote chlorophyll production. More or less similar observation was made by Asmar *et al.* (2013) who reported that by the addition of $CaSiO_3$ the production of chlorophyll in banana plants *in vitro* can be increased. The practical application of Si-rich products provides for an increase in plant productivity and the reduction of nutrient leaching (Matichenkov *et al*. 2020). Use of phyllosilicate via seed coating increased the production components and yield of the second corn crop (Rodrigues *et al.* 2019). The selected plant growth, yield and biochemical parameters of *P. vulgaris* were efficiently increased by combined PGPR and silicon fertilization under saline stress in which the marketable value of the crop can be improved (Kumar *et al.* 2020).

From the present study it may be concluded that 90 kg/ha potassium silicate fertilizers and 750 kg/ha compound fertilizer were the best for wheat production.

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