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Effects of sodium polyacrylate and potassium polymer on growth and physiological characteristics of different flue-cured tobaccos

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To investigate water retention effects and physiological regulation mechanism of water-retaining agents on the growth and development of different flue-cured tobacco varieties, a pot experiment was conducted using ‘Yuyan 6’ and ‘Yuyan 10’ to study the effects of sodium polyacrylate and potassium polymer on the agronomic characteristics, the root activity, the activity of antioxidant enzymes, the content of malondialdehyde (MDA) and proline in the leaves of flue-cured tobaccos. The results were as follows. (1) The application of water-retaining agents increased the plant height, the stem diameter, the number of effective leaves, the maximum leaf area and the root activity of flue-cured tobaccos and the effects were more significant for Yuyan 10 of relatively poor drought resistance. (2) The activity of SOD, POD and CAT of flue-cured tobaccos treated with water-retaining agents was reduced to different extents. (3) The application of water-retaining agents lowered the MDA content of flue-cured tobaccos but the effects were more significant for Yuyan 10 of relatively poor drought resistance. (4) The application of water-retaining agents decreased the proline content of flue-cured tobaccos under drought conditions, but the decrease of proline content in Yuyan 6 was larger than that in Yuyan 10. Yuyan 6 was highly drought-tolerant, so water-retaining agents could better promote the adaptability of Yuyan 10 to drought stress. Furthermore, water-retaining agent potassium polymer showed a stronger regulatory capability for the growth and physiological metabolism of flue-cured tobaccos than water-retaining agent sodium polyacrylate.

Keywords: Water-retaining agents; Flue-cured tobaccos; Growth; Physiological characteristics

INTRODUCTION

Tobacco is one of the important economic crops in China [1]. Moisture is a major consistent of tobacco plants, as well as an indispensable environmental factor in the growth and metabolism of tobacco [2]. At present, many soils of the world are rather short of water resources, especially in agricultural production [3]. The shortage of water resources in tobacco cultivation is intensified day by day. Drought stress gives rise to serious abnormal physiological and biochemical changes of tobacco plants and further decreases the output and quality of tobacco leaves [4]. Therefore, it is of great significance to develop drought-resistant and water-saving tobacco cultivation and achieve superior quality and stable output of flue-cured tobaccos.

In recent years, water-retaining agents, have been rapidly introduced in agricultural production as anti-drought chemical agents which can soon absorb moisture hundreds of times as much as their mass [5]. The role of water retaining agents has caught the attention of experts from the whole world [6]. Water-retaining agents can improve the infiltration rate of soil moisture and reduce direct surface runoff [7-9], thus playing a key role in the response to drought stress [10]. Y.H, Yang *et al.* found that the application of water-retaining agents increased the soil moisture content in different growth stages of winter wheat, as well as the accumulation of dry matter [11]. D.H. Liu *et al.* also proved that water-retaining agents significantly promoted the photosynthetic productivity and the accumulation of biomass of potatoes [12]. Under drought conditions, the application of water-retaining agents is of importance in the growth of tobaccos [13-15]. In this paper, a pot experiment was conducted using ‘Yuyan 6’ of relatively good drought resistance and ‘Yuyan 10’ of relatively poor drought resistance [16] to study the effects of sodium polyacrylate [$(C_3H_3NaO_2)_n$] and potassium polymer on the agronomic characteristics, the root activity, the activity of antioxidant enzymes, the contents of malondialdehyde ($C_3H_4O_2$) (MDA) and proline ($C_5H_9NO_2$) in tobacco leaves (see Fig. 1.), aiming to figure out the physiological regulation mechanism of different water-retaining agents in the growth of flue-cured tobaccos and provide theoretical references for water-saving tobacco cultivation.

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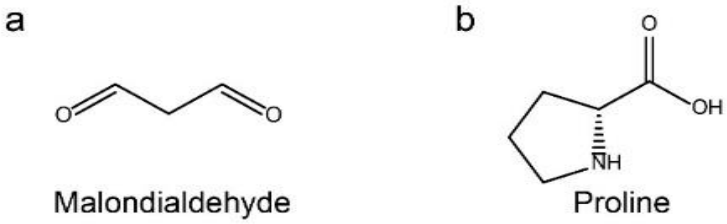

Fig. 1. a: Chemical structure of malondialdehyde; b: Chemical structure of proline.

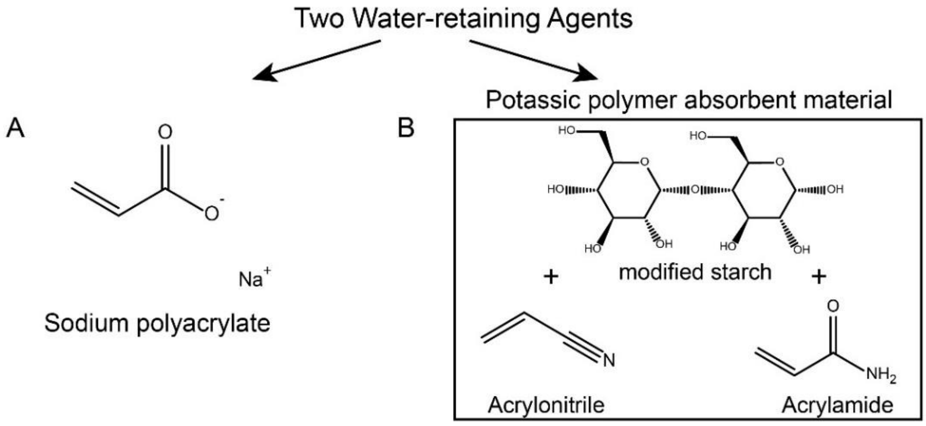

Fig. 2. Chemical structure of the effective components in two water retaining agents. A: Changhao anti-drought water-retaining agent; B: Shenghua water-retaining agent.

EXPERIMENTAL DETAILS

The pot experiment was conducted under a rainproof shelter in the agricultural experimental zone of the new campus of Henan University of Science & Technology in Luoyang in 2015. Two water-retaining agents were applied (Fig. 2.): A. Changhao anti-drought water-retaining agent, which was mainly composed of sodium polyacrylate [$(C_3H_3NaO_2)_n$], white, granulated, crystalline, with a water absorption rate of 150 times, purchased from Changhao Environmental Science & Technology Co, Ltd; B. Shenghua water-retaining agent, which was a kind of potassium polymer absorbent material prepared with modified starch [$(C_6H_{10}O_5)_n$], acrylonitrile (C_3H_3N) and acrylamide (C_3H_5NO), white powdered, with a water absorption rate of 200 times, provided by Changsha Shenghua Science & Technology Development Co., Ltd.

The flue-cured tobaccos for the experiment were 'Yuyan 6' and 'Yuyan 10' provided by Luoyang's Luoning tobacco workstation and cultivated in plastic pots with a row spacing of 100 cm×50 cm. Each plastic pot had a height of 35 cm, an inner diameter of 40 cm and was filled with 20.0 kg of cinnamon sandy soil which passed through a 0.5 cm×1 cm mesh sieve and contained organic matter 19.8 g/kg, available nitrogen 67.6 mg/kg, rapidly available phosphorous 14.5 mg/kg and rapidly available potassium 147.5 mg/kg, with a pH value of 7.45. In all treatments, NPK fertilizer and 5 g of pure nitrogen were applied to each pot. $N:P_2O_5:K_2O=1:1.5:3$. Where necessary, calcium phosphate and potassium sulfate were used to supplement inadequate phosphorus and potassium.

The flue-cured tobacco plants were transplanted on May 21, 2015. A total of six treatments were designed (Table 1) and 50 flue-cured tobacco plants were cultivated in 50 pots separately in each treatment, totaling 300 flue-cured tobacco plants. Before transplanting, water-retaining agents, NPK

Table 1. Experimental treatments

Treatments		Water Retaining Agents
Yuyan 10	CK	Without water retaining agents
Yuyan 10	T1	With water retaining agent A (sodium polyacrylate)
Yuyan 10	T2	With water retaining agent B (potassium polymer)
Yuyan 6	CK	Without water retaining agents
Yuyan 6	T1	With water retaining agent A (sodium polyacrylate)
Yuyan 6	T2	With water retaining agent B (potassium polymer)

fertilizer and soil were homogeneously blended and put into pots. Then, the flue-cured tobacco plants were watered with 2 L to resume growth and the watering volumes were equal in all treatments. Afterwards, the maximum field capacity was measured using the cutting-ring method [17], and TDR-100 soil moisture content analyzer (SPECTRUM, USA) was used to determine the soil moisture content. The flue-cured tobacco plants were subject to moderate water stress 10 d before sampling and measurement based on relative soil moisture contents at 50%, 70% and 60% of the maximum field capacity in the root extending stage, the vigorous growth stage and the maturity stage, respectively.

The plant height and the maximum leaf area of flue-cured tobaccos were measured using a tape of millimeter graduation, the stem diameter was measured with a vernier caliper and the number of effective leaves was recorded at the time [17], in which the maximum leaf area = the maximum leaf length × the maximum leaf width × 0.6345 (the leaf area index of flue-cured tobacco).

The sampling began 30 d after transplanting and later was conducted at 9:00 a.m. every 15 d. The top-down fifth fully-expanded leaves of three flue-cured tobacco plants were collected in each treatment each time. The fresh samples were placed in an ice tray and brought back to laboratory soon. The measurement of different indicators was repeated three times. The root activity was measured using the TTC method [18]; superoxide dismutase (SOD) activity was determined using the nitroblue tetrazolium reduction method [19]; peroxidase (POD) activity was measured with the guaiacol method [18]; catalase (CAT) activity was determined using the ultraviolet absorption method [19]; malonaldehyde (MDA) content was measured by the thiobarbituric acid method [18]; proline content was determined by the ninhydrin method.

RESULTS AND DISCUSSION

It can be seen from Table 2 that the plant height, the stem diameter, the number of effective leaves and the maximum leaf area of Yuyan 6 were larger than those of Yuyan 10 in CK treatment and that the application of water- retaining agents increased the plant height, the stem diameter, the number of effective leaves and the maximum leaf area of both Yuyan 6 and Yuyan 10 under drought stress. On the 30th d, 45th d and 75th d after transplanting, the plant height of Yuyan 10 in T2 treatment was significantly above that in CK treatment by 31.9%, 25.2% and 18.4%, respectively; on the 30th d, 45th d and 60th d after transplanting, the maximum leaf area of Yuyan 10 in T2 treatment increased by 27.5%, 42.9% and 20.8% respectively in comparison with CK treatment; on the 60th d and 75th d after transplanting, the number of effective leaves of Yuyan 10 in T2 treatment was significantly higher than that in CK treatment by 10.0% and 13.5%, respectively. The plant height, the number of effective leaves and the maximum leaf area of Yuyan 6 were T2＞T1＞CK in different growth stages, but the differences were insignificant. Thus, it can be inferred that the application of water-retaining agents could promote the growth of flue-cured tobaccos but the promotional effects on Yuyan 10 of relatively poor drought resistance were more significant.

The root system is an important organ for adsorption of nutrients and moisture in soil and the root activity directly affects the drought resistance of crops [20-22]. As can be seen from Table 3, from the 30th d to the 75th d after transplanting, the root activity of flue-cured tobaccos increased at first, reached a maximum on the 60th d after transplanting and decreased from then on in different treatments. The root activity of Yuyan 6 was higher than that of Yuyan 10 in CK treatment and the application of water- retaining agents improved the root activities of both Yuyan 10 and Yuyan 6. On the 30th d after transplanting, the root activity of Yuan 10 in T1 and T2 treatments displayed significant differences from that in CK treatment; 45 d, 60 d and 75 d after transplanting, the root activity of Yuan 10 in T2 treatment was significantly different from those in T1 and CK treatments; what's more, on the 60th d after transplanting, the root activity of Yuyan 10 in T2 treatment was higher than those in T1 and CK treatments by 29.4
% and 25.0%, respectively. From 30 d to 60 d after transplanting, the root activity of Yuyan 6 had no significant differences; 75 d after transplanting, the root activity of Yuyan 6 in T2 and T1 treatments significantly differed from that in CK treatment and increased by 138.33 μg/(g·h) and 249.44 μg/(g·h), respectively. Therefore, it can be concluded that the application of water- retaining agents could enhance the root activity of flue-cured tobaccos and was favorable to the growth of the root system under drought conditions.

Table 2. Comparison of agronomic characteristics of flue-cured tobacco plants in different treatments

Indicators	Flue-cured Tobaccos	Treatments	Days after transplanting (d)			
			30	45	60	75
Plant height/cm	Yuyan 10	CK	15.67±1.53 b	47.67±7.02 b	70.00±3.46 ab	100.50±0.71 b
		T1	17.33±1.53 ab	53.67±1.53 ab	72.00±10.15 a	109.00±1.41 ab
		T2	20.67±2.08 a	59.67±4.04 a	78.67±6.66 a	119.00±9.90 a
	Yuyan 6	CK	20.33±2.31 a	55.33±1.53 a	76.00±5.57 a	117.50±10.61 a
		T1	22.33±1.53 a	54.33±6.03 a	79.67±11.93 a	120.00±19.80 a
		T2	24.33±2.31 a	58.67±0.58 a	87.67±14.64 a	127.50±3.54 a
Stem diameter/cm	Yuyan 10	CK	3.80±0.17 a	7.13±0.61 a	7.50±0.87 a	7.25±0.35 a
		T1	3.83±0.29 a	7.33±0.29 a	7.60±0.36 a	7.50±0.71 a
		T2	4.00±0.50 a	7.83±0.76 a	8.17±0.29 a	8.00±0.00 a
	Yuyan 6	CK	3.83±0.29 a	7.83±0.29 b	7.83±0.29 a	8.00±0.00 a
		T1	3.93±0.06 a	8.33±0.58 ab	8.00±0.00 a	8.25±1.06 a
		T2	4.00±0.00 a	9.00±0.50 a	8.17±0.76 a	8.25±0.35 a
Number of effective leaves	Yuyan 10	CK	9.33±1.15 a	13.00±0.00 a	16.67±0.58 b	18.50±0.71 b
		T1	9.67±0.58 a	13.33±0.58 a	18.00±0.00 a	20.50±0.71 a
		T2	10.00±1.00 a	13.33±1.15 a	18.33±0.58 a	21.00±0.00 a
	Yuyan 6	CK	10.00±1.00 a	14.67±0.58 a	17.00±1.00 a	19.00±1.41 a
		T1	11.00±1.73 a	15.00±1.00 a	17.33±1.53 a	20.00±1.41 a
		T2	10.67±0.58 a	15.33±0.58 a	19.00±1.00 a	21.50±0.71 a
Maximum leaf area/cm^2	Yuyan 10	CK	386.83±28.18 b	692.66±58.28 b	928.92±26.23 b	1054.68±134.80 a
		T1	432.94±32.50 b	870. 27±51.76 ab	956.00±122.59 ab	1206.26±102.19 a
		T2	493.34±9.03 a	990.10±155.69 a	1122.43±101.14 a	1249.68±410.57 a
	Yuyan 6	CK	447.96±71.40 a	755.00±86.26 a	938.64±112.61 a	1355.50±68.59 a
		T1	499.25±32.10 a	913.77±215.12 a	1144.50±180.36 a	1452.00±69.30 a
		T2	526.00±42.99 a	941.15±114.95 a	1147.86±107.37 a	1472.25±113.49 a

Note: The data followed by different letters in each column are not significantly different at 0.05 level from each other according to Tukey Test. The same as below.

Table 3. Comparison of root activities of flue-cured tobaccos in different treatments, unit: μg/(g·h)

Flue-cured Tobaccos	Treatments	Days after transplanting (d)			
		30	45	60	75
Yuyan 10	CK	218.89±21.21b	458.89±19.64b	585.00±28.28b	130.00±30.64b
	T1	338.89±46.35a	514.72±57.75b	605.56±25.93b	239.44±25.14b
	T2	445.56±35.36a	650.00±25.93a	757.22±40.86a	387.22±45.57a
Yuyan 6	CK	290.56±7.86a	538.33±153.99a	646.11±50.28a	235.00±42.43b
	T1	377.22±66.00a	637.78±71.50a	701.11±62.07a	373.33±7.07a
	T2	375.56±76.21a	707.78±54.21a	704.44±40.07a	484.44±43.21a

Fig. 3 shows that the SOD activity declined in the whole growth stage in the different treatments. From 30 d to 75 d after transplanting, the SOD activities of Yuyan 10 in different treatments were T2<T1<CK and had significant differences. The SOD activity of Yuyan 10 in T2 treatment differed significantly from that in CK treatment and dropped by 45.7%, 33.1%, 50.3% and 39.2%, respectively; on the 75th d after transplanting, the SOD activities of Yuyan 10 in T1 and T2 treatments were significantly different from that in CK treatment and dropped by 42.1% and 43.5%, respectively. In CK treatment, the SOD activity of Yuyan 6 was higher than that of Yuyan 10. The flue-cured tobaccos differed in their responses of SOD activity to drought and the application of water-retaining agents could reduce the SOD activity of flue-cured tobaccos, but the reduction effects were diversified.

Fig. 4 shows that the POD activity increased from 30 d to 75 d after transplanting in different treatments. The increase in the POD activity in the late growth stage was probably the result of physiological and biochemical reactions of flue-cured tobacco plants in the maturity and senescence stage, that is to say, POD converted carbohydrates in the tissues of flue-cured tobaccos into xylogen. In CK treatment, the POD activity of Yuyan 10 was higher than that of Yuyan 6 because the POD activity of tobacco leaves reflected not only the extent of stress but also the drought resistance, that is, the higher the POD activity, the weaker was the drought resistance of flue-cured tobaccos. 30 d, 60 d and 75 d after transplanting, the POD activities of Yuyan 10 in T2 treatment were significantly different from those in CK treatment and dropped by 50.8%, 32.8% and 40.1%, respectively. The POD activities of Yuyan 6 in the whole growth stage were T2<T1<CK and no significant differences were observed.

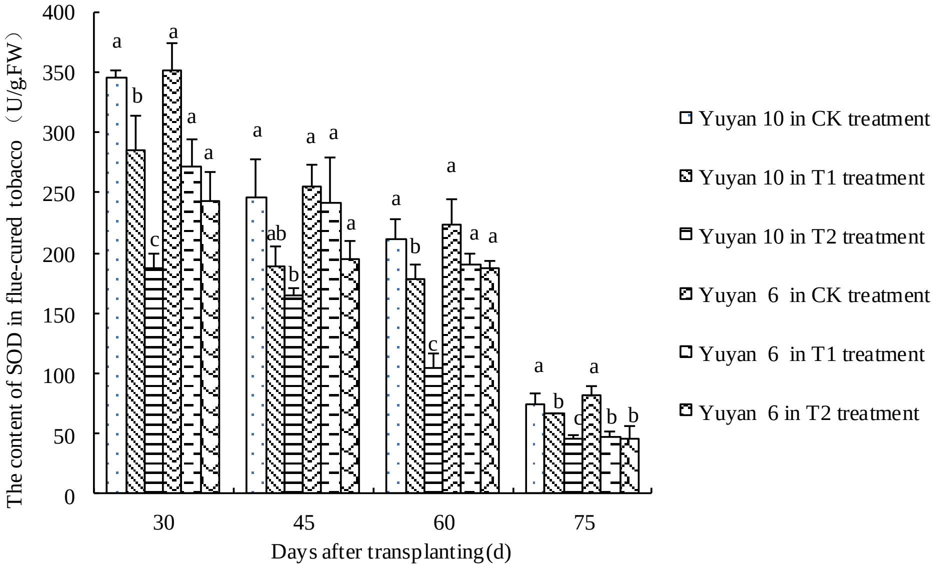

Fig. 3. Comparison of SOD activities of flue-cured tobacco leaves in different treatments

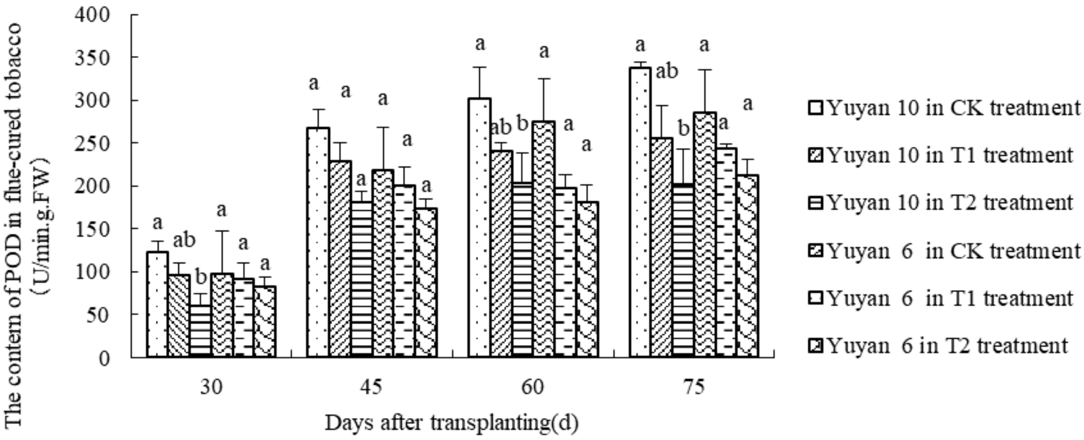

Fig. 4. Comparison of POD activities of flue-cured tobacco leaves in different treatments

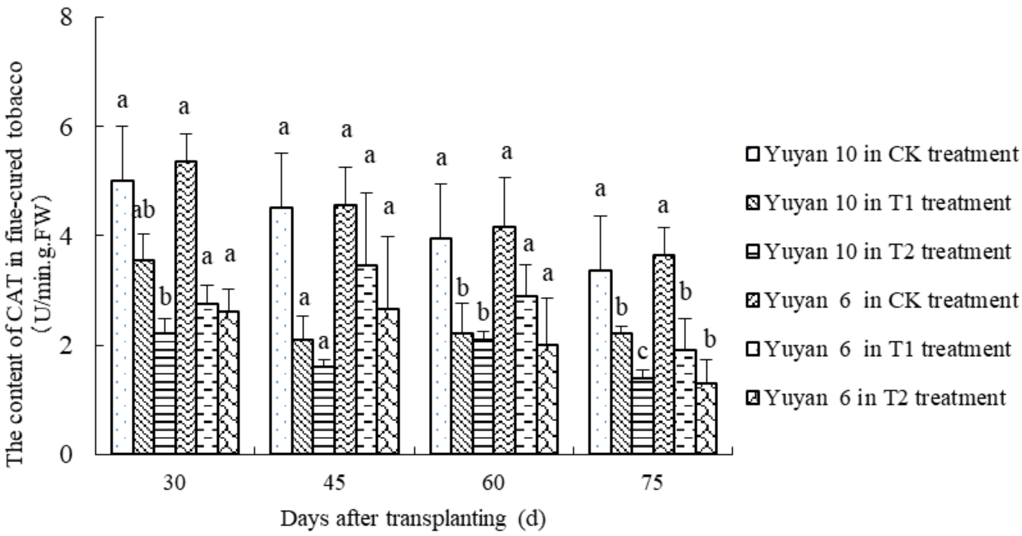

Fig. 5. Comparison of CAT activities of flue-cured tobacco leaves in different treatments

It can be seen from Fig. 5 that the CAT activity gradually decreased in the whole growth stage in the different treatments. 60 d and 75 d after transplanting, the CAT activities of Yuyan 10 treated with water retaining agents had significant differences from those in CK treatment; 60 d after transplanting, the CAT activities of Yuyan 10 in T1 and T2 treatments dropped by 44.3% and 46.8 % in comparison with CK treatment; on the 75th d after transplanting, the CAT activities of Yuyan 10 in T1, T2 and CK treatments showed significant differences. The CAT activities of Yuyan 6 were

T2<T1<CK in different growth stages and the CAT activities of Yuyan 6 in T2 and T1 treatments were lower than that of CK treatment by 47.9% and 64.4% on the 75th days after transplanting.

Malonaldehyde (MDA) is a product of cellular membrane lipid peroxidation and the MDA content is a main indicator that reflects the extent of peroxidation damages of cellular membrane system of plants [23]. It can be seen from Table 4 that the MDA contents increased from the 30th d to the 75th d after transplanting in different treatments. The MDA contents were relatively low in the early growth stage but went up in the late growth stage, which was probably due to the physiological metabolism within flue-cured tobaccos in the maturity stage. In CK treatment, the MDA contents of Yuyan 6 were lower than those of Yuyan 10 in different growth stages, which suggested that Yuyan 6 was able to maintain a certain protective endoenzyme activity under drought stress, scavenge free radicals and reduce the extent of cellular membrane lipid peroxidation. Yuyan 10 of relatively poor drought resistance suffered from severe damages and could not resist adverse water stress. In the whole growth stage, the MDA contents of Yuyan 6 in different treatments were T2<T1<CK but had no significant differences. 30 d and 45 d after transplanting, the MDA contents of Yuyan 10 treated with water-retaining agents were significantly different from those in CK treatment; from 30 d to 75 d after transplanting, the MDA contents of Yuyan 10 in T2 treatment had significant differences from those in CK treatment and dropped by 50.6%, 37.4%, 39.0% and 29.6%, respectively. Thus, it can be seen that the application of water-retaining agents could reduce the MDA contents of flue-cured tobaccos and the reduction effects on Yuyan 10 of relatively poor drought resistance were more significant.

The effects of different water-retaining agents on the proline contents of flue-cured tobacco leaves are shown in Fig. 6 and it can be seen that the proline contents of flue-cured tobaccos increased at first but dropped later from 30 d to 75 d after transplanting in different treatments. In the whole growth stage, the proline contents of Yuyan 10 in T2 treatment were lower than those in CK treatment by 46.4%, 51.7%, 51.1% and 36.5%, respectively. From 30 d to 60 d after transplanting, the proline contents of Yuyan 6 in T1 and T2 treatments significantly differed from those in CK treatment, that is, the proline contents of Yuyan 6 in T1 treatment dropped by 54.7%, 57.1% and 47.0% and the proline contents of Yuyan 6 in T2 treatment dropped by 75.6%, 67.9% and 49.7% in comparison with CK treatment. The decreases of proline content of Yuyan 6 between CK and T1, T2 treatments were larger than those of Yuyan 10.

Table 4. Comparison of MDA contents of flue-cured tobacco leaves in different treatments, unit: nmol/g

Flue-cured Tobaccos	Treatments	Days after transplanting (d)			
		30	45	60	75
Yuyan 10	CK	372.08±22.58a	518.05±45.21a	574.43±52.45a	659.87±27.90a
	T1	236.30±19.24b	412.58±28.42b	471.59±20.87ab	626.21±45.93a
	T2	183.67±9.47b	324.37±16.17b	350.63±48.26b	464.32±38.92b
Yuyan 6	CK	211.66±16.81a	422.28±24.50a	464.58±43.63a	521.94±13.36a
	T1	179.05±22.71a	410.40±59.14a	424.56±22.15a	491.90±47.37a
	T2	174.06±29.92a	314.50±71.96a	361.81±40.86a	449.21±75.63a

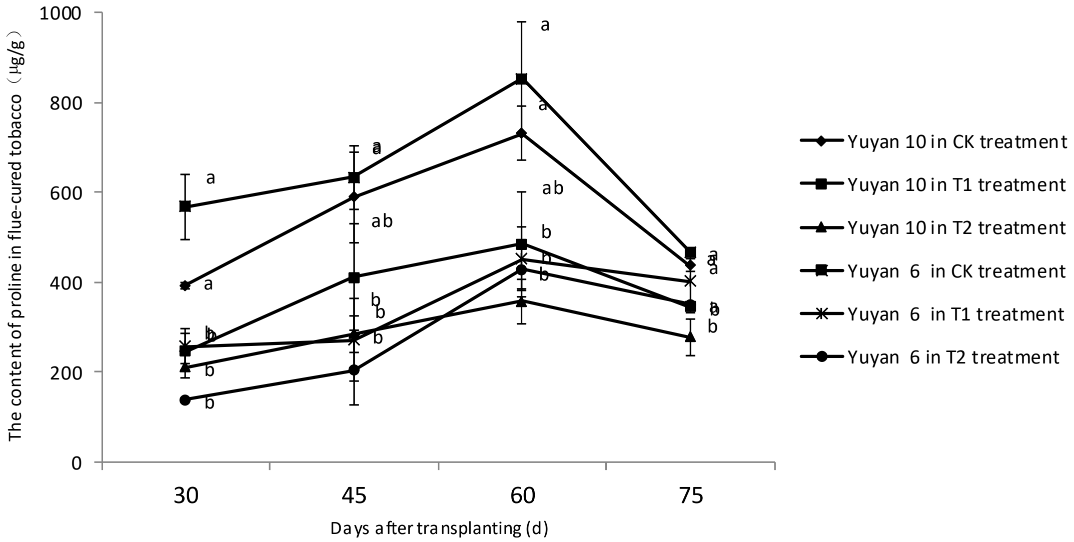

Fig. 6. Proline contents of flue-cured tobacco leaves in different treatments

Thus, it can be inferred that the application of water-retaining agents reduced the proline contents of both Yuyan 6 and Yuyan 10 under drought stress but the reduction effects on the former were larger than those on the latter.

CONCLUSIONS

The root system is the main organ for absorption of water and nutrients for tobacco plants and directly affects the growth of flue-cured tobaccos [24]. Apart from the genetic factors, the growth of the root system is mainly affected by the environmental factors like moisture content, nutrients in soil, etc. Therefore, the root activity is closely related to the soil moisture content. J. Zhang *et al.* [25] proved that the root activity of flue-cured tobaccos declined under drought stress. Our experimental results showed that the root activity of Yuyan 6 was higher than that of Yuyan 10 under drought conditions without applying water-retaining agents, so it can be inferred that the physiological metabolism of the root system of Yuyan 6 was more active. The application of water-retaining agent B (potassium polymer) enhanced the root activity of flue-cured tobaccos in the different growth stages. This is probably due to the application of a water-retaining agent which improves the soil aeration or a soil moisture sub-environment is formed around the root system and both water and nutrients are effectively conserved.

The production and scavenging of active oxygen in plants are in dynamic balance under normal conditions but a great deal of active oxygen will be accumulated under adverse stress, so the anti-oxidant enzymes like SOD, POD and CAT are of great importance to maintain the physiological functions of cells. According to relevant studies, the activity of anti-oxidant enzymes in plants generally shows an increasing tendency under drought conditions [26]. B.L. Xiao *et al.* [27] found that drought increased the SOD activity of flue-cured tobacco. In our experiment, it was found that the SOD and CAT activities of Yuyan 6 were higher than those of Yuyan 10 but the POD activity of Yuyan 10 was higher than that of Yuyan 6 under drought stress without applying water retaining agents. This was probably because the POD activity reflected the extent of stress damages and the higher the POD activity, the weaker was the drought resistance of flue-cured tobaccos. The application of water-retaining agents reduced the SOD, POD and CAT activities of flue-cured tobaccos but the reduction effects were diversified. It can be inferred that flue-cured tobaccos differed in their responses of anti-oxidant enzymes to drought.

The dynamic balance between production and scavenging of active oxygen in plants is broken under drought conditions so that a great deal of active oxygen is accumulated in plants, which leads to cellular membrane lipid peroxidation. MDA is the final product of the cellular membrane lipid peroxidation and the higher the MDA content, the greater damages plants suffer from [28]. Our experimental results showed that the application of water retaining agents reduced the MDA contents of flue-cured tobaccos and the reduction effects on Yuyan 10 of relatively poor drought resistance were more significant.

The MDA content in leaves of Yuyan 6 was significantly lower than that of Yuyan 10, which indicated that Yuyan 6 was able to reduce the cellular membrane lipid peroxidation under drought stress and the tissue membrane system of Yuyan 6 had a stronger drought-resistant ability. In comparison with Yuyan 10, Yuyan 6 could better adapt to the drought stress. When plants suffer from a drought, a great deal of osmotic regulation substances is accumulated within plants and the osmotic potential is reduced so as to adjust the cell turgor and maintain normal life activities [29]. In general, proline exists in plants in the free state and is an important osmotic regulation substance within plants. The proline content can reflect the stress degree for plants to some extent [30]. The proline content in plants is rather small (0.20~0.69 mg/g) under normal conditions but a great deal of proline is accumulated under drought conditions [31]. H.Y. Lu *et al.* [31] came to the conclusion that the application of water-retaining agents could decrease the contents of MDA and proline in leaves. Our experiment showed that the application of water-retaining agents reduced the proline content of tobacco leaves but water- retaining agent B (potassium polymer) had more significant reduction effects. Under drought conditions, the proline content of Yuyan 6 was largely increased, which was favorable to osmotic regulation, reduction of osmotic potential and improvement of drought-resistant ability, while the proline content of Yuyan 10 was slightly increased and the drought resistance of Yuyan 10 was poor.

It is reported that the constituents of water-retaining agents, the soil conditions of experimental fields, the crop species for experiment, as well as the experimental conditions like local climate may lead to differences in experimental results [32]. X.J. Guan *et al*. [33] showed that more than 90% of water conserved by high-quality water-retaining agents of good performance could be taken in by plants but about 1/3 of water conserved by water-retaining agents of poor performance could not be absorbed by plants. Some relevant studies suggest that an overdose of sodium acrylate which participates in cross-linking polymerization may result in an impairment of plants and soil structure but the water retention performance and stability will be improved and water retaining agents will be conducive to the growth of plants and soil amelioration after degradation if potassium acrylate is put into use [34]. In our experiment, water retaining agent B (potassium polymer) is mainly composed of potassium acrylate and has a moderate water absorption rate, so its water retention ability and stability are better and promotional effects for the growth and physiological regulation capability of flue-cured tobaccos are more significant than those of water- retaining agent A (sodium polyacrylate). Instead, water-retaining agent A (sodium polyacrylate) is mainly composed of sodium acrylate and its effects on the growth of flue-cured tobaccos in different growth stages are weaker. Above all, the growth and physiological metabolism of flue-cured tobaccos can be improved as long as proper water-retaining agents are applied.

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REFERENCES

1. H.W. Niu, Z.C. Xu, H.F. Shao, L. Luo, R.R. Zhao, Y.X. Xiao, W.L. Yang, K.G. Wang, *Acta Tabacaria Sinica*, **5,** 39 (2012).
2. G.S. Liu, J.H. Chen, Beijing, *Science*, **3**, 1, 2012.
3. M.R. Islam, A.E. Eneji, C.Z. Ren, Y.G. Hu, G. Chen, X. Z. Xue, *J. Agric. Biotechnol.Ecol.*, **3**, 1 (2010).
4. B.W, Cui, Y.G, Lu, Z.Z. Zhang, K. Ren, *Chinese Tobacco Sci.*, **30**, 19 (2009)
5. Y. Shi, J. Li, J. Shao, S. Deng, R. Wang, N. Li, *Scientia Horticulturae*, **124**, 268 (2010)
6. M. Sadeghi, H. Hosseinzadeh, *Asian J. Chem.*, **22**, 6743 (2010)
7. A.R. Sepaskhah, A.R. Bazrafshan-Jahromi, *Biosys. Eng.*, **93**, 469 (2006)
8. W.J. Busscher, D.L. Bjorneberg, R.E. Sojka, *Soil Tillage Res.*, **104**, 215 (2009)
9. J. Akhter,K. .Mahmood,.K.A. Malik, A. Mardan, M. Ahmad, M.M. Iqbal, *Plant Soil & Environ.*, **50**, 463 (2004)
10. I.C. Dodd, in: Advances in Plant Physiololgy (A. Hemantarajan, editor), Springer Netherlands.Vol. ***15,*** , ***274***, p. 251 (2005)
11. Y.H, Yang, P.T. Wu, J.C. Wu, S.W. Zhao, X.N. Zhao, Z.B. Huang, *Trans. CSAE* , **26**, 19 (2010)
12. D.H. Liu, Z.B. Huang, L.J. Cai, Z.X. Wei, *Acta Agriculturae Boreali-occidentalis Sinica*. **17**, 266 (2008)
13. Q.D. Han, Y. Liu, Y.T. Han, L.X. Liu, M.J. Yang, B.D. Xie, *Chinese Tobacco Sci.*, **36**, 68 (2015)
14. Y. Li, H. Shen, Z.H. Jia, W.X. Pu, Z.J. Sun, Y.F. Wang, *Chinese Tobacco Sc.*, **3**, 10 (2013)
15. Z. Chen, J.Y. Xu, Y.K. Fan, W.X. Huang, P.W. Wang, X.Y. Wen, *Chinese J. Eco-Agric.*, **24**, 1508 (2016)
16. L. Wang, J.C. Zhang, X.Q. Zhang, L. Meng, L. Zhai, *J. Southwest Forestry Univ.*, **30**,6 (2010)
17. X.H. Chen, S. Guo, G.S. Liu, L.Y. Qiu, M.D. Wang, *J. Xinyang Normal Univ.y*, **1**, 47 (2014)
18. L.M. Lu, *Beijing Sci.*, **1**, 197 (2013)
19. Q. Sun, J.J. Hu. *Northwest Agric. Fores. Univ. Sci. Technol.*, **66**, 165 (2006)
20. S. Asseng, J.T. Ritchie, A.J.M. Smucker, *Plant and Soil*, **201**, 265 (1998)
21. R. Motzo, G. Attene, M. Deidda, *Euphytica*, **66**,197 (1992)
22. Y.X. Xu, L.X. Bei, H. Zhang, G.B. Yu, K.J. Yang, C.J. Zhao, *Plant Physiol. J.*, **52**, 101 (2016)
23. L.B. Yang, H.F. Shao, X.J. Zhang, J.J. Yu, X.M. Ma, *Tobacco Science &Technology*, **10**, 45 (2002)
24. X.Y. Shang, H.B. Liu, X.Q. Zhang, J. Lin, W.J. Duan, *Acta Botanica Boreali-Occidentalia Sinica*, **30**, 357 .(2010)
25. J. Zhang, H. Liu, X.P. Li, M. Lu, S.G. Sun, J.N. Su, *Agric. Res. Arid Areas*, **3**, 1 (2014)
26. Y.B. Yun, J.X. Li, F.Z. Ding, X.K. Su. *Chinese Tobacco Sci.*, **30**, 10 (2009)
27. B.L. Xiao, D.M. ,Li, L.X. Liu. *J..Henan Agric. Sci.*, **11**, 36 (2010)
28. H.L. Hu, J. Zhang, T.X. Hu, L.H. Tu, Y.X. Pan, F.M. Zeng, *Acta Botanica Boreali-Occidentalia Sinica*, **34**, 118 (2014)
29. J.Y. He, Y.F. Ren, Y.Y. Wang, Z.J. Li, *Acta Ecologica Sinica*, **31**, 522 (2011)
30. P. Qin, Y.J. Liu, F.H. Liu, *Chinese Tobacco Sci.*, **26**, 28 (2005)
31. H.Y. Lu, Y.Y. Liu, F.W. Gao, S.G. Luo, *J. Northeast Agric. Univ.*, **37**, 299 (2006)
32. Z.B. Huang, G.Z. Zhang, Y.Y. Li, M.D. Hao ,Meni Ben-Hur, *Trans. CSAE*, **18**, 22 (2002)
33. X.J. Guan, J.C. Wu, *J. Henan Agri. Sci.*, **7**, 13 (2007)
34. W. Huang. J.H. Zhang, L.F. Zhang, Y.H. Liu, Y.H. Wang, *Chinese J. Ecol.*, **34**, 1910 (2015)

ВЛИЯНИЕ НА НАТРИЕВ ПОЛИАКРИЛАТ И КАЛИЕВ ПОЛИМЕР ВЪРХУ РАСТЕЖА И ФИЗИОЛОГИЧНИТЕ ПАРАМЕТРИ НА РАЗЛИЧНИ ОПУШЕНИ ТЮТЮНИ

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(Резюме)

За изучаване на задържането на водата и механизма на физиологичното регулиране на водозадържащи агенти върху растежа и развитието на различни сортове опушени тютюни е проведен експеримент в саксии със сортовете 'Yuyan 6' и 'Yuyan 10'. Изследвано е влиянието на натриев полиакрилат и калиев полимер върху агрономичните характеристики, кореновата активност, активността на антиоксидантните ензими, съдържанието на малонов дианхидрид (MDA) и пролин в листата на опушени тютюни. Установено е следното: (1) Използването на водозадържащи агенти води до повишаване на височината на растението, диаметъра на стъблото, броя на ефективните листа, максималната площ на листата и кореновата активност на опушените тютюни и влиянието е по-силно изразено при сорта Yuyan 10, характеризиращ се с по-малка издържливост на суша. (2) Активността на SOD, POD и CAT на опушените тютюни, третирани с водозадържащи агенти намалява в различна степен. (3) Прилагането на водозадържащи агенти понижава съдържанието на MDA, но ефектът е по-силно изразен при Yuyan 10. (4) Прилагането на водозадържащи агенти понижава съдържанието на пролин по-съществено при Yuyan 6, отколкото при Yuyan 10. Yuyan 6 е по-толерантен към суша, така че водозадържащите агенти стимулират по-добре адаптирането на Yuyan 10 към стрес от суша. Калиевият полимер демонстрира по-силен регулаторен капацитет върху растежа и физиологичния метаболизъм на опушени тютюни от натриевия полиакрилат.