Forest Chemicals Review
www.forestchemicalsreview.com
ISSN: 1520-0191
July-August 2022 Page No. 246-266
Article History: Received: 30 March 2022, Revised: 8 April 2022, Accepted: 15 April 2022, Publication: 30 April 2022

Effects of Two High Absorbent Polymer Water-retaining Agents on Soil and Tobacco Quality in Tobacco Fields

Gao Weikai[1], Guan Luohao[1], Cai Xianjie[3], Yang Xikun[2], Yang Jun[2], Song Wenfeng[4], Li Maosen[5], Wang Chuliang[1*], Ren Tianbao[5*]

[1]Guangdong China Tobacco Industry Co., Ltd, Guangzhou, 510032, China
[2]Yunnan Ruisheng Tobacco Technology (Group) Co., Ltd., Kunming 650000, China
[3]Shanghai Tobacco Group co., Ltd; Shanghai, 200082, China
[4]Yunnan tobacco company Honghezhou company, Midu, 652300, China
[5]Tobacco college of Henan Agricultural University /Henan Engineering Research Center for Biochar, Zhengzhou 450002, China
*Corresponding Author.

Abstract:

To evaluate the effects of K-PAA and attapulgite PAM on the physical and chemical properties of tobacco-growing soil and the growth and internal quality of flue-cured tobacco in Changning tobacco-growing area of Baoshan. The flue-curing tobacco variety (Nicotiana tabacum L.) HongDa was used as Planting material. Two kinds of Super Absorbent Polymers (SAP) K-PAA and attapulgite PAM were used auxiliary material, and two application methods of Concentrating application and spread application were used. The amount of water-retaining agent was 45 kg/hm2 and 90 kg/hm2, respectively, and nine treatments were set up. The agronomic characters, soil physicochemical properties and conventional chemical components of cured tobacco leaves were measured 45d, 60d and 90d after transplanting, and the sensory quality of cured tobacco leaves was evaluated. After application of SAP, the soil diameter $R < 0.25$ mm soil aggregate proportion decreased significantly ($P<0.05$), while the other large granular soil proportion increased, soil available potassium content increased significantly ($P<0.05$) and significantly ($P<0.05$) increased soil water content, total sugar and reducing sugar in tobacco leaves decreased significantly($P<0.05$), total nitrogen and nicotine content significantly($P<0.05$) increased, the chloride ion content in upper leaves dropped significantly ($P<0.05$). The effects of different SAP, application methods and application amount on tobacco plant growth and tobacco quality were different. In Baoshan Changning tobacco area, the application of SAP can promote the early growth and rapid growth of flue-cured tobacco, coordinate the ratio of glycine and potassium to chlorine in the upper tobacco leaves, and improve the tobacco smoking quality.

***Keywords**: Flue-cured tobacco, Soil, Super absorbent polymers, Soil physical and chemical properties*

Forest Chemicals Review
www.forestchemicalsreview.com
ISSN: 1520-0191
July-August 2022 Page No. 246-266
Article History: Received: 30 March 2022, Revised: 8 April 2022, Accepted: 15 April 2022, Publication: 30 April 2022

I. INTRODUCTION

Flue-cured tobacco is an important economic crop providing leaves as the main harvest object[1]. High-quality development of tobacco agriculture carries great significance for optimizing the rural industrial structure, increasing tobacco farmers' income, and promoting rural revitalization. Flue-cured tobacco prefers warmth and humidity[1-3], showing quite high water requirements throughout the growth period[4]. Periodic drought and water shortage will seriously affect the growth of flue-cured tobacco[5,6], resulting in lower yield and quality of flue-cured tobacco. In Baoshan tobacco-growing area, flue-cured tobacco often encounters drought in the early and middle growth stages, and the total rainfall during the field period of flue-cured tobacco presents an obvious downward trend in the past 20 years (Fig 1). Given the increasingly serious drought in tobacco agriculture, it is imperative to ease the drought by seeking new approaches. At present, super absorbent polymers have been widely used in tobacco production. Appropriate application of water-retaining agent can reduce soil bulk density and specific gravity[7], improve soil porosity, and promote the formation of soil aggregate structure[8], thereby achieving the purposes of slow release of water and fertilizer, reduction of soil water evaporation[9]. At the same time, it can improve soil enzyme activity, optimize the microbial community structure of crop rhizosphere[10], increase root activity[11,12], and ultimately promote soil water and fertilizer retention, stabilize the yield and quality of flue-cured tobacco[7], thus boosting high-quality development of tobacco agriculture.

Water-retaining agents usually carry a large number of polar hydrophilic groups such as $^{-}$COOH, -OH, -NH_2, which can absorb water at hundreds of times or more of their own weight. By bonding with soil particles, it affects the soil aggregate content, soil porosity, soil bulk density, thus changing the soil state and then achieving the purposes of faster irrigation water infiltration, water storage and fertilizer maintenance, and reduced soil water evaporation[13,14]. The current application modes mainly include mixed application with soil, injection and wrappage of water-retaining agent with seeds[16,17]. Different application modes create quite different effects. Improper application of water-retaining agent often leads to increased soil bulk density, soil compaction, decreased soil porosity and penetration. At the same time, different water-retaining agents have greatly different water and fertilizer retention effects[6-8,15]. Generally speaking, water-retaining agent with smaller particle size and smaller cross-linking density has greater water absorption and swelling capacity. Moreover, its water absorption performance is easily affected by ion concentration of the external soil solution. For example, polyacrylate water-retaining agent is easily affected by Ca^{2+}, SO_4^{2-}, Mg^{2+}, etc. In terms of type, natural polymeric water-retaining agent has higher salt resistance, is easier to degrade, and has more stable performance, but with a lower water absorption ratio. Synthetic polymer water-retaining agent has poor salt resistance, but with higher water absorption ratio. Polymeric water-retaining agent is in the middle of the two in terms of advantages and disadvantages, demonstrating good comprehensive performance[18-21]. Therefore, it is necessary to make a reasonable assessment of the applicable type, application mode and application amount of the water-retaining agent in light of the soil climate of the specific tobacco area, which carries important guiding significance for the promotion of this agricultural technology. This study aims to investigate the reasonable application modes and application amounts of K-PAA and attapulgite-PAM, two environmentally friendly water-retaining agents in Baoshan Changning tobacco-growing area, and to evaluate the effects of different

Forest Chemicals Review
www.forestchemicalsreview.com
ISSN: 1520-0191
July-August 2022 Page No. 246-266
Article History: Received: 30 March 2022, Revised: 8 April 2022, Accepted: 15 April 2022, Publication: 30 April 2022

treatments on soil moisture, fertility, growth of flue-cured tobacco and intrinsic quality formation of tobacco leaves.

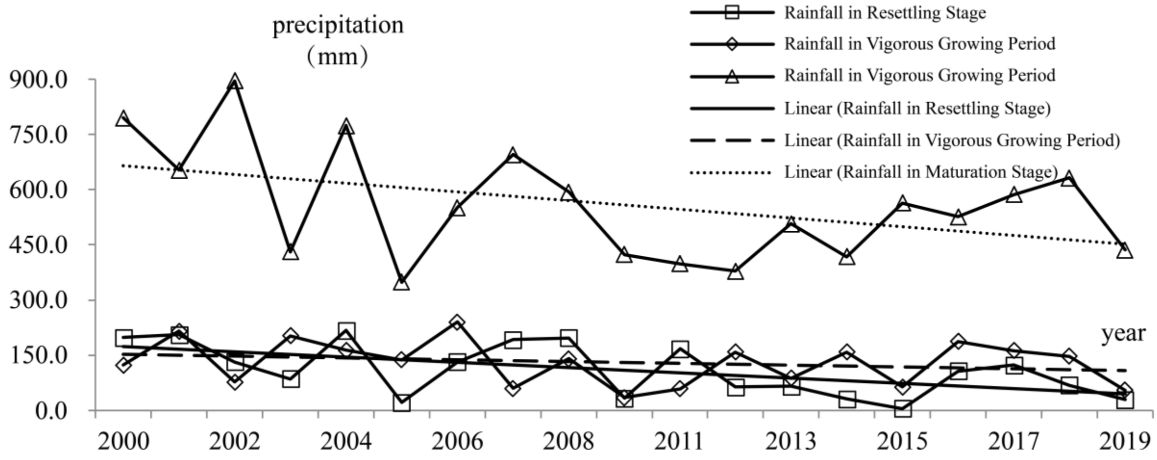

Fig 1: Rainfall during key phenological periods of flue-cured tobacco growth in Changning of Baoshan from 2000 to 2019

II. MATERIALS AND METHODS

2.1 Test Location

The experiment was conducted in Fujie Township, Changning County, Baoshan City in 2020. The main planting variety is *Nicotiana tabacum L*. Honghua dajinyuan, with planting density of 16500 plants/hm^2, leaves of 18-20 pieces/plant, and pure nitrogen of 105-120 kg/hm^2. The soil of the test site is sandy loam. The physical and chemical properties of the soil are: soil organic matter of 17.33 g/kg, Alkali hydrolyzed nitrogen of 71.48 mg/kg, available phosphorus of 15.31 mg/kg, available potassium of 153.91 mg/kg and available boron of 0.37 mg/kg, which meets the nutrient requirements of tobacco planting soil for the growth of high-quality flue-cured tobacco.

2.2 Materials

High molecular potassium polyacrylate (K-PAA), powder, particle size: 0.11~0.50mm, linear structure, degree of hydrolysis 27%~35%, potassium content 11%~15%, water absorption 560 times (deionized water), manufacturer: Renqiu Heying Chemical Co., Ltd. Attapulgite polyacrylamide (attapulgite PAM), fine granular, particle size: 1.8~0.20mm, three-dimensional network structure, water absorption multiple of 350 times (deionized water), manufacturer: Gansu hairuida Ecological Environment Technology Co., Ltd.

Forest Chemicals Review
www.forestchemicalsreview.com
ISSN: 1520-0191
July-August 2022 Page No. 246-266
Article History: Received: 30 March 2022, Revised: 8 April 2022, Accepted: 15 April 2022, Publication: 30 April 2022

2.3 Design

The experiment was arranged in random blocks. A total of 9 treatments were set, repeated for 3 times, with a small area of 50m^2 and protection rows. When transplanting, pour enough root fixing water and then cover with film. The fertilization and production standards of subsequent treatments shall be implemented according to the local high-quality tobacco production standards. The application methods of water retaining agent are divided into hole application and spreading application. Hole application: when transplanting, the water retaining agent or water retaining agent is mixed with fine soil, evenly sprinkled into the pond, watered and covered with thin soil. Spreading: when preparing the land and ridging, mix the water retaining agent with fine soil or farm fertilizer and evenly spread it between the ridges, and water it during transplanting. The processing settings are shown in Table I.

TABLE I. Experimental treatment Settings

Treatments	SAP	Usage of SAP(kg/hm^2)	Use of SAP
CK	/	0	/
T1	K-PAA	45	Hole Fertilization
T2		90	
T3		45	Surface Broadcasting
T4		90	
T5	PAM	45	Hole Fertilization
T6		90	
T7		45	Surface Broadcasting
T8		90	

2.4 Measurement Index

2.4.1 Soil determination

At 45d, 60d and 90d after flue-cured tobacco transplanting, 5 tobacco plants were randomly selected and labeled in each community, and rhizosphere soil was collected, sealed, preserved, labeled and sent for inspection. Test items: soil pH, organic matter, total nitrogen, total phosphorus, total potassium, Alkali hydrolyzed nitrogen, available phosphorus, available potassium, bulk density, total porosity, humus and aggregate structure. Detection method: the pH value is determined by NY/T 1121.2-2006 pH meter method (water soil mass ratio 2.5:1), the content of organic matter is determined by NY/T 1121.6-2006 potassium dichromate titration method, the content of alkali hydrolyzed nitrogen is determined by LY/T 1229-1999 alkali hydrolysis diffusion method, the content of available phosphorus is determined by NY/T 1121.7-2006 ammonium fluoride molybdenum antimony anti colorimetry method, and the content of available potassium is determined by NY/T 889-2004 ammonium acetate extraction flame photometric method, The total nitrogen content was determined by the Kjeldahl method (NY/T 1121.24-2012), the total phosphorus content was determined by the sodium hydroxide alkali melting method (GB 9837-88), and the total potassium content was determined by the hydrofluoric acid digestion flame photometric method (GB

Forest Chemicals Review
www.forestchemicalsreview.com
ISSN: 1520-0191
July-August 2022 Page No. 246-266
Article History: Received: 30 March 2022, Revised: 8 April 2022, Accepted: 15 April 2022, Publication: 30 April 2022

9836-88). Refer to Lu rukun's soil agrochemical analysis method to determine soil physical properties. During the measurement, the three needle probe is completely inserted into the soil (8-10cm deep) from 3-5cm away from the root of tobacco plants, and the root moisture of 3 flue-cured tobacco plants is measured at random in each community.

2.4.2 Investigation of Agronomic Characters

After the selected tobacco plants were listed, the agronomic characters of different treatments of flue-cured tobacco were investigated at 45d, 60d and 90d after transplanting according to the Chinese tobacco industry standard (YC/T 142-2010 tobacco agronomic character investigation and measurement method). Investigation items: plant height, stem circumference, number of effective leaves, maximum leaf length and maximum leaf width.

2.4.3 Determination of routine chemical components of tobacco leaves

After the tobacco leaves were roasted and graded, 1kg C3F and B2F grade tobacco leaves were sampled from each treatment for routine chemical composition detection and sensory quality evaluation. Detection method: use continuous flow analysis (YC/T 159-2002), (YC/T 161-2002), (YC/T 468-2013), (YC/T 162-2011) to determine the water-soluble sugar, total nitrogen, total vegetable alkali and chlorine of tobacco and tobacco products, and use flame photometry (YC/T 173-2003) to determine the potassium ion content of tobacco leaves.

2.4.4 Determination of routine chemical components of tobacco leaves

The sensory quality adopts the nine point system, and the indicators are: aroma quality, aroma quantity, miscellaneous gas, aftertaste, strength, concentration and irritation.

2.5 Data Analysis

Excel 2018 was used for chart drawing, and SPSS 21.0 was used for significant difference analysis.

2.6 Experimental Results

2.6.1 Effects of different treatments on soil physical properties of flue-cured tobacco at different phenological stages

Water-retaining agent improves soil physical properties such as specific gravity, bulk density and porosity by binding micro soil aggregates with particle size $R < 0.25$mm to form soil aggregates with larger particle size. As shown in Table 2, after the application of water-retaining agent, the soil bulk density and specific gravity decrease significantly. With the succession of growth period, the soil bulk density and specific gravity first decrease and then slowly recover. In the early growth stage, the soil bulk

Forest Chemicals Review
www.forestchemicalsreview.com
ISSN: 1520-0191
July-August 2022 Page No. 246-266
Article History: Received: 30 March 2022, Revised: 8 April 2022, Accepted: 15 April 2022, Publication: 30 April 2022

density is significantly lower in the attapulgite-PAM treatment than in the K-PAA treatment, while in the middle and later growth stages, the two water-retaining agents are not significantly different in terms of effect on soil specific gravity and bulk density. The soil bulk density and specific gravity increase significantly with the increasing application amount of water-retaining agent. Different water-retaining agents, application modes and application amounts exert different effect on the soil porosity, and soil porosity increases significantly with the increasing application amount of water-retaining agent.

Forest Chemicals Review
www.forestchemicalsreview.com
ISSN: 1520-0191
July-August 2022 Page No. 246-266
Article History: Received: 30 March 2022, Revised: 8 April 2022, Accepted: 15 April 2022, Publication: 30 April 2022

TABLE II. Physical properties of tobacco field soil under different treatments

Time	Treatments	Unit Weight (g/cm^3)	Specific Weight (g/cm^3)	Total Porosity (%)	Proportion of water-stable aggregate structure at all levels (%)					
					>5mm	2~5mm	1~2mm	0.5~1mm	0.25~0.5mm	<0.25mm
45d	T1	0.96b	2.33cd	59.00f	18.77c	8.81d	7.00d	9.06e	9.24d	47.14c
	T2	0.94c	2.46b	61.68e	22.08b	13.32a	7.03de	8.83ef	8.99f	39.76e
	T3	0.97b	2.32cd	58.12g	25.19a	11.88b	7.73d	12.56b	9.94c	32.71f
	T4	0.87de	2.38c	63.40d	6.73f	14.73a	8.82c	11.77c	9.06d	48.91c
	T5	0.88d	2.30d	61.78e	5.33f	12.30b	9.72b	12.12b	11.57a	48.98c
	T6	0.84e	2.39c	64.91b	7.95e	11.83b	11.13a	13.69a	9.87bc	45.55d
	T7	0.83f	2.30d	63.99c	4.95g	10.61c	6.78e	8.32f	9.88c	59.48b
	T8	0.88d	2.39c	63.24d	12.10d	12.02b	7.29d	9.75d	10.19b	48.67c
	CK	1.03a	2.57a	68.23a	7.83e	7.99e	5.00f	7.87g	8.34f	62.98a
60d	T1	0.93b	2.38d	61.10d	14.07d	11.36a	6.41c	9.59cd	10.17ab	48.43f
	T2	0.95b	2.40d	62.69d	12.17e	9.34c	6.88b	8.72e	7.86f	55.05c
	T3	0.88cd	2.54c	65.54b	17.60b	9.45cd	5.45d	8.12f	9.44c	49.96e
	T4	0.94b	2.58bc	63.60c	22.04a	10.18b	7.26a	9.23d	10.04b	41.26g
	T5	0.87de	2.21e	60.67d	11.44f	8.80e	5.43d	10.29a	10.11ab	52.95d
	T6	0.91c	2.39d	61.86d	15.65c	8.12e	4.46e	6.83h	8.71e	56.24b
	T7	0.86e	2.60ab	67.81a	13.45e	8.84de	5.08d	10.20b	9.23d	53.21cd
	T8	0.91cd	2.60ab	65.19b	9.08g	8.45e	6.29c	9.57c	10.76 a	55.87b
	CK	1.09a	2.55c	64.86c	10.26f	8.70e	5.25d	7.98g	9.16d	58.67a
90d	T1	0.91de	2.68b	63.07cd	13.80d	11.70d	6.74d	9.77c	9.05c	48.96c
	T2	0.92d	2.50c	65.15b	10.28h	12.98c	7.10c	8.66e	7.96d	53.03b
	T3	1.04b	2.68b	61.32f	11.15g	13.90b	9.24a	13.17a	10.20a	42.36f
	T4	0.99c	2.78a	64.48c	33.16b	9.05f	6.76d	9.80c	9.80b	31.45h
	T5	0.92d	2.40d	61.69ef	26.19c	8.44g	5.94f	7.86f	8.03d	43.55g
	T6	0.94de	2.52c	62.65de	36.86a	9.89e	5.97e	8.97d	8.01d	30.31h
	T7	0.93de	2.51c	62.81de	13.34e	16.15a	7.94b	7.61f	7.85d	47.13d
	T8	0.90de	2.68b	66.46a	12.12f	11.98d	8.11b	11.75b	10.24a	45.81e
	CK	1.10a	2.65b	62.68de	6.00i	8.93f	5.65f	6.26g	7.65e	65.54a

Note: Different lowercase letters in the same column of each treatment are significantly different at the 0.05 probability level, the same below.

Forest Chemicals Review
www.forestchemicalsreview.com
ISSN: 1520-0191
July-August 2022 Page No. 246-266
Article History: Received: 30 March 2022, Revised: 8 April 2022, Accepted: 15 April 2022, Publication: 30 April 2022

Obvious law is exhibited in the effect of water-retaining agent application on soil water-stable aggregate structure. Where, aggregates with particle size R<0.25mm has significantly decreased proportion, while aggregates at other levels have significantly increased proportion. According to Table 3, the percentage reduction of R<0.25mm aggregates is 13.56%, 10.04%, -3.43% higher in K-PAA treatment than in attapulgite-PAM at 45d, 60d, and 90d after transplantation, respectively. In the early, middle growth stage of flue-cured tobacco, K-PAA application has a significantly higher decrease in soil aggregate content than attapulgite-PAM; no significant difference is displayed between different application modes in the percentage reduction of soil aggregates R<0.25mm. In the early growth stage, hole application has greater percentage reduction than broadcast application in soil aggregates with particle size R<0.25mm, while in the middle and late growth period, broadcast application has greater percentage reduction than hole application in soil aggregates with particle size R<0.25mm. 90kg/hm^2 water-retaining agent has 2.15%, 1.65% and 8.17% higher percentage reduction in soil aggregates with particle size R<0.25mm than 45kg/hm^2 at 45d, 60d and 90d after transplantation, respectively.

TABLE III. Changes of soil aggregates with diameter R<0.25mm during flue-cured tobacco growth period

Time	Factors	Average Decline Rate	Time	Factors	Average Decline Rate	Time	Factors	Average Decline Rate
45d	K-PAA	33.11%	60d	K-PAA	17.04%	90d	K-PAA	32.94%
	PAM	19.55%		PAM	7.00%		PAM	36.37%
	Hole Fertilization	27.98%		Hole Fertilization	9.38%		Hole Fertilization	32.92%
	Surface Broadcasting	24.67%		Surface Broadcasting	14.65%		Surface Broadcasting	36.39%
	45kg/hm^2	25.25%		45kg/hm^2	12.84%		45kg/hm^2	30.57%
	90kg/hm^2	27.40%		90kg/hm^2	11.19%		90kg/hm^2	38.74%

2.6.2 Effects of different treatments on soil water, fertilizer and growth of flue-cured tobacco at different phenological stages

Soil water and fertilizer are important factors limiting the growth and quality formation of flue-cured tobacco. As shown in Table 4, soil water content is not significantly different between treatments before transplantation. After application of water-retaining agent, soil water content is significantly higher compared to CK. Great difference is displayed in the effects of different water-retaining agents, application modes and application amounts on the soil water content of tobacco fields during the whole growth period.

Forest Chemicals Review
www.forestchemicalsreview.com
ISSN: 1520-0191
July-August 2022 Page No. 246-266
Article History: Received: 30 March 2022, Revised: 8 April 2022, Accepted: 15 April 2022, Publication: 30 April 2022

TABLE IV. Soil water content changes under different treatments in tobacco fields

Time	Factors	Average Decline Rate	Time	Factors	Average Decline Rate	Time	Factors	Average Decline Rate
45d	K-PAA	33.11%	60d	K-PAA	17.04%	90d	K-PAA	32.94%
	PAM	19.55%		PAM	7.00%		PAM	36.37%
	Hole Fertilization	27.98%		Hole Fertilization	9.38%		Hole Fertilization	32.92%
	Surface Broadcasting	24.67%		Surface Broadcasting	14.65%		Surface Broadcasting	36.39%
	45kg/hm^2	25.25%		45kg/hm^2	12.84%		45kg/hm^2	30.57%
	90kg/hm^2	27.40%		90kg/hm^2	11.19%		90kg/hm^2	38.74%

According to Table 5, the increase of soil moisture content is 3.07%, 5.97%, 0.45% higher in K-PAA treatment than in attapulgite-PAM treatment at 3, 7, 11 weeks after transplantation. At 1~7 weeks of transplantation, K-PAA obviously increases more soil water content than attapulgite-PAM, indicating that K-PAA has water retention effect superior to attapulgite-PAM during this period. In the middle and late growth stage (7~11 weeks), the two water-retaining agents have a small gap in increase of soil water content. Hole application is obviously superior to broadcast application, and the former has 11.85%, 11.75%, and 5.71% higher increase in soil water content than the latter at 3, 7, 11 weeks after transplantation. In the middle and late growth stage, there is smaller difference between the two, but hole application can better increase soil water content than broadcast application. 90 kg/hm^2 application amount increases 9.53%, 12.14%, 6.09% more soil water content than 45 kg/hm^2 application amount at 3, 7, 11 weeks after transplantation. With the increase of application amount, soil moisture content has greater increase.

TABLE V. Analysis of soil water content in flue-cured tobacco growth period under different factors

Time	Factors	Average Growth Rate
3 weeks after Transplanting	K-PAA	19.81%
	PAM	22.88%
	Hole Fertilization	27.27%
	Surface Broadcasting	15.42%
	45kg/hm^2	16.53%
	90kg/hm^2	26.16%
7 weeks after Transplanting	K-PAA	24.30%
	PAM	18.33%
	Hole Fertilization	27.19%
	Surface Broadcasting	15.44%
	45kg/hm^2	15.24%
	90kg/hm^2	27.38%
11 weeks after	K-PAA	10.43%

Forest Chemicals Review
www.forestchemicalsreview.com
ISSN: 1520-0191
July-August 2022 Page No. 246-266
Article History: Received: 30 March 2022, Revised: 8 April 2022, Accepted: 15 April 2022, Publication: 30 April 2022

Transplanting	PAM	9.98%
	Hole Fertilization	13.06%
	Surface Broadcasting	7.35%
	45kg/hm^2	7.16%
	90kg/hm^2	13.25%

Water-retaining agent application amount affects soil water content throughout the growth period, showing relatively greater effect in the early, middle growth stages.As shown in Table 6, after application of water-retaining agent, soil organic matter, total nitrogen and alkali-hydrolyzed nitrogen have significantly decreased contents, total potassium and soil available potassium have significantly increased contents, and no significant difference is exhibited between the contents of total phosphorus and soil available phosphorus. At the same time, according to Table 7, it can be calculated that K-PAA increases 23.26%, 21.27%, -16.65% more soil available potassium than attapulgite-PAM at 45d, 60d, and 90d after transplantation, respectively, indicating that K-PAA can better increase soil available potassium than attapulgite-PAM in the early and middle growth stages of flue-cured tobacco, while attapulgite-PAM is superior in the late growth stage. In terms of application mode, hole application incurs 7.8%, 2.55% and 1.54% higher increase of soil available potassium than broadcast application at 45d, 60d and 90d after transplantation, respectively.

TABLE VI. Change of soil available K content in field during the growth period of flue-cured tobacco

Time	Factors	Average Growth Rate
45 days after Transplanting	K-PAA	33.51%
	PAM	10.25%
	Hole Fertilization	25.78%
	Surface Broadcasting	17.98%
	45kg/hm^2	23.57%
	90kg/hm^2	20.19%
45 days after Transplanting	K-PAA	15.59%
	PAM	-5.68%
	Hole Fertilization	6.23%
	Surface Broadcasting	3.68%
	45kg/hm^2	1.64%
	90kg/hm^2	8.27%
45 days after Transplanting	K-PAA	12.56%
	PAM	29.21%
	Hole Fertilization	21.65%
	Surface Broadcasting	20.11%
	45kg/hm^2	21.77%
	90kg/hm^2	20.05%

Forest Chemicals Review
www.forestchemicalsreview.com
ISSN: 1520-0191
July-August 2022 Page No. 246-266
Article History: Received: 30 March 2022, Revised: 8 April 2022, Accepted: 15 April 2022, Publication: 30 April 2022

TABLE VII. Soil chemical composition of field under different treatments during growth period

Treatments	pH	Organic Matter(g/kg)	Total Nitrogen (g/kg)	Total Phosphorus (g/kg)	Total Potassium (g/kg)	Hydrolysable Nitrogen (mg/kg)	Available P (mg/kg)	Available K (mg/kg)
	5.51	30.68	2.12	0.8	25.36	132.15	41.58	411.95
CK	4.88f	42.60a	2.50a	0.98bc	24.14d	180.93b	73.14d	40.25e
T1	5.11d	38.95d	2.33bc	1.00b	23.75d	188.77a	85.70b	876.63a
T2	6.06a	24.67g	1.70g	0.90e	27.79a	114.23g	48.22f	828.58b
T3	5.30c	40.94b	2.42b	0.95cd	28.05a	173.01c	80.84b	839.08b
T4	5.13d	40.07b	2.20e	0.93d	26.98b	167.38d	78.00c	874.88a
T5	5.35c	36.88e	2.24d	0.92d	21.61e	157.15e	69.23e	755.18c
T6	4.96e	40.97b	2.34cd	1.03a	24.99c	170.82d	89.30a	760.88c
T7	4.76f	39.94c	2.49a	1.02a	24.02d	171.74cd	83.24b	693.68d
T8	5.48b	32.31f	2.08 f	0.92d	23.80d	146.95f	52.23f	613.83e
CK	5.22cd	51.04a	2.79a	1.01b	20.92g	159.32d	82.56c	599.25e
T1	5.15de	46.08b	2.52d	1.00c	23.16e	164.69c	73.52d	638.25d
T2	5.48a	39.91e	2.27g	0.92e	29.74a	151.27d	86.68b	785.25a
T3	5.38ab	40.47d	2.34f	0.97cd	28.59b	157.86f	86.59b	662.25c
T4	5.23cd	41.05d	2.35ef	0.96d	22.25f	154.69e	64.66e	685.00b
T5	5.29bc	44.22c	2.38e	0.92e	23.33e	152.01f	65.16e	564.75fg
T6	4.89f	46.42b	2.69b	1.08a	26.13c	175.18a	103.11a	558.00g
T7	5.02e	46.72b	2.65c	1.02b	25.00d	169.82b	85.22b	571.00f
T8	5.52a	40.04e	2.34f	0.97cd	26.14c	134.93g	57.93f	567.00 f
CK	5.35d	42.90a	2.55a	1.00b	22.71e	169.32b	76.24c	494.75h
T1	5.41d	41.13b	2.43b	0.88d	22.81e	156.37c	72.75d	560.25f
T2	5.92a	32.41g	2.03d	0.79e	26.94b	152.44c	69.37e	561.00g
T3	5.51c	37.70e	2.24c	0.82e	27.47a	123.99f	73.17d	570.50e
T4	5.30e	42.50a	2.57a	0.89d	21.17f	154.52c	66.84e	535.9
T5	5.60c	38.52d	2.22c	0.87d	22.62e	145.73d	64.88f	641.25b
T6	4.94 g	41.65b	2.59a	1.06a	25.47c	184.59a	102.57a	645.00a
T7	5.07f	40.44c	2.42b	1.02b	24.29d	182.74a	89.87b	637.75c
T8	5.68b	36.93f	2.24c	0.94c	23.49d	139.25e	63.56f	633.00d

Forest Chemicals Review
www.forestchemicalsreview.com
ISSN: 1520-0191
July-August 2022 Page No. 246-266
Article History: Received: 30 March 2022, Revised: 8 April 2022, Accepted: 15 April 2022, Publication: 30 April 2022

Time	Before Transplanting	Resettling Stage	Vigorous Growing Period	Maturation Stage

Water and fertilizer conditions in tobacco fields will directly affect the field growth of flue-cured tobacco. As shown in Table 8, after the application of water-retaining agent, the plant height, maximum leaf length, maximum leaf width, and number of leaves are significantly higher in each treatment compared to CK in resettling stage, squaring stage, dome stage of flue-cured tobacco. Where, the difference is more obvious in the resettling stage, with multiple indicators significantly higher than CK, but the difference is insignificant in the middle and late stages. It is possibly because rainfall increases after squaring, water then has smaller effect on the growth of flue-cured tobacco, but no obvious law is displayed in the effects of different treatments on the agronomic characters of flue-cured tobacco.

2.6.3 Effects of different treatments on conventional chemical components of tobacco leaves

In the middle leaf, the total sugar content of CK was significantly higher than that of other treatments; The contents of total nitrogen and total alkali in each treatment increased significantly; The contents of total sugar, reducing sugar and Cl^- in upper leaves were significantly lower than those in CK, while the contents of total nitrogen, total alkali and K^+ increased significantly. As shown in Table 9, the sugar alkali ratio of middle leaves is generally within the reference value range of high-quality tobacco leaves, and the upper leaves are slightly less than the reference value. The ratio of nitrogen to alkali in the middle leaves was relatively small compared with the reference value. The potassium chloride ratio of middle leaves was between 18.88 ~ 32.60 and that of middle leaves was between 3.91 ~ 20.00. After the application of water retaining agent, the sugar alkali ratio of tobacco leaves decreased, the nitrogen alkali ratio increased slightly, the potassium chloride ratio showed different rules in different parts of tobacco leaves, the potassium chloride ratio of middle leaves decreased, and the potassium chloride ratio of upper leaves increased significantly.

2.6.4 Sensory evaluation results of different treatments of tobacco leaves

It can be seen from table 10 that the sensory quality index and score of middle tobacco leaves in each treatment in the test are higher than those in the control, and the index and score are T4 > T1 > T6 > T2 > T7 > T3 > T5 > T8 > CK in turn; The sensory quality of tobacco leaves in the middle of T4 treatment is as follows: good aroma quality, sufficient aroma, clear and sweet, slightly green and miscellaneous, ligneous gas, slightly stimulating and strong. Except that T2, T3 and T4 were slightly lower than the control, the sensory quality index and score of upper tobacco leaves were higher than the control. The index and score were T8 > T7 > T6 > T1 > T5 > CK > T2 > T4 > T3 in turn; The sensory quality of the upper tobacco

Forest Chemicals Review
www.forestchemicalsreview.com
ISSN: 1520-0191
July-August 2022 Page No. 246-266
Article History: Received: 30 March 2022, Revised: 8 April 2022, Accepted: 15 April 2022, Publication: 30 April 2022

leaves treated with T8 is as follows: sufficient aroma, obvious sweetness, burnt aroma, strong concentration, slight stimulation, miscellaneous gas, obvious sweetness, good sweetness and strong strength. According to the smoking evaluation results of middle and upper tobacco leaves, the sensory quality of T1 and T6 treatments was relatively good as a whole.

TABLE VIII. Agronomic traits of flue-cured tobacco under different treatments

Treatments	Leaf Number	Plant Height (cm)	Max of Leaf Length (cm)	Max of Leaf Width (cm)	Stem Circumference (cm)
T1	12.33abc	18.00ab	37.33bc	18.00ab	/
T2	12.67abc	23.00cd	38.00bc	18.83b	/
T3	12.00ab	18.67abc	35.33ab	18.00ab	/
T4	13.00abc	22.00bcd	36.67b	16.17a	/
T5	13.33bc	19.67abc	38.33bc	19.67bc	/
T6	12.67abc	18.33abc	37.67bc	17.83ab	/
T7	12.33abc	17.33ab	36.33b	17.67ab	/
T8	13.67c	25.00d	40.67c	21.33c	/
CK	11.67a	16.67a	33.00a	16.10a	/
T1	15.67a	54.00b	54.33bc	23.50ab	7.83ab
T2	15.00a	43.67a	55.33bc	24.50b	7.75ab
T3	14.33a	41.33a	46.00a	20.00a	7.16a
T4	15.67a	43.00a	55.00bc	24.50b	7.43ab
T5	15.00a	43.33a	52.00bc	23.67b	7.85ab
T6	15.33a	44.67a	52.00bc	22.67ab	7.24ab
T7	14.67a	41.33a	51.67abc	22.17ab	7.43ab
T8	16.00a	54.33b	55.67c	25.00b	8.04b
CK	14.33a	40.67a	49.33ab	22.00ab	7.22ab
T1	17.67a	101.67ab	72.67bc	29.67bc	8.90a
T2	18.33a	102.00ab	71.93bc	30.40c	8.79a
T3	17.67a	106.67ab	68.77ab	25.83ab	8.48a
T4	18.33a	109.67b	67.33ab	26.67abc	8.74a
T5	18.33a	99.33a	70.00abc	28.07bc	8.73a
T6	18.67a	99.33a	69.33abc	27.70abc	8.84a
T7	17.67a	100.33a	65.67a	26.00ab	8.43a
T8	19.33a	107.00ab	75.67c	30.00c	8.90a
CK	17.33a	99.17a	65.33a	25.33a	8.32a

Forest Chemicals Review
www.forestchemicalsreview.com
ISSN: 1520-0191
July-August 2022 Page No. 246-266
Article History: Received: 30 March 2022, Revised: 8 April 2022, Accepted: 15 April 2022, Publication: 30 April 2022

Table IX. Conventional chemical constituents of tobacco leaves under different treatments

Time	Reducing Sugar (%)	Total Nitrogen (%)	Total Plant Alkaloid (%)	Potassium (%)	Chloride (%)	Ratio of Sugar to Nicotine	Ratio of Nitrogen to Nicotine	Ratio of Potassium to Chloride
Resettling Stage	18.00~22.00	1.50~2.50	1.80~2.80	> 2.00	< 0.80	8~12	≈1	4~10
	19.51±0.07a	1.92±0.02	3.70±0.04	3.00±0.02	0.14±0.01	7.64	0.52	21.86
	18.59±0.04c	2.14±0.02	3.72±0.07	3.18±0.02	0.11±0.01	7.33	0.58	28.91
	18.32±0.21d	2.04±0.03	3.60±0.04	3.04±0.02	0.13±0.01	8.11	0.57	23.38
	18.17±0.14d	2.15±0.03	3.70±0.01	2.95±0.00	0.13±0.01	7.78	0.57	22.69
	18.55±0.27b	2.10±0.00	3.50±0.03	3.08±0.02	0.12±0.01	8.34	0.6	25.67
	19.14±0.12a	2.07±0.03	3.36±0.06f	3.03±0.01	0.12±0.01	8.4	0.62	25.25
	19.21±0.09a	2.22±0.03	4.00±0.03	3.02±0.02	0.16±0.01	7.18	0.55	18.88
Squaring Stage	18.36±0.23d	2.03±0.03	3.80±0.03	3.27±0.02	0.13±0.01	7.62	0.54	25.15
	18.72±0.24b	1.91±0.03	3.40±0.03	3.20±0.03	0.10±0.01	8.62	0.55	32.6
	17.45±0.12e	2.20±0.02	4.95±0.03	2.67±0.03	0.18±0.01	5.52	0.46	14.83
	17.87±0.15d	2.22±0.02	4.89±0.04	2.55±0.04	0.20±0.01	5.83	0.45	12.65
	19.32±0.26b	2.24±0.03	4.84±0.01	2.73±0.01	0.19±0.01	5.58	0.46	14.37
	17.51±0.21e	2.23±0.01	4.87±0.01	2.40±0.03	0.16±0.01	5.51	0.46	15
	18.92±0.15b	2.31±0.02	4.52±0.03	2.52±0.02	0.20±0.01	5.91	0.51	11.6
	18.58±0.21c	2.22±0.02	4.81±0.02	2.41±0.01	0.18±0.01	5.52	0.46	13.39
	16.76±0.20f	2.33±0.01	4.01±0.01	2.50±0.03	0.15±0.01	5.67	0.51	15.73
	16.85±0.20f	2.32±0.03	3.50±0.07	2.40±0.02	0.12±0.01	4.52	0.48	20
Doming Stage	20.36±0.12a	2.10±0.01 e	4.52±0.08 c	2.19±0.01 e	0.56±0.02 a	6.53	0.46	3.91

Forest Chemicals Review
www.forestchemicalsreview.com
ISSN: 1520-0191
July-August 2022 Page No. 246-266
Article History: Received: 30 March 2022, Revised: 8 April 2022, Accepted: 15 April 2022, Publication: 30 April 2022

TABLE X. Sensory quality evaluation of tobacco leaves under different treatments

Impurity Gas	Aroma Concentration	Irritancy	Aftertaste	Flammability	Ash Content	Score(H)
6.7	7.1	6.5	7.2	8	7.6	7.21
6.6	7.2	6.3	6.8	8	7.7	6.79
6.4	6.7	6.5	6.8	7.9	7.6	6.59
6.8	7	6.9	7	8	7.7	7.23
6.2	6.7	6.5	6.5	7.9	7.6	6.54
6.9	7.2	6.9	7	8	7.7	7.19
6.7	7.3	6.4	6.6	7.9	7.5	6.72
6.3	6.9	6.5	6.2	7.9	7.5	6.48
6	6.6	6.2	6.3	7.8	7.5	6.24
7	7.6	6.6	6.7	7.2	7	7.19
6.5	6.9	6.9	6.4	7.5	7.2	6.76
6.4	7	6.3	6.2	7.4	7.3	6.51
6.6	7.2	6.2	6.3	7.4	7.3	6.64
6.9	7	7	6.9	7.4	7.2	7
7.3	7.8	6.9	7	7.4	7.2	7.28
7.3	7.8	6.9	7.2	7.4	7.1	7.37
7.5	7.7	6.7	7.1	7.4	7.3	7.41
6.5	7	6.5	6.7	7.3	7.2	6.77
6.5	7	6.5	6.7	7.3	7.2	6.77

Leaf Position	Treatments	Total Sugar (%)
		20.00~25.00
Middle Leaf	T1	28.27±0.07
	T2	27.25±0.19
	T3	29.19±0.20
	T4	29.20±0.21
	T5	29.18±0.20
	T6	28.24±0.21
	T7	29.10±0.20
	T8	28.95±0.08
	CK	29.62±0.17
Upper Leaf	T1	27.31±0.18
	T2	28.55±0.30
	T3	27.01±0.08
	T4	26.81±0.10
	T5	26.75±0.07
	T6	26.55±0.15
	T7	26.13±0.05
	T8	23.93±0.15f
	CK	29.53±0.11a

Forest Chemicals Review
www.forestchemicalsreview.com
ISSN: 1520-0191
July-August 2022 Page No. 246-266
Article History: Received: 30 March 2022, Revised: 8 April 2022, Accepted: 15 April 2022, Publication: 30 April 2022

Level	Treatments	Fragrance Quality	Fragrance Quantity
C3F	T1	7.9	7
	T2	7	6.8
	T3	6.8	6.4
	T4	7.4	7.5
	T5	6.8	6.5
	T6	7.4	7.3
	T7	6.6	7
	T8	6.7	6.5
	CK	6.3	6.3
B2F	T1	7.2	7.7
	T2	6.8	7
	T3	6.7	6.6
	T4	6.8	6.8
	T5	7	7.1
	T6	7.3	7.5
	T7	7.3	7.7
	T8	7.4	7.7
	CK	6.9	6.9
	CK	6.9	6.9

2.7 Discussion

2.7.1 Effects of different treatments on soil physical properties and water content of flue-cured tobacco at different phenological stages

In this experiment, the two water-retaining agents demonstrate quite different water and fertilizer retention properties in different phenological stages of flue-cured tobacco, primarily due to the differences in the molecular structure, particle size and functional group of the two water-retaining agents. K-PAA is powdery, with small particle size, linear molecular structure, low cross-linking density within the molecule, and main hydrophilic groups of -COOK and -COOH, which belongs to synthetic polymer water-retaining agent. Attapulgite-PAM is fine-grained, with larger particle size, three-dimensional network structure in molecule, great cross-linking density inside the molecule, and main hydrophilic groups of -COOK, -OH, -COOH, etc. The polymeric attapulgite contains more than 20 elements such as Ca^{2+}, Mg^{2+}, Fe^{3+}, which belongs to semi-synthetic polymer water-retaining agent. Therefore, in this study, in the early growth stage, attapulgite-PAM significantly reduced soil bulk density, while K-PAA exerted little effect on soil bulk density. In the middle and late growth stages, the two water-retaining agents create not significantly different effects on soil bulk density. On the one hand, this is because K-PAA with linear structure has relatively smaller particle size, greater specific surface area and faster early-stage water absorption rate compared to attapulgite-PAM with three-dimensional network structure, making it easier to block the soil pores, which is inconducive to reducing soil bulk density. At the same time, in the early growth stage, K-PAA can more effectively bond with soil particles, thereby reducing the proportion of soil aggregates with a particle size $R < 0.25$mm and increasing the proportion of other soil aggregates with relatively large particles. Therefore, in terms of water absorption performance, water absorption rate is faster in the early stage, but flue-cured tobacco easily absorbs water and swells in the stage, which blocks soil pores and increases soil bulk density [7]. On the other hand, attapulgite-PAM has a higher cross-

Forest Chemicals Review
www.forestchemicalsreview.com
ISSN: 1520-0191
July-August 2022 Page No. 246-266
Article History: Received: 30 March 2022, Revised: 8 April 2022, Accepted: 15 April 2022, Publication: 30 April 2022

linking density in polymer molecule, and can provide abundant trace elements for the replacement of ions in the soil solution, resulting in stronger salt tolerance and more stable water retention performance. With the progress of the growth period and the repeated water absorption of the water-retaining agent [20], water-retaining agent has decreased water-absorbing capacity, and the effects of the two on soil aggregates are not so much different in the late growth stage. During the whole growth period, soil bulk density and specific gravity decrease first and then slowly increase after the application of water-retaining agent, which is similar to the findings of Bai Gangshuan et al. [7]. For its reason, the water-absorbing function of water-retaining agent molecules declines after repeated water absorption, swelling and degradation of soil microorganisms and sunlight [10, 20], and leaching and deposition of soil particles during the growth period also play a role. Different water-retaining agents, application modes and application concentrations exert certain different effects on soil porosity. Under hole application, the soil bulk density presents an upward trend with the increasing application amount of water-retaining agent, but the increase range is small. Also, the soil specific gravity increases significantly. Soil porosity increases with the increasing application amount of water-retaining agent, which is similar to the findings of Bai Gangshuan et al.[21].

2.7.2 Effects of different treatments on soil chemical composition of flue-cured tobacco at different phenological stages

The different molecular structures, particle sizes and functional groups of the two water-retaining agents also affect the fertilizer-retention ability of tobacco soil. In this study, soil organic matter and total nitrogen present a downward trend in soil applied with water-retaining agent during the growth period, which is different from some current studies. It’s possibly because the water-retaining agent improves the soil microenvironment and promotes absorption of soil nutrients by the root system, which leads to decreased soil organic matter and total nitrogen content. In terms of field growth of flue-cured tobacco, tobacco plants applied with water-retaining agent display better field growth. The total phosphorus and total potassium contents are not significantly different, while content of soil available potassium increases significantly, which is similar to the findings of Mao Sishuai et al.[23]. Different treatments exert great effect on soil available potassium content, demonstrating obvious law. For its reason, K-PAA used in this experiment contains a large number of -COOK functional groups, K^+ dissociates after rapidly absorbing water in the early growth stage, which significantly increases the soil available potassium content, but due to the relatively rapid decline in the performance, the water-retaining agent dissociates much less K^+ in the later period. The granular attapulgite-PAM with high cross-linking density is more likely to form channels in its molecules to store nutrients after water absorption and swelling, which can slow down the release of soil nutrients. Moreover, its aggregated attapulgite has rich trace elements, strong ion adsorption and ion exchange, which can adsorb potassium ions in soil and slowly release it, resulting in longer synergistic effect on soil available potassium. In the vigorous growing stage, water-retaining agent barely increases soil available potassium, mainly due to the potassium requirement law of tobacco plants. In the vigorous growing stage, tobacco plants grow rapidly and require a relatively large amount of potassium, so there is smaller potassium content in the soil. Hole application better increases soil available potassium than broadcast application, while increased concentration of water-retaining agent does not significantly increase soil available potassium.

Forest Chemicals Review
www.forestchemicalsreview.com
ISSN: 1520-0191
July-August 2022 Page No. 246-266
Article History: Received: 30 March 2022, Revised: 8 April 2022, Accepted: 15 April 2022, Publication: 30 April 2022

2.7.3 Effects of different treatments on the growth of flue-cured tobacco and the intrinsic quality of tobacco leaves

In this study, after the application of water-retaining agent, there was significantly decreased total sugar and reducing sugar in tobacco leaves, while the total nitrogen, nicotine, and K^+ generally increased. The Cl^- content is different between the middle and upper leaves, which increases slightly in middle leaves, but decreases significantly in the upper leaves. Where, the changes of total sugar, reducing sugar, and nicotine content are quite different from the findings of Mei Yanan et al.[24], Bai Gangshuan, et al.[7,25], but are similar to findings of Xu Lu et al.[26]. It's possibly because obvious drought stress was set in the former experiment, but the stress was significantly eased after the application of water-retaining agent, with activity of tobacco plants increased and content of total sugar and reducing sugar on the rise. In this experiment, drought stress was mainly set in the early, middle development stages, with no obvious drought stress in the late stage. Moreover, the two experimental tobacco-growing areas were quite different in terms of primary plant varieties, ecology, soil conditions and conventional chemical components of tobacco leaves. Therefore, the author believes that the two conclusions are less comparable. The later experimental site is Panzhihua with climate and soil conditions closer to this study. The tested varieties are all dajinyuan, so the conclusion is relatively more comparable. In this study, after the application of water-retaining agent, the content of total sugar and reducing sugar in the upper leaves decreased, and the content of total nitrogen and total alkali increased. For its reason, on the one hand, the root system of flue-cured tobacco ages in the late growth stage. Coupled with soil leaching and deposition, the soil porosity decreases, the overall activity of the plant is poorer, and the total sugar and reducing sugar content decreases. On the other hand, the content of total sugar and reducing sugar is also related to the maturity of tobacco leaves. The present study found that with the increase of tobacco leaf maturity, the content of total sugar and reducing sugar presented a downward trend, while the content of total nitrogen and nicotine displayed an upward trend[27-29]. It is thus speculated that the decrease of two sugars in this experiment is because the application of water-retaining agent advances the growth process of flue-cured tobacco, and increases the maturity of upper leaves.

Cl^- mainly exists in the form of water-soluble chlorine, which is extremely mobile in tobacco plants. It enters the roots of tobacco plants through the symplast pathway. The flow direction has relation with the transpiration rate of plant organs. Generally, organs with higher transpiration rate have higher Cl^- content. In addition, due to the greatly different soil chlorine content between the various tobacco-growing areas, its content is not obviously related to leaf position in field production[30, 31]. In this experiment, the chlorine content in upper leaves decreased significantly after the application of water-retaining agent. For its reason, on the one hand, the replacement of Cl^- by water-retaining agent results in decreased Cl^- content in the soil[19, 20], and at the same time, the water-retaining agent contains a large number of hydrophilic groups OH^- which antagonizes the absorption of Cl^-[32,33]. Moreover, water-retaining agent can dissociate a large number of anions and cations, among which K^+, SO_4^{2-}, etc. are inconducive to the absorption of Cl^-. On the other hand, Cl^- content in tobacco leaves is positively correlated with Cl^- content in soil[2, 33-35], and nearly 60% Cl^- in tobacco leaves comes directly from soil[33]. Baoshan Changning tobacco-growing area located in the southwest generally has low soil chlorine content[32]. The two factors lead to insufficient Cl^- supply in the soil, so upper tobacco leaves have significantly decreased Cl^-. The content of potassium ion in tobacco leaves is usually positively correlated with the content of soil available potassium. In this study, the content of soil available potassium increased significantly after the application of water-retaining agent, while potassium content in the middle leaves was not significantly different, though potassium content in the upper leaves increased significantly. For its reason, the absorption of potassium ions in flue-cured tobacco is mainly active, and its transport direction is affected by root pressure and transpiration rate. However, the tobacco plants age in the mature stage of flue-cured tobacco, with activity declined and root potassium absorption decreased. Therefore, upper leaves have lower potassium content than middle leaves. In this study, with the potassium ion proportion above 3%, the middle leaves belonged to potassium-rich tobacco leaves[22] whose potassium absorption was close to saturation, so the positive correlation between soil available potassium and potassium content in tobacco leaves is mainly reflected in the upper leaves.

III. CONCLUSION

Compared with attapulgite-PAM, K-PAA can aggregate more soil aggregates in the early growth stage of flue-cured tobacco, thus increasing soil bulk density. After its application, soil water content is higher, and at the same time, more K^+ is dissociated, with soil available potassium content increased. On the other hand, attapulgite-PAM has better stability, which can reduce soil bulk density and increase soil porosity in the early growth stage, and can better increase soil available potassium in the later stage after application. Hole application has better water retention effect than broadcast application. Under the application amount gradient in this experiment, the water retention performance increases with the increase of application amount. Application of water-retaining agent can regulate the growth and quality formation of flue-cured tobacco, promote the early growth and rapid development of flue-cured tobacco in the early growth stage, coordinate the sugar-alkali ratio and nitrogen-alkali ratio of tobacco leaves, thus improving the overall smoking quality of tobacco leaves.

ACKNOWLEDGEMENTS

This work was supported by Research on Key Technologies of potassium and alkali extraction and reduction of Honghe tobacco based on the demand of "Shuangxi" brand (2022440000340014); Henan young backbone teachers funding project (2020GGJS047); Research and popularization of soil micro ecological improvement and optimized fertilization technology for tobacco planting in Shangluo (2021611000270042).

REFERENCES

[1] LIU G S (2003) Tobacco Cultivation. No. 2 North Agricultural Pavilion Road, Chaoyang District, Beijing: China Agriculture Press.
[2] HU G S, ZHENG W (2000) Nutrition of flue-cured tobacco. Beijing: Science Press.
[3] HAN J F (2003) Tobacco Cultivation physiology. Beijing: China Agriculture Press.
[4] Duan S H, YANG Y J, LIU J L, et al. (2012) Research progress on water requirement of tobacco. Tobacco Science

in China 33: 99-105.
[5] ZHENG D F, XU J Y, LU X P, et al. (2015) Spatial-temporal characteristics of flue-cured tobacco water demand and irrigation demand index in Yunnan Province. Chinese Journal of Applied Ecology 2607: 2091-2098.
[6] LI X, ZHANG D, QING H, et al. (2019) Effects of water retaining agent combined with pea turning pressure on soil improvement and flue-cured tobacco quality in newly reclaimed tobacco soil in seasonal arid area. Journal of Soil and Water Conservation 33: 288-293.
[7] BAI G S, HE D F, GENG W, et al. (2020) Effects of different water retaining agents on soil properties and flue-cured tobacco growth. Journal of China Agricultural University 25: 31-43.
[8] Hou X Q, LI R, HE W S, et al. (2015) Comparison of effects of two water-retaining agents on soil physical properties and potato yield in drylands. Journal of Nuclear Agricultural Sciences 29: 2410-2417.
[9] HUANG Z B, ZHANG G Z, LI Y Y, et al. (2002) Determination of characteristics of water retaining agent and its application in agriculture. Transactions of the Chinese Society of Agricultural Engineering 01: 22-26.
[10] TIAN L, LIU J H, ZHAO B P, et al. (2021) Effects of combined application of water retaining agent and microbial microbial fertilizer on soil physical and chemical properties and oat yield in dryland. Soil and Fertilizer Science in China 04: 109-117.
[11] Han J J, Liu Y, Han Y T, et al. (2015) Effects of microbial preparation on root physiological characteristics of flue-cured tobacco under drought stress. Chinese Tobacco Science 36: 68-72
[12] ZHENG Y N, ZHAO M Q , HE F, et al. (2017) Effects of polyacrylates on soil physicochemical properties and root growth of flue-cured tobacco. Chinese Tobacco Science 38: 39-44
[13] Wroblewska K, Debicz R, Babelewski P (2012) The influence of water sorbing geocomposite and pine bark mulching on growth and flowering of some perennial species. Hortorum Cultus 10: 203-216
[14] Malekian A, Valizadeh E, Dastoori M, et al. (2012) Soil water retention and maize (Zea mays L.) growth as effected by different amounts of Pumice. Australian Journal of Crop Science 3: 450-454
[15] ZUO G L, YE H Y, DU C J, et al. (2011) Effects of soybean straw based water retaining agent on soil physical properties and tobacco growth in Nanyang Tobacco field. Transactions of the Chinese Society of Agricultural Engineering 27: 15-19
[16] Yang L, Han Y, Yang P, et al. (2015) Effects of Superabsorbent Polymers on Infiltration and Evaporation of Soil Moisture Under Point Source Drip Irrigation. Irrigation and Drainage 64: 275-282
[17] Lejcuś K, [pitalniak M, Dąbrowska J (2018) Swelling Behaviour of Superabsorbent Polymers for Soil Amendment under Different Loads. Polymers 10: 271
[18] CHEN G L, WANG J, WANG C M, et al. (2021) Effect of different ions and pH on water absorption performance of water retaining agent. Biochemical Engineering 7: 16-22
[19] ZHEN Q, WANG B T (2021) Study on adsorption and sustained-release performance of zinc fertilizer with different particle size water-retaining agents. Soil and Fertilizer Science in China 03: 257-263
[20] HUANG Z B, SUN P C, ZHONG J, et al. (2016) Progress in application of polymer water retaining agent in soil water and fertilizer conservation and pollution control. Transactions of the Chinese Society of Agricultural Engineering 32: 125-131
[21] JI B Y, ZHAO C P, WU Y, et al. (2021) Effects of different particle sizes of water retaining agents on soil structure and water characteristics in continuous dehydration-rehydration water. Journal of Soil and Water Conservation 35: 375-383
[22] DU W, TAN X L, YI J H, et al. (2007) Quality evaluation of tobacco leaf by chemical constituents. Acta Tabacaria Sinica 03: 25-31
[23] MAO S S, Islam M. Robiul, JIA P F, et al. (2011) Effects of water retention agent and fertilizer rate on oat production in Sandy land. Journal of Triticeae Crops 31: 308-313
[24] MEI Y N, ZHAO S M, ZHAO M Q, et al. (2018) Effects of water retention agent on soil nutrients and flue-cured

Forest Chemicals Review
www.forestchemicalsreview.com
ISSN: 1520-0191
July-August 2022 Page No. 246-266
Article History: Received: 30 March 2022, Revised: 8 April 2022, Accepted: 15 April 2022, Publication: 30 April 2022

tobacco quality in dry land of western Henan province. Agricultural Research in the Arid Areas 36: 149-155
[25] BAI G S, GENG W, HE D F (2019) Effects of water retention agent on soil properties and flue-cured tobacco growth in Qinba Mountain area. Journal of Zhejiang University (Agriculture & Life Science) 45: 343-354
[26] XU Lu, ZHANG D, QING H, et al. (2017) Effect of water retaining agent combined with ryegrass green fertilizer on soil improvement and flue-cured tobacco quality. Journal of Mountain Science 35: 727-733
[27] XU Z C, ZHAO R R, WANG L X, et al. (2014) Research progress of tobacco maturity. Journal of Northeast Agricultural University 45: 123-128
[28] SUN Y Y, JIN Z W, HUANG M D, et al. (2016) Relationship between SPAD value and maturity of fresh tobacco leaves and quality of flue-cured tobacco leaves.Chinese Tobacco Science 37: 42-46
[29] LIU S S, OU M Y, MA K, et al. (2016) Research Progress on the relationship between Tobacco Maturity and quality and its influencing factors.Acta Agriculturae Jiangxi 28: 75-79
[30] LI Y P, XU X Y, GAO F H, et al. (2012) Effects of altitude and leaf position on 10 chemical constituents in mature fresh tobacco leaves of flue-cured tobacco. Southwest China Journal of Agricultural Sciences 25: 1620-1624
[31] FANG Z C, LI F L, LI C J, et al. (2011) Analysis of chemical components between leaf positions of Lijiang flue-cured tobacco.Journal of Yunnan Agricultural University (Natural Science) 26: 35-40
[32] LIU P, ZHU J F, GUO L, et al. (2013) Research progress on sources and control measures of chlorine ion in flue-cured tobacco. Acta Agriculturae Jiangxi 25(03): 74-77
[33] ZHANG X, FAN Y K, HUANG Y J, et al. (2006) Study on the main sources of absorption of chlorine in flue-cured tobacco and its distribution in vivo. Soil and Fertilizer 02: 62-64
[34] QIN S (2001) Characteristics of chlorine in tobacco-planting soil and application of chlorine-containing potassium fertilizer in Guizhou. Journal of Southwest Agricultural University 05: 471-473
[35] YOU X Y, ZHOU F, XING X X, et al. (2019) Effects of water and fertilizer integration on chlorine content in flue-cured tobacco leaves and chloride ion migration in tobacco soil. Journal of Yangzhou University (Agriculture & Life Science edition) 40: 38-43