Effects of flue-cure tobacco transplanting date on leaf growth dynamics and establishment its simulation model

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Introduction

Transplanting date is the key factor for high quality flue-cured tobacco production. Choosing optimal transplanting date is the requirement for best yield and quality of flue-cured tobacco. In this paper, the impact of transplanting stage, tobacco leaf position on the dynamics of flue-cured tobacco leaf growth was studied by selecting flue-cured tobacco with three different transplanting dates. And at the same time the dynamics model of the flue-cured tobacco leaf growth was established by using leaf growth time and active accumulated temperature as the independent variable. This could provide the evidence for further improving the growth potential and appearance quality of flue-cured tobacco leaf.

Materials and methods

Experimental design

The tobacco variety was K326. Three different transplanting dates were 4th May(T_1), 14th May(T_2) and 24th May(T_3) respectively. Every treatment had three replicates. The process of extension of length and width of four leaf positions was measured every three days.

Data analysis

The software Curve Expert1.38 was used for model establishment.

The parameters needed for simulation were shown as follows:

The growing duration at the maximum growth rate: $t_{Vmax}=(b-\ln d)/c$; The growing amount at the maximum growth rate: $W_{Vmax}=a(d+1)^{-1/d}$; The average growth rate: $V_a=ac/(2d+4)$. The corresponding time at active growth stage: $D=(2d+4)/c$. There were three distinct increasing stages in Richards growing curve. The deduced corresponding durations of initial growth stage, rapid growth stage and stable growth stage were D_1, D_2 and D_3 respectively. According to D_1, D_2 and D_3, the inferred corresponding parameters of leaf growth amount and active accumulated temperature equation were C_1, C_2 and C_3.

Results and discussion

The establishment of optimal model

The four simulation equations were shown below(equation 1-4). Both equation 1 and 2 didn't meet the rule of dry matter accumulation variation, while equation 3 and 4 met with this rule. When d was equal with 1, equation 3 was the special form of equation 4. Therefore Richards's equation was chosen for simulation of tobacco leaf growth dynamics.

$$\lim_{x\to+\infty} f(x)=\lim_{x\to+\infty}[(a+bx+cx^2+dx^3)]=+\infty \quad (1)$$

$$\lim_{x\to+\infty} f(x)=\lim_{x\to+\infty}[(ab+cx^d)/(b+x^d)]=c \quad (2)$$

$$\lim_{x\to+\infty} f(x)=\lim_{x\to+\infty}[(a/(1+e^{b-cx})^{1/d}]=a \quad (3)$$

$$\lim_{x\to+\infty} f(x)=\lim_{x\to+\infty}[(a/(1+e^{b-cx})]=a \quad (4)$$

The validation of the Richard's equation

The dynamic simulation was done by using the measurement of leaf length and width of flue-cured tobacco with different transplanting stages while Richards's equation was employed. The process of tobacco leaf at the 10th position transplanted on 14th May was simulated with four simulation equations by using the software Curve Expert1.38 (Tab. 1). The correlation coefficient of the measurement and the simulation values were above 0.96 . It showed that the dynamic characteristics of flue-cured tobacco leaf growth along with growth time or active accumulated temperature variation at the different leaf position at the different transplanting stages could be accurately reflected by the simulation model.

Tab. 1 the parameters of tobacco leaf growth models

Variable	Model	The parameter of leaf length					The parameter of leaf width				
		a	b	c	d	R^2	a	b	c	d	R^2
Growth time	MMF	-615.1	8.47*10^4	67.78	5.8	0.99	-940.1	1.03*10^4	27.79	5.1	0.99
	Cubic equation	-6.15	15.16	-0.61	1.50*10^-4	0.99	-111.8	12.14	-0.1	0.001	0.99
	Rational Model	65.58	8.77	0.34	1	0.99	16.61	8.66	0.33	1	0.99
	Richards	66.07	0.80	0.79	0.001	0.99	16.87	1.1	0.8	0.01	0.99
Active accumulated temperature	MMF	-816.4	1.96*10^1	71.84	1.74	0.98	-210	1.8*10^1	10.47	1.1	0.98
	Cubic equation	-385.6	1.46	-0.001	1.00*10^-6	0.98	-116.1	0.58	-40.04	9*10^-5	0.99
	Rational Model	65.47	8.8	0.01	1	0.99	16.55	8.61	0.01	1	0.99
	Richards	65.84	0.91	0.01	0.001	0.99	16.75	0.94	0.01	0	0.99

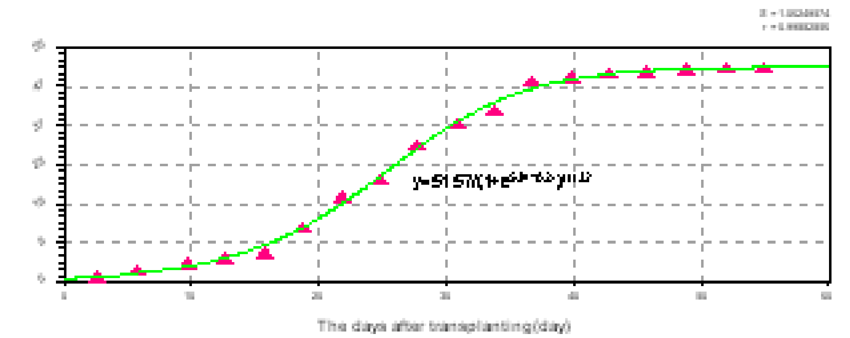

Fig. 1 the simulation of Richard's equation at the first leaf position transplanted on 4th May

The dynamic characteristics and the model parameters of tobacco leaf growth at the different transplanting dates

The results shown in Tab. 2 indicated that the sequence of growth time with different transplanting dates corresponding to the maximum rate of leaf length was $T_1>T_2>T_3$. At the same transplanting date, the growth time corresponding to rapid growth stage of all the leaf positions was shorter than that in initial growth stage and stable growth stage. The sequence of the active accumulated temperature which needed in three different growth stages of leaf length dynamic variation at the different leaf position was the initial growth phase < rapid growth stage < stable growth stage. The growth time and active accumulated temperature of early transplanted (T_1) flue-cured tobacco was larger than those of late transplanted (T_3) tobacco at the three stages of the rate of leaf length dynamic variation. The dynamic characteristics of leaf width at the different transplanting dates had the similar results with that of leaf length (Tab. 3)

Tab. 2 the characteristic parameters of tobacco leaf length at the different transplanting dates

Leaf position	Transplanting date	t_{Vmax}	V_t	W_{Vmax}	D	D_1	D_2	D_3	C_1	C_2	C_3
5	T_1	11.15	1.11	18.15	19.19	17.88	8.94	17.18	648.0	841.1	1110.7
	T_2	16.81	1.08	11.47	18.84	19.88	17.88	16.16	447.7	766.1	1166.9
	T_3	11.19	1.07	14.11	14.41	16.04	10.11	11.64	791.5	619.5	878.0
10	T_1	18.90	1.11	15.51	11.58	11.71	10.18	19.61	761.1	1001.1	1460.5
	T_2	15.50	1.15	14.11	10.94	10.46	10.07	19.01	691.9	911.8	1151.0
	T_3	18.54	1.77	11.16	18.68	14.04	8.99	16.98	566.4	771.0	1166.1
15	T_1	41.16	1.01	16.16	15.14	14.86	17.00	11.09	709.6	1151.6	1171.4
	T_2	18.10	1.18	17.15	40.95	18.14	19.70	17.18	610.1	1098.9	1001.1
	T_3	15.18	1.51	19.11	11.11	17.78	15.01	18.10	644.6	1007.7	1691.1
20	T_1	46.11	1.11	15.06	55.47	11.78	16.69	50.16	715.8	1166.1	1590.7
	T_2	51.06	1.15	17.80	17.40	44.47	17.18	14.81	1014.9	1111.8	1911.1
	T_3	41.45	1.11	11.04	17.91	11.11	18.14	14.41	756.1	1197.1	1011.1

Tab.3 the characteristic parameters of tobacco leaf width at the different transplanting dates

Leaf position	Transplanting date	T_{Vmax}	V_t	W_{Vmax}	D	D_1	D_2	D_3	C_1	C_2	C_3
5	T_1	11.11	1.79	11.96	17.90	18.01	8.61	16.01	649.1	817.0	1164.0
	T_2	18.80	1.54	8.90	15.71	15.01	7.56	14.14	561.6	719.8	1071.7
	T_3	11.66	0.87	9.08	19.44	17.59	8.14	9.01	414.1	611.5	808.9
10	T_1	19.70	1.49	8.51	15.54	15.96	7.48	14.11	800.1	996.6	1157.1
	T_2	16.16	1.11	9.90	11.18	10.91	10.67	10.10	701.1	946.1	1404.7
	T_3	18.99	1.14	8.99	19.71	14.15	9.49	17.91	569.1	789.6	1106.1
15	T_1	45.74	0.88	8.51	18.09	18.98	17.51	15.51	888.5	1194.8	1771.0
	T_2	41.08	0.85	9.80	11.11	11.57	15.01	18.11	749.7	1111.1	1799.7
	T_3	18.18	0.90	11.11	19.84	11.60	17.16	16.58	711.7	1051.9	1461.1
20	T_1	49.06	0.41	8.87	54.68	15.91	16.11	49.64	801.7	1414.1	1598.7
	T_2	49.97	0.78	9.58	14.17	41.70	16.54	11.11	947.7	1149.1	1099.9
	T_3	41.01	0.88	10.16	11.75	15.44	15.18	16.77	811.4	1100.0	1819.5

Conclusion

(1) Richard's equation was chosen for simulation of tobacco leaf growth dynamics because it met with the rule of dry matter accumulation variation.

(2) The correlation coefficient of the measurement and the simulation values were above 0.96. The dynamic characteristics of flue-cured tobacco leaf growth along with growth time or active accumulated temperature variation at the different leaf position at the different transplanting stages could be accurately reflected by the Richard's model.

(3) The sequence of growth time with different transplanting dates corresponding to the maximum rate of leaf length was $T_1>T_2>T_3$. The growth time and active accumulated temperature of early transplanted (T_1) flue-cured tobacco was larger than those of late transplanted (T_3) tobacco at the three stages of the rate of leaf length dynamic variation.

(4) The dynamic characteristics of leaf width at the different transplanting dates had the similar results with that of leaf length.