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Prediction of growth and dry matter production of flue-cured Virginia tobacco (*Nicotiana tabacum*) using mathematical models in irrigated Alfisols of Andhra Pradesh

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ABSTRACT

Field experiments were conducted during 2005–07 on 'Kanchan' flue-cured tobacco (*Nicotiana tabacum* L.) under irrigated condition to study the effect of planting dates on dry matter accumulation, leaf weight, growth parameters and to develop suitable mathematical models to predict the drymatter and leaf weight by using growth and weather parameters. Late planting showed reduction in cured leaf yields, leaf area, dry matter accumulation but specific leaf weight increased compared to early and normal planting. Maximum crop growth rate and net assimilation rate were recorded between 40 and 80 days after planting. Among various growth parameters, leaf area index and specific leaf weight had highest positive correlation with total dry matter production and leaf weight. Dry matter accumulation and leaf weight showed positive correlation with sunshine hours, evaporation, maximum temperature and difference of maximum and minimum temperatures. Leaf area index can alone predict the total dry matter (R^2=0.96**) and leaf weight (R^2 =0.93**) of flue-cured virginia tobacco with high degree of accuracy. By including the specific leaf weight and weather parameters, viz temperatures, rainfall and sunshine hours the accuracy was further improved. Predicted values of total dry matter and leaf weight with the selected multiple regression equations, correlated significantly with actual values. These prediction equations will help in formulating the production and marketing regulation strategy of FCV tobacco in northern light soils of Andhra Pradesh.

Key words: Crop growth rate, Flue-cured tobacco, Leaf area index, Net assimilation rate, Specific leaf weight

Tobacco is one of the important commercial crops cultivated in India and is the third largest producer and exporter in the world (Parker 2009). Tobacco contributes Rs 3 000 crores of foreign exchange and Rs 10 000 crores of excise duty to the national exchequer (Tobacco Board 2008). Among the different tobacco types grown in India, flue-cured Virginia tobacco is cultivated in Andhra Pradesh and Karnataka in an area of 0.213 million ha producing 253 million kg leaf annually (Tobacco Board 2008). In Andhra Pradesh, FCV tobacco is cultivated in West Godavari, East Godavari and Khammam districts to an extent of 26 000 ha in Alfisols under irrigated condition producing 55 million kg tobacco (Tobacco Board 2008). Unlike in other crops, as the economic product in tobacco being leaf, well-balanced leaf growth is necessary for harnessing the full yield potential coupled with quality. Understanding the factors responsible for leaf mass accumulation and their interaction with climate during vegetative phase helps in their manipulation for realizing higher yields. Hence, an attempt was made to study the effect of dates of planting on various growth parameters and the association of different weather and growth parameters with total dry matter production and leaf weight in the popular variety 'Kanchan' (*Nicotiana tabacum* L.) grown in northern light soils of Andhra Pradesh. Yield predictions with suitable mathematical model will help in predicting the total yield so that marketing strategy can be prepared for realizing higher profitability.

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MATERIALS AND METHODS

Field experiments were conducted at Research farm of CTRI Research Station Jeelugumalli, West Godavari District, Andhra Pradesh during 2005–07 with 'Kanchan' tobacco to study the influence of planting dates and climate on total dry matter accumulation, leaf weight and growth parameters. Soil samples were collected before planting and were analyzed for soil properties using the standard methods The soils are typic Haplustalfs, sandy loam (sand 84%, silt 5% and clay 11%), slightly acidic (*p*H 5.5) in reaction, low in soluble salts (EC: 0.16 dS/m), chlorides (16 ppm), organic carbon (0.38%) and available N (158 kg/ha), high in available available P (35 kg/ha) and medium in available K (196 kg/ha). The rainfall received during 2005–06 and 2006–07 was 1 530 and 1 080 mm, respectively. The treatments were three planting dates, viz D_1, 15 September; D_2, 1 October and D_3, 25 October and replicated 8 times. The recommended doses of fertilzers (115 kg N, 60 kg P_2O_5 and 120 kg K_2O/ha) were applied in three split doses. At 10 days after planting, 22.5 kg N, entire dose of P and 60 kg K_2O were applied/ha in the form of di-ammonium phosphate and sulphate of potash. At 25–30 days after planting, 62.5 kg N and the 60 kg K_2O/ha were applied in the form of calcium ammonium nitrate and sulphate of potash. At 40–45 days after planting the remaining nitrogen dose of 31.25 kg/ha was applied in the form of calcium ammonium nitrate. The observations on fresh and dry weights of plant parts (leaf, stem and root) were recorded on five randomly selected plants at frequent intervals during the crop growth period. Yield data (green leaf yield, cured leaf yield and grade index) were collected. The plants were topped at bud stage leaving 24 leaves on the plant. The suckers were controlled using a fatty alcohol based suckericide, decanol @ 4%. Leaves were harvested as and when they matured (8–10 harvests). While recording the weights of different plant parts, the weight of leaves harvested by that stage were added to the leaf weight as on that stage to get the cumulative weights. From the recorded observations, total dry matter production, leaf weight (Watson 1947), crop growth rate (Watson 1947), leaf area index, specific leaf weight (Huber 1983), net assimilation rate (Watson 1958) were computed. During the crop growth period the weather parameters, viz minimum temperature (min. T.), maximum temperature (max. T.), rainfall, rainy days, bright sunshine hours, evaporation were recorded daily. The correlations co-efficients were calculated between total dry matter, leaf weight, growth (crop growth rate, net assimilation rate, specific leaf weight and leaf area index) and climatic parameters. Regression equations were computed for the total drymatter and leaf weight in relation to various growth parameters and weather parameters (Gomez and Gomez 1984). Dry matter yield and leaf biomass were predicted with developed equations and correlated with actual values.

RESULTS AND DISCUSSIONS

Effect of planting dates

Date of transplanting affected the total dry matter production, leaf weight, crop growth rate, leaf area index, specific leaf weight and net assimilation rate (Fig 1). Total dry matter and leaf weight increased with increase in crop duration. Among the three dates of planting, higher total dry matter, leaf weight, leaf area index were recorded in D_1 and D_2 compared to D_3. The duration of the crop was less (139 days) in D_3 planting compared to D_1 (164 days) and D_2 (155 days) planting. Specific leaf weight increased as the age of the crop advances and in D_3 planting more specific leaf weight was recorded which might be due to lower leaf area index. Average cured leaf yields obtained in D_1 (1 783 kg/ha) and D_2 (1 877 kg/ha) planting were higher compared to D_3 (1 336 kg/ha). Lower yields were obtained in D_3 even though specific leaf weight increased in D_3 because of reduction in leaf area index. Dry matter accumulation

Table 1 Correlations among growth parameters and weather parameters

Parameter	TDM	LW	LAI	SLW	CGR	NAR	Min.T	Max.T	~ of Temp.	RF	R days	SS	E
TDM	1.000												
LW	0.965**	1.00											
LAI	0.979**	0.966**	1.00										
SLW	0.831**	0.861**	0.803**	1.00									
CGR	0.061	–0.143	–0.037	–0.084	1.00								
NAR	–0.540**	–0.618**	–0.618**	0.559**	0.470**	1.00							
Min.T	–0.628**	–0.501**	–0.583**	0.560**	–0.279*	0.244*	1.00						
Max.T	0.527**	0.607**	0.508**	0.562**	–0.265*	–0.398**	–0.026	1.00					
~ of Temp.	0.805**	0.745**	0.758**	0.768**	0.083	–0.419**	–0.836**	0.576**	1.00				
RF	–0.301**	–0.213	–0.249*	–0.292**	–0.329**	–0.150	0.515**	–0.002	–0.424**	1.00			
R days	–0.741**	–0.646**	0.088	0.094	0.11	0.070	–0.167	–0.167	0.038	0.512**	1.00		
SS	0.683**	0.617**	0.621**	0.644**	0.191	–0.246*	–0.663**	0.510**	0.825**	–0.560**	0.232	1.00	
E	0.488**	0.530**	0.443**	0.540**	–0.120	–0.253*	–0.206	0.747**	0.580**	–0.244*	–0.169	0.656**	1.00

*P = 0.05 and **P = 0.01.

TDM, Total dry matter; LW, leaf weight; LAI, leaf area index; SLW, specific leaf weight; CGR, crop growth rate; NAR, net assimilation rate; Min.T, minimum temperatures; Max.T, maximum temperature; ~ of Temp., Difference in min.T and max.T; RF, rainfall; R.days, rainy days; SS, sunshine hours; E, evaporation

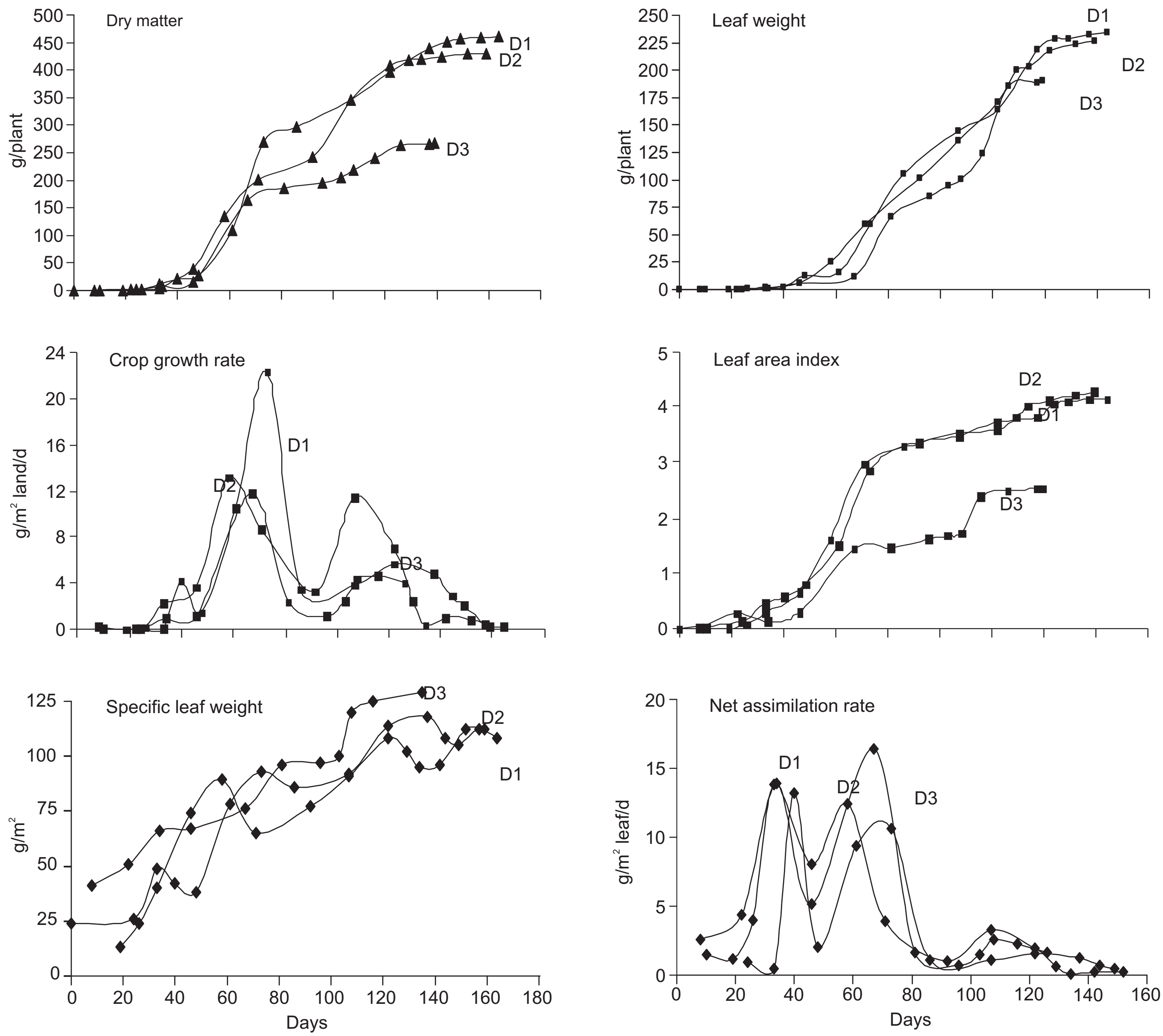

Fig 1 Effect of different dates of planting on leaf area, dry matter production and crop growth parameters of flue-cured tobacco D_1, 15 September ; D_2, 1 October; D_3, 25 October

followed typical sigmoid curve accurately as described by the logistic equation (Moustakas and Ntzanis 2004). Crop growth rate and net assimilation rate was maximum between 40–80 days after planting in all the three dates of planting.

Correlations between dry matter, leaf weight and growth and weather parameters

Among the various growth parameters, total dry matter showed highest significant positive association with leaf area index, followed by specific leaf weight (Table 1). Total dry matter and leaf weight were positively correlated with leaf area index, specific leaf weight, maximum temperature, difference between maximum and minimum temperature, sunshine hours and evaporation but negatively correlated with net assimilation rate, minimum temperature and rainfall. Among the weather parameters, maximum temperature, difference in maximum and minimum temperatures and sunshine hours showed significant and positive correlation with leaf area index and specific leaf weight. Dry mass/unit area increased with increasing light intensity and duration (Chen and Huang 1970) and increased light duration enhanced the relative width of leaves (Raper and Downs 1976). Hence these two environmental parameters had a dominating influence on tobacco production. Crop growth rate and net assimilation rate are negatively associated with temperature and rainfall.

Table 2 Multiple regression equations for predicting the total dry matter of FCV tobacco in northern light soils of Andhra Pradesh

Intercept	Regression co-efficient										R^2
	LAI	SLW	CGR	NAR	Min.T	Max. T	RF	Rainy days	SS	E	
12.51	104.39**										0.957**
–115.01		4.27**									0.696**
196.58			2.30								0.004
272.59				18.59**							0.292**
–16.80	93.3**	6.63**									0.964**
–36.67	92.16**	0.764**	3.95**								0.974**
–52.27	99.14**	0.795**		–4.14**							0.972**
–50.26	95.76**	0.80**	2.86**	2.27*							0.976**
–123.5	93.08**	0.577**	3.058**	2.343*	–0.358	4.25	–0.22	4.88	2.98	1.04	0.981**

*P = 0.05, **P = 0.01

LAI, Leaf area Index; SLW, specific leaf weight; CGR, crop growth rate; NAR, net assimilation rate; Min.T, minimum temperatures; Max.T, maximum temperature; RF, rainfall; SS, sunshine hours; E, evaporation

Table 3 Multiple regression equations for predicting the leaf weight of FCV tobacco in northern light soils of Andhra Pradesh

Absolute constant	Regression co-efficient										R^2
	LAI	SLW	CGR	NAR	Min.T	Max. T	RF	Rainy days--	SS	E	
–11.09	62.43**										0.934**
–96.74		2.68**									0.742**
116.30			–3.27								0.020
150.89				–12.89**							0.382**
–44.17	49.96**	0.75**									0.954**
–33.70	55.05**	0.703**	–2.17**								0.963**
–42.59	49.68**	0.743**		–0.189							0.954**
–44.56	53.36**	0.733**	–3.06**	1.81*							0.966**
–160.1	54.75**	0.734**	–2.03**	1.76*	2.36	1.45	–0.045	0.72	2.49	2.18	0.975**

*P = 0.05, **P = 0.01

LAI, Leaf area Index; SLW, specific leaf weight; CGR, crop growth rate; NAR, net assimilation rate; Min.T, minimum temperatures; Max.T, maximum temperature; RF, rainfall; SS, sunshine hours; E, evaporation

Regression equation

Multiple Regression equations were computed by taking total dry matter and leaf weight as dependent variables, weather and growth parameters as independent variables (Tables 2, 3). Leaf area index can alone predict the total dry matter (R^2=0.96**) and leaf weight (R^2=0.93**) of flue-cured tobacco with high degree of accuracy. By including the specific leaf weight the accuracy was increased for total dry matter (R^2=0.964**) and leaf weight (R^2=0.954**). The accuracy was further enhanced by adding the weather parameters, viz temperatures, rainfall and sunshine hr (R^2=0.980** for total dry matter and 0.974** for leaf weight). Crop growth rate cannot predict the total dry matter and leaf weight as the R^2 values were very low. The R^2 value of net assimilation rate with total dry matter and leaf weight were higher compared to crop growth rate, however they were low (R^2=0.292 with total dry matter and R^2=0.382 with leaf weight). Hence, crop growth rate and net assimilation rate alone should not be used for prediction of total dry matter and leaf weight.

Table 4 Correlations between the actual and predicted values of dry matter and leaf weight

Parameter	Total dry matter	Leaf weight
LAI	0.979**	0.963**
SLW	0.831**	0.861**
LAI + SLW	0.982**	0.963**
LA I+ SLW +CGR	0.987**	0.966**
LAI + SLW + CGR+NAR	0.988**	0.969**
LAI + SLW + CGR+ NAR + weather parameters	0.990**	0.975**

LAI, Leaf area Index; SLW, specific leaf weight; CGR, crop growth rate; NAR, net assimilation rate; weather parameters (minimum temperature, maximum temperature, rainfall, sunshine hours, evaporation)

Total dry matter and leaf weight values were predicted with the multiple regression equations and correlated with actual values. Actual values correlated significantly with predicted values (Table 4). Hence, these equations can be used for predicting the total dry matter and leaf weight. Similarly, Overman (1999) developed equations for prediction of optimum time of planting for FCV tobacco.

It can be concluded that the optimum date of planting for flue cured tobacco will be 15 September to 1 October. Total dry matter and leaf weight can be predicted to a reasonable degree of accuracy with the help of growth parameters, viz leaf area index, specific leaf weight and weather parameters which will help in yield predictions for formulating the production and marketing regulation strategy of flue-cured tobacco in northern light soil of Andhra Pradesh.

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