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PREDICTION OF CRITICAL WEED COMPETITION PERIOD BY CROP MODELING IN GREEN GRAM

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ABSTRACT

The total biomass produced by the three green gram cultivars *viz.*, Co 4, NARP 1 and Co GG 89047 from the herbicide applied field experiments at different phenological stages of crop growth were fitted into three mathematical models namely Gompertz, Richard's and Logistic to find out the critical weed competition period and its impact on crop growth. The Gompertz model showed high predictability (R^2) ranging between 95.6 and 99.9 per cent in estimating the TDMP of cultivars nearer to actual values. Besides the values of Chi-square (X^2), RSS, RMSD the Gompertz model showed better goodness of fit to simulate the crop growth in terms of TDMP. Among the cultivars, the Co 4 showed comparatively higher value of R^2 for all models at all weed management system with corresponding low values of X^2, RSS and RMSD than other two cultivars. The hand weeding and pre-emergence metolachlor treatments recorded high R^2 values than unweeded control indicating the suppression of weeds on crop growth.

KEY WORDS : Green gram, weeds, competition period, modeling

Mathematical model is an equation or set of equations that represents the behaviour of a system. The traditional growth analysis describing crop growth over time on some assumptions has certain limitations (Evans, 1972). However, these limitations are overcome with the application of mathematical functions which smother the crop growth curve. Most of these functions are asymptotic in nature and include final size of crop growth as an essential parameter.

The success of weed management programme directed towards the minimization of herbicide use, largely depends upon the ability to predict the effect of weeds on crop yield. Thus models of weed invasion population growth and control have served as a frame work for organizing biological information on weeds and for developing weed control strategies (Mortimer *et al.*, 1980). Kropff (1988) using simulated data showed that a close relationship exists between relative leaf area of the weeds/dry matter and yield loss over a wide range of weed densitites and relative times of weed emergence. According to Praveen Rao (1990) the logistic growth curve elucidate the dry matter capitalization asymptotical to potential upper asymptote in time series with crop ontogeny. The present investigations were carried out to find out the critical weed competition period employing mathematical models in a herbicidal weed management experiment in green gram.

MATERIALS AND METHODS

The paper contains the results of the experiment conducted in the fields of Tamil Nadu Agricultural University, Coimbatore, during the year 1991 (*Kharif* season) under irrigated conditions on vertisol soils. Three cultivars *viz.*, Co 4, NARP and Co GG 89047 with a field maturity period of 85 to 90 days were grown. The herbicide metolachlor was applied as pre-emergence (3 days after at the rate of 1.00 kg ha^{-1}), besides the handweeding and an unweeded control was maintained.

The data on periodical total dry matter production (TDMP) of the individual cultivars, recorded in the control, handweeding and metolachlor treatment were regressed against stages by fitting following functional growth models *viz.*, Gompertz, Richards and Logistic as suggested by Causton and Venus (1981). These models were fitted to find out the treatments and the cultivar responses for the TDMP.

The formula of the individual model followed is given below

Gompertz $Y = A \exp(-e^{B-kt})$

Richards $Y=A\,(1+e^{B-kt})^{-1/n}$

Logistic $Y=A\,(1+e^{B-kt})^{-1}$

A = Maximum value of the parameter than could be obtained in the field condition.

B, K = are parameters to be estimated.

t = time in days ; n indicatate the shape of the curve and

Y = the parameter to be estimated.

From the estimated value of the parameter models sensitivity test criteria like sum of residuals, residual sum of squares (RSS), root mean square deviation (RMSD), Chi-square test (X^2) and coefficient of determination (R^2) were worked out. The sum of residuals is the sum of difference between observed (o) and predicted variable (p) = (o-p) residual sum of squares = [$\sum$ (o-p)2]. Root mean square deviation = $[\sum(o-p)^2/n]^{0.5}$. The models performance in simulated data was assessed based on lower values of sensitivity test criteria.

RESULTS AND DISCUSSION

Damage relationship is that quantity yield losses caused by weed infestations are essential for any short or long term economic analysis. The traditional growth analysis describing crop or weed growth over time on some assumptions has certain limitations. However, these limitations are overcome with the help of mathematical models which take into account of short term weather effect on crop growth and by differentiation models provide instantaneous growth rates of crop under different weed management practices.

In the present experiment, data on dry matter produced at different phenological stages of crop growth were fitted using Gompertz, Richards and Logistic models and the results are presented in Table 1. In all the three cultivars and at three weed management treatments, Gompertz model showed

Table 1. Mathematical models alongwith functions describing the dry matter production of green gram cultivars under weed management practices

Cultivar	Treatments	Models	Functional form	R^2	RSS	X^2	RMSD
Co 4	C	Gompertz	DMP = 16 exp. [-exp. (2.5570 - 0.0682 t)]	0.9842**	4.05	0.52	0.82
		Logistic	DMP = 16 [1 + exp. (5.5923 - 0.1099 t)]$^{-1b}$	0.9610**	13.09	5.15	1.47
		Richards	DMP = 16 [1 + exp. (3.1456 - 0.0874 5)]$^{-1.0526}$	0.9567**	15.44	5.89	1.60
	HW	Gompertz	DMP = 21 exp. [-exp. (2.3440 - 0.0575 t)]	0.9996**	2.54	0.36	0.65
		Logistic	DMP = 21 [1 + exp. (3.1374 - 0.0544 t)]$^{-1}$	0.9792**	28.53	3.77	2.18
		Richards	DMP = 21 [1 + exp. (2.8456 - 0.0462 t)]$^{-1.0526}$	0.9751**	34.90	4.46	2.41
	PE$_{ML00}$	Gompertz	DMP = 21 exp. [-exp. (2.4786 - 0.0615 t)]	0.9874**	5.75	0.70	0.97
		Logistic	DMP = 21 [1 + exp. (3.8393 - 0.0696 t)]$^{-1}$	0.9844**	12.15	2.29	1.42
		Richards	DMP = 21 [1 + exp. (2.1394 - 0.0571 t)]$^{-1.0526}$	0.9812**	16.52	2.94	1.65
NARP 1	C	Gompertz	DMP = 16 exp. [-exp. (2.3695 - 0.0632 t)]	0.9786**	4.60	0.63	0.87
		Logistic	DMP = 16 [1 + exp. (5.4457 - 0.1055 t)]$^{-1}$	0.9504**	16.63	2.81	1.66
		Richards	DMP = 16 [1 + exp. (3.8472 - 0.0746 t)]$^{-1.0526}$	0.9500**	16.62	5.63	1.66
	HW	Gompertz	DMP = 20 exp. [-exp. (2.8874 - 0.0786 t)]	0.9675**	14.19	1.53	1.53
		Logistic	DMP = 20 [1 + exp. (6.0481 - 0.1220 t)]$^{-1}$	0.9635**	18.00	5.93	1.73
		Richards	DMP = 20 [1 + exp. (3.0647 - 0.0472 t)]$^{-1.0526}$	0.9618**	20.65	8.27	1.85
	PE$_{ML00}$	Gompertz	DMP = 20 exp. [-exp. (2.9401 - 0.0809 t)]	0.9795**	17.03	1.89	1.71
		Logistic	DMP = 20 [1 + exp. (6.1280 - 0.1248 t)]$^{-1}$	0.9621**	18.73	6.40	1.76
		Richards	DMP = 20 [1 + exp. (2.1873 - 0.0675 t)]$^{-1.0526}$	0.9596**	21.19	8.27	1.87
Co GG 89047	C	Gompertz	DMP = 16 exp. [- exp. (3.2441 - 0.0908 t)]	0.9591**	13.47	7.44	1.49
		Logistic	DMP = 16 [1 + exp. (6.2571 - 0.1323 t)]$^{-1}$	0.9579**	13.30	4.79	1.48
		Richards	DMP = 16 [1 + exp. (3.4876 - 0.1287 t)]$^{-1.0526}$	0.9549**	14.78	6.10	1.56
	HW	Gompertz	DMP = 21 exp. [- exp. (2.8827 - 0.0767 t)]	0.9719**	14.52	1.52	1.55
		Logistic	DMP = 21 [1 + exp. (6.1168 - 0.1211 t)]$^{-1}$	0.9651**	19.60	6.04	1.80
		Richards	DMP = 21 [1 + exp. (3.1472 - 0.1375 t)]$^{-1.0526}$	0.9619**	22.54	7.86	1.93
	PE$_{ML00}$	Gompertz	DMP = 21 exp. [- exp. (2.8500 - 0.0764 t)]$^{-1}$	0.9588**	17.80	1.86	1.72
		Logistic	DMP = 21 (1 + exp. (6.0520 - 0.1202 t)]$^{-1}$	0.9660**	19.46	7.33	1.80
		Richards	DMP = 21 [1 + exp. (3.8416 - 1375 t)]$^{-1.0526}$	0.9634**	22.18	9.38	1.92

R^2 = Regression coefficient X^2 = Chisquare

RSS = Relative Sum of Squares RMSD = Relative Mean Square Deviation.

high predictability (R^2) ranging from 95.6 to 99.9 per cent in estimating the TDMP of green gram cultivars nearer to actual values. In addition the values of chi- square. (X^2), RSS and RMSD the Gompertz model showed the better goodness of fit to simulate the crop were Logistic and Richards. The Logistic model estimated the TDMP to an extent of 95.0 to 98.1 per cent of the actual data. Further in these models, RSS and RMSD were relatively higher.

Considering the cultivar response to the model fitting, the Co 4 showed comparatively higher values of R^2, for all models at all weed management systems with corresponding low values of X^2, RSS and RMSD than other two cultivars *viz.*, NARP 1 and Co GG 89047. The R^2 values indicated the estimated values very close to the observed values. Regarding the effect of weed management on DMP of crop in all the cultivars, the handweeding and pre-emergence application of metolachlor recorded marginally high R^2 values than unweeded control indicating reduction in the suppression of weeds on crop growth. However there was no reduction in the values of X^2, RSS and RMSD in unweeded control as compared to less weeds in handweeding and pre-emergence metolachlor. Considering the overall performance, Gompertz model showed relatively better goodness of fit in describing the TDMP of green gram cultivars than other two models.

The accumulation of biomass during certain interval of time as well as TDMP for the whole growth period by the crop bears a relationship with yield potential of most of the annual crops. The prodction and accmulation of biomass by crop is conditioned by many biotic and abiotic factors, of which, the competition by weeds with crop has been established for many factors. Though the competition of weeds with crop is assessed by convention with crops, as well as the weed management practices to be followed for augmenting the productivity. In this regard, among the three models, which were used by fitting the TDMP of cultivars used, the Gompertz model

Table 2. Point of inflection (β/k) indicating the days at which higher growth rate occurrs in cultivars under weed management practices

Treatment	Cultivar		
	Co 4	NARP 1	Co GG 89047
C	37.46	37.44	35.71
HW	40.73	36.72	37.57
$PE_{M1.0}$	40.26	36.34	37.30

β/k derived from Gompertz model

exhibited a better goodness of fit and predicted the values very close to the actual values observed. However, it was followed by Logistic and Richards's models. The better goodness of fit with Gompertz model obtained in the present investigations is amply supported by the findings of Kropff (1988) in sugar beet.

The β/K which indicated the point of inflection (the duration at which the weeds had high competition to the crops) for higher DMP in the Gompertz model did not vary much among weed management practices in NARP and Co GG 89047, while it was delayed by three days in freely low weed situations (handweeding and metolachlor) than weedy situations (37.5 days) (Table 2). This delay in point of inflection might be due to higher dry matter produced in Co 4 green gram in the latter two treatments than under unweeded control. Weed competition lowered DMP by 8.03 per cent and 7.96 per cent as compared to handweeding and pre-emergence metolachlor respectively.

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