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Estimation of critical period of weed control in mulberry cultivation by application of calibration problem extended to non-linear models

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ABSTRACT

Calibration problem is normally used for estimation of an unknown value of an independent variable (X) corresponding to an observed value of a dependent variable (Y) which is functionally related to X. This paper is concerned with the development of a confidence interval (C.I.) for an unknown value of X corresponding to a specified or predetermined value of Y, where the relationship between X and Y may be linear or non-linear. The problem of weeds in mulberry cultivation is severe. The produce of mulberry cultivation is the leaf which is entirely dependent on the physiological condition of the plant. If weeds or unwanted plants make any disturbance to the mulberry plants, the leaf production declines, directly. The control of weeds in proper time in mulberry cultivation, therefore, is vital. In the presentation piece of investigation, an attempt has been made to estimate the critical period of weed control (CPWC) in mulberry cultivation. We apply calibration techniques to linear and non-linear models to estimate the best period for weed control for, at least, 90% of leaf production for four different seasons (viz., August, 1992 to November,1992; November,1992 to March,1993; April, 1993 to June, 1993 and August 1993 to November, 1993.

Key words : Weed control, mulberry, calibration problem.

The dose-response curve for a given treatment can be quantified by the estimate of the dose necessary to produce a specified value of response. A confidence interval for that expected dose would be useful as an interval estimator of treatment effect. The traditional linear calibration problem involves the prediction of an independent variable X, which is most likely to have produced an observed or specified value of a dependent variable Y. It is assumed that X and Y are functionally related through a linear regression model, denoted by $Y_i = \beta_0 + \beta_i X_i + \varepsilon_i$, for i = 1, 2, …, n, where Y_i is the dependent variable, X_i is the independent variable, β_0 and β_i are unknown parameters and ε_i's are independent, identically distributed (iid) as N (0, σ^2), as σ^2 is an unknown parameter. Let y be a realization of a response variable Y and x be the associated unknown variable X, such that E (y) = $\hat{\beta}_0 + \hat{\beta}_i$ x. Therefore, x = {E(y) - $\hat{\beta}_0$}/ $\hat{\beta}_i$. If E(y) is estimated by an observed value of Y by y_0, the maximum likelihood estimator of the corresponding X value $x_0 = (y_0 - \hat{\beta}_0)/\hat{\beta}_i$, where $\hat{\beta}_0$ and $\hat{\beta}_i$ are the maximum likelihood estimators (Graybill, 1976). Similarly, if the value of Y is given as a specified constant, say, y_c, the maximum likelihood estimator of $x_c = (y_0 - \hat{\beta}_0)/\hat{\beta}_i$, which is nothing but common linear calibration problem.

The calibration problem can also be extended to non-linear dose-response models for which Y and X are related through a non-linear function and y_c is a specified constant. Let $y_i = f(x_i, \underline{\boldsymbol{\beta}}) + \varepsilon_i$, for i = 1, 2, …, n, where $\underline{\boldsymbol{\beta}}$ is a px1 vector of unknown parameters, ε_i ~ iid N(0, σ^2), Once the model has been fit to the data x_c has been estimated either through inverse function or through iterative process as $x_c = f^{-1}(y_c, \underline{\boldsymbol{\beta}})$.

The confidence interval (C.I.) of $x_c = f^{-1}(y_c, \underline{\boldsymbol{\beta}})$ can be determined (Schwenke and Milliken, 1991) as $x_c \pm t_{(\alpha/2;\ n-p)} (\text{MSE}.\underline{h}'(\underline{Z}'\underline{Z})^{-1} \underline{h})^{½}$, where MSE is the estimate of σ^2 based on n – p degrees of freedom, $\underline{h}$ is a p x 1 vector with elements $h_j = (\delta f^{-1}(y_c, \underline{\boldsymbol{\beta}})/\delta \beta_j)$, $\underline{Z}$ is an n x p matrix with elements $Z_{ij} = (\delta f (x_c, \underline{\boldsymbol{\beta}})/\delta \beta_j)$, p is the number of parameters in the model. This C.I. will provide an interval estimator of x_c for given y_c.

Using the above calibration technique, an attempt has been made in the present piece of investigation to identify the critical period of weed control for 90% of assured yield in mulberry cultivation. Time of weed control studies are designated to estimate the length of times at the beginning and at the end of the growing season when presence of weed has little impact on crop yield. It is during the remainder of the growing season that weed control can be most beneficial, which is commonly known as critical period of weed control (CPWC) (Weaver and Tan, 1983). The method of identification of CPWC has been statistically standardized by Blankenship *et.al*, 2003, using non-linear models. However, those methods involve the use more advanced statistical procedures through sophisticated modern statistical packages (e.g., SAS, etc.). The present method is more simpler (even can be solved by scientific calculator or by MS office except the curve estimation part) than the above methods by Blankenship, *et.al*, 2003.

MATERIALS AND METHODS

The investigation reported in this paper were carried out in different seasons of 1992-93 and 1993-94 at the Instructional farm, Bidhan Chandra Krishi Viswavidyalaya, N. B. Campus, Pundibari, Coochbehar, West Bengal. The variety of mulberry plant was Mandalaya (S1).

DATABASE

Kundu (1995) conducted the above experiments on weeds of mulberry field for four seasons in the years 1992-93 and 1993-94. The seasons were Aug.,'92- Nov.,'92; Nov.,'92- March, '93; April, '93 – June, '93 and Aug.,'93 – Nov., '93. The recorded yield data of the above mentioned four seasons for five weed control treatments, viz., (i) Weed free check (0), (ii) weed free after 5 days of pruning (5), (iii) weed free after 25 days of pruning (25), (iv) weed free after 50 days of pruning (50) and (v) un weedy control (75) with three replications were used as the database for the study.

SOFTWARE

The analysis was done in the computer laboratory of the Department of Agricultural Statistics, BCKV, Mohanpur, using SPSS, ver. 7.5.

Table 1 : Leaf yield of mulberry plants in four different seasons for five weed control treatments.

Sl. No.	Weed control treatments (No. of weedy days)	Leaf yield of mulberry plants (t ha^{-1})			
		Season 1	Season 2	Season 3	Season 4
1	0	10.63	9.97	10.66	9.40
2	0	10.63	9.93	9.74	9.50
3	0	9.75	10.01	9.58	9.80
4	5	9.13	9.28	9.22	9.20
5	5	9.38	9.73	9.44	8.50
6	5	9.38	9.0	9.66	8.60
7	25	8.8	8.79	9.0	8.80
8	25	8.5	7.65	9.4	8.00
9	25	8.75	8.72	9.16	8.89
10	50	7.6	7.67	8.44	7.70
11	50	7.06	6.42	8.25	8.40
12	50	7.31	7.05	8.69	7.50
13	75	6.5	5.57	7.36	5.50
14	75	5.62	5.80	7.89	6.00
15	75	5.62	5.69	7.33	5.00

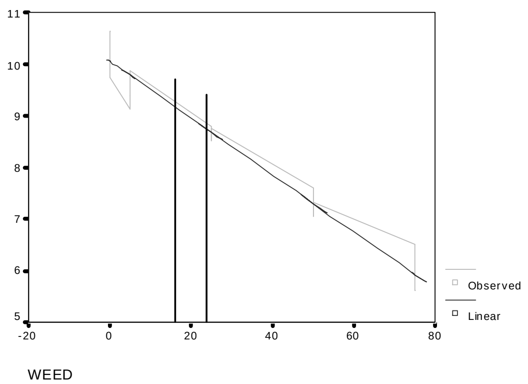
Table 2 : The critical period of weed control developed through linear calibration technique

	Linear Model	R^2 (Multiple Corr.Coeff.)	90% Yield (y_c) (t ha^{-1})	Starting time for weeding (days after pruning)		
				Lower	Estimated	Upper
Season 1	y = 10.056 - .055x	0.973	9.05	14	18	22
Season 2	y = 9.788 -0.55x	0.972	8.91	14	18	22
Season 3	y = 9.846 - 0.03x	0.937	8.861	27	32	37
Season 4	y = 9.493 - 0.46x	0.916	8.547	12	20	28

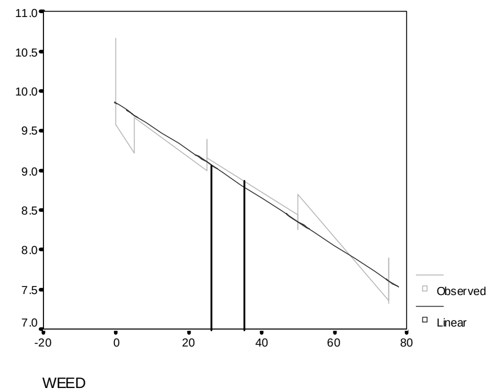
Table 3 : The critical period of weed control developed through non-linear (exponential) calibration technique

	Exponential Model	R^2 (Multiple Corr.Coeff.)	90% Yield (y_c) (t ha^{-1})	Starting time for weeding (Days after pruning)		
				Lower	Estimated	Upper
Season 1	$y = 10.167\ e^{-0.007x}$	0.972	9.151	11	15	20
Season 2	$y = 9.898\ e^{-0.0072x}$	0.972	8.908	10	14	18
Season 3	$y = 9.872\ e^{-0.0034x}$	0.941	8.885	25	31	37
Season 4	$y = 9.630\ e^{-0.0064x}$	0.899	8.668	11	17	23

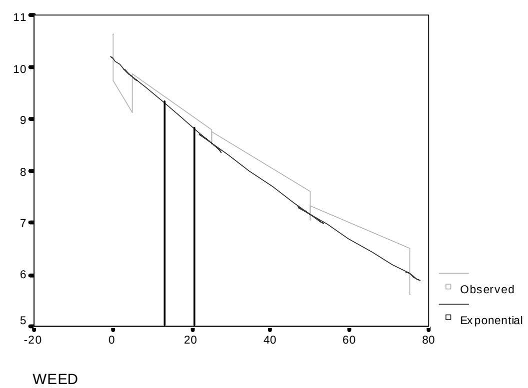
Season 1



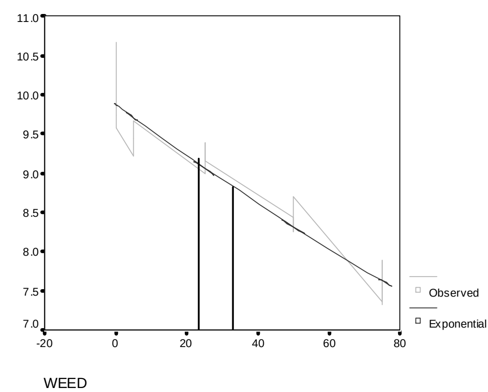
Season 3



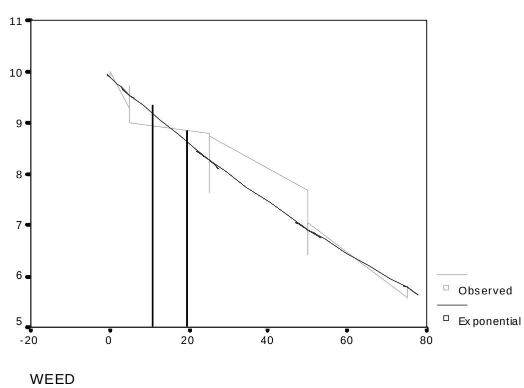
Season 1



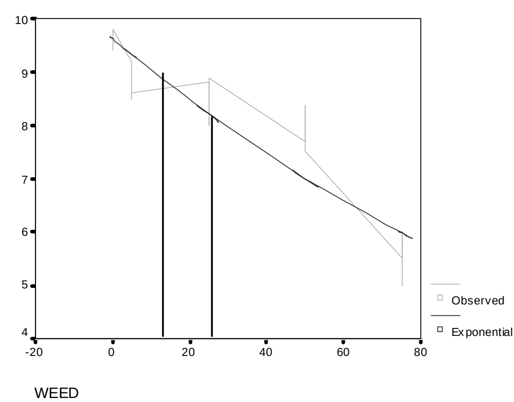
Season 3



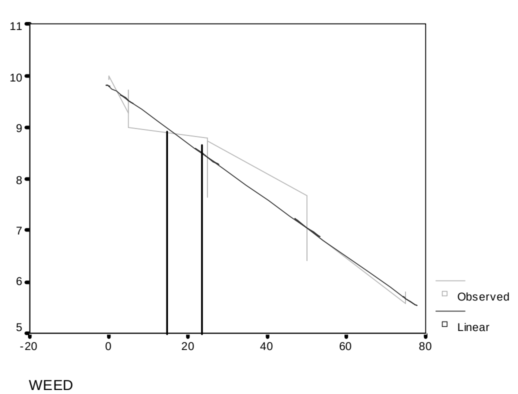
Season 2



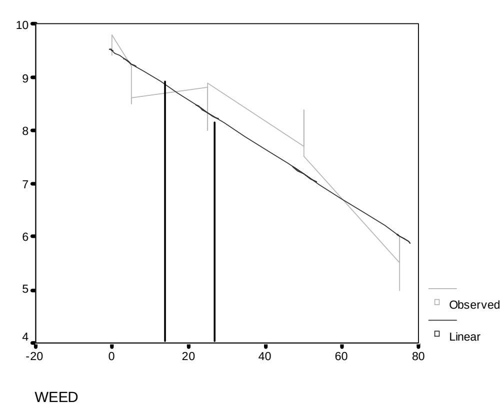
Season 4



Season 2



Season 4



RESULTS AND DISCUSSION

Table 1 represents the leaf yield of mulberry in four seasons viz., Season 1 or Aug.,'92- Nov.,'92; Season 2 or Nov.,'92- March, '93; Season 3 or April, '93 – June, '93 and Season 4 or Aug.,'93 – Nov., '93 for abovementioned five treatments (viz., 0, 5, 25, 50 and 75) each with three replications during the years 1992-93 and 1993-94. Simply, there are 15 observations for each season. Table 2 represents the critical period of starting the weed control for at least 90% of leaf yield in mulberry by using the linear calibration technique. Results of Season 1 and Season 2 suggest that the 1st weeding should start within the interval 14 to 22 days for 90% of leaf yield. But the result of Season 3 suggests that the 1st weeding in mulberry should start within 27 to 37 days. The delay in starting the 1st weeding for this season may be due to comparatively dry and hot weather in the zone. Lastly, table 3 represents the critical period of starting the weed control for at least 90% of leaf yield in mulberry by using the nonlinear (exponential) calibration technique. Season 1,2 and 4 require 1st weeding within the interval 11 to 23 days. But here also the result of Season 3 suggests that 1st weeding can be started with a short delay, between 25 to 37 days.

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