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BATTESE, GEORGEE. and Ahmad, Munir

University of Agriculture Faisalabad, Pakistan, Depm1ment of Ecunumellics, University of New England, Armidale, NSW, Australia.

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A Probit Analysis of the Incidence of the Cotton Leaf Curl Virus in Punjab, Pakistan

MUNIR AHMAD and GEORGE E. BATTESE

Factors affecting the incidence of the cotton leaf curl virus (CLCV) in Punjab, Pakistan are investigated using a probit model. The results indicate that the history of a cotton variety grown on the farm, better land preparation before sowing, and use of pesticides and phosphorus fertiliser significantly reduce the probability of incidence of the CLCV disease. The farmers having greater areas under cotton are less likely to be affected by the disease. Fields of the more experienced farmers, who have greater years of formal education, are also less likely to be affected, because these farmers are believed to be better managers. However, the probability of damage was positively related to age of the farmer, which implies that the aged farmers have less managerial capabilities. The intensity of the disease varied from district to district and also from variety to variety. Use of greater amounts of nitrogenous fertiliser, more severe insect attacks, and late sowing of the cotton crop significantly increase the incidence of the CLCV disease.

1. INTRODUCTION

Agricultural production in Pakistan is dominated by the crop production sector, which accounts for more than 62 percent of the component of the GDP due to agriculture. Cotton is the second most important crop in Pakistan (wheat being the first). It is cultivated on 10 percent of the total cropped area. The province of Punjab contributes 89 percent of the cotton production in Pakistan. In addition, cotton is grown on 67 percent of the area under cash crops.

Cotton, the silver fibre of Pakistan, contributes towards the overall well-being of the economy in many ways. It provides edible oil, animal feed, fibre, and fuel to a large proportion of the urban and rural populations. It supplies raw material for about 1200 ginning units, 180 spinning units, about 470 textile mills, and 50 vegetable oil mills operating in the country. It is also a major export item from the crop sector because it directly or indirectly contributes about 66 percent to Pakistan's export earnings [Government of Pakistan (1995)]. Hence, any misfortunes on cotton farms affect the

Munir Ahmad is Assistant Professor, Department of Farm Management and Agricultural Social Science Research Centre, University of Agriculture, Faisalabad, Pakistan. George E. Battese is Associate Professor, Department of Econometrics, University of New England, Armidale, NSW, Australia.

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balance of payments of the country and the well-being of millions of people, either directly or indirectly.

The area under cotton increased by about 63 percent during the period from 1971-72 (1.74 million hectares) to 1991-92 (2.83 million hectares). However, it has remained almost constant since 1991-92. The per hectare cotton yield, on the other hand, has exhibited a cyclical pattern over the last 25 years. It decreased from 363 kgs. in 1971-72 to 232 kgs. in 1976-77, followed by an upward trend to 363 kgs. per hectare in 1982-83 [Government of Pakistan (1995)]. The factors contributing to this variable trend were the poor weather and attacks from insects [Government of Pakistan (1988)]. Further, with the sudden withdrawal of the subsidy on pesticides in 1983 [Chaudhry (1995)], the cotton yield declined to a record low of 222 kgs. per hectare in 1983-84 [Government of Pakistan (1995)]. That disastrous failure of the cotton crop proved, in fact, to be a blessing in disguise for the economy as a whole. The agricultural extension services and the private pesticide dealers became very active. They took some bold initiatives in developing and introducing appropriate plant-protection packages for the cotton crop. The farmers growing cotton also readily realised the need for providing adequate plant-protection coverage for the crop. The subsequent years, therefore, witnessed a dramatic increase in the use of chemicals on cotton crops. Widespread adoption of these packages significantly reduced the cotton damage due to insects during the 1980s. Some very important innovations in varietal improvements also came about during the same period. As a result, per hectare cotton yields increased to a record high of 768 kgs. per hectare in 1991-92 [Government of Pakistan (1995)]. Unfortunately, the crop in 1992-93 was severely infected by the cotton leaf curl virus (CLCV).[1] Since then the yield per hectare has shown a steep downward trend. It was as low as 487 kgs. per hectare in 1993-94.

The CLCV menace is not new in Pakistan and its history goes back to 1967, when it first appeared in cotton fields in the district of Multan [Hussain and Ali (1975)]. Because of casual occurrence and minor loss, the disease did not attract much attention from scientists or the government until it covered more than 50 percent of the total cotton area, of which 20 percent was severely affected [Ali *et al.* (1993)].

Ali *et al.* (1993) argued that the intensity of the CLCV disease varied with the varieties grown. The attack was also more severe in some areas than in others. The extent and severity of the CLCV disease was thought to be correlated with the intensity of insect attack (especially the white fly). It was also observed that the lush green cotton fields were infected more than those showing yellowish colour. One might infer from this that the higher incidence on lush fields was due to extensive vegetative growth resulting from the higher use of nitrogenous fertiliser. Another observation that

[1]According to Ali *et al.* (1993), it is characterised by either upwards or downwards curling of the leaves. Veins of the leaves become thickened, first near the leaf margin and then the process moves inwards, forming a dark green thickened main vein. It is fatal disease and spreads rapidly from plant to plant, destroying the whole canopy of crop in a very short period of time.

has been made by the biological scientists is that the fields near orchards were more vulnerable to attack than fields having no such surroundings. However, no previous attempt has been made to statistically test these observations and notions. The main objective of this study is to identify the factors contributing to the CLCV disease and to statistically test their significance using recently acquired farm-level survey data.

The remainder of the paper is divided into four sections. Section 2 contains a discussion of the data and the model to be estimated. Section 3 contains the empirical results and some concluding remarks are made in Section 4.

2. DATA AND MODEL

The data used in this study are from the 1995 survey for the crop year 1993-94, conducted by the Agricultural Social Science Research Centre (ARP-II) of the University of Agriculture, Faisalabad. The data were collected from the two cropping zones of Punjab, the cotton zone and the mixed-cropping zone, which cover 80 percent and 20 percent of the total area under cotton in the Punjab, respectively.

A multi-stage cluster sampling design was used to select the sample of cotton farmers. Firstly, all the constituent districts in both the cropping zones were ranked in a descending order in accordance with area under cotton. Subsequently, four districts from the cotton zone, Khanewal, Rahim-Yar-Khan, Bahawalnagar, and Vehari, and two districts from the mixed zone, Jhang and Okara, were selected. Secondly, one representative *tehsil* (sub-district) from each of the six selected districts was chosen using the above-mentioned selection criterion. Thirdly, three villages per *tehsil* were selected randomly. Finally, a simple random sample of 24 farmers was drawn from each sample village. The overall sample thus comprised 432 farmers. A well-constructed questionnaire, which was pre-tested under field conditions, was used to obtain the desired data from the sample farmers using trained personal interviewers.

The data obtained in the survey include information regarding the inputs used and other farm-specific and variety-specific details. However, the damage accrued to the cotton crop in terms of output was not directly measured. The only information imparted by the farmers was whether the variety-specific cotton field was infected by the CLCV disease or not. Fifteen varieties of cotton were grown by the sampled farmers. However, the number of varieties grown at each farm varied from one to five. We consider the different fields on which the different varieties of cotton were grown by the farmers as the basic unit of our analysis. The survey resulted in observations for a total of 766 fields for the sample farmers. Nine observations were dropped because of incomplete information. Consequently, the remaining 757 observations were used in the analysis.

For the analysis of these data, the binary choice models are appropriate [Amemiya (1981)]. Three common forms are the linear probability, logit, and probit models. The linear probability model has several statistical deficiencies and is thus not considered suitable for this study [Capps and Kramer (1985); Spector and Mazzeo

(1980)]. The logit probability model is associated with the logistic distribution and the probit model assumes a standard normal distribution. These distributions are very similar to each other and thus applications of the logit and probit models have yielded similar results [Capps and Kramer (1985); Epperson *et al.* (1988); Maddala (1986)]. The selection of the model to be used is generally a matter of convenience [Hanushek and Jackson (1977)]. Thus the probit specification is used in this analysis.

The probit model can be written as

$$Y_i^* = X_i\beta + \varepsilon_i \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (1)$$

$$Y_i = \begin{cases} 1 \text{ if } Y_i^* \geq 0 \\ 0 \text{ if } Y_i^* < 0 \end{cases}$$

where

- Y_i is an observed dichotomous dependent variable which takes value 1 when the ith cotton field is infected with the CLCV disease and 0 otherwise;
- Y_i^* is the underlying latent variable that indexes the incidence of the CLCV disease;
- X_i is a row vector of values of k regressors for the ith field;
- β is a $k\times1$ vector of parameters to be estimated; and
- ε_i is an error term, which is assumed to have standard normal distribution.

The probability, P_i, of the incidence of the CLCV disease on the ith field is defined by

$$P(Y_i=1) = P(Y_i^* \geq 0) = P(\varepsilon_i \geq -X_i\beta) = \Phi(X_i\beta), \quad \ldots \quad \ldots \quad (2)$$

where $\Phi(.)$ denotes the distribution function for the standard normal random variable.

The magnitude of the marginal effect of an explanatory variable upon the probability of the incidence of the CLCV disease cannot be assessed directly from the parameter estimates. For a non-dichotomous variable, the marginal probability is defined by the partial derivative of the probability that $Y_i = 1$ with respect to that variable. For the jth explanatory variable, the marginal probability is defined by

$$\partial P_i / \partial X_{ij} = \phi(X_i\beta)\beta_j, \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (3)$$

where $\phi(.)$ denotes the standard normal density function and β_j is the coefficient of jth explanatory variable in the model (1). This can be interpreted as approximately the change in the probability of incidence of the CLCV disease associated with a one-unit increase in the jth explanatory variable. The marginal probability values are estimated at the mean values of the explanatory variables [Kwakyi *et al.* (1989); Polson and Spencer (1991) and Capps and Kramer (1985)]. For a dichotomous variable, the marginal probability should be defined as the difference between the probabilities of incidence of the CLCV disease when the variable takes the values 1 and 0, while holding all other variables constant at the mean values.

Definitions of all the variables included in the model are given in Table 1. The model includes some traditional inputs, such as land preparation (LANDPRE), seed (SEED), nitrogen applied (NIT), phosphorus applied (PHOS), pesticides (PESTEXP), number of irrigations (IRRIGNO), and area sown under the particular variety (ASOWN).

The possible effect of sowing time is accounted for by using the variable, TIMSOW. Time of sowing in Jhang and Okara districts of the mixed-cropping zone starts from May 15. In the other four districts of the cotton-cropping zone, the time of sowing starts from mid-June. To be consistent in both the zones, the first day of the time of sowing is considered as 1 (i.e., TIMSOW=1 for May 15 in the mixed zone and June 15 in the cotton zone). The sowing dates are indexed from this base.

The white fly is considered to be the carrier of the CLCV disease. Most of the farmers cannot identify the different types of insects. Farmers were asked to indicate the intensity of any attacks by insects on their fields, according to a scale 0 to 3 (see INSECT in Table 1). Obviously this required the farmers to exercise their judgement on the amount of insects seen, the extent of their attacks on the cotton crops, etc., because no objective measure was given to define 'low' versus 'high' intensity of insect attack.

The possible effect of soil salinity on cotton damage is accounted for by using the variable, SALTY. To assess the role of management factors on the incidence of the CLCV disease, personal characteristics of the farmers, such as farming experience (EXPER), age of the farmer (AGE), and years of schooling (EDUC), are used. The number of plant thinnings (PTHIN), which is associated with thinning of dense plant populations and the removal of diseased plants, is also used as an explanatory variable. Because the orchards are considered to be the host plants of the virus, the variable ORCH is included in the model to assess their possible effect on the incidence of the disease in fields growing cotton.

District effects, such as temperature, rainfall, and land quality, are accounted for by using the last five of the six district-specific dummy variables, D2, D3, …, D6. Dummy variables for the varieties, S-12, NIAB-78, CIM-109, CIM-240, MNH-93, BH-36, and Other Varieties are denoted by V1, V2, …, V7, respectively. The last six of these dummy variables are used to test the differences among the varieties of the intensity of the CLCV disease.[2] The susceptibility of these varieties to the virus is compared with that of S-12, which is the most susceptible variety to the CLCV disease

[2]About 15 varieties were grown by the sampled farmers. However, Other Varieties consists of 9 out of 15 varieties which account for only about 10 percent of the cases.

Table 1

Definitions of Variables and Descriptive Statistics for Fields of Sample Cotton Farmers in Punjab

Variable	Description	Mean	S. Deviation
Y	1 if the field is infected with CLCV; 0 otherwise	0.53	0.50
GROWPRD	Years the variety has been grown	3.7	2.7
LANDPRE	Land preparation cost (in Rs 100/acre)	5.5	1.6
SEED	Cotton seed sown (in kgs./acre)	6.4	1.5
NIT	Nitrogen applied (in kgs./acre)	61.9	24.2[a]
PHOS	Phosphorus applied (in kgs./acre)	10.5	10.2[b]
IRRIGNO	Number of irrigations applied	6.5	1.6
PESTEXP	Pesticide cost in Rs 100/acre)	12.4	4.8
INSECT	Intensity of insect attack: 0=nil; 1=low; 2=medium; and 3=high	2.51	0.64
ASOWN	Area of the variety sown (in acres) on the farm	9.9	16.0
TIMSOW	Time of sowing (days since start).	15.5	11.6
SALTY	Salinity level: 0=nil; 1=low; 2=moderate; and 3=high	0.41	0.61
PTHIN	Number of plant thinnings	1.09	0.58
EXPER	Years of farming experience	21.4	13.6
AGE	Age of the farmer	42.5	13.7
EDUC	Years of formal education	5.9	4.9
ORCH	1 if any orchard is near; 0 otherwise	0.26	0.44
D1	1 if Jhang district; 0 otherwise	0.12	0.32
D2	1 if Okara district; 0 otherwise	0.18	0.39
D3	1 if Khanewal district; 0 otherwise	0.18	0.39
D4	1 if Rahim-Yar-Khan district; 0 otherwise	0.14	0.35
D5	1 if Bahawalnagar district; 0 otherwise	0.20	0.40
D6	1 if Vehari district; 0 otherwise	0.18	0.39
V1	1 if Variety sown in S-12; 0 otherwise	0.14	0.35
V2	1 if Variety sown in NIAB-78; 0 otherwise	0.20	0.40
V3	1 if Variety sown in CIM-109; 0 otherwise	0.08	0.27
V4	1 if Variety is CIM-240; 0 otherwise	0.29	0.45
V5	1 if Variety is MNH-93; 0 otherwise	0.11	0.32
V6	1 if Variety is BH-36; 0 otherwise	0.08	0.27
V7	1 if Other Varieties; 0 otherwise	0.10	0.30

[a] About one percent of the observations were zero.

[b] About 26 percent of the observations were zero.

and, as a consequence, its cultivation has recently been banned in the province of Punjab. The significance of district and variety effects is tested using the generalised likelihood-ratio test.[3]

Descriptive statistics for the variables included in the model are given in last two columns of Table 1. The sample means of the binary variables are the proportions of the sample fields taking on the particular qualitative attributes. For example, about 53 percent of the fields were infected with the cotton leaf curl virus and 26 percent of the fields had some type of orchards in their surroundings.

2. EMPIRICAL RESULTS

In the estimation of the probit model, the method of maximum likelihood is preferred [Capps and Kramer (1985)]. The model is estimated using the econometric programme LIMDEP [Greene (1995)]. Empirical results for the probit model are given in Table 2. Since little is known about the relationship between the incidence of the CLCV disease and the explanatory variables, a 20 percent level of significance is used, as suggested by Manderscheid (1965) and Harper *et al.* (1990), for such cases. Besides, the main interest is in knowing whether the particular variable has a negative or positive influence on the incidence of the CLCV disease.[4]

A total of 28 parameters is estimated. The results indicate that 20 of the parameter estimates are significant at the 10 percent level and three are significant at the 20 percent level. The variables whose coefficients are significant at the 10 percent level are land preparation, use of nitrogenous and phosphatic fertilisers, use of pesticides, intensity of insect attack, time of sowing, area sown under the particular cotton variety, and experience, age, and education of the farmers. The district-specific dummy variables, D3, D4, D5, and D6, and the variety-specific dummy variables, V3, V4, V5, V6, and V7, had coefficients which are significant at the 10 percent level. Thus the probabilities of incidence of the CLCV disease in the four districts, Khanewal, Rahim-Yar-Khan, Bahawalnagar, and Vehari, are significantly different from that for Jhang. Further, the probabilities of incidence of the CLCV disease for the varieties CIM-109, CIM-240, MNH-93, BH-36, and Other Varieties are significantly different from that for S-12. The variables whose coefficients are significant at the 20 percent level are the number of years the variety has been grown (GROWPRD), thinning (PTHIN), and the proximity of orchards (ORCH).

The generalised likelihood-ratio (GLR) tests, given in Table 3, show that the factors in the probit model are significant in explaining the incidence of the CLCV

[3]The generalised likelihood-ratio statistic, GLR, is defined by GLR = $-2[L_R - L_{UR}]$, where L_{UR} and L_R are the values of the logarithm of the likelihood function of the unrestricted and restricted models, respectively, where the latter model is obtained when the appropriate variables are excluded from the model.

[4]With the large number of variables included in our model, it is expected that multi-collinearity will reduce the precision of estimation of the individual parameters. Although deleting some variables from the model would be expected to increase the precision of estimation, it actually results in biased estimation of the coefficients of other variables unless the excluded variables have zero coefficients.

Table 2

Maximum-likelihood Estimates and Marginal Probabilities for the Explanatory Variables in the Probit Model

Variable	Coefficient	Standard Error[1]	Marginal Probability[2]
Constant	1.56**	0.54	–
GROWPRD	–0.039*	0.025	–0.016
LANDPRE	–0.068**	0.037	–0.027
SEED	0.025	0.045	0.010
NIT	0.0056**	0.0033	0.002
PHOS	–0.0146**	0.0064	–0.006
IRRIGNO	–0.055	0.045	–0.022
PESTEXP	–0.036**	0.017	–0.014
INSECT	0.418**	0.094	0.167
ASOWN	–0.0135**	0.0051	–0.005
TIMSOW	0.0084**	0.0050	0.003
SALTY	0.091	0.087	0.036
PTHIN	–0.14*	0.11	–0.055
EXPER	–0.0259**	0.0083	0.010
AGE	0.0203**	0.0081	0.008
EDUC	–0.017**	0.013	–0.007
ORCH	0.14*	0.14	0.057
D2 (Okara)	–0.39	0.33	–0.079
D3 (Khanewal)	–1.84**	0.34	–0.595
D4 (Rahim-Yar-Khan)	–3.24**	0.38	–0.883
D5 (Bahawalnagar)	–0.86**	0.31	–0.223
D6 (Vehari)	–1.47**	0.32	–0.456
V2 (NIAB-78)	–0.10	0.25	–0.035
V3 (CIM-109)	–0.38**	0.28	–0.145
V4 (CIM-240)	–0.64**	0.20	–0.248
V5 (MNH-93)	–0.32**	0.22	–0.121
V6 (BH-36)	–1.09**	0.26	–0.415
V7 (Other Varieties)	–0.65**	0.24	–0.251

[1]The estimated standard errors of the estimators for the coefficients are given correct to two significant digits. The estimates for the coefficients of the explanatory variables are given to the corresponding number of digits behind the decimal points as for the standard errors.

[2]The marginal probabilities are given correct to the third digit behind the decimal points.

**Significant at the 10 percent level.

*Significant at the 20 percent level.

Table 3

Generalised Likelihood-ratio Tests for Parameters in the Probit Model

Null Hypothesis	GLR	$\chi^2_{0.01}$	Decision
H_0: $\beta_j = 0$ (df=27)	384.3	47.0	Reject H_0
H_0: No district and variety effects (df=11)	219.7	24.7	Reject H_0
H_0: No district effects (df=5)	169.8	15.1	Reject H_0
H_0: No variety effects (df=6)	24.0	16.8	Reject H_0

disease. The null hypotheses of no district effects and no varietal effects are rejected at the one percent level of significance, both jointly and separately.

The values in the last column of Table 2 give the estimated changes in the probabilities of the crop being infected with the CLCV disease for unit changes in the different explanatory variables. For the non-dichotomous variables (i.e., the variables before ORCH in Table 1), marginal probabilities are mostly small values. Those which have marginal probabilities greater than 0.05 in absolute value are the variables INSECT and PTHIN. The intensity of insect attack notably increased the probability of the incidence of the CLCV disease. The marginal probability shows that at each higher level of intensity the probability of incidence of the disease is estimated to increase by 0.167. The probability of incidence of the CLCV disease for the high level of insect attack is estimated to be about 0.6.

The coefficient of plant thinning is negative and statistically significant at the 20 percent level, given that a one-tailed test is conducted. The estimated probability of incidence of the disease is 0.6 with zero plant thinning. The probability of viral attack decreases by about 0.055 with each additional plant thinning.

All other non-dichotomous variables have marginal probabilities of less than 0.05 in absolute value. Among these variables, those which help in reducing the probability of incidence of the CLCV disease are GROWPRD, LANDPRE, PHOS, IRRIGNO, PESTEXP, ASOWN, EXPER, and EDUC. For each year the same variety grown on the farm decreases the probability of the incidence of the CLCV disease attack by about 0.016. This may be due to the fact that farmers generally keep their own healthy seed for sowing the next year. Each additional 100 rupees spent on land preparation is estimated to reduce the probability of the incidence of the CLCV disease by about 0.027. The use of each additional five kgs. of phosphorous is estimated to decrease the probability of the CLCV attack by about 0.029.

The irrigation variable also shows resistance against the CLCV attack. Each additional irrigation is estimated to decrease the probability of the incidence of the disease by 0.022. However, its impact is not statistically significant at the 20 percent level. It was reported that some of the farmers during the survey thought that increasing the number of the irrigations resulted in higher incidence of the CLCV disease. The empirical results obtained may indicate that most of the farmers were using less water than was desirable.

The results show that each additional 100 rupees spent on pesticide applications reduces the probability of damage due to the CLCV disease by 0.014. The farms having larger area under cotton of a particular variety also have lower probability of the incidence of the CLCV disease. Each additional acre sown under cotton is estimated to reduce the probability of the incidence of the disease by only 0.005. These two results imply that the larger farmers having a higher resource base are in a better position to take possible measures to protect their cotton crops from the CLCV attack.

Each additional year of farming experience reduces the probability of damage due to infection by about 0.010. Almost the same result is associated with a one-year increase in the formal education of the farmers. These results imply that the more experienced and educated the farmers are better managers who have a lower risk of damage to their cotton crops.

The remaining non-dichotomous variables, SEED, NIT, TIMSOW, SALTY and AGE, increase the probability of the incidence of the CLCV disease. Although not statistically significant at the 20 percent level, each additional kg. of seed increases the probability of disease attack by 0.010. This implies that the more densely populated a field of cotton, the higher is the risk of damage due to the CLCV disease. The marginal probability for nitrogen fertiliser shows that each additional 10 kgs. of nitrogen increases the probability of the CLCV disease by about 0.022. Higher applications of nitrogen may increase the susceptibility of cotton crops to the CLCV disease because of their more lush condition, as claimed by the biological scientists.

A crop sown late is also found to be at a higher risk of being infected by the CLCV disease. Delay in the sowing of the crop by seven days is estimated to increase the probability of the crop getting infected by the disease by about 0.024. Cotton crops sown on soils affected by salt also have a higher risk of infestation, but the impact is not statistically significant. One of the possible reasons for this positive relationship between the CLCV attack and the soil salinity is that the plants are already under stress conditions, which in turn reduces the crop's resistance to the disease. The results further show that the probability of the incidence of the disease has a statistically significant positive relationship with the age of the farmer. However, the increment in the probability of incidence of the disease with each additional year of age is only 0.008.

The results of the dichotomous variables show that the presence of orchards near the cotton fields has higher probability by about 0.057 than those fields which do not have such surroundings. The impact of proximity of orchards is statistically significant at the 20 percent level, given that a one-tailed test is conducted. This result supports the claim of the biological scientists that the orchards act as hosts to the virus.

The results for the district-level dummies show that Khanewal, Rahim-Yar-Khan, Bahawalnagar, and Vehari are significantly less affected than Jhang. The probabilities of incidence of the CLCV disease in the six districts are graphed in Figure 1. However, Okara district is also less affected than Jhang district, but the difference is not statistically significant. The probabilities of cotton infestation in Okara, Khanewal, Rahim-Yar-Khan, Bahawalnagar, and Vehari are less than in Jhang by 0.079, 0.595, 0.883, 0.223, and 0.456, respectively. These results show that the cotton zone as a whole is at a lower risk than the mixed-cropping zone.

The results of the variety-specific dummy variables included in the model show that CIM-109, CIM-240, MNH-93, BH-36, and Other Varieties are significantly less affected than S-12. However, NIAB-78 is also less exposed to the CLCV disease, but the parameter estimate is not statistically significant. The probabilities of incidence of the CLCV disease for the seven different varieties of cotton are graphed in Figure 2. The probabilities of cotton infestation of NIAB-78, CIM-109, CIM-240, MNH-93, BH-36, and Other Varieties are less than that for S-12 by 0.035, 0.145, 0.248, 0.121, 0.415, and 0.251, respectively. These results show that BH-36 is the least affected variety, followed by CIM-240, while the performance of NIAB-78 is about the same as that of S-12. Although BH-36 proved to be the most resistant variety to CLCV disease, it is unpopular among the cotton growers because of its late maturity.

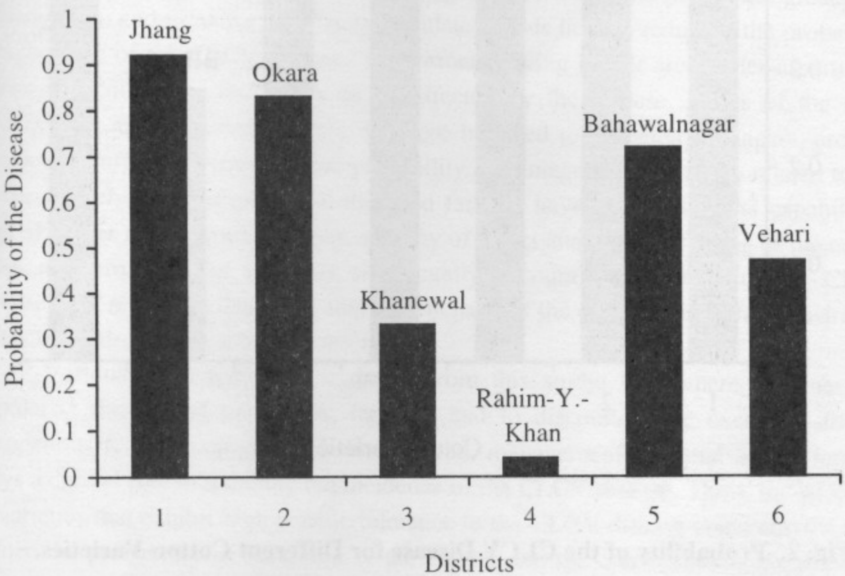

Fig. 1. Probability of the CLCV Disease in Various Districts.

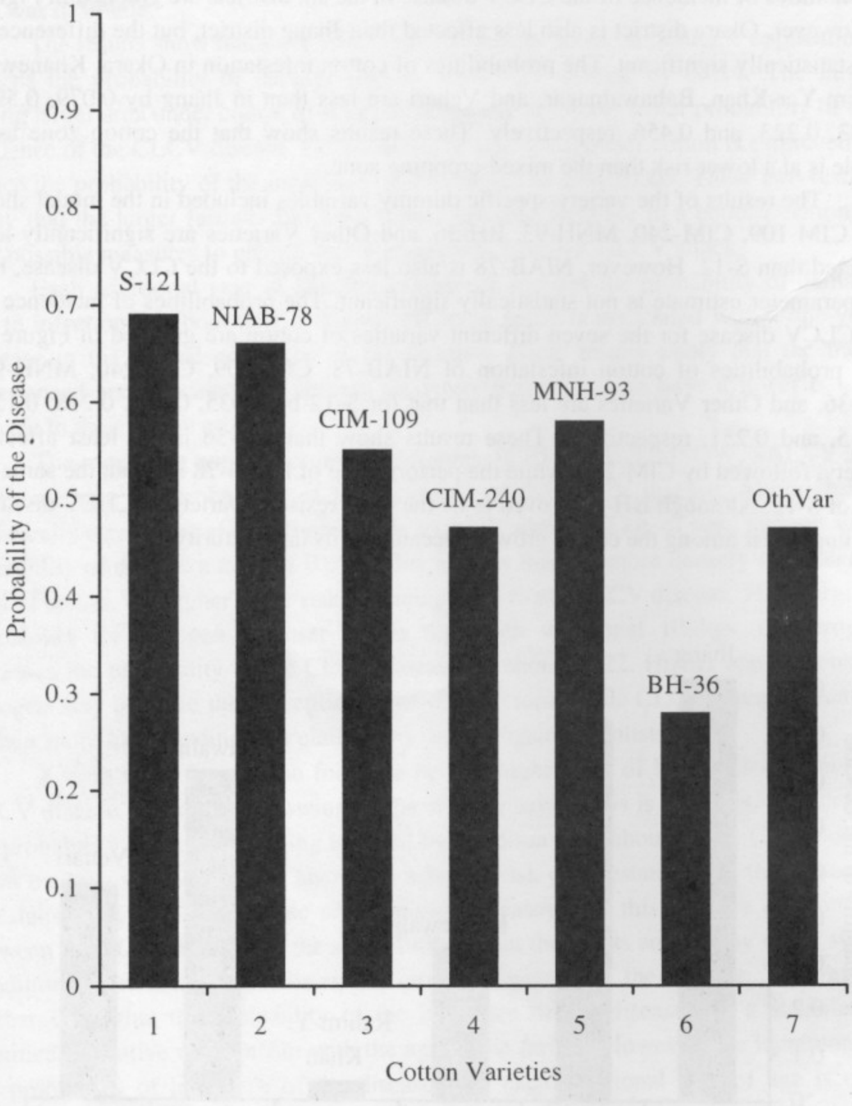

Fig. 2. Probability of the CLCV Disease for Different Cotton Varieties.

The percentage of the cases of incidence of the CLCV disease which were correctly classified under the probit model was 79 percent. The pseudo-R^2, proposed by McFadden (1974), is the measure most commonly used for goodness-of-fit for the binary choice models. The value of the McFadden pseudo-R^2 of 0.37 shows that the model explains about 37 percent of the variability in the incidence of the CLCV disease in fields of cotton of the sample farmers. The magnitude of this statistic is reasonably high because of the cross-sectional nature of the data. According to Sonka, Hornbaker, and Hudson (1989), obtaining the McFadden pseudo-R^2 in the range of 0.2 to 0.4 is typical in the case of qualitative choice models. The pseudo-R^2, proposed by McKelvey and Zavoina (1975), which is considered to be the best measure to use for binary choice models [Windmeijer (1995)], is calculated to be 0.39.

4. CONCLUDING COMMENTS

The objective of the above analysis was to study the factors influencing the incidence of the Cotton Leaf Curl Virus epidemic in Punjab, Pakistan. This analysis is the first of its kind on the Pakistani data. The results of this study should therefore be carefully interpreted.

The results indicate that the history of a cotton variety grown on the farm, better land preparation before sowing, use of phosphorus fertiliser and pesticides, greater use of irrigation, and thinning of densely populated fields help in reducing the probability of incidence of the CLCV disease. The farmers having higher area under a particular variety of cotton are less likely to be affected by the disease. Fields of the more experienced and educated farmers, who are believed to be better managers, are less likely to be affected. However, the probability of damage was positively related to age of the farmer, which implies that the aged farmers have less managerial capabilities. Use of higher nitrogenous fertiliser, severity of insect attacks, late sowing of the cotton crop, and proximity of orchards significantly encourage the attack of the CLCV disease. Our results further show that the intensity of the disease varied from district to district and also from variety to variety.

Various inferences can be drawn from this study. First, there is a need to popularise the use of phosphatic fertiliser and to discourage the excessive use of nitrogenous fertiliser on cotton farms. Second, management potential of the farmers plays a crucial role in reducing the incidence of the CLCV disease. Third, the adoption of varieties that exhibit high genetic tolerance to the CLCV disease could significantly reduce the probability of incidence of the disease and the corresponding yield losses. Therefore, the adoption of stress-tolerant varieties and appropriate technological methods should be encouraged. Moreover, the use of varieties which are highly susceptible to the CLCV attack should be discouraged.

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