A Logit Analysis of Bt Cotton Adoption and Assessment of Farmers' Training Need

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ABSTRACT

Bt cotton across the world led to spectacular farm level benefits. India granted approval for its commercial cultivation since 2002 and there has been phenomenal increase in its acreage. The present study made an attempt to use Logit regression model to identify the factors which influenced the adoption of Bt cotton. The study was conducted with randomly selected 120 adopters and 60 non-adopters of Bt cotton from Punjab and Karnataka. Logit analysis revealed significant influence of size of holding, capital base, extension contact, innovativeness, achievement motivation, and perception about Bt cotton on adoption decision of the farmers for Bt cotton, whereas in contrary to a priori expectation, information source pluralism, mass media exposure, social participation and education were not found to have a significant influence. Plant protection measures, identification of quality seed, and use of refuge line were identified as the most important training needs of the farmers. Comparative analysis of training needs of farmers of Punjab and Karnataka with Mann-Whitney U test revealed significant difference in areas of identification of quality seed (P<.01), planting density (P<.01), use of fertilizers (P<.01), sowing (P<.01), use of micronutrients (P<.05), use of plant growth regulators (P<.05) and disease management (P<.01).

Keywords: Logit regression model; Extension contact; Innovativeness; Achievement motivation; Risk perception;

Concerns and controversies notwithstanding, India embarked upon commercial deployment of genetically modified crops in form of *Bt* (*Bacillus thuringiensis*) cotton in 2002 to address the agrarian and ecological distress with the belief that its resistance against the most devastating American Bollworm (*Helicoverpa armigera*) insect pest will help in containing colossal yield loss, reducing the burgeoning consumption of expensive, toxic and environment damaging pesticides as well as assuring better yield, income and health to farm families. Though there have been mounting claims and counter claims with respect to beneficial and adverse impacts of *Bt* cotton, Indian subcontinent surpassing China became the leader in *Bt* cotton area in Asia just after five years of adoption. The largest increase in the number of beneficiary farmers of *Bt* cotton in 2008 was in India where an additional 1.2 million more small farmers planted *Bt* cotton which now occupies 82 per cent of total cotton (*ISAAA*, *2008*). The average productivity of Bt cotton stood at 8.3 quintals per acre as compared to 6.8 quintals from non-Bt hybrid cotton crop, while the profit as percentage of investment with regard to non-Bt hybrid cotton and Bt cotton stood at 62 per cent and 73 per cent in Maharashtra; 80 per cent and 78 per cent in Gujarat, 44 per cent and 57 per cent in Andhra Pradesh and 42 per cent and 49 per cent in Tamil Nadu - Karnataka cluster (Business standard, Feb.07,2007).

Even with the initial leap in adoption and profit earning, the *Bt* cotton was fraught with controversies mainly on account of rampant sale of spurious seeds, lack of technical knowledge among farmers and lack of flow of scientific information about the potential impacts of Bt technology.

Several farm level empirical studies have amply shown the economic benefits of Bt cotton (*Smale, et al. 2006*) but its inconsistency and differential performances (*Sahai and Rahman, 2003*) as well as the risk perception and apprehension among the farmers about the potential impact on human, cattle and soil due to lack of educational interventions kept the controversy and debate alive. Services from public extension system were non-existant as the technology (Bt cotton seeds) was deployed from private companies and hence the farmers were solely dependent upon seed dealers for information, who unlike public extension system had more vested interest to earn profit by enhancing the sale of seeds than in educating the farmers and solving their problems. Amidst such scenario adoption decision making about such technology like Bt cotton by farmers needs closer examination. Largely the decision whether to adopt or not to adopt is dependent upon conscious evaluation of social, economic, technical, cultural and situational perspective of any technology. Resource endowments are the major determinants of observed adoption behaviour in economic constraints model (*Aikens et.al., 1975*), where lack of access to capital and inadequate farm size could significantly impede adoption decisions (*Karki et al., 2004*). This study aimed at estimating and explaining the parameters of adoption process of *Bt* cotton and to assess the farmers' training need in Bt cotton cultivation.

METHODOLOGY

The study was conducted in Dharwad and Haveri districts of Karnataka and Bhatinda and Mansa districts of Punjab. Bt hybrids were commercially introduced in Karnataka in 2002, while in Punjab in 2005. An interview schedule based survey of randomly selected 180 farmers (30 adopters of Bt cotton and 15 non-adopters of Bt cotton from each district of both the states) was done to collect information about the adoption, cultivation and profit earned of Bt cotton as well as the factors associated with adoption decision. Univariate and multivariate logit and probit models have been used extensively in studying adoption behaviour of farmers (*Adeogun et al., 2008*). However, *Shekya and Flinn (1985)* have recommended probit model for continuous dependent variables taking value between 0 and 1, while logit model for discrete dependent variables taking binary value of either 0 or 1. Logistic regression is categorized under Limited Dependent variable model and is extensively used in social research when the dependent variable is dichotomous. The dependent variable takes the value 1 with a probability of success (p), or the value 0 with probability of failure (1 - p). This type of variable is called a Bernoulli (or binary) variable. Here in this study, farmers were grouped as adopters and non-adopters of Bt. Cotton based upon whether or not they cultivate Bt cotton on their farm. A value of 1 was given to adopter and value 0 was given to non-adopter.

As mentioned previously, the independent or predictor variables in logistic regression can take any form. That is, logistic regression makes no assumption about the distribution of the independent variables. They do not have to be normally distributed, linearly related or of equal variance within each group. The relationship between the predictor and response variables is not a linear function in logistic regression; instead, the logistic regression function is used, which is the logit transformation of *p*:

$$P_i = \frac{e^{(b_0 + b_1 X_1 + ... + b_n X_n + m_i)}}{1 + e^{(b_0 + b_1 X_1 + ... + b_n X_n + m_i)}}$$

Where Pi = (1 for adoption and 0 for non-adoption); b0……br are the parameters to be estimated or the coefficient of the predictor variables; r is the number of independent or predictor variables used in the model; "i" is the ith observation (or) farmer; and µi is the random error. Since logistic regression calculates the probability of success (p) over the probability of failure (q), the results of the analysis are in the form of an odds ratio (p/q). Unlike multiple regressions where method of least squares is used, logistic transformation being nonlinear in nature uses the maximum likelihood estimate (MLE) method to find the most likely estimates for the coefficients. Instead of minimizing the squared deviations (least squares) MLE maximizes the likelihood that an event will occur. The best fit Logit model was adjudged based upon the statistics namely likelihood ratio which is denoted as -2 log likelihood (-2LL). The minimum value of -2 log likelihood is 0, which corresponds to a perfect fit, hence; lower its value the better is the model. Chi-square test of significance and Nagelkerke R2 value provides the basis to represent the overall model fit. Wald statistics provides the statistical significance for each estimated coefficient (â). The estimated coefficients (âo âi …. ân) tell about the influence of a variable on the dependent variable. Since the model is in non-linear form, it is difficult to interpret the coefficients directly. For better interpretation the coefficients are transformed into Odds' ratio. Hence they are expressed in terms of logarithms. Therefore, the analysis provides transformed (antilog) value as exponentiated logistic coefficient of respective original coefficient. If âi (the original coefficient) is positive, its transformation (the exponentiated coefficient) will be greater than 1, meaning that the odds of an event happening will increase for any positive change in the independent variable (*Hair et al, 2007*). However, a coefficient just represents the expected change in the logit, when the independent variable increases by one unit. Little is conveyed by the coefficients as to what extent and how an independent variable affects the dependent variable in conjunction with the other variable. The âi coefficient determines the direction of the effect on P(Y=1) for the relevant Xi's, but its magnitude depends on ? âi Xi, thus it depends on the magnitude of all the Xi's (*Aldrich and Nelson, 1984)*. Therefore, just reporting parameter estimates is not sufficient for understanding the impacts of independent variables. Of the several methods for effective interpretation suggested by *Long (1997*), the marginal effects analysis was adopted for this study. The marginal changes or marginal probability (MP) are computed by taking the first partial derivative with respect to the corresponding independent variables as per the equation below:

$$MP_k = \frac{\partial P}{\partial X_k} = \left\{ (e^{xb}) / (1 + e^{xb})^2 \right\} b_k$$

According to *Park (2004)* the marginal change could be interpreted as: for one unit increase in Xk from the baseline, the probability of an event is expected to increase/ decrease by the magnitude of marginal change, *ceteris paribus*. However, the marginal changes are not appropriate for interpreting the impacts of dummy variables. Since the model is not linear, two unit of change in X brings about square of change in the marginal probability and not twice of it as interpreted in conventional regression analysis. Hence proper care is required while making interpretation.

The training need assessment was accomplished on a three-point continuum of "Most needed", "Somewhat needed" and "Not needed" with respective weightage of 3, 2 and 1; and the test of significance was computed using Mann-Whitney U Test

RESULTS AND DISCUSSION

The synthesis of the adoption process presented by *Feder et.al.(1985)* suggests that generally the level and quality of human capital affect the choice of new technologies in agriculture and for early adopters and for an efficient use of inputs, it plays a particularly positive role *(Sheikh et al, 2003)*. The factors, along with their descriptive statistics, hypothesized to influence adoption of Bt cotton and included in the logit model are presented in Table-1 and a positive relationship with adoption of Bt cotton was expected in case of level of education, size of holding, size of irrigated land holding, own capital base, social participation, scientific orientation, information source pluralism, extension contact, mass media exposure, achievement motivation and innovativeness, while negative relationship was hypothesized for the factors like age of the farmers and perception (negative) about Bt cotton technology.

Table 1. Definition and descriptive statistics of variables used in the empirical model

Variable	Definition and measurement	Mean value	SD
Age (X_1)	Age of the farmer, measured in years	39.0067	8.9739
Education (X_2)	Farmer's education level; If illiterate – 0, Primary -1, High school – 2, College - 3	1.7933	0.6271
Size of holding (X_3)	Farm size, measured in acres	7.1600	4.5156
Capital (X_4)	Capital for farming; If own capital -2, borrowed capital-1	1.3733	0.5378
Size of irrigated land holding (X_5)	Irrigated farm size, measured in acres	2.6200	2.5295
Information sources pluralism (X_6)	Number of information sources used by the farmer; If pluralistic sources of information used by the farmer -2, otherwise – 1.	1.6467	0.4796
Social participation (X_7)	Membership in farmers' organization/association; If a non-member -0, member -1, Office bearer -2	1.4067	0.5321
Scientific orientation (X_8)	Index worked out on scale 1- 5	0.3413	0.1301
Extension contact (X_9)	Contact with extension agent, measured with Index worked out on scale 1- 5	1.7867	.7103
Achievement motivation (X_{10})	Index worked out on scale 1- 5	2.1400	.6658
Innovativeness (X_{11})	Index worked out on scale 1- 5	2.6391	.7516
Mass media exposure (X_{12})	Index worked out on scale 1- 5	1.8600	.7330
Perception about Bt Cotton(X_{13})	Index worked out on scale 1- 5	2.6114	.7784

The regression results of Logit model are given in Table-2, which show the coefficients (B), their standard errors, the Wald Chi-Square statistic, associated p-values, odds ratio (Exp (B)) and marginal probability (marginal effects). The significant chi-square value, 82 per cent of accuracy of prediction of classes and Nagerkerke R2 value (.572) show the over all fit of the model was better.

The positively significant coefficients of explanatory variables indicate their positive influence on adoption decision of farmers towards Bt cotton. As expected, the variables such as size of holding, irrigated land holding, capital base, extension contact, innovativeness, achievement motivation, and perception about Bt cotton had positively significant influence on adoption decision for Bt cotton. In contrary to *a* priori expectation, information source diversity, mass media exposure, social participation and education were not found to have a significant influence on adoption decision of farmers. Unlike the major agricultural technologies, the public extension system had negligible role to play in dissemination of Bt cotton as its deployment was solely from the private sector and seed dealers primarily were involved in sale and dissemination of Bt cotton. Therefore, information source diversity and mass media didn't have significant role. Though overtly the pubic extension system had little to contribute in diffusion process of Bt cotton, still it remained the most reliable source for farmers for drawing conviction and reinforcement while taking plunge in adopting Bt cotton.

Table 2. Regression result of Logit regression model

Variable	B	Standard error	Wald	df	Significance P-value	Exp (B)	Margina probability
Constant	-12.902	3.179	16.471	1	.000	.000	-
Age	0.020	0.027	0.526	1	.468	1.020	0.003192
Education	0.315	0.407	0.596	1	.440	1.370	0.050277
Size of holding	0.458	0.143	10.283	1	.001**	1.581	0.073102
Capital	1.285	0.592	4.709	1	.030*	3.614	0.2051
Size of irrigated land holding	-0.717	0.237	9.122	1	.003**	.488	-0.11444
Information sources pluralism	0.264	0.596	0.196	1	.658	1.302	0.042137
Social participation	0.131	0.529	0.061	1	.804	1.140	0.020909
Scientific orientation	5.746	2.689	4.566	1	.033*	312.831	0.917122
Extension contact	-0.798	0.390	4.180	1	.041*	.450	-0.12737
Achievement motivation	1.432	0.442	10.504	1	.001**	4.185	0.228562
Innovativeness	0.899	0.456	3.892	1	.049*	2.457	0.14349
Mass media exposure	0.324	0.442	0.537	1	.464	1.382	0.051714
Risk perception	0.991	0.406	5.944	1	.015*	2.693	0.158174

Chi square = 79.639 (P< .0001); -2 loglikelihood = 111.136; Nagelkerke R2 = 0.572;
Accuracy of prediction of classes = 82 %; Level of significance : ** (P< 0.001); * (P< 0.05)

The size of holding had positively significant coefficient and the marginal probability shows that the probability of adoption was likely to increase by a factor of 0.07 with unit increase (one acre) in land holding size which is in line with the expectations. As with increase in landholding, the farmers had better choices and options for experimenting with new technologies as compared to farmers with small holding, which facilitated the adoption process. Interestingly the coefficient for size of irrigated land holding was significant but negative. Irrigated conditions in the locale of the study generally were not readily available so proportion of irrigated land holding was very less and the possession of irrigated land holding would demand additional investment and thus increase the cost of cultivation of Bt cotton. That is why the sign for irrigated land holding was negative. The odds of adoption was found to increase by a factor of 0.2 with every unit increase in capital base. Generally the farmers had to purchase Bt cotton seeds on cash payment and they had to book their seed requirement in advance, therefore, possession of own capital base promoted adoption of Bt cotton.

Perceived risks associated with any technology act as retarders of their adoption; however, positive and favourable perception augments the adoption process. The coefficient of perception was positively significant and the probability of adoption was likely to increase by a factor of 0.158 with unit increase in perception about

Bt cotton. Though farmers harboured risks but largely held positive perception of Bt cotton due to spectacular field performance in terms of effective management of bollworm, which has been the most devastating pest of cotton; reduced use of pesticides; higher yield and higher monetary return. The coefficient of scientific orientation was positively significant, which implies that it increased the possibility of adoption by providing rational understanding and dispelling the unfounded myths and concerns about the technology. Particularly with Bt cotton, the proposition holds true as with the very deployment of Bt cotton in India, the nation was rife with perception on numerous health related risks and concerns. The news of death of goats and sheep feeding upon Bt cotton plants in Andhra Pradesh was so pressing that the nation witnessed incessant debate and protests. Uprooting and burning of Bt brinjal and Bt rice plants under field trials by farmers express their apprehension and need for proper understanding of the principle of the technology. However, in spite of such perceptual conflict, the acreage of Bt cotton had mercurial growth, but certainly better scientific orientation of farmers could help them make informed and rational analysis of the technology and related risks and concerns. It is evident from the Table-2 that the odds of adoption was likely to increase by a factor of 0.917 with increase of one unit in scientific orientation of farmers, which goes as per *a* priori expectation. Similar results were obtained for the variables of innovativeness and achievement motivation. With per unit increase in these two variables odds of adopting Bt cotton could increase by a factor of 0.143 and 0.228, respectively.

Extension contact is generally known to propel the adoption process. In this study though it had significant coefficient value, the sign was negative. Does it mean that with per unit increase in extension contact, the odds of adopting Bt cotton is likely to reduce by a factor of 0.127. The result in the first instance looks awkward. However, viewed differently, it indicates that since the public extension system had very low to no role in dissemination of Bt cotton as the technology didn't emanate from national agricultural research system. As a result, the flow of information and guidance about Bt cotton were not available in sufficient quantum and regularity from public extension system, and that's why the sign was negative for extension contact in terms of promoting adoption of Bt cotton. Deployment of Bt cotton in India has been private oriented and dealer driven. Private seed dealers are the major players in distribution and dissemination of Bt cotton, therefore, farmers approach them for procurement and advice. Mass media exposure didn't exhibit significant influence in adoption of Bt cotton, which reveals that farmers relied more on subjective evaluation information from their neighbours and fellow farmers for making adoption decision about Bt cotton. As a result, contrary to *a* prior expectation, information source pluralism too didn't have significant coefficient. Similarly the influence of explanatory variables of age and education was not in accordance with expectation. Generally higher age and lower education make a person more skeptical to innovation and resistant to change, while lower age and higher education help in decreasing risk aversion factors and increases rate of adoption. However, in this study their influence on adoption was not found to be significant. It shows that perceived benefits of Bt cotton is so intense that diffusion of Bt cotton has permeated well through the age and education barriers.

Training needs of farmers: At farm level it was observed and recorded from the farmers that they would have availed the benefits of the Bt cotton technology much better and earlier had there been extension support systems for agro-techniques about Bt cotton. Besides seeds, there weren't any educational interventions from the seed dealers about crop management practices and consequently they suffered from the problems of inappropriateness of some Bt hybrids in diverse conditions' matrix of rainfed/ irrigated and light/ heavy soil conditions; problems of refuge line plantation; problems of reddening of leaves; planting density; etc. Hence, to provide impetus to successful utilization of Bt cotton technology, it is essential to develop intervention for capacity building of farmers in effective husbandry of Bt cotton. The assessment of farmers' training need was done. The training need was described as the gap in knowledge and skills as perceived by the individual in effective utilization of Bt cotton and biosafety measures which needs to be bridged with adequate training. It was measured through respondents self anchoring on three-point continuum of training need ie. "Most needed", "Some what needed" and "Not needed" with corresponding weightage of 3, 2 and 1 respectively. Based on higher mean scores important training needs were identified.The mean scores above 2 indicated plant protection measures, identification of quality seed, and use of refuge line as the most important areas in which

Table- 3. Comparative analysis of farmers' training needs (N=120)

S.No.	Statement	Mean Score		Man-Whitney U	Wil-coxon W
		Punjab (N=60)	Karnataka (N=60)		
1.	Identification of quality seed	2.217	1.783	1215**	3035
2.	Seed rate	1.550	1.633	1695.5	3525.5
3.	Planting density	1.500	1.900	1239**	3069
4.	Sowing	1.550	2.033	1184**	3014
5.	Use of refuge line	2.167	2.183	1717	3547
6.	Weed management	1.800	1.667	1592	3422
7.	Identification of Critical stages and Irrigation management	1.550	1.700	1521	3351
8.	Use of fertilizers	1.900	1.550	1300.5**	3130.5
9.	Plant protection measures	2.300	2.450	1611	3441
10.	Identification and management of Physiological disorders	1.583	1.667	1720	3550
11.	Use of micronutrients	1.600	1.933	1384*	3214
12.	Use of plant growth regulators	1.517	1.783	1379*	3209
13.	Disease management	1.733	2.367	1012**	2842
14.	Picking of cotton	1.467	1.333	1732.5	3562.5
15.	Identification of harvest maturity	1.650	1.750	1636.5	3466.5
16.	Precautions in using chemicals	1.900	1.867	1685.5	3575

*P<.05 & **P<.01

the farmers of Punjab required training (Table -3). The plant protection measures took the top priority area for training need (MS 2.3) by the farmers though they claimed that the use of Bt cotton had reduced the number of pesticide sprays. Farmers of Karnataka also showed high training need in areas of plant protection followed by disease management, use of refuge line, sowing and use of micronutrients, which obtained mean scores 2 and above. Irrespective of the states, plant protection was the most important training need for the farmers. This may be due to high incidence of mealy bug in recent times, which is emerging as a major pest in cotton. The comparison of means of training need data of farmers of Punjab and Karnataka with non-parametric tests of Mann-Whitney U and Wilcoxon W (Table-3) reveals that the farmers of both the states varied significantly in training need in areas such as identification of quality seed (P<.01), planting density (P<.01), use of fertilizers (P<.01), sowing (P<.01), use of micronutrients (P<.05), use of plant growth regulators (P<.05) and disease management (P<.01). In other training areas farmers from both the states did not differ.

CONCLUSION

Diffusion of Bt cotton across the cotton growing countries, particularly in India, has been phenomenal. A Logit regression model was employed for identifying not only the salient factors influencing the adoption decision for Bt cotton but also their marginal probabilities to assess the quantum change in the probability of adoption. The model revealed positively significant influence of size of holding, capital base, extension contact, innovativeness, achievement motivation, and perception about the technology on adoption decision of the farmers for Bt cotton, whereas in contrary to *a priori* expectation, information source pluralism, mass media exposure, social participation and education were not found to have a significant influence on adoption decision of farmers. High yield, less pesticide use, less labour requirement and easy picking of cotton were perceived by the farmers as the major advantages of Bt cotton. Plant protection measures, identification of quality seed, and use of refuge line were identified as the most important areas of training need of the farmers. It is drawn from the study that to prepare the farmers for speedy adoption of technologies developed with modern approaches of genetic manipulation which trigger concerns and protests, strategy has to focus more on educational and perception building interventions as well as training in Bt cotton cultivation techniques, besides stressing upon the identified socio-psychological characteristics like scientific orientation, innovativeness, achievement motivation and positive perception. The role of public extension system need to be stressed upon for capacity building of farmers for optimum harnessing of the benefits of new generation technologies like Bt cotton.

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