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Economics of Insecticide use and Potential for Bt Maize Varieties in the Control of Stalkborer in Kenya.

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Abstract: Maize is the staple food crop and source of income for majority of the Kenyan population and many sub-Saharan African countries. The increasing Kenyan population demands an increase in maize production if intermittent food deficits have to be averted. Since the introduction of improved maize varieties in mid-1960, the start of *Green Revolution* period, maize yields increased drastically up to 1970s and started declining from 1980's to-date. The key contributory factors are nutrient mining, sub-optimal input use and insect pest damage. Of the insect pests, stalk borer is of economic importance. Currently, KARI and CIMMYT are developing maize varieties that are tolerant to stalk borer damage. In order to evaluate the potential impact of these interventions economics of stalk borer control at farm level was evaluated. Surveys complemented with on-farm trials were executed in six major maize growing zones of Kenya. Farmers were randomly selected and a sample-frame established after which a total of 1854 households were randomly selected using random sampling technique. Each household was interviewed using structured questionnaire. Data on method of stalk borer control and the type insecticides used was collected. Partial budget and economic surplus models were used. The results indicated that very few farmers control stalk borer in maize despite significant stalk borer losses of about 15%. Therefore if Bt maize is introduced in Kenya it is likely to reduce these losses. This will benefit many hungry and poor Kenyans with improved household food supply and on farm incomes, in line with Government policy of food security and poverty eradication.

Introduction

Cereals are important crops for majority of the population in sub-Saharan in Africa (SSA). In Kenya maize is not only used as food but also serves as an important income generating enterprise contributing 25% of agricultural employment and 20% of agricultural production (Government of Kenya, 1986; 1994 and 2001). In order to meet the food and financial obligations of the ever-increasing human population in Kenya and other SSA countries, maize production has to be intensified. Currently about 100 million people and about 300,000 people are food insecure in African and Kenya respectively (World Bank, 2002). During the "green revolution", between 1960s-1970's, maize production in Kenya increased drastically. This was attributed to development of new innovations, which included, diverse maize varieties (Benin *et al*, 2002) accompanied with improved agronomic packages. The succeeding period from 1980's to-date have experienced progressive yield decline. However, the current farmer yield is about 1.5 ton per hectare against the potential of 8 tons/ha (Government of Kenya, 2002). One of the major contributory factors to yield loss is insect-pests. Of the insect pests, stalk borers is of major economic importance (Mulaa, 1995). There are a number of technological options developed to control stalk borers, which are broadly categorized into cultural, chemical and biological methods. Insect Resistant Maize for Africa (IRMA) project, initiated in 1999 is in the process of developing Bt maize, which is resistant to stalk borers. However, there is limited information on the economics of insecticide use and potential for Bt-maize in the control of maize stalk borer in Kenya. This paper was designed to address this gap. The study was guided by the following objectives; to estimate the economic value of crop losses due to stalk borers in Kenya, based on natural infestation in farmers' fields and to analyse farmer perceptions on new maize varieties. It was hypothesized that, i) there is no significant difference between benefits accruing from controlling stalk borer and no control and ii) both socio-economic and biological-physical factors (AEZ) significantly influence farmers to adopt insecticide in the control of stalk borer.

Materials and Methods

Study area

Seven major maize zones as described by Jaetzold and Schmidt (1982) and Hassan (1998) were selected (Figure 1). The zones included Low tropics (LT), Moist transitional Tropics (MT), High Tropics (HT), Moist-mid-altitude zones (MM), Dry transitional and Dry moist tropics (DM/DT). However of these zones HT, MT and MM grow more maize than the rest. The population size in these six zones is estimated to be more than two thirds of Kenya's population (Government of Kenya, 1999).

Conceptual framework

Farmers' decisions on adoption of technologies are based on the economic theory of the household farm (Sadoulet and Janvry 1995; Perrin et al 1976). According to Perrin *et al* 1976, farmers are interested in profits (farmers' objective) accruing from an intervention in order to protect themselves against risk and maximize their utility. On the other hand they are constrained by low household income, semi/un-skilled labour and poor management. Therefore, there is need to consider cost outlay, benefits and risks in the development and dissemination of new maize varieties. When adopting insecticide in the control of stalk borer in maize, farmers give due consideration to net benefits accruing from this technology. In addition, undertaking marginal analyses reveals the net benefits as the amount of costs or investment levels increase. Therefore, marginal benefit is the increase in net benefit accruing from a given investment.

Factors that positively or negatively influence adoption of innovations are; farm (e.g. acreage, soil fertility, slope etc.), farmer (e.g. age, sex, source of cash etc) technological attributes and farming objective (e.g. food or cash generation).

Study design

Data for this study was generated through on-farm trials carried out between 2001-2003 and survey carried out in 2002/3. Two plots measuring 100 square metres were overlaid on farmers' fields. One plot was treated with insecticide (bull dock) while the other was control. Input-output data was monitored and collected through multiple visits. This trial was carried out in a total of 150 farms.

During the survey 1800 respondents were randomly selected and interviewed using a structured questionnaire. The sample size was based on the population density. Data collected included biological and socio-economic; household profile, asset endowment, type of enterprises, soil fertility trends, yield trends, sources of agricultural information, credit, sources of incomes, sales and purchases made and prices.

Data analysis

Partial budgeting, marginal analysis, economic surplus, logit and tobit response models were used to evaluate the qualitative and quantitative implications of economic use of insecticide. The models were specified as shown in equations 1-7.

Partial budgeting

Net benefits were computed on-farm trials in order to evaluate the economic viability of controlling stalk borers in maize. Net benefits (NB) are Gross benefits (net maize yield [Y_i] multiplied by maize price) minus Total variable costs-TVC (all inputs [X_i] multiplied by their respective prices [P_x] (equation 1).

$$NB = Y_i P_y - X_i P_x \qquad \text{Equation 1}$$

Marginal analysis

The concept of marginal analysis was used to evaluate the changes in the amount invested in controlling stalk borers in various maize zones in Kenya. The marginal Rate of Return (MRR) was computed by dividing the marginal net benefit (MNB) by marginal cost (MC) as shown in equation 2.

$$MRR = MNB / MC \qquad \text{Equation 2.}$$

Economic surplus model (ES model)

To analyze the welfare effects of Bt maize on producers and consumers in a partial equilibrium framework, ES model was used. The model utilizes consumer (CS) and producer (PS) surplus concepts whose summation gives total consumer surplus (TS). The underlying theory and assumptions about the model are: i) the competitive demand price of a maize unit measures the value of the unit to the demander, ii) competitive supply price for a maize unit measures the value of the unit to the supplier, iii) when evaluating the net benefits and costs of Bt maize, the costs and benefits accruing to each member should be added irrespective of the individual's social and economic status. Based on these, the total annual benefits from Bt-maize-induced supply shift are equal to the area below the demand curve and between the two supply curves (Figure 3), i.e. this area is summation of benefits to consumers and producers (equation 3&4).

$\Delta CS = P_o Q_o Z (1+0.5Z\eta)$ (area P_0abP_1 in figure 2) Equation 3

$\Delta PS = P_o Q_o (K-Z)(1+0.5Z\eta)$ (area P_1bcI_1 minus P_oaI_o in figure 2) Equation 4

$\Delta TS = \Delta CS + \Delta PS$ (area I_0acI_1 in figure 2) Equation 5

Where K is the vertical shift of the maize supply function expressed as a proportion of initial price, η is the absolute value of elasticity of demand, ε is the elasticity of maize supply, and $Z=K\varepsilon/(\varepsilon+\eta)$ is the reduction in price relative to its initial value due to supply shift.

Logit Model: This was used to evaluate factors influencing incidence of insecticide adoption. Logit model is a logistic distribution bound between 0 and 1. The model was specified (Amemiya, 1981) as shown in equation 4.

$$\log\left[\frac{\Pr ob(event)}{\Pr ob(no\_event)}\right] = \beta_0 + \beta_1 X_1 + ... + \beta_k X_k \qquad \text{Equation 6}$$

Where β_{is} are estimated coefficients and X, are independent variables as given Table 1.

Tobit model: This model explains the intensity of insecticide adoption by farmers. Adoption of insecticide use in maize was defined as a truncated continuous variable where non-adopters were using no chemical and adopters were using varying amounts of insecticides. The Tobit regression model (Amemiya, 1973) was specified as;

$$Y_i = \beta X_i + u_i \qquad \text{Equation 7}$$

Where Y is a continuous truncated variable, X is a set of independent variables, β is a vector of parameters including constants, which are estimated using maximum likelihood method and u is the error term. Variable descriptions are given in Table 1.

Table 1: Variables used in the Logit and Tobit models for regression analyses.

Variable name	Nature of variable	Variable description
Dependent variable		
Dumchem (logit)	Binary 1=adopters	Adopters of insecticide use. 1=adopter; 0 otherwise
Insecticide-Y_i (Tobit)	Continuous	Amount of insecticide use in kilograms
Independent variables		
Vartype	Binary	Maize variety type
Acre	Continuous	Acreage under maize
YldMze	Continuous	Yield per acre
InsectQty	Continuous	Amount of insect used on maize stalk borers
Herb	Continuous	Amount of Herbicide
Fert	Continuous	Amount of fertilizer use
Hlab	Continuous	Hired labour
QtyMzeSel	Continuous	Quantity of maize sold

Age	Continuous	Age of household head
Gender	Binary	Gender of household head
Educ	Continuous	Education of household head in years
TimeOnFam	Continuous	% Time on-farm of household head
ExtTrain	Binary	Farmer training
ExtCont	Binary	Extension contact
Coop	Continuous	Membership to co-operative society
Credit	Continuous	Amount of credit
DUrban	Continuous	Distance to most important input market
IntrCrop	Binary	Intercropping of maize and other crops
DumyMT	Binary	Dummy MT=1; 0=others
DumyLT	Binary	Dummy LT=1; 0=others
DumyMM	Binary	Dummy MM=1; 0=others
DumyDT/DM	Binary	Dummy DT/DM=1; 0=others
DumChem	Binary	Dummy for use of chemical in the control of stalk borers

Results and Discussion

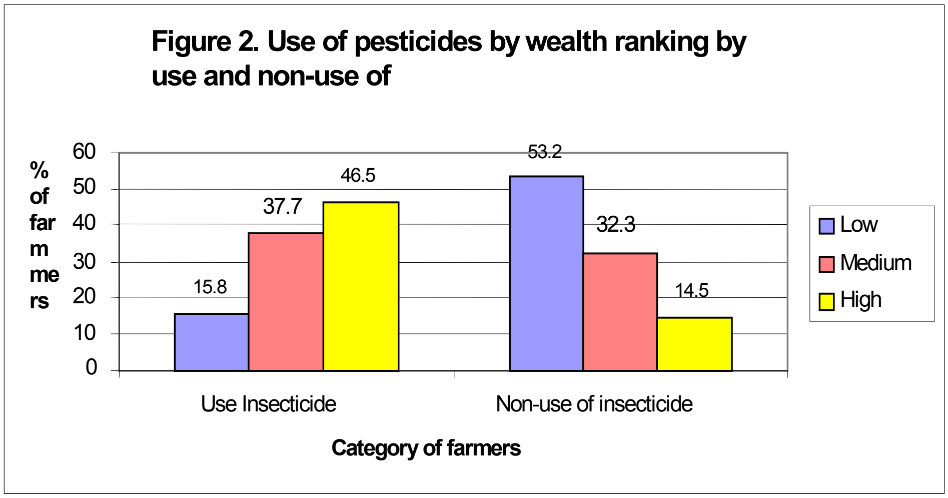
Household characteristics

Of the 1800 household in the sample size 88% were male and 12% females (Table 2). The average age of household heads ranged between 48 and 52 years. Years in school for majority of farmers in the study area were 7, indicating primary level of education. The acreage under maize for adopters and non-adopters ranged from 0.9 to 4.4 acres in MM and HT respectively (Table 2). There was great variability in quantities of maize sold, which significantly varied between adopters and non-adopters in all the AEZs except HT. The districts in the latter AEZ are a net exporter of maize (Barasa *et al*, 2002). Despite cooperatives being favorable change agents in the use of insecticides, percentage of farmers in cooperatives was low.

Table 2: General characteristics of farmers in agro-ecological zones of Kenya (crop intensification)

Variable		LT		MT		MM		DMM DT		HT		All
		Adopters	Non-adopters	Adopters	Non-adopters	Adopters	Non-adopters	Adopters	Non-adopters	Adopters	Non-adopters	
%Sex of household heads	Male	91	89	87	88	0	92	89	88	85	81	88
	Female	9	11	13	12	0	8	11	12	15	19	12
Acreage under maize		4.3	3.5	2.8	2.5	1.5	0.9	2.1	3.6	4.4	3.6	
Annual quantity of maize sold (Kg)		20	151	1361	1800			283	48	5999	6846	
% Membership in co-operatives		3	1	10	11	0	2	0	2	1	2	
Age of household head (years)		49	52	49	49	48	50	48	50	49	47	
Education (years in school)		8	7	6	7	7	7	7	7	7	7	

Source: Field survey 2003



Farm level Input utilization

Table 3 and Figure 2 show the results of insecticide use by different wealth rank groups in AEZs of Kenya. Majority of farmers not controlling stalk borer are in low and medium resource base brackets indicating their weak purchasing power due to cash constraints. In addition most farmers using insecticides are in high resource base category. However, there are no significant differences amongst wealth ranks.

Table 3: Percentage of farmers using Insecticide to control stalk borers in maize by wealth ranking and AEZ in Kenya, 2002/03.

AEZ	Wealth ranking	% Count of wealth ranking			F-value	Significance
		Low	Medium	High		
LT	Use Insecticide	51	39	10		
	Non-use of Insecticide	68	24	8	1.061	0.350
MM	Use Insecticide	67	33	0		
	Non-use of Insecticide	71	22	93	0.197	0.821
DT/DM	Use Insecticide	25	50	25		
	Non-use of Insecticide	53	36	11	1.069	0.345
HT	Use Insecticide	5	37	58		
	Non-use of Insecticide	9	47	44	0.990	0.372
MT	Use Insecticide	25	75	0		
	Non-use of Insecticide	30	44	27	0.083	0.920
All	Use Insecticide	15.8	37.7	46.5		
	Non-use of Insecticide	53.2	32.3	14.5	0.299	0.942

Source: Field survey 2003

Insecticides compete for cash with other purchasable farm inputs. Table 4 shows the annual quantities of some inputs used at household level. The amount of insecticide use was lowest in MM and highest in HT. This could be attributed to most farmers being commercially oriented in HT. Most farmers use family labour more than hired labour in many of the farm activities. Credit fuels adoption of innovations. For those farmers who received credit, the highest amount was reported in HT and MT among adopters while the lowest was in MM, LT and DM/MDT.

Table 4: Insecticide use by maize variety type and AEZs in Kenya 2002/2003

Variety Type	Use of chemicals	Number of farmers using insecticides to control stalk borer					ALL
		Moist Tropics	Low Tropics	Moist mid-altitude tropics	Dry moist and dry transitional tropics	High tropics	
Improved	No	522	209	0	54	315	1100
	Yes	61	60	0	1	77	199

	Total	583	269	0	55	392	1299
	Chi-Square	364.53	82.532	---	51.073	144.5	624.9
Local	No	106	---	111	231	24	472
	Yes	2	---	1	7	3	13
	Total	108		112	238	27	485
	Chi-Square	100.148***	---	108.036***	210.824***	16.333***	434.4***

Source: Field survey 2003

As shown in Table 4, there are significant differences (high chi-square values) between numbers of farmers using commercial insecticides. Given that very few farmers control stalk borer, significant maize yield losses that farmers are experiencing could be attributed to stalk borers in all the AEZs.

Access to input-output markets

Accessibility to inputs and outputs determine whether people are in a position to adopt some technologies. Long distance and poor road network to input markets negatively influence the input and output pricing which has implications on acquisition of chemicals for use. This contributes to high transaction costs of acquiring insecticides. In all the input-output markets, the nearest markets had a higher bad to total road distance ratio than the most reliable and important markets. This means that in all the nearest and most important markets, road infrastructure tend to increase the transaction costs.

Benefits of stalk borer control to the economy

Average losses of maize yields for both short and long seasons ranged from 3.6% to 15.8% depending on agro-ecological zones. As indicated by Hugo De Groote *et al.* (2002), the results from economic surplus models (Table 7) show that if there will be maize varieties resistant to all stalk borer specie in Kenya, then, within one year the amount of benefits that would accrue to producers and consumers would be Kshs. 16.3 million and 32.7 million respectively (with BCR of 31 and IRR of 83%). While within a period of 25 years the benefits that would accrue to producers and consumers would be Kshs. 70million and 139 million respectively (and with BCR of 36 and IRR of 30%).

Table 7: Economic surplus model for Bt maize control

Scenario	Period	Discounted rate	Elasticities Supply	Demand	Economic surplus (benefits)			Costs (discounted)	Benefit/ costs Ratio	Internal Rate of return (IIR)
					Producer	Consumer	Total			
Resistance to all stalk borers scenario	1year	10	0.8	-0.4	16.3	32.7	49	6.76	31	83
	25 years	10	0.8	-0.4	69.5	139	208.5			
No resistance to *B.fusca* scenario	1year	10	0.8	-0.4	1.9	3.8	5.7	6.71	3.6	30
	25 years	10	0.8	-0.4	8.1	16.1	24.2			

Source: Hugo et al 2002

Table 8 shows the partial budget and marginal analyses of controlling maize stalk borers in maize using commercial insecticides. The MRR values show that it is economical to control stalk borers in maize in all the maize AEZs apart from DM/DT. This could be attributed to the low crop yields in the latter AEZs due to stalk borer favourable climatic conditions. The highest impact will be realized in HT (MRR=4.5) and MT (MRR=3.8). Therefore if interventions were targeted to these zones more impact would be felt.

Tables 8: A partial budget analysis of treated verses non-treated maize plots for the control of maize stalk borers

	LT		MM		HT		MT		DM/DT		ALL	
	Treated	Non-treated	Treated	Non-treated	Treated	Non-treated	Treated	Non-treated	Treated	Non-treated	Treated	Non-treated
Yield	4303	3719	4125	3585	7812	7078	3456	2872	1730	1584	4924	4313
Price per kg	12	12	12	12	12	12	12	12	12	12	12	12
Revenue	51636	44628	49500	43020	93744	84936	41472	34464	20760	19008	59088	51756
Total cost	3026	1446	2844	1394	4348	2753	2579	1117	2023	616	3230	1677
Net benefits	48610	43182	46656	41626	89396	82183	38893	33347	18737	18392	55858	50078
MB	5,428		5,030		7,213		5,546		345		5,779	
MC	1,580		1,450		1,595		1,462		1,407		1,553	
MRR	3.4		3.5		4.5		3.8		0.2		3.7	

Source: On-farm trials 2001-2003

Risks in insecticide use to farmers

Use of insecticides can be hazardous to the household members' health either knowingly or unknowingly. Table 9 shows some of the variables that can indicate the insecticide risk levels of farmers. Though majority (63%) of farmers read labels on packaging materials there is still a sizeable proportion (37%) that cannot read. The latter group poses a danger to over-dose or under-dose the insecticides. In addition very few farmers (20%) in the sample population wore protective measures when handling chemicals. This means that most of the farmers pre-dispose themselves to poor health hazards. However, the survey results indicate that only 1% of the sampled farmers had had accidental poisoning.

Table 9: General characteristics of chemical use in the control of stalk borers in maize production

Variable	Response	% Response (n=260)
Does farmer Read labels?	Yes	63
	No	38
Does farmer use protective clothes?	Yes	20
	No	80
Has there been Accidental poisoning to household members?	Yes	1
	No	99

Source: Field survey 2003

Farmer opinions on biotechnology products

Biotechnology is a manipulation of living things to produce goods and services useful to human beings. Genetically Modified Organisms (GMO) products like Bt-maize, a new innovation in Kenya is part of biotechnology. Before adopting new technologies farmers have to be aware, try on small scale and finally adopt them. Farmers were asked on the awareness of the biotechnology and GMO products. From Table XI, most of the farmers sampled were not aware of advances in new biotechnological issues including GMOs. Tissue culture was used as proxy to the GMOs because it is more widespread in Kenya. Tissue culture is a tool used in biotechnology involving propagating whole plant from a very small amount of plant tissue even just a single cell of mother plant with desirable characteristics. GMO, which is a genetic modification or transformation, involves the transfer of genes from one source to another like in the case of Bt maize where the genes from soil bacteria *Bacillus thurinciencis* are transferred to a maize plant to protect it against stalk borer infestation. Given the low awareness level particularly for rural folk, it calls for public awareness campaign on the advantages of these techniques in order to keep pace with the rest of the world. There is need to ally fears and speculations to the target group in terms of bio-safety issues undertaken, health issues, environmental concerns and the ethics of moving genes as we undertake the noble path of introducing GMO in the country. This will enhance the adoption of Bt-maize and other biotechnology innovations.

Regression results

Table 11, shows that the factors that significantly influence the adoption of insecticides in the control of maize stalk borers were maize variety type, amount of inorganic fertilizer (basal and top-dress), quantity of maize sold, farmer training, membership to co-operatives, and the location of the farm in terms of AEZs. Maize variety type (local or improved) could have some tolerance to stalk borers infestation. Thus, a more tolerant maize variety decreases the adoption of insecticides. Increased use of inorganic fertilizers increases the maize yields, which positively influences the farmers to use insecticides to increase yields. Production of maize for purpose of selling also increases the adoption of insecticides. Contacts with extension and trained staff on the use of insecticides to control stalk borers increases the adoption. Co-cooperative societies give trainings and credit to farmers. This influences farmers to use insecticides. Some of the farmers may have Knapsack sprayers, which can be used to spray maize crops.

Table 11 below shows the results of Tobit model on the intensity of insecticide use on maize. The variables that significantly explain the intensity of insecticide use were maize zone, variety type (indicating crop diversity), amount of herbicide use, yield of maize, inorganic fertilizer use, hired labour use, age and gender of household head, quantity of maize sold and time spent by household head on the farm and the location of the farmers by AEZs (MT).

Table 11: Tobit maximum likelihood estimates and marginal effects of factors influencing the intensity of adoption of insecticides use in maize production in Kenya

Variable	Coefficient	Std error	t-value	Mean of variable
Variety type	-13.237***	1.640	-8.071	1.302
Acreage under maize	0.028*	0.130	0.215	3.052
Yield per acre	0.005*	0.003	1.777	16.937
Amount of Herbicide	0.036***	0.016	2.230	1.355
Amount of fertilizer use	-0.001	0.002	-0.475	291.787
Hired labour	0.04***	0.001	3.574	145.831
Quantity of maize sold	-0.001	0.001	-1.090	1511.758
Age of household head	-0.013**	0.066	-1.964	-176.935
Gender of household head	0.012*	0.007	2.734	-212.467
Education of household head in years	-0.005*	0.005	-1.855	-255.740
Time on-farm of household head	0.005*	0.002	1.748	-245.719
Farmer training	-0.010	0.011	-0.928	-2.148
Extension contact	0.024	0.031	0.759	-4.058
Membership to co-operative society	0.001	0.003	0.141	-27.388
Amount of credit	0.000	0.000	0.248	4321.381
Distance to nearest input market	-0.001	0.006	0.181	-3.593
Intercropping of maize and other crops	-0.014	0.011	-0.311	-0.482
Dummy MT=1; 0=others	-3.712**	1.916	-1.938	0.387
Dummy LT=1; 0=others	-0.447	1.881	-0.238	0.151
Dummy MM=1; 0=others	-6.242	5.798	11.077	0.063
Dummy HT=1; 0=others	-0.001	0.002	-0.439	-361.186
Constant	267.0060		126.140	

Ratio of adoption=0.477????; significance ***, **, * 1%, 5%, 10% respectively
Log likelihood function=-1720.004;

Conclusions

Based on these results, it is economical to control stalk borers in maize in Kenya. The amount of benefits accruing to the economy both at national and household levels is significant. However, the highest impact of introducing the Bt-maize in Kenya will be realized in High Tropics and Moist Transitional maize zones of Kenya. Therefore, efforts by IRMA project to utilize research funds to breed for stalk borers tolerant maize variety are justified. This will not only save farmers from enormous financial losses but also increase the country's food security and save the scarce foreign exchange resources used to import maize. In addition, this will also limit the importation of insecticides. The study also revealed that the majority of farmers do not use insecticides to control stalk borers, implying significant losses to both household and national economies. Therefore, an environmentally friendly integrated approach to stalk borer control will reduce these losses. Despite the inelastic demand of maize products on the market, adoption of Bt-maize and other stalk borer controlling technologies will significantly increase maize yields and therefore contribute to economic growth of Kenya's economy. In order to enhance adoption of Bt-maize due considerations can be given to the following factors, maize variety, other purchasable input like fertilizers, hired labour, farmers awareness including policy makers, characteristics of the target group like education levels and stalk borer pressure across AEZ s

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