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Economic Impacts of Chemical Pesticides Use on Fadama Crop Farming in Sudano-Sahelian Zone

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ABSTRACT Primary data were collected from users and non-users of chemical pesticides in fadama farming. The data collected included number of plots, farm size, types of crops grown, prices and quantities of outputs of the farms. In addition, the application costs of pesticides (material cost, labour for applying and equipment) were collected from pesticides users. The data were analysed using descriptive and inferential statistics, partial budgetary and marginal analyses, and sensitivity and regression techniques. The results indicated that the chemical pesticides users operated smaller mean number of plots, larger mean farm size, obtained higher crop yield as such larger output per farmer. None of the chemical pesticides users used herbicides. Budgetary analysis and regression technique indicated that chemical pesticides use was economically rational at the present chemical pesticide technology, and relative input-output prices. An investment of one naira in chemical pesticides use returns 2.21naira in addition to the one naira invested, as such based on economics only their use should be encouraged. However, pesticides use will be irrational if ceteris paribus, prices of chemical pesticides rise by more than 86%.

INTRODUCTION

In order for people in developing countries to be food secure, there should be a sustained increase in food supply, most of which must come from developing countries themselves. For developing countries to achieve this feat, increase in agricultural production through either increase in farmland area put into production or increase in productivity (yield) or both is a necessity. Whichever process the increase is achieved, an inefficient way of employing resources in food production is to have the output totally, or partially, destroyed by pests. Pests are organisms that harm or destroy crops, thereby affecting food supplies. They could be categorised into vertebrates (animals), insects, weeds and pathogens (viruses, bacteria, fungi, and helminths). Developing countries have recorded enormous pre- and post harvest losses of crops due to pests (IFPRI, 1996). The UN Food and Agriculture Organisation estimates that in the developing countries, pests, weeds and disease destroy about 40 percent of crops while they are still in the fields and 6 to 7 percent of crops after harvest. In Africa and Asia, preharvest losses are estimated at 50 percent of crops. These alarming losses must be reduced if an increasing world population is to be fed largely from existing farmland. Cramer (1967), FAO (1975), Pimentel (1992) and Oerke et al. (1995) put crop losses due to pests worldwide at between one-third and one-half of attainable crop production, with the crop losses in developing countries at the high side and the greatest crop damage caused by insects, followed by pathogens and weeds. The distribution and frequency of appearance of pests are functions of ecological, agro climatic, and socio-economic conditions, and changes in patterns of crop production (Yudelman et al., 1998). Increased trade and commerce bringing about the spread of pests of all kinds into ecologies lacking natural enemies; and the growing human population creating higher demand for food thereby making farmers to change cultural practices, (such as intensification of cropping, reduction in crop rotation, and increase in monoculture) to increase food supply, all result in increase in pest activities. Traditional farming, although generated small surplus, was able to keep low the proportion of pest losses in production through the use of natural checks and balances, and farm management practices such as multiple cropping, crop rotation, and shifting cultivation. The relatively more modern methods of pest management could be grouped into chemical pesticides and non-chemical strategies. The non-chemical strategies of pest management include plant breeding, the use of biological control agents, biotechnology (biopesticides and genetic engineering), and Integrated Pest Management (IPM). The IPM is a flexible approach, which combines a range of pest control methods that simultaneously generate highest value to the farmer and environmentally acceptable and sustainable outcomes. Chemical pesticides are made from organic, inorganic and synthetic chemicals.

There exists a wide range of chemical pesticides. Thus, there are insecticides, herbicides, fungicides, nematicides, rodenticides and miticides. Another line of classification is on their intended use, giving rise to pesticides called defoliants, desiccants, fumigants and plant regulators. Chemical pesticides have been found to be effective in pests management. Oerke et al. (1995) stated that if not for chemical control of weeds (herbicides use), wheat production in U.S. would have decreased by thirty percent. Knutson et al. (1990) indicated that application of fungicides and herbicides prevented the decrease in yield that could have occurred in wheat production. Farah (1994) opined that some crops would have been completely wiped off without the use of chemical pesticides. One of the factors affecting the effectiveness and efficiency of chemical pesticides is the application technique. Pimentel and Levitan (1986) stated that less than one percent of applied pesticides actually reach the target pests. Efforts are urgently been directed at improving the delivery systems, including the development of ultra-low volume sprayers that could be easily handled by small-scale farmers.

Dinham (1995) stated that Pesticide Action Network projected a rapid increase in demand and consumption of chemical pesticides by developing countries in the years ahead because of lack of a viable alternative. At present, most especially in developing countries, there is an inadequate state of knowledge about actual losses from pests and the real and potential gains from pest management. A modern pest management method in existence in developing countries is chemical pest management as chemical pesticides are in the agricultural input markets for farmers to purchase and use to improve crop yields. It is necessary to know if the use of chemical pesticides is of economic benefits to the farmers. An economic indicator of the productivity of pesticides is the value of the crop that could be produced from an additional dollar spent on pesticides (Carlson and Castle, 1972). Headley (1968), indicated that U.S. agriculture could produce an average of four dollars of additional product for each pesticide dollars expended, and Strickland (1970) returned a figure of five dollars for England. Olaifa and Alimi (1988) stated that application of carbaryl to okra was economical with the highest marginal returns obtained at 0.17% and 0.35% of carbaryl, applied three times before harvest in the early and late seasons respectively.

This study intends to determine the quantity and value of crops saved by chemical pest management and the economic effects of its use in fadama farming of Sudano-Sahelian zone of Nigeria. The result obtained will assist the individual farmers, and the agricultural policy makers on whether to support/promote the use of chemical pesticides based on its economics.

RESEARCH METHODOLOGY

Study Area

The study was conducted in Kebbi state, which is located in the Sudano-Sahelian zone of Nigeria. The study area has two distinct seasons - a dry season of dust laden harmattan followed by hot period preceding a short rainy season of four to five months. The annual rainfall ranges from 500 to 750mm with the highest rains recorded in the months of July and August. Highest temperature occurs in the months of March and April and can be as high as $43^{o}C$. It has a sparsely scattered vegetation of trees, together with shrubs and grasses. Crop farming, in the dry season in this area is restricted to the low lying river valleys called ‘Fadama’ under a variety of irrigation systems. Relatively high moisture content in the soil and air of fadama combined with high temperature can greatly influence the development of insect pests.

Sampling Technique

Multi-stage sampling technique was used in selecting the sample. Two Local Government Areas (LGAs) and four villages from each LGA were selected using purposive sampling technique based on the presence of fadama farms. Ten respondents, each of users and non-users were selected from each village using simple random sampling technique. A total of eighty respondents were interviewed from each category (users and non-users).

Data Collection

Primary data were collected from the users and non-users of agricultural chemical pesticides using structured questionnaires. The data collected included quantity, price and application costs of pesticides; farm size, type of crops grown; yield and prices of outputs etc.

Analytical Techniques

Data were analysed using descriptive and inferential statistics; partial budgeting and marginal analyses; regression technique and sensitivity analysis.

Descriptive and Inferential Statistics: The frequency distribution, proportion and arithmetic mean of relevant variables were computed. Inferential statistics of difference between two means tested at 5% level was used to establish significant difference in the users and non-users of pesticides.

Partial Budgeting, Marginal and Sensitivity Analyses: Partial budgeting and marginal analyses were used to indicate the superiority of chemical pesticides in fadama farming.

Partial budgeting is a method of organising data and information about the costs and benefits of various alternative treatments/technologies (CIMMYT, 1988; Alimi and Manyong, 2000). The alternative treatments in this case are pesticide use and non-pesticides use in fadama farming. The relevant costs to use in Partial Budget Analysis (PBA) are costs that vary between alternative treatments, which for this study are material (pesticide) cost, equipment (sprayer depreciation or rent) cost, and application (labour) cost. These costs are added together to obtain Total Cost that Vary (TCV) which is subtracted from Gross Field Benefits (GFB) to give Net Benefit (NB). GFB is the product of yield (Kg/ha) and the price per unit (/kg) of output (gross revenue).

Marginal analysis in PBA is the comparison of change in TVC with change in NB. This comparison reveals the increase in benefits associated with a given increase in cost for using a technology (pesticides). PBA is based on a unit, which in crop farming is one-hectare farm size. Thus, in this study, PBA is based on a farm size of one hectare, and variable costs and benefits are assumed to vary directly with farm size. It is basically the computation of Marginal Rate of Return (MRR), which is compared with Acceptable Minimum Rate of Return (AMRR). MRR is the ratio of marginal net benefit to marginal cost. The marginal net benefit is the difference between the NB of two consecutive treatments while the difference between the TCV is the marginal cost. AMRR is the minimum return that farmers expect to earn from an enterprise or technology, which technically is the sum of returns to management and capital. A technology/ alternative treatment is considered economically worthwhile if MRR is higher than AMRR.

Sensitivity analysis was performed to show the percentage change in mean pesticide price that will make application of pesticides uneconomical. It implies redoing a marginal analysis with alternative prices. Price sensitivity analysis was carried out by varying the mean pesticides price.

Regression Technique: Two variables regression analysis was carried out. The dependent variable is NB (a quantitative variable) and a binary independent variable (use/non-use of pesticides). The regression model is stated thus:

$$Y_i = b_o + b_1 D_i + m_i \quad \text{.........................(i)}$$

where NB = Net Benefit in monetary term(Naira) from fadama farming

D_i =1 for pesticides use; 0 for non-use of pesticides

Model (i) is an analysis of variance regression model since the only independent variable is binary (Gujarati, 1988). This model will indicate if holding all other factors constant, use of pesticides increases the level of NB. Assuming that the disturbances satisfy the usual assumptions of the classical linear regression model,

the Mean NB for non-pesticides users = $E(Y_i / D_i = 0) = b_0$

Mean NB for users = $E(Y_i / D_i = 1) = b_0 + b_1$

b_0 gives the mean NB of non-users, b_1 states the amount by which NB of users is higher than non-users. $(b_0 + b_1)$ show the mean NB of users.

A test of null hypothesis

H_o: $b_1 = 0$, there is no difference in the NB of users and non-users; against the alternative hypothesis

H_1: $b_1^1 \neq 0$, difference exists in the NB of the two categories.

If b_1 is positive and statistically significant then the mean NB of users is significantly higher than non-users.

RESULTS AND DISCUSSION

Comparison of Farm Characteristics of Users and Non-users

The characteristics of farms of chemical pesticides users and non-users are as indicated in Table 1. Significant proportion of users (70%) had at most four plots with half of this proportion (35%) keeping one or two farm plots. About three-fifths of non-users had either five or six plots.

The mean number of plots of users (3.4) was less than that of non-users (4.0) and the difference is significant. The maximum farm size of non-users lied between 0.46 and 0.65 ha while that of users was in the farm size range 0.66 - 0.85 ha. While less than fifty percent of users had farm size smaller than 0.45 ha, almost all non-users (97.5%) were in this range. The mean farm size of users was 0.47 ha, and the non-users recorded 0.311 ha. Although, both groups were smallholders, the users' farm size was significantly bigger than non-users. The larger mean farm size combined with smaller mean number of plots of users over non-users implies bigger mean plot size. The common crops grown by both groups (users and non-users) and of relatively reasonable size were onion, pepper, and tomatoes, which were either sole crop or intercrop. Almost about the same proportion (two-fifths) practised monocropping in the two categories. More than fifty percent of the farmers grew onions, and next in importance were pepper and tomatoes in that order. It could be concluded that the cropping pattern of chemical pesticides users and non-users are similar. Considering the mean enterprise farm size, each of the onion and pepper farm sizes of the users was higher significantly than the non-users and the reverse was the case for tomato farm size where the non-users recorded significant higher farm size. For each of the three enterprises, (onion, pepper and tomato), the users had significant higher output and yield than the non-users. Relating mean yield of users to non-users (Table 1), pesticides use increased onion yield by 28.8%, pepper by 26.0% and tomatoes by 41.20%. The larger farm sizes and higher yields realized by the users over non-users will lead to higher output obtained by the users. The higher physical output obtained by users brought about by higher yield resulted from increased management system (use of chemical pesticides), since it is the only marked difference between the two groups. None of the chemical pesticides users used herbicides. The costs incurred exclusively by the chemical pesticides users and not by the non-users could be put into three categories. These are material (pesticides) cost, equipment (sprayer) rent cost and labour (pesticides application) cost all of which rationally should vary with the quantity of pesticides used and or farm size. The distribution of pesticides user respondents according to pesticides application variable input cost components is as shown in Table 2. The mean cost incurred by farmers in purchasing pesticides was N875. Either depreciation or rent on sprayer came up to a mean of N235. Labour cost for applying pesticides was a mean of N143.75. All these variable cost components incurred by chemical pesticides users only, came up to a mean cost (cost per farmer) of N1253.75 on a mean farm size of 0.472ha. This represents the monetary value of additional investment made by users over non-users. The justification for this extra investment will depend on the amount of additional returns brought about by the action of pesticides application. PBA was used in demonstrating the justification for the use of chemical pesticides (as indicated below).

Partial Budgetary, Marginal and Sensitivity Analyses

It was shown in Table 1 that the pesticides users obtained higher yield for each of the crops than users. Based on physical quantity per unit area (yield) alone, the use of chemical pesticides could be supported but economic justification requires in addition, the use of prices of inputs and outputs, as adverse relative prices of input and output can make higher yield obtained meaningless. The mean prices of output per unit (/kg) were N19.61 for onion, N31.58 for pepper and N2.78 for tomato.

The enterprise combination for pesticides users was 0.216 ha of onion: 0.201 ha of pepper: 0.055 ha of tomato which approximately is ratio 8:7:2 of onion to pepper to tomato respectively while that of non-users was approximately ratio 9:7:5 of onion: pepper: tomato respectively. Assuming one-hectare farm size (PBA unit of analysis for crop enterprise) and taking the enterprise combination of users, the average yield and values for other components of PBA for users and non-users are indicated in Table 3.

The Gross Field Benefits (mean revenue) of chemical pesticides users (N38,917.50) was higher than non-users (N30,401.0). Pesticides use over non-use brought about increase in revenue of about 28%, which was as a result of increase in yield obtained by the users. While the Total Cost that Vary for users (on one hectare farm size) was N2656.40, the non-users expended nothing (zero

Table 1: Farm characteristics of chemical pesticides users and non-Users

Characteristics	*Distribution (%)*		*Mean*		
	Users	*Non-users*	*Users*	*Non-users*	t_c
Number of Plots:			3.4	4.3	3.7*
2-Jan	35.00	17.50			
4-Mar	35.00	25.00			
6-May	30.00	57.50			
Farm Size(ha):			0.472	0.311	4.5*
0.10-.0.25	10.00	27.50			
0.26-0.45	45.00	70.00			
0.46-0.65	22.50	2.50			
0.66-0.85	22.50	-			
Cropping Pattern:					
Sole-Onion	21.25	20.00			
Pepper	16.25	12.50			
Tomato	6.25	8.75			
Mixed-Onion +	38.75	35.00			0.73
Peppers +	11.25	12.50			
Tomato	6.25	11.25			
Enterprise Size(ha):					
Onion			0.216	0.13	3.74*
Pepper			0.201	0.104	2.53*
Tomatoes			0.055	0.077	-1.99*
Yield (Kg/ha)					
Onion			2641.8	2058.8	2.63*
Pepper			994.1	789.2	2.11*
Tomatoes			4931.2	3492.1	2.97*
Quantity of Pesticides Used (Litres)					
<0.50	5.00	-			
0.51-1.00	55.00	-			
1.01-1.51	40.00	-	0.93		

Source: Analysis of Field Data
*Means significant at 5%level

Table 2: Distribution of respondents according to pesticides application: Variable input cost components

Components	*Distribution (%)*	*Mean*
Material (Pesticides)		
Cost (₦)		
501-800	55	
801-1100	15	
1101-1400	30	875
Equipment (Sprayer)		
Rent (₦)		
101-200	40	
201-300	35	
301-400	25	235
Pesticides Application		
{Labour (₦)}		
51-150	62.5	
151-250	31.25	
251-350	6.25	143.8

Sources: Analysis of field data

naira) as they did not perform the activities of pesticides application. Thus, the additional investment, which users made over and above the non-users, was N2656.40 per hectare. The Marginal Net Benefits (change in net benefits between use and non-use of pesticides) was N5860.10, and the Marginal Cost (change in Total Cost that vary) was N 2656.40 which resulted in MRR of 2.21. It implies that for each N1/ha on the average invested in pesticides use, pesticides users recover their N 1, plus an additional N 2.21/ ha in net benefits.

In order to justify the use of pesticides, MRR was compared with AMRR. Based on the assumption that fadama farmers would want AMRR of 100% for using pesticides technology, and since analysis indicated MRR of 221%, then pesticides use at the present yields, and prices of inputs and outputs is rational (economical). Thus, based on economic justification only, farmers should be encouraged to shift to pesticides use in fadama farming. Price sensitivity analysis carried out (Table 3) indicated that it would be irrational for fadama farmers to shift to chemical pesticides use, if ceteris paribus, prices of chemicals pesticides on the average increase by more than 86% of their current prices. At the pesticides price increase of 86%, the MRR is 100% (1.00), which is equal to the assumed AMRR (100%).

Regression Results of NB on Use/Non-use

Table 3: Partial budget and price sensitivity analysis for chemical pesticides application

Items *Increase in pesticides prices*	*Without pesticides*	*With pesticides and variation in pesticides prices*			
		0	*50%*	*86%*	*100%*
Average yield(Kg/ha):					
Onion	2058.8	2641.8	2641.8	2641.8	2641.8
Pepper	789.2	994.1	994.1	994.1	994.1
Tomato	3492.1	4931.2	4931.2	4931.2	4931.2
*Output(Kg):					
Onion	968.8	1243.2	1243.2	1243.2	1243.2
Pepper	324.9	409.3	409.3	409.3	409.3
Tomato	410.8	580.1	580.1	508.1	508.1
Benefits (N):					
Onion	18999.1	24379.2	24379.2	24379.2	24379.2
Pepper	10259.8	12925.5	12925.5	12925.5	12925.5
Tomato	1142.1	1612.8	1612.8	1612.8	1612.8
Gross field benefits (N/ha)	30401.0	38917.5	38917.5	38917.5	38917.5
Cost of pesticides(N/ha)	0	1853.8	2780.7	3448.1	3707.6
Cost of equipment (Rent-N/ha)	0	497.9	497.9	497.9	497.9
Cost of labour to apply (N/ha)	0	304.7	304.7	304.7	304.7
Total cost that vary (N/ha)	0	2656.4	3583.3	4250.7	4510.2
Net Benefits (N/ha)	30401.0	36261.1	35334.2	34666.8	34407.3
Marginal Analysis					
Marginal Net Benefits		5860.1	4933.2	4265.8	4006.3
Marginal cost (N)		2656.4	3583.3	4250.7	4510.2
Marginal Rate of Return		2.21	1.38	1.00	0.88

Source: Analysis of field data

- indicates the output of 1ha farm size with enterprise combination of ratio 8:7:2 of Onion: Pepper: Tomato
  Note: One U.S.dollar = One hundred and eleven Naira (N)

of Pesticides

The empirical results corresponding to regression model (i) are as follows:

The results of regression analysis of equation (i) above is as stated in equation (ii):

$$Y = \underset{(4.17)}{30.29^*} + \underset{(2.12)}{5.93^*D_i} \quad \text{............ (ii)}$$

$R^2 = 0.5834$

Values in brackets are the t-ratios.

*Significant at 5% level.

The R^2 indicates that 58.38% of the variation in NB is as a result of use/non- use of chemical pesticides.

The interpretation of the regression results indicates that both b_0 and b_1 are positive and statistically significant as the null hypothesis tested for each of them was rejected. This implies that the mean NB of non-users is about N30290, which is smaller than the mean NB of users by N5930. Regression, as did budgetary and marginal analyses, confirms the economic superiority of chemical pesticides use over non-use.

CONCLUSION

Data collected from chemical pesticides users and non-users were analysed using descriptive and inferential statistics, partial budgeting and marginal analyses, regression and sensitivity techniques.

Pesticides users cultivated smaller mean number of plots, larger mean farm size, obtained higher crop yield resulting in larger output and revenue per user than non-users. None of them applied herbicides. The Net Benefit obtained by users was significantly higher than non-users Investing one naira in agricultural chemical pesticides use brings a return of 2.21 over and above the one naira invested, thus making pesticides use rational at the present pesticides use technology, and input-output price ratio. Price sensitively analysis indicated that cateris paribus, increase in price of chemical pesticides by more than eighty six percent will make pesticides use economically unjustifiable.

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