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Factors influencing selection of plant protection chemicals: A statistical appraisal

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Abstract
Ever increasing population coupled with diminishing available land for agricultural purposes poses serious concern to the planners to meet the challenging demand for food and nutritional security. To boost the productivity from per unit use of natural resources per unit time plant protection chemicals are used. There is hue and cry about the indiscriminate and non-judicious use of such chemicals leading to environmental and health hazard. In this study an attempt has been made to study the farming groups in terms of their mode of selection of plant protection chemicals and the influencing factors. Based on information from 100 farm families from a selected agriculturally developed village the study reveals five distinct groups of farmers. Descriptive study of five groups reveals that most of the farmers (34%) are guided by the shopkeepers in selecting chemicals for plant protection. The correlation study along with Fisher's Discriminant Analysis reveals that age of the farmer, education, total land holding and cropping intensity are the major governing factors in group discrimination. Younger generation of farmers are tend to have better education to decide up on the plant protection chemicals mainly guided by brand of the chemicals and learning by doing; in the process they are able to minimise the agricultural expenditure to harvest better net return and savings from agriculture.

Keywords: Chemicals, discriminant, factors, plant protection

Introduction
Agriculture holds a prime importance in the socio-economic fabric of India. Agriculture and allied sectors remain the backbone of the Indian economy and account for 17% (Approx.) of the country’s GDP. The Green Revolution towards the beginning of 1970s had major economic effects in terms of the production and productivity. The Green Revolution led India from a food deficient country to a food surplus economy. It has not only helped to satisfy the demand of India’s huge population but has also helped in increase exports of agricultural products. Despite all its achievements, Indian agriculture is still grappling with challenges like high monsoon dependency, unpredictable and changing weather patterns, reduction in arable land, comparatively low per hectare yield in majority of the crops, increase in pest attacks, lower farmer incomes etc. Every year in India, pests and diseases eat away, on an average, 20-30% of food, worth about Rs. 45000 crore, produced by the farmers and thus plant protection chemicals have an increasing role to play in enhancing crop productivity. The role of pesticides has become critically important with the modernization of agriculture and increased use of modern inputs such as chemical fertilizer, irrigation and modern seeds, which provide a favourable climate for rapid growth of pests. Over the past five decades use of plant protection chemicals has drastically increased many folds and India is now one of the leading producers of agrochemicals in the world. The high yielding varieties (HYVs) of wheat, rice, maize and other crops have been developed under the protection umbrella provided by the broad spectrum, synthetic organic pesticides (Pradhan, 1983) [7]. The indiscriminate use of these pesticides has caused irreparable damage to our environment and also contributed to an aggravation of pest problems. Apart from the obvious effects on crops and the food chain, agrochemicals have a wide area of application. Due to these many uses, they seep into the surrounding land and water bodies, even contaminate ground water. Many of the chemical pesticides can have harmful effects on human beings either as acute or chronic toxicity. Acute exposure to pesticides can lead to death or serious illnesses. In this regard Cole *et al.* (2011) [2] opined that the use of highly hazardous pesticides by smallholders constitutes a classical trans-sectoral 'wicked problem'. Mccauley *et al.* (2008) [6] designed to use the Comet assay to describe the association of markers of DNA damage in oral leukocytes with biomarkers of pesticide exposure.

Alsaed *et al*. (2011) [1] identified the types and estimates the quantity of pesticides used in selected Palestinian districts. Study revealed that a total number of 217 pesticides including 13 soil sterilizers, while 134 kinds with different active ingredients (insecticides 62; fungicides 45; herbicides 20) were applied in all districts. Tyagi (2011) [8] observed the ill-effects of methyl parathion - a pesticide on liver enzymes of fresh water fish *Channa punctus* (Bloch). Methyl parathion is supposed to increase the level of certain liver enzymes (*viz*. SGOT, SGPT) to a alarming level, which induces hepatic degradation, resulting in fish death. According to Crago *et al*. (2012) [3] ill effects of disposed pesticides and disposed plastics in aquatic environment disrupt androgen synthesis. Kaur *et al*. (2011) [4] pointed the potential risk of pesticides to farmers and environment with the relation between occupational exposure to various pesticides and presence of DNA damage. The effect of endosulfan on oxidative stress and bio degradation also shown on aquatic as well as human lives (Khan *et al.,* 2012) [5]. Taking all the pros and cons of uses pesticides in to the account the main challenge for the plant protection specialists remain the same from the very beginning i.e. to increase the agricultural productivity by manifold to feed the ever rising population. Like wise to that of use of antibiotics in medical science, farmers are also using chemicals for protection of crops without knowing actually the type of chemicals to be used in specific disease or pest, guided by so many factors beyond cause and effect relationship and thereby inviting pressure on farming economy, besides health and environmental degradation. Exposure to pesticides and there by its health and environmental impacts can be minimized at community level by judicious selection, appropriate and proper use of agrochemicals, adopting recommended methods of mixing, applying, storing, disposing and practicing use of proper personal protective equipments. India being the land of small and marginal farmers, lacks the proper guidance regarding the judicious use of agrochemicals. Thus the source of these chemicals become much important in their way and extent of application. In this study, an attempt has been made to examine the correlates in the process of selecting plant protection chemicals.

Materials and Methods

This study was undertaken in Fatepur village of Haringhata block (22.96ºN Lat. and 88.57ºE Long.) of Nadia district in West Bengal to determine the factors affecting the uses of plant protection chemicals by the farmers in the village. Several socio-economic factors were identified for better understanding of this objective.100 farmers from the selected village were contacted after repetitive visits to collect necessary information and their socio-economic data keeping the objective in mind. Information from the farmers was collected by personal interview of the respondents with the help of structured questionnaire.

Statistical tools and techniques used: The data, after collection, were processed and analysed with the help of i) Descriptive Statistics, ii) Correlation and Regression Study and iii) Discriminant Analysis. To get the complete overview of the collected data, several descriptive measures *viz*. mean, median, mode, maximum value, minimum value, standard error, standard deviation, skewness and kurtosis are studied. To start with the study of association, Pearson's correlation among the influential variables with the assumption of linear relationship between the variables is attempted to. The most powerful and widely accepted statistical tool in describing the relation between the dependent variable and the independent variable is the regression analysis. In a regression model, the dependent variable is presented as the function of one or more independent variable and the error term, $Y=f(X_i,u)$, where i stands for ith independent variable and u is the random component i.e. error term $u_i \sim$ i.i.d. $N(0, \sigma^2)$. The step down regression is the procedure to find out the most important variable(s) in the relational model. Firstly, the regression model with all the regressors is fit and in a stepwise way the least significant variable is left out from the model. This procedure is continued until the final model consisting of all significant variable(s) at specified level is obtained.
One of the most important multivariate statistical tools to distinguish among the individual elements of a population in forming different groups taking care of multiple number of variables is the discriminant analysis. The objectives of discriminant analysis are to test the existence or otherwise of any significant differences among the groups and to test whether the variables under consideration are contributing towards intergroup discrimination. Discriminant Function Analysis (DFA) is essentially a multiple regression where the dependent variable Y is a categorical variable, which is used to determine relative contributions of the variables to discriminate among K groups. Suppose we have an observation *X*o. Then, based on the Discriminant function l(*X*) = *a*ˆ*tX*, one can allocate this observation to some class.

Allocate X_0 to population 1 if

$$\hat{Y}_0 = \hat{a}^t X_0 = \left(\bar{X}_1 - \bar{X}_2\right)^t S_{pooled}^{-1} X_0 \geq \frac{1}{2}\hat{a}^t\left(\bar{X}_1 + \bar{X}_2\right)$$

$$= \frac{1}{2}\left(\bar{X}_1 - \bar{X}_2\right)^t S_{pooled}^{-1}\left(\bar{X}_1 + \bar{X}_2\right)$$

Otherwise, if $\hat{Y}_0 = \hat{a}^t X_0 = \left(\bar{X}_1 - \bar{X}_2\right)^t S_{pooled}^{-1} X_0 < \frac{1}{2}\left(\bar{X}_1 - \bar{X}_2\right)^t S_{pooled}^{-1}\left(\bar{X}_1 + \bar{X}_2\right)$, then allocate X_0 to population 2 where, $\bar{X}_1$ and $\bar{X}_2$ are mean vectors of the groups, $\hat{a}^t$ is the discriminant coefficient and S_{pooled}^{-1} is the pooled sample variance-covariance matrix of the two groups under comparison.

With the help of the above mentioned Discriminant Analysis we have tried to find out the variables contributing significantly towards discrimination groups of sources affecting the decision of using a particular plant protection chemical.

Results and Discussion

Following 15 variables *viz*. age of the respondent (X_1), educational qualification (X_2), family size (X_3), total land holding in hectare. (X_4), agricultural land holding in hectare (X_5), cropping intensity (X_6), total income (X_7), agricultural income (X_8), total expenditure (X_9), agricultural expenditure (X_{10}), per hectare agriculture expenditure (X_{11}), family savings (X_{12}), agriculture savings(X_{13}), per hectare net return(X_{14}), percentage saving from agriculture (X_{15}) are supposed to influence the decision of plant protection chemicals used by the farmers and as such are used for the study purpose.

The following table 1 reveals that age of the farmers varies from 27 to 63 with the average age lies 52 years. So far about the distribution of age is concerned mean, median and mode all are equals to 52 years, thereby indicating that it follows almost normal distribution. Though the educational standard of the head of the families varies between illiterate to graduate, the mean educational level shows around 6th standard where as the median lies around 8th standard indicates at least 50% of the farmers are having the qualification of 8th standard or more. As far as the agricultural land holding is concerned, it shows maximum of 0.935 ha to as low as 0.1 hectare and on average the farmers have 0.47 hectare of arable land. The positively skewed platykurtic nature of distribution indicates that there has been accumulation of marginal farmers among the farmers surveyed. As far the average cropping intensity is concerned the average value of 204.30 with lowest cropping intensity of 120% accompanied with highest cropping intensity of 300% clearly indicates that the area is agriculturally resourceful with assured irrigation. Under the assured irrigation situation, the average as well as lowest cropping intensity should have been far better and programme in augmenting cropping intensity is suggested for this zone. Agricultural income of the family varies from Rs.25000 per annum to Rs.120000 with the mean around Rs.66000. The average agricultural income per hectare is around Rs1,41 lakhs with positive skewness and platykurtic nature clearly indicates that there is scope for improving per hectare agricultural income from land with assured irrigation facility. The positive skewness of agricultural income says presence of small agricultural income family. Positive skewness and leptokurtic nature of almost all the income, expenditure and savings clearly indicates that most of the studied farmers belong to respective low ranges, which is not at all desirable in an agriculturally resourceful area like this one.

Correlation Study

Table 2 depicts the correlation among the independent variables. Age and education are negatively correlated as previously educational facilities and awareness have got importance in recent past. Family size is significantly correlated with total income (0.602) and agricultural income (0.355). Expenditure is significantly and negatively correlated with education (-0.295) as educational attainments leads to more meaningful purpose of expenditure thus reducing it. Agricultural income, agricultural expenditure, total income and total expenditure is highly correlated with each other. A person who earns more spends more. Table shows that net agricultural income is highly correlated with cropping intensity, total income, agricultural income and total expenditure. A new variable is here introduced for better understanding the impact of pesticide choosen (i.e. total count of pest(X_{16}) in the field of the respondents) and also further analysis the factors discriminating in opting a given plant protection chemical.

Table 1: Descriptive Statistics

Measures	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}	X_{11}	X_{12}	X_{13}	X_{14}	X_{15}
Min	26.00	0.00	2.00	0.20	0.10	120.00	85000	25000.00	50000.00	10000.00	27456.16	10000.00	9000.00	13478.48	16.67
Max	63.00	15.00	8.00	1.07	0.93	300.00	240000	120000.00	180000.00	49500.00	274561.56	80000.00	102000.00	305512.14	510.00
Mean	52.00	5.84	3.98	0.59	0.47	204.30	138600	66420.00	103100.00	27127.40	64903.04	35500.00	39292.60	99105.56	138.60
Std. Error	0.81	0.63	0.18	0.02	0.03	7.39	4934	3127.51	4181.81	1365.70	5345.71	2433.82	2842.38	9442.58	14.59
Median	52.00	8.00	4.00	0.53	0.47	191.50	130000	65500.00	100000.00	25825.00	54186.20	30000.00	35000.00	82368.47	91.55
Mode	52.00	0.00	3.00	0.53	0.40	300.00	120000	50000.00	120000.00	35000.00	37440.21	20000.00	25000.00	64183.22	85.71
Std. Deviation	5.75	4.49	1.27	0.18	0.18	52.29	34891	22114.81	29569.88	9656.99	37799.88	17209.69	20098.63	66769.15	103.16
Kurtosis	7.47	-1.39	2.72	0.07	-0.24	-0.93	0.29	-0.07	0.64	-0.61	19.17	0.21	0.54	1.06	2.59
Skewness	-1.68	-0.21	1.41	0.32	0.31	0.34	0.76	0.51	0.92	0.31	3.77	0.93	0.80	1.17	1.53

Table 2: Correlation Table

	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}	X_{11}	X_{12}	X_{13}	X_{14}	X_{15}	X_{16}
X_1	1															
X_2	-0.592**	1														
X_3	0.173	-0.14	1													
X_4	0.155	-0.24	0.195	1												
X_5	0.138	-0.19	0.121	0.942**	1											
X_6	-0.14	0.199	-0.07	-0.253	-0.18	1										
X_7	0.262	-0.21	0.602**	0.134	0.177	0.286*	1									
X_8	0.135	-0.05	0.355*	0.23	0.249	0.36*	0.564**	1								
X_9	0.226	-0.295*	0.678**	0.133	0.114	0.17	0.87**	0.608**	1							
X_{10}	-0.01	-0.09	0.257	0.48**	0.508**	0.22	0.29*	0.418**	0.25	1						
X_{11}	0.075	-0.06	-0.054	0.478**	-0.493**	0.359*	0.091	0.043	0.11	0.275	1					
X_{12}	0.146	0.067	0.038	0.027	0.139	0.295*	0.532**	0.096	0.05	0.133	-0.002	1				
X_{13}	0.153	-0.01	0.267	0.022	0.03	0.291*	0.485**	0.9**	0.549**	-0.021	-0.085	0.042	1			
X_{14}	0.054	0.067	0.09	0.563**	-0.609**	0.375**	0.256	0.493**	0.368**	-0.319*	0.391**	-0.108	0.696**	1		
X_{15}	0.048	-0.04	0.176	0.062	-0.13	0.05	0.027	0.564**	0.366**	-0.184	-0.083	-0.57**	0.708**	0.628**	1	
X_{16}	-0.05	-0.02	0.009	-0.07	-0.07	0.05	0.033	0.091	0.17	-0.011	0.114	-0.236	0.105	0.12	0.326*	1

Note: * and ** denote significant at p=0.05 and p=0.01 respectively

After getting the strength of association ship among the independent variables, now our task is to find out the exact relationship of the dependent variable i.e. net return with those of the independent variables as presented below:

Table 3: Step down regression results

Step	Model	Coefficient	SE	t	Sig.	R^2
1	Intercept	-7836	16075	-0.487	0.628	0.868
	Age	245.4	246.8	0.994	0.326	
	Education	199.6	319.4	0.625	0.535	
	Family Size	-1254	1002	-1.252	0.217	
	Total Landholding	-777	2743	-0.283	0.778	
	Agril. Landholding	-2899	2626	-1.104	0.276	
	Cropping Intensity	-50	25.9	-1.93	0.06	
	Agril. Income	0.933	0.064	14.632	0.00	
2	Intercept	-7189	4221	-1.703	0.095	0.85
	Agril. Landholding	-3119	880.8	-3.542	0.001	
	Agril. Income	0.864	0.053	16.282	0.000	

Table. 3 reveals the relationship between the net return on seven independent factors which can explain 87% variation as depicted by the value of R2 =0.868. It is also found that not all independent variables are equally effective in explaining the variations of the dependent variable, as depicted by their respective coefficients and their significance value of t-test. In step down regression analysis the variables are discarded from the full model in a stepwise manner according to their relative level of significance. Finally, it is seen that among other variables agricultural income and agricultural land holding are most significant. This definitely supports the scenario of more land leads to more crop which leads to greater income. Thus, that trend is reflected in the above situation and agricultural land is obviously a main factor for net return.

The primary objective of our study is to determine the factors governing uses of plant protection chemicals or pesticides. This leads to the question of selecting or preferring any particular pesticide and the reason or force behind choosing such pesticides/chemicals. Studying the responses from the farmers the reasons were identified and the respondents were classified in 5 different group *viz*.

a) Learning by doing and good brand
b) Suggestions from shopkeeper
c) Work experience and efficiency
d) Talking to each other and nearest resource centre
e) Availability of plant protection chemicals

On analysis of records reveals that there are 16%, 34%,20%, 20% and 10% of the farmers respectively in five different groups.

Having discussed the socio-economic correlates of the farmers and the nature of agricultural system followed in the studied area along with their inter relationship, it is now imperative to know the influential factors in deciding the plant protection chemicals used by the above mentioned 5 groups of farmers. As has already been discussed 5 different groups of farmers are identified based on their mode of selection of plant protection chemicals guided by 10 identified correlated influential variables *viz*. age of the respondent (X_1), educational qualification (X_2), family size (X_3), total land holding in hectare (X_4), agricultural land holding in hectare (X_5), cropping intensity (X_6), agricultural income (X_8), agricultural expenditure (X_{10}), agriculture savings(X_{13}) and total count of pest(X_{16}). In deciding the influential factors to discriminate the selection procedures among the 5 groups of farmers Fisher's Discriminant analysis is used. The group behaviour with respect to the 10 influential variables are presented in table 4.

Table 4: Mean table of explanatory variables across group discriminating factors

Group	Age	Education	Family Size	Total Land holding	Agril. Land holding	Agril. Expenditure	Agril. Income	Agril. Savings	Cropping Intensity	Pest Count
Group 1	49.62	6.5	3.75	0.55	0.45	24875	70750	45875	195	2.25
Group 2	52.65	6.76	4.18	0.59	0.47	26401.18	65000	38598.82	202.71	2.53
Group 3	54.5	3.2	3.8	0.57	0.44	25680	63000	37320	219.3	2.4
Group 4	50.9	6.2	3.9	0.65	0.53	30050	67500	37350	203.6	2.7
Group 5	50.8	6.2	4.2	0.53	0.44	30150	69000	38950	196	2.4

From table 4 it is found that farmers of younger generations having average education at par with the other groups have tendency to select branded chemicals through learning by doing. On the other hand the aged group of farmers i.e. the third group of farmers have tendency to select plant protection chemicals through life long working experience. Comparatively big farmers mostly decide the plant protection chemicals through mutual discussions with each other and depending upon the availability of resources. Though the farmers of younger generations have got least cropping intensity compare to others, these group of farmers harvest more from agriculture compare to others as depicted in from highest agricultural income followed by highest agricultural savings as a consequence of lowest pest count. Most probably with their comparatively better educational background these group of farmers manage to restrict the pest count vis-a-vis the expenditure on this account resulting in more savings from agriculture.

Table 5: Ranking of the variables in group discriminations

Group Comparison	Age	Education	Family Size	Total Land holding	Agril. Land holding	Agril. Expenditure	Agril. Income	Agril. Savings	Cropping Intensity	Pest Count
Group 1 vs Group 2	3	7	4	1	9	10	8	2	5	6
Group 1 vs Group 3	5	1	9	4	7	8	3	10	2	6
Group 1 vs Group 4	6	7	5	2	9	10	8	1	3	4
Group 1 vs Group 5	4	10	1	3	7	9	8	2	6	5
Group 2 vs Group 3	10	1	7	5	9	4	8	6	2	3
Group 2 vs Group 4	1	5	3	10	2	7	4	6	8	9
Group 2 vs Group 5	2	3	9	1	10	6	4	8	5	7
Group 3 vs Group 4	4	3	8	2	10	9	1	7	5	6
Group 3 vs Group 5	10	1	4	2	6	8	5	9	3	7
Group 4 vs Group 5	7	5	9	1	10	6	4	8	3	2

From the above table 5, it's worth noting that total land holding plays major role in discriminating most of the group combinations especially between group 1 and group 2(“learning by doing and good brand" and "shopkeeper's suggestions”); group 2 and group 5 ("shopkeeper's suggestions” and "availability of chemicals") and group 4 and group 5("talking with each other and nearest resource centre" and availability of chemicals"). On the other hand, Education plays important role in differentiating between “Group 1 and group 3”; "group 2 and group 3" and “group 3 and group 5". The factor age also plays role in discriminating between certain groups. Most interesting features of these rankings that these are based on relative contribution in the group discrimination. Though total land holding, education, age etc. are influencing the group of farmers in deciding the type of plant protection chemicals to use, cropping intensity plays an uniform and moderate role in such group discrimination.

Table 6: Linear discriminant scores (D^2) among the groups

	Group 1	Group 2	Group 3	Group 4	Group 5
Group 1	-				
Group 2	3.9194	-			
Group 3	4.011	1.263	-		
Group 4	5.313	0.913	1.708	-	
Group 5	4.207	4.935	5.691	5.921	-

Among the 5 groups of farmers based on their *Modus operandi* in selection of plant protection chemicals, maximum group differences is recorded between group 4 and group 5 i.e. talking to each other and nearest resource centre and availability of plant protection chemicals with highest D^2=5.921. Whereas, lowest inter-group distance (0.913) is recorded between group 2 and group 4 i.e. suggestions from shopkeeper and talking to each other and nearest resource centre. Given the fact that a good percentage of farmers (30%) are illiterate and marginal in nature, majority of the farmers decide plant protection chemicals to be used through discussions, availability of the chemicals and as suggested by the nearby shopkeepers. Thus, the scientific management of plant protection is generally governed by the availability and local knowledge rather than the science of type of infestation and chemicals required for scientific management to combat the pest and disease attack.

Thus from the above study one can conclude that though for better return from agriculture though efficient management of crop using scientific knowledge of plant protection is utmost required, in the study area this is mostly taken care by the local knowledge, wisdom and the availability of plant protection chemicals. Thereby most probably the economics of farming, health and environmental hazards are not given due considerations. Moreover from the study it is also revealed that the younger generation of farmers having better education compared to the aged farmers are relying on branded chemicals and thereby to some extent minimising the agricultural expenditures to reap better harvest vis-a-vis savings from agriculture. In mitigating such situations, most probably the extension services are required to be augmented in educating the farmers and the steps are to be taken to make the right type of plant protections chemicals available during the peak crop seasons.

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