Performance of IPM Techniques on Pesticide use and Yield of Vegetables

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ABSTRACT

Background: Integrated Pest Management (IPM) is an approach for plant protection that was designed to reduce the need of chemical control. It is a complex, knowledge-based technology that combines biological, cultural and chemical control methods to keep pests below economically acceptable level. This study was done to assess the impact of IPM technology on pesticides use and yield of vegetable crops.

Methods: A total of five hundred vegetable grower farmers from Banke and Surkhet districts of Lumbini and Karnali provinces, respectively, were purposively selected as the study area. These districts are the major vegetable growing areas in Nepal. Yield function was developed in estimating the functional relationship. Pesticide input was used as independent variable to know the effect of pesticide on vegetable yield. To detect the impact of IPM-technology on vegetable yield linear regression was used in this study.

Result: IPM practicing farmers were significantly younger and more educated than control farmers. Pesticides and bio-pesticides were the major inputs used for controlling pests and diseases. Based on the sign and coefficient of the IPM (practice) variable, it has been concluded that use of IPM has positive and significant effect on the net revenue from the vegetables.

Key words: IPM Technology, Impact, Vegetable, Linear regression, Yield function.

INTRODUCTION

The use of synthetic pesticides in agriculture has increased exponentially after the introduction of high-yielding varieties and hybrids in the late 1940s. At the beginning of the current millennium the world pesticide use exceeded 2.5 million tons and the world pesticide expenditures were around $ 32.0 billion (EPA, 2002). The negative consequences on human health, water quality, biodiversity and wild life associated with the release of large quantities of toxic products in the environment has increasingly become a matter of concern (Harper and Zilberman, 1989; Agne et al., 1995). Integrated Pest Management (IPM) is an approach toward plant protection that was designed to reduce the need for chemical control. It is a complex, knowledge-based technology (Hall and Duncan, 1984) that combines biological, cultural and chemical control measures to keep pests below economically acceptable levels (USDA, 1993).

Integrated pest management technology, a package of practices that utilizes natural predators and careful timing of right doses, is one of the most important measures to cut the use of pesticides. It is not surprising evidence that the application of pesticides during the periods has increased substantially along with incredible amount of subsidies (Irham and Mariyono, 2002). This was considered one of the key successes in the intensification program in Indonesia, that is, the substantial increase in crop production because of the increase in crop yield through intensive use of inputs including chemical pesticides. But, most of the researchers believe that without indiscriminate use of pesticides, increase in application of pesticides lead to a number of consequences such as elimination of natural enemies, pesticide-resistant pests and frequent pest outbreaks, so that crop losses increase (Barbier, 1989; Conway and Barbier, 1990; Rola and Pingali, 1993; Zilberman and Castillo, 1994; Saha et al., 1997). In addition, pesticides also impacted on human health (Wilkinson, 1988; Rola and Pingali, 1993; Antle and Capalbo, 1994; Antle and Pingali, 1994; Kishi et al., 1995; Nhachi, 1999) and the environmental contamination (Pimentel et al., 1993; Bond, 1996).
**MATERIALS AND METHODS**

**Source of data**

The data were generated from a farm survey conducted in two districts in 2017/18. Five hundred vegetable grower farmers were purposively selected in the survey, out of them two hundred and fifty of them who have practiced IPM technology. Banka and Surkhet districts of Lumbini and Karnali provinces respectively were selected as the study area. The selected region constitutes one of the major vegetable production centers of Nepal, where Integrated Pest Management Innovation Lab (IPM-IL) program funded by USAID has been promoted.

**Underlying theory**

A production function explained in the microeconomic theory was used as fundamental analysis. Related to the introduction of new technology, the production function was mathematically expressed as follows:

\[ Y = f(X, L, T, S) \]

where

- \( Y \) is output,
- \( X \) is vector of inputs, 
- \( L \) is land, 
- \( T \) represents different technology and 
- \( S \) represents different states of nature.

In Asian developing countries, it has been pointed out by Hayami and Rutan (1985) agricultural production technology exhibits constant returns to scale. This means that output will multiply by a factor \( \theta \) if all inputs and land are multiplied by the same factor, such that:

\[ \lambda Y = f(\lambda X, \lambda L, \lambda T, \lambda S) \]

for any \( \lambda > 0 \). If \( \lambda = 1 \), the production function can be expressed as yield function, that is:

\[ y = f(x, T, S) \]

where

\[ y = Y L \]  and \( x = X L \). Variable land, \( L \) collapses because it becomes unity and constant.

**Econominc modeling**

Yield function was developed in estimating the functional relationship. Pesticide input was used as independent variable to know the effect of pesticides on vegetable yield. To detect the impact of the IPM-technology on vegetable yield, a dummy variable was introduced into the model. A Cobb-Douglas model was used in this study. Soekartawi et al. (1986) stated that the Cobb-Douglas model suitable to estimate agricultural production functions. In terms of a log-linear functional form, the Cobb-Douglas model is formulated as:

\[ y = \alpha + \sum_{i=1}^{8} \beta_i \ln(x_i) + \gamma T + \sum_{j=1}^{8} \delta_j S_j + \epsilon \]

where

- \( y \) is yield of vegetable (kg/ha);
- \( x \) is inputs for \( i = 1, 2, \ldots, 8 \);
- \( T \) is dummy variable for IPM- users;
- \( S_j \) is dummy variables for \( j=1 \) for growing seasons; 
- \( \alpha \), \( \beta_i \), \( \gamma \) and \( \delta \) are coefficients of regression; and
- \( \epsilon \) is error terms.

Having a strong claim about the superiority of the IPM technology, it was assumed that if the all farmers have adopted the technology, there was no difference in productivity between IPM-users and non-users. Descriptive analysis on pest infestation, pesticide use and micro-economic indicators are primarily used to justify the estimated econometric outcome (Mariyono, 2007).

**Impact of IPM practice on income from vegetable**

The farmers who adopted at least one or more IPM practices were treated as IPM adopters. The income from vegetable yield was considered as dependent variable and was measured on the basis of inputs required for vegetable growing. Linear regression analysis was applied to identify the impact of IPM practice on vegetable yield. Though in such case, other analytical models may apply, the linear regression is an appropriate model that allows the examination on the impact of each independent variable on the dependent variable (Paudel and Thapa, 2004). The model is presented below:

\[ Y = B_0 + B_1 X_1 + B_2 X_2 + \ldots + B_n X_n \]

where

- \( Y \) = dependent variable (Income from vegetable yield and pesticide use),
- \( B_0 \) = intercept, \( B_1, B_2, \ldots, B_n \) = coefficient of the explanatory variables, \( X_1, X_2, X_n \) = explanatory variables (seed treatment, soil solarization, bio-fertilizers, jholmol, pheromone traps mulching and bio-pesticides).

**Results and Discussion**

IPM practicing farmers were significantly (8.27 year; \( P < 0.01 \)) younger and more educated than control farmers (more people had completed the secondary school; \( P < 0.01 \)). Similarly, there were significant differences in average total land holdings (\( P < 0.01 \)) and average area under cucumber (\( P < 0.01 \)), eggplant (\( P < 0.01 \)), bitter gourd (\( P < 0.01 \)) and cauliflower cultivations (\( P < 0.01 \)) between IPM practicing and control farmers. There was no significant difference in average area under tomato cultivation (0.07 and 0.06 ha for IPM and control farmers, respectively). The detail is given in Table 1.

It has been found that IPM adopters had significantly lowered the pesticide cost as compared to non-adopters. It may be indicated that IPM adoption reduced dependency on chemical pesticides, which may positively affect human health and the environment. Due to low cost of pesticides, IPM adopters may receive higher net returns on vegetable crops. In summary, IPM adopters maximized their profit by sinking cost compared to non adopters; Similar, finding was found in some other studies (Karim et al., 2013; Gautam et al., 2017; Pretty and Bharucha, 2015). The adoption of IPM practices also had a significant effect on farmer technology efficiency level. Higher technology efficiency is due to the improvement in extension services, such as training and demonstrations; as these factors are necessary have and had a significant impact on adoption (Rahman et al., 2018; Rahman and Norton, 2019).

**Impact of IPM practice on tomato yield**

The impact of IPM practice on yield of tomato is given in Table 2. Even though the coefficient determination is relatively low, overall test showed high level of significance. It has affirmed that bio-fertilizers, jholmol, pheromone traps,
mulching practices and bio-pesticides inputs significantly increased the yield of tomato. On the other hand, seed treatments and soil solarization has significantly reduced the yield. It is logical because seed treatments and soil solarization have no impact on yield. The study done by Gautam et al., 2017; Rahman et al., 2018; and Rahman and George, 2019 have also found that IPM is not always effective in increasing the productivity. This may be due to the fact that farmers were found to be unresponsive when it came to adopt the full package of IPM and that yield is also driven by other factors than IPM. Lichtenberg and Zilberman (1986) also found that pesticides have positive impact on yield or production if susceptible pest infestation exists. Bio-fertilizers, jholmol, mulching practices and bio-pesticides used were found significant in the yield of tomato. The estimated function for tomato income was:

\[
Y = 1.449 - 0.007 X_1 + 0.264 X_2 + 0.185 X_3 + 0.037 X_4 + 0.150 X_5 + 0.273 X_6
\]

Impact of IPM practice on cucumber yield

The impact of IPM practice on cucumber yield is given in Table 3. Seed treatment, soil solarization, bio-fertilizers, jholmol and mulching inputs significantly increased the yield of cucumber. On the other hand, jholmol and bio-pesticides has significantly reduced the yield. Seed treatment, bio-fertilizers, pheromone traps and mulching were found significant whereas soil solarization, jholmol and use of bio-pesticides were not significant. Mariyono (2007) in his study also found that use of bio-pesticides has no impact on yield of rice. The estimated function for cucumber income was:

\[
Y = 0.642 + 0.137 X_1 + 0.018 X_2 + 0.181 X_3 + 0.016 X_4 + 0.255 X_5 + 0.350 X_6 - 0.018 X_7
\]

Impact of IPM practice on eggplant yield

The impact of IPM practice on eggplant yield is given in Table 4. Seed treatment, soil solarization, bio-fertilizers, jholmol and mulching inputs significantly increased the yield of eggplant. On the other hand, pheromone traps and bio-pesticides have significantly reduced the yield. Mariyono and Irham, 2001; Mariyono et al. 2002 also found that IPM technology has escalated in rice production. Seed treatment, bio-fertilizers, jholmol, pheromone traps and mulching were found significant whereas soil solarization and use of bio-

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**Table 1:** Descriptive Statistics of the IPM practice and conventional practice.

| Variable                  | IPM practice | Conventional practice | t-value | P value |
|---------------------------|--------------|-----------------------|---------|---------|
| Age (yr)                  | 37.82        | 46.09                 | -9.49***| 0.00    |
| Education*                | 2.45         | 1.48                  | 11.556***| 0.00    |
| Pesticides cost (Rs/ha)   | 196297.2     | 219708                | -19.79***| 0.00    |
| Tomato area (ha)          | 0.07         | 0.07                  | 0.50    | 0.61    |
| Cucumber area (ha)        | 0.03         | 0.04                  | -3.28***| 0.001   |
| Bitter gourd area (ha)    | 0.02         | 0.03                  | -1.8784*| 0.0609  |
| Cauliflower area (ha)     | 0.05         | 0.04                  | 3.0940***| 0.0021  |

*Education level 1=Illiterate, 2=Primary School, 3=Secondary School, 4=Graduate

*** Significant at p<0.01; ** significant at p<0.05; * significant at p<0.1

Source: Field Survey (2017).

**Table 2:** Regression results of yield function of tomato.

| Variables (IPM practices) | Unstandardized coefficients | Standard error | Standardized coefficients Beta | t-value | P value |
|---------------------------|------------------------------|----------------|-------------------------------|---------|---------|
| Constant                  | 1.449                        | 0.782          | 1.853*                        | 0.064   |
| Seed treatment            | -0.020                       | 0.085          | -0.007                        | -0.232  | 0.817   |
| Soil solarization         | -0.073                       | 0.080          | -0.029                        | -0.911  | 0.363   |
| Bio-fertilizers           | 0.278                        | 0.070          | 0.264                         | 3.982***| 0.000   |
| Jholmol                   | 0.298                        | 0.064          | 0.185                         | 4.629***| 0.000   |
| Pheromone traps           | 0.094                        | 0.083          | 0.037                         | 1.141   | 0.255   |
| Mulching                  | 0.178                        | 0.069          | 0.150                         | 2.583** | 0.010   |
| Bio-Pesticides            | 0.325                        | 0.0507         | 0.273                         | 5.745***| 0.000   |
| R²                        |                              |                | 0.568                         | 81.192***| 0.00    |

*** Significant at p<0.01; ** significant at p<0.05; * significant at p<0.1

Source: Field Survey, 2017.
pesticides were not significant. The estimated function for eggplant income was:
\[ Y = 1.000 + 0.018 X_1 + 0.093 X_2 + 0.143 X_3 + 0.251 X_4 - 0.143 X_5 + 0.423 X_6 - 0.045 X_7 \]

**Impact of IPM practice on bitter gourd yield**

The impact of IPM practice on bitter gourd yield is given in Table 5. Seed treatment, bio-fertilizers, jholmol, pheromone traps and mulching practices inputs significantly increased

### Table 3: Regression results of yield function of cucumber.

| Variables            | Unstandardized coefficients B | Standard error | Standardized coefficients Beta | t-value | P value |
|----------------------|-------------------------------|----------------|-------------------------------|---------|---------|
| Constant             | 0.642                         | 1.658          | 0.387                         | 0.699   |
| Seed treatment       | 0.332                         | 0.131          | 0.137                         | 2.535** | 0.012   |
| Soil solarization    | 0.041                         | 0.126          | 0.018                         | 0.322   | 0.747   |
| Bio-fertilizers      | 0.197                         | 0.071          | 0.181                         | 2.784***| 0.006   |
| Jholmol              | -0.044                        | 0.154          | -0.016                        | -0.282  | 0.778   |
| Pheromone traps      | 0.494                         | 0.110          | 0.255                         | 4.475***| 0.000   |
| Mulching             | 0.439                         | 0.083          | 0.350                         | 5.256***| 0.000   |
| Bio-Pesticides       | -0.033                        | 0.101          | -0.018                        | -0.321  | 0.748   |
| R²                   | 0.516                         | 0.516          |                               |         |
| F-test               | 17.516***                     | 17.516***      |                               |         |
| Durbin Watson        | 1.572                         | 1.572          |                               |         |

*** Significant at p<0.01; ** significant at p<0.05; * significant at p<0.1

Source: Field Survey, 2017.

### Table 4: Regression results of yield function of eggplant.

| Variables            | Unstandardized coefficients B | Standard error | Standardized coefficients Beta | t-value | P value |
|----------------------|-------------------------------|----------------|-------------------------------|---------|---------|
| Constant             | 1.000                         | 1.533          | 0.652                         | 0.515   |
| Seed treatment       | 0.264                         | 0.154          | 0.108                         | 1.708*  | 0.090   |
| Soil solarization    | 0.219                         | 0.148          | 0.093                         | 1.475   | 0.142   |
| Bio-fertilizers      | 0.163                         | 0.096          | 0.143                         | 1.697   | 0.092   |
| Jholmol              | 0.504                         | 0.128          | 0.251                         | 3.945***| 0.000   |
| Pheromone traps      | -0.286                        | 0.128          | -0.143                        | -2.236**| 0.027   |
| Mulching             | 0.578                         | 0.152          | 0.423                         | 3.801***| 0.000   |
| Bio-Pesticides       | -0.070                        | 0.179          | -0.045                        | -0.390  | 0.697   |
| R²                   | 0.508                         | 0.508          |                               |         |
| F-test               | 13.268***                     | 13.268***      |                               |         |
| Durbin Watson        | 1.681                         | 1.681          |                               |         |

*** Significant at p<0.01; ** significant at p<0.05; * significant at p<0.1

Source: Field Survey, 2017.

### Table 5: Regression results of yield function of bitter gourd.

| Variables            | Unstandardized coefficients B | Standard error | Standardized coefficients Beta | t-value | P value |
|----------------------|-------------------------------|----------------|-------------------------------|---------|---------|
| Constant             | 1.349                         | 1.625          | 0.830                         | 0.408   |
| Seed treatment       | 0.117                         | 0.139          | 0.044                         | 0.843   | 0.400   |
| Soil solarization    | -0.102                        | 0.136          | -0.040                        | -0.749  | 0.455   |
| Bio-fertilizers      | 0.617                         | 0.065          | 0.519                         | 9.522***| 0.000   |
| Jholmol              | 0.355                         | 0.094          | 0.207                         | 3.755***| 0.000   |
| Pheromone traps      | 0.152                         | 0.136          | 0.059                         | 1.116   | 0.266   |
| Mulching             | 0.083                         | 0.079          | 0.057                         | 1.058   | 0.291   |
| Bio-Pesticides       | -0.099                        | 0.114          | -0.046                        | -0.865  | 0.388   |
| R²                   | 0.540                         | 0.540          |                               |         |
| F-test               | 19.796***                     | 19.796***      |                               |         |
| Durbin Watson        | 1.617                         | 1.617          |                               |         |

*** Significant at p<0.01; ** significant at p<0.05; * significant at p<0.1

Source: Field Survey, 2017.
the yield of bitter gourd. On the other hand, use of soil solarization and bio-pesticides has significantly reduced the yield. It is logical because bio-pesticides have no impact on yield. Mariyono (2007) in his study also found that use of pesticides has no impact on yield of rice. Bio-fertilizers and jholmol were found significant whereas seed treatment, soil solarization, pheromone traps, mulching practice and use of bio-pesticides were not significant. The estimated function for bitter gourd income was:

\[ Y = 1.349 + 0.044 X_1 - 0.040 X_2 + 0.519 X_3 + 0.207 X_4 + 0.059 X_5 + 0.057 X_6 + 0.046 X_7 \]

**Impact of IPM practice on cauliflower yield**

The impact of IPM practice on cauliflower yield is given in Table 6. Soil solarization, bio-fertilizers, jholmol, mulching practice and bio-pesticides inputs significantly increased in yield of cauliflower. Bio-fertilizers, mulching and bio-pesticides were found significant whereas seed treatment, soil solarization, jholmol and pheromone traps were not significant. Lichtenberg and Zilberman (1986) also found that pesticides have positive impact on yield or production if susceptible pest infestation exists. The estimated function for cauliflower income was:

\[ Y = 0.427 + 0.000 X_1 + 0.035 X_2 + 0.270 X_3 + 0.025 X_4 - 0.009 X_5 + 0.245 X_6 + 0.380 X_7 \]

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