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Need for agrochemicals in era of organic farming: An economic study

G. K. VANI, [1]G. BHANDARI, [2]V. R. RENJINI, [3]S. SAHU AND [4]P. MISHRA

Department of Agricultural Economics, College of Agriculture, JNKVV, Jabalprur, Madhya Pradesh
[1]National Dairy Research Institute, Karnal,Haryana
[2]Indian Agricultural Research Institute, Pusa- 110001, New Delhi
[3]West Bengal State University, Barasat, West Bengal
[4]College of Agriculture, Powarkheda, JNKVV, Jabalpur, Madhya Pradesh

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ABSTRACT

Over the last half century, global gross agricultural output has more grown exponentially debunking the Malthusian fear of food supplies being outstripped by rapid population growth. Green revolution has changed the scenario of food production but with higher cost to environment. To reduce damage to environment from use of chemical-intensive production practices, researchers suggest organic agricultural practices. The present study attempts to find out the contribution and relationship of chemical use to agricultural growth at global context. This will help to understand the scenario at aggregate level and will indicate how feasible the recommended substitution is. Secondary data and simple regression have been used for this purpose. The findings of the study indicate that though excess use of pesticides and fertilizers results in low yield levels but still we cannot substitute organic farming for agrochemicals based farming.

Keywords: Agricultural growth, agrochemicals and organic farming

In the 17th century, the eminent economist Thomas Malthus wrote an essay on the principle of population cautioning the world of impending mass starvation owing to rapid rise in population. These warnings failed to materialize even when the global population grew many folds because of the green revolution which enhanced the agricultural production avoiding widespread famine and malnutrition. Today, the average person in the developing world consumes roughly 25% more calories per day than before the Green Revolution (Hicks, 2011). But, five decades after the green revolution, the world has realized that the increase in food sufficiency has come with a cost of land and water degradation. Characterized by heavy use of fertilizers and other agrochemicals, modern farming practices had failed to withstand sustainability criteria and are now operating under diminishing returns. This realization has led to a shift in preference from input-intensive farming to organic farming and has made organic agriculture as one of the fastest growing agriculture based industry in the world (Bhavsar, 2017; Seufert *et al.*, 2017). Estimates record an increase of 8.9% per annum in land under organic farming worldwide from 15.8 million hectare to 37.2 million hectares over the last ten years. The growth rate of organic markets has been recorded as high as ten percent per annum (Lernoudand and Helga, 2014). The UNEP and the UNCTAD in their report named 'Organic Agriculture and Food Security in Africa' discussed that organic agriculture can be more conducive to food security than most conventional systems, and that it is more likely to be sustainable in the long term. The study found an average of 116% increase in crop yields in 114 projects analysed (United Nations, 2008). Moreover, lack of organically acceptable fertilizers in sufficient quantity poses challenge in obtaining good yields.

Though, this growing share of organic agriculture is quite promising with respect to sustainability but its reliability in ensuring food security for the continuously growing population is still under doubt. In the words of Cambridge chemist John Emsley: "*The greatest catastrophe that the human race could face this century is not global warming but a global conversion to 'organic farming'-an estimated 2 billion people would perish*" (Halweil, 2006). A study conducted in Bhutan in 2012 and 2013 revealed that there were no significant differences between the yields and returns from organic and inorganic paddy production but benefit cost ratio was significantly higher in inorganic paddy cultivation (Tashi and Wangchuk, 2016). The scientists at University of Minnesota and the McGill University in Montreal conducted a Meta-analysis of 66 studies involving 34 different crop species across conventional and organic methods. They conclude that, overall, organic yields are considerably lower than conventional yields (Biello, 2012). Lower prevalence of pest and diseases on organic farms can be effect of being surrounded by conventional farms which use agrochemicals to control pests and diseases (Trewavas, 2001). In case of organic farming more area will be required to produce same quantity as compared to conventional farming, ranging from 1.5 to 2 times higher (Rafael, 2007; Trewavas, 2001).

Email: kumaragri.vani1@gmail.com

With this background, the present study attempted to estimate the extent of substitution possible between organic and agrochemical based farming and henceforth discussed its feasibility at the global level.

MATERIALS AND METHODS

Present study is based on secondary data obtained from FAO STAT website (Food and Agriculture Organization, 2014) and 'The World of Organic Agriculture 2014' report (Lernoud and Helga, 2014) on 67 countries. This study had following hypotheses to test through empirical results as

1. Increase in area under organic farming had not contributed significantly to the global agricultural output.
2. Importance of fertilizers had reduced due to greater emphasis on pro-organic practices.
3. There was no synergy between organic farming and capital employed in agriculture.

To test these hypotheses, year 2002 was selected for carrying out analysis which also coincides with data availability on most of the indicators required. Table-1 provides details on variables considered in the present study.

Table 1: Description of variables considered in the study

Variable	Description	Mathematical notation
Area Organic	Proportion of arable land and permanent crops land under organic cultivation in ith country for the year 2002. It includes area both in conversion and already certified as organic	X_{1i}
Chem	Total agrochemical[1] (tonne) used per hectare of arable land and permanent crop land in ith country for the year 2002 including fertilizers. This variable was available only for 40 countries out of 67 in the sample.	X_{3i}
Fert	Average fertilizers (tonne) used per hectare of arable land and permanent crop land in ithcountry for the period 1998- 2002.	X_{4i}
Capital	Gross capital stock (US Dollar at 2005 constant prices) in agriculture per hectare of arable land and permanent crop land of ith country for the year 2002.	X_{2i}
Output	Total output (physical) of crops (tonne) per hectare of arable land and land under permanent crops in ith country for the year 2002. All crops include annual crops like cereal, pulses, fiber crops, coarse grains, vegetables, annual spice crops as well as perennial crops like fruits, plantation crops	X_i

To take care of the residual effect of fertilizer applied in the previous years, data on past five years of fertilizer is averaged with the respective weights being 5, 4, 3, 2 and 1 for recent to old data point in time. This would helpin estimating better effect of fertilizer on crops.

Multiple linear Regression analysis was chosen to empirically test the hypotheses. Following regression equations were used

1. $Y_i = \alpha_1 + \beta_{11}X_{1i} + \beta_{21}X_{2i} + \beta_{31}X_{3i}$ [**Model 1**]

$$Y_i = \alpha_2 + \beta_{12}X_{1i} + \beta_{22}X_{2i} + \beta_{32}X_{4i} + v_1W_{1i} + v_2W_{2i} + v_3W_{3i} \quad \text{[Model 2]}$$

Where,

$W_{1i} = X_{1i}X_{2i}$ [**Area Organic* Capital**]

$W_{2i} = X_{1i}X_{4i}$ [**Area Organic*Fert**]

$W_{3i} = X_{2i}X_{4i}$ [**Capital* Fert**]

[1]*Agrochemicals include both pesticides and fertilizers defined in earlier. Here both pesticides and fertilizers were combined and are used as one variable to avoid the problem of multi-collinearity.*

In both the models dependent variable is total output of crops per hectare of area under crop cultivation. This dependent variable was regressed on area under organic cultivation, total stock of capital and total amount of agrochemicals used in the model 1. By the first hypothesis, it is expected here that coefficient of variable X_{1i} [Area Organic] would not be significantly different from zero. This means that increase in area under organic cultivation had no significant contribution towards world agricultural production. Model 2 has regression of total output on area under organic cultivation, total stock of capital, fertilizer, interaction of area under organic cultivation with capital and fertilizer variables, and interaction of capital and fertilizer. Interaction variables W_{2i} and W_{1i} were added to test for second and third hypotheses, respectively. Interaction variable W_{3i} was added to the Model 2 for including the possibility of increase in fertilizer efficiency as a result of increase in capital stock available to the farm in a given country.

Heteroscedasticity is a major problem in the regression analysis of cross-sectional data. In case of heteroscedasticity, conditional variance of dependent variable depends on value of independent variable. In context of above regression equations, it is expected that as area under cultivation increases across countries, conditional variance of outputwill increase because with larger availability of land for agricultural operations, there are plenty of options regarding cropping pattern which are not available otherwise. To avoid this problem, all variables have been expressed in per hectare of arable land and permanent crop land. Various tests to detect the problem of heteroscedasticity have been suggested, among which two commonly used are Goldfeld-Quandt Test and Breusch–Pagan (BP) (Porter *et al.*, 2004). Present study uses both the test to detect the problem.

'BP test' tests for whether the estimated variance of the residuals or errors from a regression is dependent on the values of the independent variables. For example, to test heteroscedasticity by fitting the following linear regression model

$$y = \beta_0 + \beta_1 X + u$$

We can get residuals i.e., $\hat{u}$. According to the Ordinary Least Square principles, these residuals are normally distributed with mean zero given the independent variables, an estimate of this variance can be obtained from the average of the squared values. If the assumption does not hold, then variance is linearly related to independent variables. Such a model can be examined by regressing the squared residuals on the independent variables, by following equation,

$$\hat{u}^2 = \gamma_0 + \gamma_1 X + v$$

This is the basis of the Breusch–Pagan test. If an F-testconfirms that the independent variables are jointly significant then the null hypothesis of homoscedasticity can be rejected.

In Goldfeld-Quandt test, whole series of dependent variable is arranged in either ascending or descending and which is then divided into two parts after excluding few central observations (usually one fourth of total observations). F test is performed to check the equality of variance of two groups of observation. If F test confirms significance means there is presence of heteroscedasticity.

To overcome the problem of heteroscedasticity, heteroscedasticity consistent variance covariance matrix was used to estimate heteroscedasticity consistent estimator in the regression analysis (Zeileis, 2004, 2006). To perform this analysis R version software (R Core Team, 2017) was used and sandwich package was employed to calculate Heteroscedastic Consistent estimator.

RESULTS AND DISCUSSION

In the table 2 provides the results of regression analysis. Result of Model 1 indicates that coefficient of variable Area Organic is not significant. This means that there was no significant impact of proportion of area under organic farming on national crop output. However, these results suffer from heteroscedasticity problem as confirmed by Goldfeld-Quandt test where F test confirmed it by p value of 5.88834E-21. To re-confirm the results of Goldfeld-Quandt test, BP test was conducted which also confirmed the problem of heteroscedasticity. This problem of heteroscedasticity could arise from other variables like Capital and Chem.

Model 1A provides the result of heteroscedasticity consistent estimators. From these results it is confirmed that organic farming has no significant impact on total crop output as its coefficient is statistically not significant. But the significance of the coefficient for Chem was in line with the scientific research that since green revolution agrochemical usage has improved agricultural production. Model 2, excludes the Chem which was significant variable in the first model and includes only Fert to see separate effect of fertilizer on production. This model also includes all three possible interactions. Although the sign of coefficient for variable Area Organic is negative but the coefficient is

Table 2: Results of regression analysis of total physical production on explanatory variables

Independent variables	Model 1	Model 1A*	Model 2
Intercept	2.705	2.3606e-17	0.09150**
Area Organic	12.229	3.6383e-02	-0.01000
Capital	0.0003 **	1.5138e-01	-0.01337
Chem	31.293 ***	8.4012e-01 *	-
Fert	-	-	1.51648***
Area Organic*Capital	-	-	0.10355
Area Organic*Fert	-	-	-0.16804
Capital*Fert	-	-	-0.11947***
Adjusted R^2	0.950	0.950	0.9606
Sample size	40	40	67
F stat	420.1	-	269.4***

*Note: Signif.codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1 ; * Heteroscedasticity consistent estimates*

statistically insignificant. This suggests that increase in area under organic cultivation did not add significantly to increase in production. The coefficient of variable Fert was significant and positive indicating that increase in fertilizer usage on global scale would result in higher agricultural productivity. This result also attest to the proven fact that in many developing and under-developed countries per hectare fertilizer usage is still far below that of developed country agriculture. The coefficient value of Fert can be interpreted as every additional tonne of fertilizer per hectare if used in the world agriculture would increase the world agricultural production by about 1.5 tonne on an average. Negative sign of coefficient for interaction variable Area Organic*Fert suggests support to a fact that interaction between larger proportion of area under organic cultivation with higher fertilizer usage is negatively correlated with increase in world agricultural production, but the coefficient is statistically non-significant. Statistically non-significance of this variable could be because of less number of countries with larger share of area under organic cultivation. This result shows that importance of fertilizers had not reduced due to greater emphasis on pro-organic practices. The coefficient of variable Area Organic*Capital is statistically not significant leading to acceptance of the third hypothesis. This means that there was no synergy between organic farming and capital employed in agriculture towards increasing the world agricultural production. This could be due to low levels of mechanization on organic farm which are located in under-developed and developing countries around the world. High value of coefficient of determination in both models suggests that linear specification had good fit on the cross-section data used in this study. Negative and significant coefficient of Capital*Fert indicates that excess use of these two inputs resulted in negative effect on the world agricultural production.

From the foregoing analysis, it can be inferred that organic cultivation had no significant impact on total crop output in the year 2002. However, qualitative improvements accruing from organic farming to ecology and environment cannot be denied. Also, agriculturist should continue to apply fertilizer and pesticides. But indiscriminate use of agrochemicals must be avoided at all cost. This study found no synergistic effect of organic agriculture with capital on the world agricultural production. This study was based on historic data. It could not control for time and country specific effect. Future studies however must use panel data to find the role of organic farming in more robust ways.

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