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Why do Smallholder Farmers Apply Inorganic Fertilizers below the Recommended Rates? Empirical Evidence from Potato Production in Eastern Ethiopia

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Abstract

Evidences suggested that use levels of inorganic fertilizers in potato production in Ethiopia are below the recommended rates. This study is aimed at accessing factors contributing to this. The study utilized data collected from 171 randomly selected potato producing households. A two-limit Tobit model result revealed that variation in districts, access to irrigation, frequency of extension contact, and livestock holding significantly affected intensity of adoption of both DAP and Urea in potato production. In addition, access to credit and annual income significantly determined adoption intensity of DAP. It is therefore, essential to give due emphasis to these determinants in supporting smallholder farmers in order to enhance potato productivity.

Keywords: Inorganic fertilizers; Adoption index; Intensity of adoption; Two-limit tobit model; JEL:D13; D24; Q12

Introduction

Potato (*Solanum tuberosum* L.) is a strategic food security crop in Ethiopia as lives of millions depend on the crop for cash income, food and, nutritional security. The crop is nutritionally rich in calories, vitamins, and nutrients and a good source of income [1,2]. The crop ranks first in area coverage and third in both total production and productivity among the root crops grown in Ethiopia. During the main cropping season 2015/16, a total potato production accounts for about 943,233 tons with an average productivity of 13.5 t/ha in Ethiopia. Area under potato production was about 70,132 ha, with a total of 1.4 million households engaged in cultivating the crop in the same year [3].

Many factors limit the productivity level of the crop. Among these, lack of improved variety along with the recommended packages is the major ones [1,2,4]. Doss et al. [5] expected that farmers adopt new varieties of seed first and then fertilizer. However, this was not the case in all areas they investigated. In Ethiopia, they observed areas where fertilizer adoption outstripped adoption of improved varieties. By and large, unless soil fertility is not improved, the use of other technologies such as high-yielding varieties will not have a significant impact to realize fruitfulness of the efforts [6]. Concurrent to this, farmers' use of fertilizers to the best of the recommendation rate in crop production remains low for various reasons [7,8].

In eastern Ethiopia, potato is a source of income for various potato value chain participants; thereby supporting the livelihood of millions [9-11]. East Hararghe is characterized by intensive land use associated with small landholding, suitable agro-ecology for cash crops like potato [12] and high domestic and export market niches for vegetables [10,11]. In spite of these opportunities to support potato production in the country in general and in eastern parts of the country in particular [1], productivity from the crop remains low. This situation is not different from the realities that yields of potato are relatively low in developing countries [13]. Prior studies conducted in potato technology adoption revealed low level of adoption of related technologies in the country [14-16].

Use levels of DAP (Di-Ammonium Phosphate) in potato production was about 21% while only about 1% of land under potato production received Urea application in East Hararghe zone [17]. Though studies show that farmers applied both organic and inorganic fertilizers, use of inorganic fertilizers is low [18]. Low levels of inorganic fertilizer application are due to several factors. These include, socioeconomic and institutional factors [19,20], technical knowledge [21,22], high costs [23-25], farmers risk taking behavior [26], and geographical conditions [26-29]. However, the effects of these factors were found not universal [8,30,31].

Factors determining the low use level of inorganic fertilizers in potato production in eastern Ethiopia were scantily known. The objective of this study is, therefore, to explore determinants of intensity of adoption of DAP and Urea in potato production in East Hararghe zone of Ethiopia.

Methodology

Description of the study area

The study was conducted in three districts, Gurawa, Haramaya, and Kombolcha of East Hararghe zone in eastern Ethiopia.

Gurawa district: Gurawa is one of the districts in East Hararghe zone with high agricultural production potential. The altitude of the district ranges from 500 to 3230 meters above sea level (masl). The district has an estimated total population of 300,661 [32]. The district is known for its production of staple crops (wheat, barley, and Irish potato) and fruit (apple) production [12].

Haramaya district: Haramaya is one of the districts of east Hararghe Zone. The district has an estimated total population of 352,031 according to CSA [32]. The altitude of this district ranges from 1400 to 2340 masl which enable the area to be categorized under the Ethiopian highlands.

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It is situated in the semi-arid tropical belt of eastern Ethiopia. The mean annual rainfall received ranges from 600 to 1260 mm with bimodal nature. The relative humidity varies between 60 and 80%. Minimum and maximum annual temperatures range from 6°C to 12°C and 17°C to 25°C, respectively. Mixed crop and livestock production system is practiced in the district. Crop production with the diverse cropping system is the dominant agricultural system where maize, sorghum, and vegetables production is common in the area.

Kombolcha district: Kombolcha is also one of the eighteen districts in East Hararghe Zone. The altitude of the district ranges from 1600-2400 masl. The district is strategically located between the two main cities Harar and Dire Dawa. In addition, due to its proximity to Djibouti, the district has access to potential markets in the area. The total population of Kombolcha district [32] is 178,058. Lowland and midland agro-ecological zones characterize the district's climate. Annually, the district receives mean annual rainfall of 600-900 mm, which is bimodal and erratic in distribution. The major crops produced in the district include sorghum, maize, vegetables (potato, tomato, cabbage, onion, and carrot), khat, groundnut, coffee, and sweet potato.

Sampling procedure

A cross-sectional study design was used. Household survey questionnaire was administered to collect data from the smallholder farmers drawn from the study districts. Multistage sampling technique was employed. The steps involved were purposive selection of the three districts which are known for their potato production, followed by random selection of two representative *Kebeles* from each district making a total of six *Kebeles*. As final respondents, a total of 171 household heads were randomly chosen from a population of potato growing farmers in the selected *Kebeles*.

Data sources and methods of data collection

Primary data on household socioeconomic characteristics, farm characteristics, institutional factors, use of inorganic fertilizers, and other variables were collected using structured questionnaire during 2015/2016 production year. Additional information on recommended inorganic fertilizer rates were collected from secondary sources.

Specification of econometric model

The selection of econometric model requires taking into account the nature of the dependent variable, among others. The dependent variable, the adoption index, is a continuous value between zero and one in this study. It is an index value ranging from 0 to 1, for which 0 indicates the non-adopter, 1 represents the full adopter of the inorganic fertilizer, and values lying in between 0 and 1 indicate the level of the adoption within the ranges of the two-limits. A dependent variable which bears a zero value for a significant portion of the observations requires a censored regression model (Two-limit Tobit model). Such censored regression is preferred because it uses data at the limit as well as those above the limit to estimate regression. Following the work of Maddala [33] the Tobit model can be derived by defining a new random variable y^* that is a function of a vector of variables.

The equation for the model is constructed as:

$$y^* = X_i + \beta_i + \varepsilon_i \qquad (1)$$

Where y^* is unobserved for values less than 0 and greater than 1 (called a latent variable) which represents an index for adoption of DAP and Urea fertilizer technologies; X_i represents a vector of explanatory variables; β_i is a vector of unknown parameters; and ε_i is the error term.

By representing y_i (a particular agricultural technology adoption index) as the observed dependent variable, the two- limit Tobit model can be specified as:

$$Y_i = \begin{cases} 0 \; if \; Y_i^* \leq 0 \\ Y_i^* \; if \; 0 < Y_i^* < 1 \\ 1 \; if \; Y_i^* > 1 \end{cases} \qquad (2)$$

Censored regression models (including the standard Tobit model) are usually estimated by the Maximum Likelihood (ML) method. The log likelihood function is specified with an assumption that the error term ε follows a normal distribution with mean 0 and variance δ^2. The Tobit coefficients can be interpreted as coefficients of a linear regression model. Accordingly, factors that influence use intensity of inorganic fertilizers (DAP and Urea separately) was identified using Two-limit Tobit model.

Based on theoretical justifications and prior literature, a number of explanatory variables have been hypothesized to influence the adoption of agricultural technologies, inorganic fertilizers in particular. As a result, several hypothesized variables influencing the decision of intensity of adoption of inorganic fertilizers; DAP and Urea, were included.

Definition of variables

Dependent variable: The dependent variable was an index computed from the intensity of use of inorganic fertilizers. This variable is computed for DAP and Urea separately in order to run two-limit Tobit models. The index values are censored between 0 and 1. Accordingly, DAP use intensity index, the dependent variable in the first model is the ratio of the rate actually applied to that of the recommended DAP rate, where the actual rate is the ratio of total DAP applied on potato plots to total area allocated for the crop. Similar procedure was followed to compute Urea use intensity index.

Predictor variables: Tables 1 and 2 shows lists of predictor variables hypothesized to affect use intensity of inorganic fertilizers (DAP and Urea) in potato production.

Results and Discussion

Descriptive results

The result revealed that about 28% of the respondents had extension contact in a weekly basis implying that they had obtained farm and technology related information from extension personnel. On the other hand, 25% of the farmers had a fortnight basis contact and the same proportion had a monthly basis contact while 11% of the farmers had no contact at all. In terms of irrigation, about 45% of the sampled households have access to irrigation in potato production. Access to credit was found to be low in the study area (13%). On average, about 53% of the respondent households were members to cooperative institution.

Land holding is low in the study areas where it is only about 0.51 ha on average. This necessitates farmers either to intensify their crop production or to focus on cash crops. As potato is primarily produced for market in the study area and it is also a high yielding commodity, the small landholding has created an opportunity to focus on potato production. In addition, livestock ownership in TLU was about 3.95 per household in the sampled districts.

Dependency ratio is 1.33 indicating that one active member of a household supports more than one additional family members. In terms of income, households in Kombolcha earn a higher income (about

Variable	Type of Variable	Description of the variable	Expected sign
Independent variables			
District	Categorical	These are Gurawa, Haramaya, and Kombolcha	+/-
Age	Continuous	Age of household head (in years)	+
Education of household head	Dummy	1 if literate, 0 otherwise	+
Family size	Discrete	Number of individuals in a household	+/-
Distance from all-weather roads	Continuous	Distance from all-weather roads in Km	-
Distance from market	Continuous	Distance from market in Km	-
Frequency of extension contact	Categorical	0 if no contact, 1, 2, 3, and 4 if there is contact in daily, weekly, fortnightly, and monthly basis, respectively.	+/-
Access to irrigation	Dummy	1 if there is access, 0 otherwise	+
Access to credit	Dummy	1 if there is access, 0 otherwise	+
Total land size	Continuous	Total land size in ha	+
Number of plots	Discrete	Number of plots owned	+/-
Cooperative membership	Dummy	1= if member, 0 otherwise	+
TLU	Continuous	Livestock holding in tropical livestock units	+
Dependency ratio	Continuous	The ratio of dependent members to active members	-
Annual income	Continuous	Annual income in ETB from crops, livestock, and off farm activities	+

Table 1: Summary of the predictor variables in use intensity of DAP and Urea.

Predictor variables	DAP			Urea		
	Coefficient	SE (Robust)	t-value	Coefficient	SE (Robust)	t - value
District (*Gurawa* is a reference)						
Haramaya	0.581***	0.128	4.56	0.708***	0.132	5.37
Kombolcha	0.351***	0.124	2.82	0.407***	0.127	3.20
Age	0.001	0.006	0.14	-0.002	0.006	0.32
Education status	0.046	0.105	0.44	0.133	0.106	1.25
Family size (number)	0.013	0.021	0.64	0.011	0.021	0.53
Distance to all weather road (km)	0.023	0.055	0.42	0.014	0.062	0.22
Distance to market (km)	0.007	0.020	0.35	0.007	0.020	0.34
Extension contact frequency (no contact is a reference)						
Every day	-0.255	0.232	1.10	-0.274	0.229	1.20
Every week	-0.352*	0.200	1.76	-0.425**	0.211	2.01
Every fortnight	-0.333*	0.186	1.78	-0.351*	0.211	1.66
Every month	-0.280	0.193	1.45	-0.341*	0.191	1.78
Access to irrigation	0.315***	0.107	2.95	0.181*	0.102	1.77
Access to credit	-0.506**	0.223	2.27	-0.068	0.267	0.25
Farm size (ha)	0.094	0.239	0.39	0.013	0.222	0.06
Membership to cooperative	0.138	0.106	1.30	0.090	0.109	0.82
Livestock ownership	-0.036**	0.017	2.05	-0.030*	0.016	1.92
Dependency ratio	-0.018	0.053	0.33	-0.059	0.051	1.16
Annual income ('000' Birr)	0.006*	0.003	1.90	-		-
Constant	0.422	0.340	1.24	0.862**	0.409	2.11
Log likelihood	-108.13			-99.89		
LR Chi² (18) (17)	4.89***			5.42***		
Number of observations (N)	171			171		
Pseudo R^2	23.23%			23.38%		

Table 2: Parameter estimates of the Two-limit Tobit model.

25,070 Birr per year), followed by those in Haramaya (about 24,350 Birr per year), and Gurawa district (about 16,660 Birr per year).

Farmers in the study area have used about 68% of the recommended rate of DAP where the recommended rate is 195 kg ha^{-1} in potato production. Likewise, the figure is about 75% for Urea utilization in potato production out of the recommended rate of Urea (165 kg ha^{-1}) for potato. The result shows that use levels of these inorganic fertilizers in potato production by and large falls below the recommended rates. This is an indication that there is a yield gap in potato production associated with underutilization of these fertilizers.

Determinants of adoption of DAP and urea in potato production

The two-limit Tobit models for both DAP and Urea showed a good fit at 1% level of significance. Moreover, the overall variance inflation factors (VIF) of all predictor variables in the two-limit Tobit model is found to be less than 10, indicating that multicollinearity was not a severe problem. The model result for DAP use intensity showed that the socioeconomic, demographic, and institutional factors including variation in district, access to irrigation, access to credit, frequencies of extension contact, livestock holding, and annual income were found to significantly determine the use of DAP in potato production. Besides, the model result for Urea use intensity revealed that all other aforementioned determinants of DAP use level, other than access to credit and annual income were also found to significantly influence the use intensity.

In concurrence with socioeconomic, institutional, and other predictors, variations in district was found significantly explaining the use intensity of DAP and Urea in potato production. This could be as a result of differences in potentiality of the districts in potato production. Most importantly, the differences could be due to the variation in terms of factors such as edaphic and climate variables, among others. Accordingly, the result revealed that farmers in potato production potential districts, namely Haramaya and Kombolcha as compared to those in Gurawa district, were found to apply more DAP and Urea. This result is in line with prior studies [22,34,35] that revealed the variation in districts determining use levels of crop technologies in general, and DAP and Urea fertilizer use in crop production in particular.

Farmers access to irrigation explained DAP and Urea adoption intensity positively and significantly. Keeping other factors constant, having access to irrigation was found to favour the farmers likelihood of adoption intensity of DAP and Urea in potato production by the factor of 0.315 and 0.181, respectively. This could be due to the fact that irrigation is an important factor in potato production [36], a crop which has a market orientation goal of production. Using irrigation makes the supply of potato all year round that result in a year round income source for producers and other potato value chain actors. Moreover, irrigation has an added advantage of improving the efficiency of application of inorganic fertilizers as it enhances nutrient uptake by plants [37]. This result is consistent with earlier findings that indicated positive influence of irrigation on use of crop technologies [35,36].

The results for frequency of extension contact was negative in explaining use intensity of DAP and Urea fertilizers in potato production, against the expectation. Potato producing farmers who had no contact with extension personnel were found to have more likelihood of applying these fertilizers as compared to those who had different frequencies of extension contact. This might have happened as a result of giving less focus on advising farmers on the use of inorganic fertilizers at the expense of giving more focus on other technologies. Hence, the negative influence of frequency of extension contact clearly indicates that the potential plan of having many extension personnel could not help to realize the intended positive effect unless due attention is given on the efficiency of extension personnel to deliver timely and appropriate technological information.

Livestock holding was found to negatively and significantly determine DAP and Urea use intensity. Usually, households with more number of livestock holding do minimize capital constraints to purchase agricultural inputs as well as to capacitate their risk taking behaviour in using crop technologies. In fertilizer adoption, however, it is against this expectation owing to the fact that manure obtained from livestock could substitute the inorganic fertilizers, as also revealed by other studies [22,38].

Access to credit negatively explained adoption intensity of DAP, against the expectation. This could be because credit users might be financially constrained as compared to the non-users as farmers' income is relatively better in the study area. As a result, credit users might have used the money they borrowed for activities other than purchase of inorganic fertilizers.

Annual income was found to significantly and positively determine DAP use intensity in potato production. This could be due to the fact that farmers with better income do not face financial constraints for purchasing DAP. This result is consistent with prior studies that showed positive influence of annual income on adoption of crop technologies [39,40].

Conclusion

This study analyzed determinants of adoption intensity of inorganic fertilizers in potato production. Data collected from a total of 171 farmers sampled from Gurawa, Haramaya, and Kombolcha districts were analyzed using Two- limit Tobit model and descriptive analysis. Descriptive results indicated that about 68% of the recommended DAP rate was applied by the sampled farmers. Likewise, about 75% of the recommended Urea use level was applied in potato production. By and large, these results showed that there is underutilization of inorganic fertilizers in the study districts. Tobit model results revealed that variation in district, access to irrigation, access to credit, frequency of extension contact, livestock holding, and annual income were found to significantly determine the use of DAP and Urea in potato production. In addition, access to credit and annual income were also found to significantly determine adoption intensity of DAP.

Recommendations

Access to irrigation is found to determine the use level of inorganic fertilizers in potato production positively indicating that irrigation is becoming a vital input in the changing climate. It is, therefore, necessary to expand small scale irrigation facilities and to encourage farmers to get access to available water sources.

Uses of inorganic fertilizers are still lagging behind the recommended levels in potato production. Thus, farmers should be encouraged to increase use levels of these fertilizers in order to optimize the productivity of the crop. Moreover, the study revealed the importance of considering variations in location. Therefore, important cautions should be taken while advising and distributing inorganic fertilizers to farmers in various potato producing locations across districts.

Extension personnel play a crucial role in supporting farmers in using appropriate technologies like inorganic fertilizers. However, under situations where the message is either unavailable or its technical aspect is overlooked, it is unlikely for the farmers to materialize the expected benefit out of the system. The current study revealed that potato is less emphasized in terms of extension messages related to use of inorganic fertilizers. It is, therefore, important for the extension personnel to consider the technology in potato production while advising farmers and providing extension services.

The study indicated that livestock ownership supplement the use of inorganic fertilizer in potato production. Hence, it is advisable for farmers to rear livestock like small ruminants besides crop production. In addition, it is necessary to diversify income sources to enable farmers to access and use recommended levels of inorganic fertilizers.

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