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Econometric Analysis of Effects of Nitrogenous Fertilizer Usage on Tomato Yield in Tokat, Turkey

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A R T I C L E I N F O

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A B S T R A C T

This study aims to investigate the effects of nitrogen fertilizer application on tomato yield by using econometric models. The data obtained by questionnaire from 53 farmers who produce tomatoes in Tokat province constitute the main material of the study. The *Simple Random Sampling Method* was used to determine the sample size with a 90% confidence interval and 10% margin of error. Nine models were tried to determine the best model to explain the effect of nitrogenous fertilizer usage in tomato cultivation. The data in the models were used to calculate the growers' optimal fertilizer amount of use (physical optimum and economical optimum values were calculated) and the results were compared to the ones suggested by the experts. As a result, through the statistical studies, quadratic model was found to be the most suitable one. It has been determined that tomato farmers use less (10.54 kg da^{-1}) or excess (23.48 kg da^{-1}) N fertilizer than the level at which economic optimum is achieved.

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Introduction

There are many different input applications to increase the yield per unit area in agricultural production. Fertilization is one of the most important of these applications. According to many research, balanced fertilization provides more than 50% increase in yield under favorable conditions (Esengun et al., 1999; Bayramoğlu, 2010). Fertilizer, especially nitrogen, can cause serious environmental problems by infiltrating the groundwater and accumulating nitrates in plants that affect human health negatively (Guler, 2006). Unconscious usages of pesticides and fertilizers, improper tillage practices, residual risk, deterioration of soil's physical structure, the deterioration of loss and nutrient balance of organic matter and vitality, salinization, brings about important environmental issues such as desertification (Aksoy, 1999).

Various biological wastes with mineral and organic fertilizers are used improve the physical and chemical properties of soil in the world for many years and to increase the efficiency of materials. Turkey organic matter in the soil, except for limited maintenance is generally poor (Dinç et al., 2001).

Although the consumption of fertilizer, in a continuous increase per unit area in Turkey is currently well below the world average. In particular, grain yield per unit area and quantity of agricultural production is low (Eraslan et al., 2010). Therefore, determination of economic, ecological and technical (physical) quantity of fertilizer application is important.

The aim of this study is to evaluate and compare different quantitative models that explain the effects of nitrogen fertilizer application on tomato yield. In addition, the economic gains or losses of the farmers were determined using the selected model.

Material and Methods

The study constitutes the main material of the data obtained from 53 farmers who grow open field tomatoes in the central district of Tokat province. The data used in this study belong to the production period of 2012-2013 and were collected by questionnaire method.

Nine quantitative models were tested to determine the relationship between the N fertilizer level and tomato yield.

A yield function is given below (Gujarati, 1995):

$$Y = f(X_i/X_j) \quad (1)$$

It is expressed that the Cobb-Douglas type function and the quadratic forms of the polynomial functions which are among the most commonly used as mathematical models to explain the fertilizer-yield relationship are the best explanatory ones (Rehber, 1989). It is assumed that N fertilizer costs are variable and other costs are fixed. In the study, technical and economical use of fertilizer levels was determined. When the first function is derived from the input (fertilizer) and equal to zero, the technical optimum level for fertilizer use can be determined. For the calculation of the level of fertilizer application at economic optimum, the N_{op} was calculated by setting the first derivative of the N fertilizer response curve equal to the ratio between the cost of fertilizer and the price of crop (Karkacıer, 2001).

Economic optimum is: $dy / dx = P_x / P_y$,

Where, P_x is the price of the input (N fertilizer) per unit, and P_y is the price of output (tomato) per unit. In the study, N fertilizer cost and tomato price are 1.19 kg^{-1} \$ and 0.20 kg da^{-1} \$, respectively. The amount of fertilizer suggested by the Institute for Research fertilizer use is taken into account in determining the economic optimum.

Afterwards, economical optimum fertilizer dose was compared to the (±%10) farmers' applications. The use of less than 10% of the optimum fertilizer dose is considered as a low use level and the use of more than 10% of the same dose usage is considered as a high use level. The farmers among these use the fertilizer in an economical level. Several quantitative studies made in this area in Turkey (Oruc and Gürler, 1995; Altintas and Karkacier, 2002; Demirtas and Yilmaz, 2003).

Results and Discussion

In the study, the values of the determination coefficient of the obtained models vary between 0.00 and 0.07. In all models, R^2 values are low for other factors (high yielding seed, irrigation etc.) that affect crop yield.

Since the highest determinant coefficient is obtained by using the quadratic model, the economical optimum level for the use of nitrogen fertilizer is determined by the help of the quadratic model (Table 1). The signs of the estimated coefficients are in the expected direction and statistically significant at the 1% level.

Quadratic function is as follows:

$$Y_N = 3381 - 2{,}1\ N - 0{,}058\ N^2 \quad (2)$$

The difference between the amount of fertilizer recommended by the experts and the amount of fertilizer used by the farmers was determined as 37.63 kg da^{-1} at the technical optimum level and 10.02 kg da^{-1} at the economic optimum level (Table 2).

In this study, it is determined that the farmers used a lower amount of nitrogenous fertilizer than suggested. In a research made in Kazova Plain in Tokat Province, the suggested amount of nitrogenous fertilizer usage is 35.00 kg da^{-1} (Sahin et al., 2011), while in a study carried out by the research institute in the same province, this amount was found out to be 26.7 kg da^{-1} (Noyan et al., 2002). In a study carried out in Tarsus district of Mersin province, Oktem and Bicer (1994) suggested the economic optimum level of nitrogenous fertilizer as 18.5 kg da^{-1} for tomatoes; while Dagdeviren and Ozer (1996) have determined this level as 16 kg in a study in Harran plain, Bilgin (1996) as 12 kg da^{-1} in Aegean region, Sefa et al. (1996) as 18 kg da^{-1} in Bursa Province, Silva et al. (1997) as 20 kg da^{-1}, Kemble et al. (2000) as 17-20 kg da^{-1} in Alabama and Işık (2001) as 17.7 kg da^{-1} in a study carried out in Konya Province. It is seen that the research results differ from the studies carried out in the region but they go around similar values with the suggested amounts in the other studies.

Approximately half of the surveyed farms (45.28%) used more fertilizer than the amount recommended by the research institute and 11.32% used less fertilizer. It has been determined that some farmers lost 241.48 kg da^{-1} in yield using 10.54 kg da^{-1} less nitrogenous fertilizer than the recommended amount. On the other hand, The amount of nitrogenous fertilizer used more than the recommended level was determined as 25 kg. The yield loss for these farms was calculated as 104.41 kg da^{-1}. The amount of loss of money for farms that used excess N fertilizer for tomato was 48.82 \$ da^{-1} (Table 3). Money loss is out of the question in farmers that use less fertilizer.

Table 1 Functional relationships between nitrogenous fertilizer use and tomatoes yield

Models	Equations	R^2
Linear	$Y = 3443 + 6{,}4\ N$	0.04 (6)
Cubic	$Y = 4195 - 115\ N + 3{,}59\ N^2 - 0{,}0319\ N^3$	0.29 (4)
Quadratic	$Y = 3381 - 2{,}1\ N - 0{,}058\ N^2$	0.00 (1)
Square root	$Y = 3153 - 1{,}7\ N + 3201\ \sqrt{N}$	0.07 (7)
Exponential (log-log)	$\log Y = 3{,}47 + 0{,}0106 \log N$	0.01 (2)
Semi-log (lin-log)	$Y = 3214 + 6 \log N$	0.01 (2)
Semi-log (log-lin)	$\log Y = 3{,}51 + 0.00153\ N$	0.15 (3)
Cobb-Douglas	$Y = 3.42\ N^{0.0106}$	0.01 (2)
Reciprocal	$Y = 3560 - 60\ (1/N)$	0.03 (5)

Table 2 Comparison of the farmers' nitrogenous fertilizer usage and yield level with technical and economic optimum (kg da^{-1})

Efficiency Kind	Farmers' usage (1)	Suggested amount by research institute (2)	Difference (1 - 2)
Technical Optimum	18.10	55.73	-37.63
Economic Optimum	16.68	26.70	-10.02

Table 3 Comparison of nitrogenous fertilizer usage levels in tomato production

Variables	Less Nitrogen Used Farms	Excess Nitrogen Used Farms
Average Nitrogen Usage (kg da^{-1}) (1)	16.16	50.18
Nitrogen Dose at Economic Optimum Level (kg da^{-1}) (2)	26.70	26.70
Less (-) and Excess (+) Nitrogen Use (kg da^{-1}) (3 = 1 - 2)	-10.54	23.48
Average Yield (kg da^{-1}) (4)	3125.00	3261.87
Yield at Economic Optimum Level (kg da^{-1}) (5)	3366.28	3366.28
Loss of Yield (kg da^{-1}) (6 = 5 - 4)	241.48	104.41
Loses of Money ($ da^{-1}) (7 = 3 * P_N + 6 * P_Y)	35.76	48.82

Note: P_Y = $ 0.20 per kilo P_N = $ 1.19 per kilo

Conclusions

As a result, help of the quadratic model determines the economical optimum level for the use of nitrogen fertilizer. Therefore, the quadratic model is the most suitable model selected to explain the nitrogen fertilizer - yield relationship in tomato production. It has also been determined that some tomato producers in the region use fertilizer at different levels as recommended. This leads to loss of yield and money. The use of excessive and unconscious fertilizers in agricultural production causes soil pollution and water pollution as well as damage to land. Therefore, producers should be aware of fertilization.

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