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ESTIMATION OF THE OPTIMAL NITROGEN FERTILIZER APPLICATION FOR DIFFERENT INPUT/OUTPUT PRICES AND VARIETIES OF TRITICALE (× *TRITICOSECALE* WITTM.) IN BULGARIAN THRACIAN PLAIN AND DOBRUJA REGION

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Abstract

Triticale is known with its high grain yield potential. This man-made plant is interesting also because its nutritional value which exceeds those of wheat and rye. Triticale breeding studies focus on productivity, green mass, nutritional content, etc. These studies showed the importance of nitrogen fertilizer optimization for triticale. This article focuses on the economic issues of such experiments and provides a systematic approach for studying these aspects. First, the production function is constructed, estimated and the main issues related to this process are discussed. Second, the maximum yield is determined, considering: the variety of triticale; the differences in the regions where the experiments were conducted; and the weather conditions. Third, the yield that maximizes the profit is calculated using the current prices of triticale and nitrogen fertilizer. Finally, the demand for nitrogen fertilizer is estimated. The presented frame can be expanded and to include more parameters.

Key words: *triticale, production function, optimization*

INTRODUCTION

Triticale (× *Triticosecale* Wittmack) is an amphiploid created by interbreeding of two different plants - wheat and rye. The first fertile hybrids occurred from an intergeneric (interspecies) hybridization. Most of the current varieties are descendants of the primary hybrids, which have either common (*Triticum aestivum* L.) or durum (*Triticum durum* Desf.) wheat as a female parent and cultivated rye (Secale cereale L.) as a male parent [6] [10] [12].
Triticale is a crop that exhibits a high productive potential. This is inherited from the dense spike of wheat and the long spike of rye [3] [4] [11] [13].
The combination of the rye's resistance to biotic stress with the wheat's high yield potential resulted in the man-made small grain Triticale (× *Triticosecale* Wittmack). This artificial plant is interesting because of its nutritional value that largely surpasses those of wheat and rye. Triticale breeding studies often focus on major agronomic features such as grain yield, biomass, nutritional value, earliness etc. [2] [8] [9].
Apart from the properties of different cultivars, not many studies have been conducted on crop management and optimization. These studies [1] [5] [7] [14] showed the importance of nitrogen fertilizer optimization for triticale yield. All of them however, consider mainly the technical parameters of the relation between the yield and level of fertilization, quality of the grain ext. In addition, most of the authors work with small data sets and this result in unreliable coefficient when regression analysis is used.
This article focuses on the economic issues of such experiments and provides a systematic approach for studying these aspects. First, the production function is estimated and the main issues related to this process are discussed. Second, the maximum yield is determined, considering: the variety of triticale; the differences in regions where the experiments were conducted; and the weather conditions. Third, the yield that maximizes the profit is calculated using the current prices of triticale

and nitrogen fertilizer. Finally, the demand for nitrogen fertilizer is estimated. The presented frame can be expanded to include more parameters.

MATERIALS AND METHODS

For determining the triticale nitrogen optimal application, data from two parallel field trials have been used. The one was carried out in the northern Bulgaria in the region of Dobruja (43°39'33.0"N 28°02'05.5"E) on *Luvic Phaeozem* soil, and the other – in the southern Bulgaria, Thracian valley (42°08'26.2"N 24°48'21.1"E) on *Mollic Fluvisol* soil, respectively. Five varieties have been examined – AD-7291 (standart), Rozen, Sadovec, Rakita and Zariad. Four nitrogen rates were tested - N_0, N_6, N_{12} and N_{18} kg/da. The trials were set following the split-plot method in 4 replications, the size of the experimental area being 15 m^2.

The production function describes the link between the level of production and the application of inputs. In this article the yield is a function of the applied nitrogen fertilizer, the variety of triticale, the region where the experiments were conducted, and the nature conditions. The effect of nitrogen fertilization is modelled with a cubic function.

In order to estimate the differences in the yields between the varieties and the influence of nature conditions dummy variables are used. There are four variety of triticale and therefore three dummy variables are included into the regression equation. The base variety is assumed to be AD-7291. The experiments are conducted in two regions and therefore one dummy variable is included. The base category in this case is the experiment conducted in Dobruja area. All varieties are expected to have higher yields compared to AD-7291 and also that the yields in Dobruja region is higher compared to these in Thracian valley.

The weather conditions could be very different at least for one of the years during the experiment. If we do not control for them we may have a model misspecification or omitted variable. In this case the regression coefficients could be bias. We control for the weather with two dummy variables for the second and third year of experiment.

Table 1. Definition of variables

Variables	Definition	Measure	Expected sign
Yield	Dependent variable	kg/da	
	Fertilization		
Nitrogen	Continuous variable	kg/da	+
Nitrogen^2	Continuous variable		-
	Varieties		
AD-7291	Based category	0	
D-Rakita	Dummy variable	1 if Rakita	+
D-Sadovec	Dummy variable	1 if Sadovec	+
D-Rozen	Dummy variable	1 if Rozen	+
D-Zariad	Dummy variable	1 if Zariad	+
	Location		
Dobruja	Based category	0	
D- Thracian valley	Dummy variable	*1 if Thracian valley*	-
	Nature		
First year of experiment	Based category	0	
D-Second year of experiment	Dummy variable	1 -if second year	+/-
D-Third year of experiment	Dummy variable	1 -if second year	+/-

Source: Own construction.

The base category is the first year of experiment. The definition of the variables is presented in Table 1.

The biological optimum is the level of nitrogen application that produces maximum yield. In order to determine this level the standard procedure for maximizing a function is used.

The first order condition requires that the first derivative of the production function to be equal to zero.

This means that marginal physical product (MPP) of nitrogen must be equal to zero or the last kilogram of nitrogen produces zero additional production. The second order conditions require that the second derivative of the production function to be smaller than zero.

This means that the marginal physical product of fertilizer should decline.

$$\max_{x}\ y = f(x, D_i)$$
$$FOC:\quad y' = f'(x) = 0 \quad \Rightarrow \quad MPP = 0$$
$$SOC:\quad y'' = f''(x) < 0 \quad \Rightarrow \quad MPP' < 0 \ for\ maximum$$

The economic optimum is the level of nitrogen application that generates maximum profit. In order to determine this level first the profit function is constructed. The profit is equal to revenue minus cost. The revenue equals to the price (p) multiplied by the production function of triticale –f(x). The cost is price of nitrogen fertilizer (v) multiplied by the quantity of fertilizer used (x). Again the standard procedure for maximizing a function is used. The first order condition requires the first derivative of the profit function to be equal to zero. This means that value of marginal physical product of nitrogen should be equal to the price of nitrogen. The second order condition requires the second derivative of the profit function to be smaller than zero. This means that the marginal physical product of fertilizer must decline.

$$\max_{x} \Pi = pf(x, D_i) - vx - FC$$
$$FOC:\quad \Pi' = pf'(x) - v = 0$$
$$\Rightarrow \ pMPP - v = 0$$
$$\Rightarrow \ pMPP = v$$
$$SOC:\quad \Pi'' = pf''(x) < 0$$
$$\Rightarrow \ MPP' < 0 \ for\ maximum$$

RESULTS AND DISCUSSIONS

The descriptive statistics and the correlation matrix are presented in table 2. The total number of observation is 100. The average yield for the period is 425 kg/da. The lowest yield recorded is 144 kg/da, while the highest is 933 kg/da.

The regression results are presented in the table 3. For the first model F-statistics is 62.4, which indicates that the independent variables included in the model contribute well to explanation of the dependent variable (the average yield). The R^2 is 0.86 indicating that the model describes well the experimental data. All regression coefficient are statistically significant at 0.05 level, except for the dummy variables for Sadovec variety and for the third year of experiment. Therefore, statistical support is not found for the yields' differences between the control-AD-7291 and Sadovec. Statistical support was also not found for the differences between the meteorological conditions of the first and third year.

One question that we need to answer is what to do with the variables that are not statistically significant. If we do not find statistical support for their influence on the yield we can drop them from the model unless there are strong theoretical arguments in their favour. In our case, we drop the dummy variables for Sadovec variety and for the third year of the experiment and estimated the model again.

For the second model F-statistics is 80.17 and R^2 is equal to 0.86. All variables are statistically significant. The yield from the base variety AD-7291 is lower compared to Rakita variety with 160.7 kg/da, to Rozen variety with 52.2 kg/da, and to Zariad variety with 43.3 kg/da. Due to more suitable soil and nature conditions in Dobruja area, the yields in Thracian valley are on average lower with 202.91 kg/da. During the second years of the experiment due to better weather conditions the yields were higher with 125.11 kg/da compared to the other two years.

$$\max_{x} y = 333.2249 + 19.9703\text{x} - 0.5286x^2 + 160.7\text{Drakita} + 52.2\text{Drozen} + 43.3\text{Dzariad} + 125.11436\text{Dsecond year}$$

Taking the first and second derivative of the production function we obtain the level of fertilizer application for achieving the maximum possible yield – 18.89 kg/da. After substituting this level of nitrogen in the production function we can obtain the maximum yield.

$$\max_{x} \Pi = 0.3(333.2249 + 19.9703\text{x} - 0.5286x^2 + 160.7\text{Drakita} + 52.2\text{Drozen} + 43.3\text{Dzariad} + 125.11436\text{Dsecond year}) - 0.4x$$

In order to obtain the economic optimum, first profit function is constructed. We use the current price of triticale -0.40 leva/kg and the price of nitrogen fertilizer -0.30 leva/kg.

Taking the first and second derivative of the profit function against, we obtain the level of fertilizer application for achieving maximum profit – 17.63 kg/da. After substituting this level into the production we obtain the yields that maximize the profit. The calculated yields are presented in the Tables 4 and 5.

Table 2. Descriptive statistics

	Depend.	Fertilization		Varieties				Nature		Location
	Yield	*Nitr.*	*Nitr.^2*	*D-Rakita*	*D-Sadovec*	*D-Rozen*	*D-Zariad*	*D-Second year*	*D-Third year*	*D-Thracian valley*
Mean	425.89	9.00	126.00	0.20	0.20	0.20	0.20	0.40	0.40	0.60
St. Error	16.94	0.67	12.66	0.04	0.04	0.04	0.04	0.05	0.05	0.05
St. Dev.	169.41	6.74	126.63	0.40	0.40	0.40	0.40	0.49	0.49	0.49
Min.	144.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Max.	933.00	18.00	324.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Count	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

Source: Own construction

Table 3. The effect of production factors on triticale yields (Production function)

Varieties	**Model 1**			**Model 2**		
	Coefficients	*t Stat*	*P-value*	*Coefficients*	*t Stat*	*P-value*
Intercept	354.5570	13.10	0.00	333.2249	18.01	0.00
Fertilization						
Nitrogen	19.9703	5.80	0.00	19.9703	5.80	0.00
Nitrogen^2	-0.5286	-2.88	0.00	-0.5286	-2.89	0.00
Varieties						
D-Rakita	161.6000	7.74	0.00	160.7000	8.90	0.00
D-Sadovec	1.8000	0.09	0.93			
D-Rozen	53.1000	2.54	0,01	52.2000	2.89	0.00
D-Zariad	44.2000	2.12	0.04	43.3000	2.40	0.02
Location						
D-Thracian valley	-210.3250	-14.24	0.00	-202.9143	-14.86	0.00
Nature						
D-Second year	106.5875	5.46	0.00	125.1143	9.16	0.00
D-Third year	-25.9375	-1.33	0.19			
	R Square=0.86; F=62.4; n=100			R Square=0.86; F=80.17; n=100		

Source: Own construction

The differences between the biological and economics yields are not large. However, in turn of the fertilizer use, the difference is more than one kilogram per decar.

This may not seem an important, but if a farmer cultivates 50 thousand decares he can save around 50 tons of fertilizer with a value of 20,000 leva (10,000 EUROS). This estimation concerns only the money paid for fertilizer, but does not include the transport and distribution costs.

Deriving the demand for nitrogen fertilizer from the profit function allows calculating the changes of optimal level of fertilizer for different prices of triticale and nitrogen fertilizer.

When the price of nitrogen goes up and the price of grain goes down, the optimal use of fertilizer decreases. The estimated values are presented in Table 6.

$$\max_x \Pi = p(333.2249 + 19.9703x - 0.5286x^2 + 160.7\text{Drakita} + 52.2\text{Drozen} + 43.3\text{Dzariad} + 125.11436\text{Dsecond year}) - vx$$

$$\Rightarrow x = 18.88943773 - 0.945874934V/P$$

Table 4. Biological and economic optimum for Dobruja region

Variety		Dobruja			
		First and third year		Second year	
		Biological	Economic	Biological	Economic
Nitrogen	kg/da	18.88944	17.62830	18.88944	17.62830
AD-7291/Sadovec					
Yield	kg/da	521.84	521.00	646.95	646.11
Conditional Profit	leva/da	149.00	149.25	186.53	186.78
Rakita					
Yield	kg/da	682.54	681.70	807.65	806.81
Conditional Profit	leva/da	197.21	197.46	234.74	234.99
Rozen					
Yield	kg/da	574.04	573.20	699.15	698.31
Conditional Profit	leva/da	164.66	164.91	202.19	202.44
Zariad					
Yield	kg/da	565.14	564.30	690.25	689.41
Conditional Profit	leva/da	161.99	162.24	199.52	199.77

Price of triticale =0.30 leva/kg; Price of nitrogen=0.40leva/kg

Source: Own estimation

Table 5. Biological and economic optimum for Thracian valley

Variety		Thracian valley			
		First and third year		Second year	
		Biological	Economic	Biological	Economic
Nitrogen	kg/da	18.88944	17.62830	18.88944	17.62830
AD-7291/Sadovec					
Yield	kg/da	318.92	318.08	444.04	443.20
Conditional Profit	leva/da	88.12	88.37	125.66	125.91
Rakita					
Yield	kg/da	479.62	478.78	604.74	603.90
Conditional Profit	leva/da	136.33	136.58	173.87	174.12
Rozen					
Yield	kg/da	371.12	370.28	496.24	495.40
Conditional Profit	leva/da	103.78	104.03	141.32	141.57
Zariad					
Yield	kg/da	362.22	361.38	487.34	486.50
Conditional Profit	leva/da	101.11	101.36	138.65	138.90

Price of triticale = 0.30 leva/kg; Price of nitrogen = 0.40 leva/kg
Source: Own estimation.

Table 6. The optimal use of fertilizer depending on price changes

Price of fertilizer leva/kg	Price of triticale leva/kg			
V	p= 0.4	p= 0.3	p= 0.2	p= 0.1
	Economic optimum - Nitrogen kg/da.			
0.10	18.6530	18.5741	18.4165	17.9436
0.20	18.4165	18.2589	17.9436	16.9977
0.30	18.1800	17.9436	17.4706	16.0518
0.40	17.9436	17.6283	16.9977	15.1059
0.50	17.7071	17.3130	16.5248	14.1601
0.60	17.4706	16.9977	16.0518	13.2142
0.70	17.2342	16.6824	15.5789	12.2683
0.80	16.9977	16.3671	15.1059	11.3224
0.90	16.7612	16.0518	14.6330	10.3766
1.00	16.5248	15.7365	14.1601	9.4307
1.10	16.2883	15.4212	13.6871	8.4848
1.20	16.0518	15.1059	13.2142	7.5389
1.30	15.8153	14.7906	12.7413	6.5931

Source: own calculation.

CONCLUSIONS

The present study was conducted to evaluate the optimal nitrogen fertilized for varieties of triticale. It focuses on the economic aspects and determines the optimal level of nitrogen application for different input-output prices. The presented frame can be expanded and to include more parameters.

We found statistical support that the yields of Rakita, Rozen, Zariad variety are higher compared to the one of AD-7291-the standard. However, we did not find statistical support for the differences between the standard and Sadovec variety. We also found that the yields in Dobruja area are higher compared to these in Thracian valley. The weather conditions during the second year of the experiment were favourable and the yields were higher compared to the first and second year. Using the current prices, the differences in nitrogen application in biological and economic optimum is about 1 kg/da. Derived demand function for nitrogen fertilizer allows optimal level to be determined for different input/output prices.

The relation between the nitrogen fertilization and yield is best described by the neoclassical production function. This function has three distinctive production phases. The first phase starts at zero application of nitrogen and ends up where marginal physical product (MPP) becomes equal average physical product (APP) of nitrogen. The second phase ends up where marginal physical product becomes zero. This coincides with the maximum production. In our study we use quadratic function for the relation between the nitrogen fertilization and yield. The quadratic function shows only two phases of production-second and third. In order to capture the property of all three phases however, more experimental data are needed for the first phase.

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