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EVALUATION OF THE NITROGEN USE IN WHEAT CROP IN RELATION TO AMMONIUM NITRATE FERTILIZER

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Abstract

This study evaluated the use of nitrogen in wheat crop, in terms of Agronomic Efficiency (AE) and Partial Factor Productivity (PFP). The experiment was conducted in the specific conditions of the Banat University of Agricultural Science and Veterinary Medicine of Timisoara (BUASVM), Timis County, Romania. Nitrogen (N) was provided on the basis of ammonium nitrate, in the range 0 - 250 kg a.s. ha^{-1}, in 11 experimental variants (T1 to T11). The AE index varied between 14.631 (T2) and 9.138 (T11), with a maximum (27.211) corresponding to the N75 dose (T4). The PFP index recorded decreasing values from 90.497 (T2) to 16.725 (T11). The AE index variation in relation to N was described by the polynomial equation of degree 4 (R^2 = 0.975, p <0.01), and the AE index variation according to Y was described by a polynomial equation of degree 3 (R^2 = 0.722, p = 0.0233). In relation to the calculated progressive increase yield (ΔPY) the AE variation was described by a linear equation (R^2 = 0.780, p <0.001). The PFP index variation in relation to N was described by a polynomial equation of degree 3 (R^2 = 0.994, p <0.001), and in relation to N and Y, as simultaneous influence, was described in statistical safety conditions (R^2 = 0.885, p = 0.0144).

Key words: *Agronomic Efficiency (AE), mineral fertilizer, Partial Factor Productivity (PFP), Progressive Increase Yield (ΔPY), wheat*

INTRODUCTION

Agricultural production and productivity of agricultural systems are subject to changes of varying magnitude, in relation to ecological, economic and social elements that influence the functionality of agricultural systems [15, 34, 35, 37, 43, 45].

Particular attention has been paid to the evaluation of agricultural productivity in relation to fertilizers, due to the importance of nutrients in the quantitative and qualitative formation of production [7, 18].

Fertilizer utilization depends on soil conditions [24, 26, 29, 46], climatic conditions [16, 22], crop plants [25, 26] relationships of interdependence in soil nutrients [31], the role of nutrients in plant metabolism [5, 30, 51], fertilizer assortment [1, 6, 42, 50], agricultural technologies and practices [4, 48, 49].

The effectiveness of fertilizers has been studied and evaluated in relation to crop productivity, quality of agricultural production, yields, quality indices, but also in relation to some aspects of environmental quality [3, 32, 39, 41].

Among the nutrients, special attention has been paid to nitrogen (N), through different molecular, eco-physiological, agronomic, economic, environmental approaches, and various indices have been formulated that express the efficiency of nitrogen use [2, 10, 33].

The efficiency of nitrogen use varies in relation to different influencing factors, and has been studied in relation to different crops, plant density, soil and climatic conditions, elements of technology, etc. [8, 10, 40].

In order to improve the use of N, studies and approaches have been carried out in different directions, and it is of interest to improve the genetic potential of cultivated plants [21], [38], the adjustment of agricultural technologies by fertilization [14, 36], nutrient management [9, 12, 44], adjustment of the plants hydric regime [19, 27, 28], optimization of agricultural production systems

[23].

In the context of the interest for the analysis of the efficiency of fertilizer use, of the capitalization of nutrients from fertilizers, of the increased interest for nitrogen (N), the present study evaluated the efficiency of N use in wheat culture, based on two indices, Agronomic Efficiency (AE) and Partial Factor Productivity (PFP), under the conditions of mineral fertilization with nitrogen.

MATERIALS AND METHODS

The experiment on the influence of nitrogen fertilization on autumn wheat cultivation was organized within the Didactic and Experimental Resort (DER) BUASVM Timișoara, Timiș County, Romania. Alex wheat cultivar was cultivated, a productive wheat cultivar with good bakery quality indices. Nitrogen (N) was administered as granulated ammonium nitrate (GAN), with an active substance content of 33.5% N, of which 50% in ammonium form (NH_4^+), and 50% in nitric form (NO_3^-).

The fertilizer was applied in the spring, differentiated on 11 experimental variants (T1 to T11), in doses calculated to ensure nitrogen in the range 0 - 250 kg a.s. ha^{-1} (a.s. - active substance). The variation of N doses was achieved at a rate of 25 kg a.s. The experimental variants were placed randomly, in three repetitions, with a harvestable surface of 18 m^2. The agricultural year 2017 - 2018 was considered for this study.

To evaluate the efficiency of nitrogen (N) use in wheat crop, two indices were calculated, Agronomic Efficiency (AE) [13, 17], relation (1), and Partial Factor Productivity (PFP) [17], relation (2).

$$AE = (Y - Y_0)/F \quad (1)$$

where:

AE – Agronomic Efficiency; Y – production for each variant fertilized with nitrogen (T2 to T11); Y_0 – production to the control variant (T1); F – dose of N corresponding to production Y.

$$PFP = Y/F \quad (2)$$

where:

PFP – Partial Factor Productivity; Y – production for each variant fertilized with nitrogen (T2 to T11); F – dose of N corresponding to production Y.

Experimental data were analyzed by the Anova Test (Alpha = 0.001, p <0.05) to assess the statistical safety of the data and the presence of variance in the recorded data set. The EXCEL computing module (Microsoft Office), the PAST software [20], and the Wolfram Alpha software (2020) [47] were used for mathematical and statistical data processing and analysis.

RESULTS AND DISCUSSIONS

Starting from the wheat production data [11], the efficiency of nitrogen use in wheat crops was evaluated, based on Agronomic Efficiency (AE) [13, 17], relation (1), and Partial Factor Productivity (PFP) [17], relation (2). The values obtained for the nitrogen use efficiency, based on the two indices considered (AE and PFP) are presented in Table 1.

Table 1. AE and PFP index values, wheat crop, Alex cultivar, under the influence of ammonium nitrate fertilizer

Experimental variants		Nitrogen use indices	
Trial	N (kg a.s. ha^{-1})	AE	PFP
T1	0	-	-
T2	25	14.631	90.497
T3	50	24.692	62.625
T4	75	27.211	52.500
T5	100	21.221	40.188
T6	125	19.827	35.000
T7	150	17.440	30.084
T8	175	16.305	27.143
T9	200	14.454	23.938
T10	225	11.848	20.278
T11	250	9.138	16.725

Source: original data for AE and PFP calculated based on N doses, and production data [11].

In the case of the AE index, increasing values were registered, starting from 14.631

corresponding to the N0 dose (T1), up to 27.211 registered at the N75 dose (T4), and the related production.

Starting from the N100 dose and the related production obtained (T5), there was a decreasing trend of AE values, associated with N and Y values used in the calculation, so that at N100 the AE value was 21.221 (T5), and at the maximum dose used in the study (N250) and related production, the value of AE was 9.138 (T11).

The PFP values registered a decreasing distribution in relation to the fertilizer doses, between 90.497 registered at N0 (T1, control) and 16.725 registered in the case of N250 (T11) and the related productions (Y).

The ANOVA single factor test confirmed the presence of the variance in the experimental data set, and statistical safety of the data (F> Fcrit, p <0.001, for Alpha = 0.001).

Agronomic Efficiency (AE) represents the productivity recorded as a result of nitrogen inputs (N), and varies differently in relation to N as an independent variable, respectively in relation to Y as an N-dependent variable. However, the expression of the production also depends on other inputs, elements of technology, the state of health of the plants, or on environmental factors during the vegetation period. The variation of AE was analyzed in relation to the nitrogen doses (N) and in relation to with production (Y).

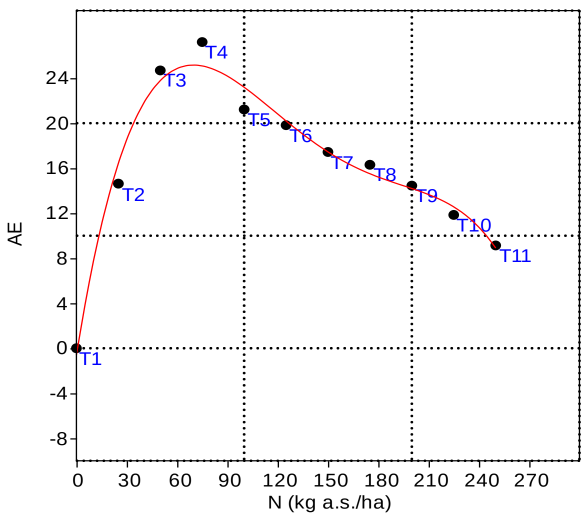

Fig. 1. Graphic distribution of AE values in relation to N, wheat crop, Alex cultivar
Source: original graph

In the case of the present study, the variation AE according to N was described by a polynomial equation of order 4, equation (3), in conditions of $R^2 = 0.975$, $p < 0.01$, with the graphical distribution in Figure 1.

$$AE = -8.118E-08x^4 + 5.078E-05x^3 - 0.01119x^2 + 0.9302x - 0.5825 \quad (3)$$

where:
AE - Agronomic Efficiency;
x – nitrogen fertilizer (N)

The AE variation according to the recorded production (Y) was described by a polynomial equation of order 3, equation (4), in conditions of $R^2 = 0.722$, $p = 0.0233$, with the graphical distribution in Figure 2.

$$AE = 4.525E-09x^3 - 5.414E-05x^2 + 0.2059x - 226.6 \quad (4)$$

where:
x – recorded production (Y, kg ha^{-1})

The variation of AE in relation to progressive increase yield (ΔPY) was evaluated, where ΔPY was calculated according to equation (5).

$$\Delta PY = Y_i - Y_{i-1} \quad (5)$$

where:
ΔPY – progressive increase yield; Y_i – current production, at the dose of F_i fertilizer; Y_{i-1} – production at the previous dose of fertilizer (F_{i-1}).

From the calculation of the progressive increase yield (ΔPY) it was found the increase of ΔPY in the fertilization interval N25 - N75 (T2 to T4) with values between 365.78 - 868.63 kg (ΔPY = 365.78 kg corresponding to N25; ΔPY = 868.83 kg corresponding to N50; ΔPY = 806.25 corresponding to N75). Starting with dose N100 (T5) to N200 (T9), the progressive increase yield (ΔPY) registered positive values, but decreasing, from ΔPY = 356.25 kg (N100, T5) to ΔPY = 37.50 kg (N200, T9). From dose N225 (T10) to N250 (T11) the progressive increase yield (ΔPY) recorded negative values, ΔPY = -

225.00 kg at dose N225 (T10), respectively ΔPY = -381.25 kg at N250 (T11).

In the case of Agronomic Efficiency (AE), as an index for expressing the efficiency of nitrogen use, there was a decrease in the values of variants T10 and T11 (table 1) and a deviation of the distribution from the model described by equation (4), figure 2. Phenomenon it is much better explained by the negative values recorded for ΔPY corresponding to variants T10 and T11.

The regression analysis facilitated the description of the AE variation in relation to ΔPY, equation (6), under conditions of R^2 = 0.780, p <0.01. The graphic distribution is presented in Figure 3.

$$AE = 0.0125\,x + 14.817 \qquad (6)$$

where:

x – progressive increase yield (ΔPY), calculated on the basis of equation (4).

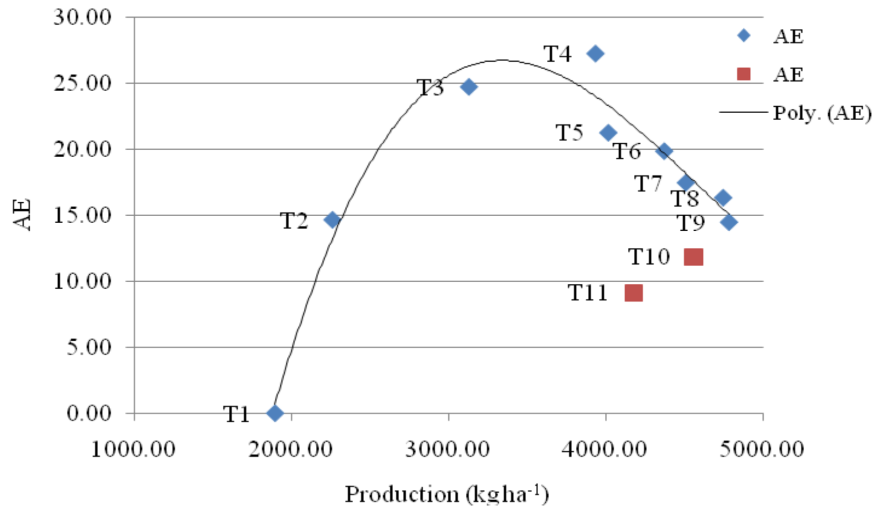

Fig. 2. Graphic distribution of AE values in relation to production (Y), wheat crop, Alex cultivar
Source: original graph.

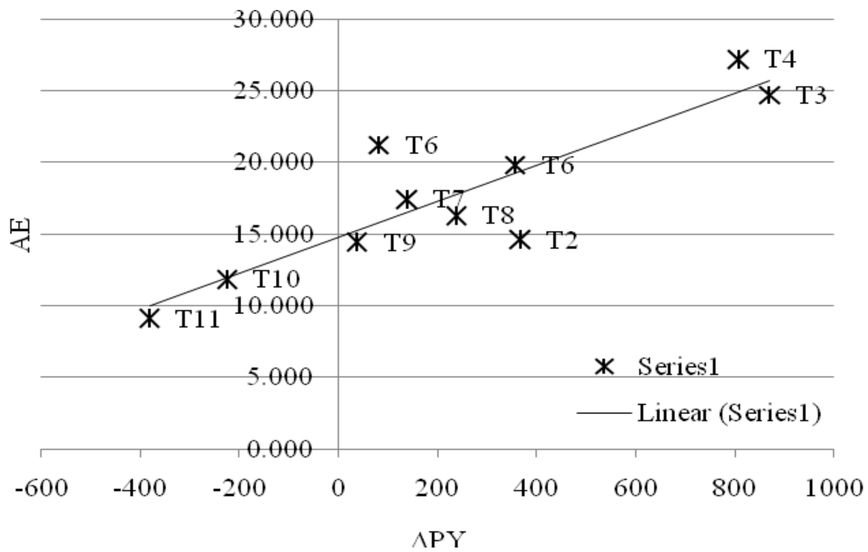

Fig. 3. AE variation in relation to ΔPY, wheat crop, Alex cultivar, nitrogen fertilization (ammonium nitrate)
Source: original graph

Similarly, the variation of PFP in relation to nitrogen doses (N) was analyzed, a variation that was described by equation (7), under conditions of R^2 = 0.994, p <0.001.

$$\text{PFP} = -1.296E-05x^3 + 0.006985x^2 - 1.345x + 118 \quad (7)$$

where:
x – nitrogen doses (N, a.s. kg ha^{-1})

Regression analysis was used to evaluate the variation of PFP in relation to nitrogen dose (N) and production (Y) as a simultaneous influence, and equation (8) was obtained, under conditions of R^2 = 0.885, p = 0.0144. The graphical distribution of the PFP variation in relation to N and Y is shown in the form of a 3D model, figure 4, and in the form of isoquants, figure 5. From the analysis of the values of the coefficients of equation (8), as well as of the graphical distribution models (figures 4 and 5), it was found that nitrogen (N) had a more pronounced contribution in the variation of the PFP index values, than the production (Y).

$$\text{PFP} = ax^2 + by^2 + cx + dy + exy + f \quad (8)$$

where:
PFP – Partial Factor Productivity; *x* – nitrogen dozes (N); *y* – production (Y); a, b, c, d, e, f – coefficients of the equation (8); a= -0.00903132; b= -0.00002297; c= 1.97376846; d= 0.05497934; e= 0.00025221; f= 0

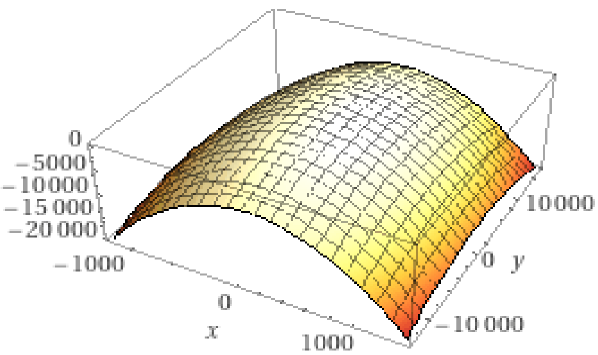

Fig. 4. 3D model of PFP variation in relation to nitrogen dose (x-axis) and production (y-axis)
Source: original graph

The efficiency of fertilizers has always been in the attention of farmers, researchers and decision makers, from different perspectives, such as agricultural technologies, agricultural profitability, fertilizer industry, environmental protection, satellite technology, imaging analysis, computer science, etc. [15, 33, 43]. All these approaches aimed at the efficiency of fertilization works through the level and quality of agricultural production, as well as increasing the efficient use of nutrients from applied fertilizers, in other words increasing fertilization efficiency, agricultural yields and economic efficiency [3].

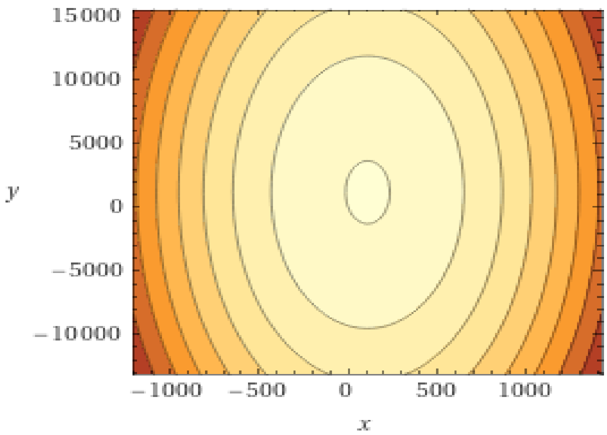

Fig. 5. Representation in the form of isoquant of the PFP variation in relation to the nitrogen dose (x-axis) and the production (y-axis)
Source: original graph.

Nitrogen was the nutrient for which special interest was given both in the number of studies and research, and in the approaches to assessing and directing the efficient use of nitrogen in relation to agricultural crops, based on various calculated indices [10].
In the present study, the variation of the efficiency of nitrogen use (N) from fertilizers (ammonium nitrate) in wheat crop was found, based on the two calculated indices, AE and PFP in relation to N and Y respectively.
Under the experimental conditions, the dose of N varied by a step of 25 kg ha^{-1}, and the corresponding yields were obtained (as a variable dependent on N). Doses of fertilizer quantitatively covered a wide spectrum of N, from 0 to 250 kg ha^{-1}.
Wheat plants benefited from a sufficient supply of N by fertilization, but the level of production, only from the N perspective, could not be higher. The level of production recorded showed that the N factor, used unilaterally, reached its potential and other factors of production need to be improved, in order to increase production and indirectly and to increase the capitalization of N from fertilization.
But in order for the production to be higher, in

the conditions of the cultivated wheat Alex cultivar, other inputs, or elements of technology, as factors influencing the wheat plants and culture, would have been necessary (eg grain density at sowing, time of sowing, fertilization with complex fertilizers, PK, plant health, density of harvestable ears etc.).
In the conditions of a higher production, on the background of a more efficient technology, in the conditions of the same doses of N, the indices AE and PFP would have registered other values, making the use of N from the fertilizer more efficient.
Therefore, increasing the efficiency of N use of fertilizers depends on the harmonization of different inputs and elements of technology, which make the use of N to increase, to be found in production and production quality indices.

CONCLUSIONS

The Agronomic Efficiency (AE) and Partial Factor Productivity (PFP) indices facilitated the evaluation of the use of nitrogen, provided by fertilization with ammonium nitrate, in wheat crop, Alex cultivar.
The two indices showed a specific variation in relation to the fertilizer dose (N) and the production (Y). The variation of the indices was expressed by polynomial equations, in conditions of statistical safety.
The expression of production (Y) also depends on other inputs, elements of technology, the health of crops, or environmental factors during the vegetation period, elements that make the use of fertilizers variable.
Single fertilization, only with N, is not enough. Balanced fertilization of crops is necessary to increase the efficiency of each nutrient, and as N is used in the highest amounts, and also presents the highest risks in relation to the environment, requires complex approaches to nitrogen use efficiency growth, from sustainable perspectives for farmers and the environment.

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