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VARIATION OF NITROGEN USE EFFICIENCY FROM MINERAL FERTILIZER ASSOCIATED WITH SOME FOLIAR TREATMENT

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Abstract

The study evaluated the variation in the efficiency of nitrogen use from mineral fertilizers, associated with foliar fertilization in wheat, based on biological yield. Two specific indicators (Agronomic Efficiency - AE, Partial Factor Productivity - PFP) were calculated to quantify the efficiency of nitrogen use. The study was organized within the Didactic and Experimental Resort, BUASVM Timisoara. The 'Alex' wheat cultivar was cultivated, under the conditions of a chernozem type soil, medium fertility, and non-irrigated culture system. The 2020 – 2021 agricultural year was taken into account. Biological yield (BY, g m^{-2}) was evaluated at physiological maturity (BBCH code 9, Senescence). Polynomial models of the 2nd degree described the variation of BY in relation to nitrogen (N) on each level of foliar fertilization (Super Fifty – SF), in differentiated conditions of statistical certainty ($p<0.05$ for the SF2 variant). There was an increasing variation in the AE and PFP values associated with foliar fertilization (SF), up to the level of SF2 and SF3 variants (2 – 3 L ha^{-1}), followed by a decreasing trend. The regression analysis led to obtaining an equation-type mathematical model that described the BY variation in relation to N and SF, as a direct and interaction effect, under statistical safety conditions ($p<0.001$, $R^2=0.957$). Based on the values of the obtained equation coefficients, the optimal doses were calculated ($x_{opt}=137.05$ kg ha^{-1} N active substance, $y_{opt}=2.92$ L ha^{-1} SF, concentration 1.168 %).

Key words: *agronomic efficiency, biological yield, nitrogen fertilizer, Partial Factor Productivity, wheat*

INTRODUCTION

Fertilizers represent important inputs in agriculture and at the same time factors with a high contribution in forming plant production and supporting soil fertility [28, 31, 32].

Fertilizers have been studied in relation to soil health and quality [21, 27, 33], the type of agricultural system [9], crop productivity and agricultural production [8, 12, 43], the sustainability of agriculture [21], but also in relation to the production and market of fertilizers [3, 22, 28], and farmers' options for fertilizer resources [20, 38, 41].

Mineral fertilizers are important for sustaining agricultural yields, yields that would decrease with variable percentages in relation to the crop (eg wheat, rice, corn), the type of nutritive element (eg NPK), but also the doses applied and the climate and soil conditions [24, 39, 43].

The rate of fertilizers use varies in relation to different analysis criteria (point of reference, countries and regions, agricultural systems, types of farms, categories of farmers, agricultural crops etc.), depending on socio-economic and ecological conditions [7, 20, 25, 34, 36].

Different methods, techniques, models, each with specific indices and safety parameters, were used to evaluate the use of fertilizers from physico-chemical, biological, ecological, practical, economic perspectives [4, 10, 16, 26, 44].

The efficiency of the use of fertilizers is a topical issue, all the more associated with the economic crisis and the need of farmers to find solutions to support agricultural production in sustainable budgets [2, 45].

Among the nutrients with a major role in the formation of agricultural production, nitrogen has been the most studied in relation to the efficiency of use, in order to optimize the doses of fertilizers [6, 11, 37], productions (quantitative and qualitative) and yields [19, 23], ecosystem protection etc. [1, 11].

The study aimed to evaluate the efficiency of nitrogen utilization from mineral fertilizers applied to the soil, expressed through the lens of biological production in wheat, the 'Alex' cultivar, associated with foliar fertilization with a biofertilizer product based on algae extracts.

MATERIALS AND METHODS

The field experiment on the wheat crop, the 'Alex' cultivar, was organized within the BUASVM Timisoara, Didactic and Experimental Resort (DER), Timis County, Romania.

The soil was chernozem type, with medium fertility, and the culture system was not irrigated.

Nitrogen was administered in five doses, between 0-200 kg N a.s. ha^{-1} (a.s. – active substance). Ammonium nitrate was used, in doses that ensured the amount of active substance per variant (0 – N0, 50 kg a.s. ha^{-1} – N50; 100 kg a.s. ha^{-1} – N100; 150 kg a.s. ha^{-1} – N150; 200 kg a.s. ha^{-1} – N200). The fertilizer was applied in the spring, uniformly on each experimental variant.

The Super Fifty product was used in concentrations between 0 – 2% (calculated at a solution amount of 250 L ha^{-1}), respectively the following concentrations were used: 0% (SF0), 0.4% (SF1), 0.8% (SF2), 1.2% (SF3), 1.6% (SF4) and 2% (SF5).

From the combination of the two factors, N and SF, 30 experimental variants resulted. The experimental variant had an area of 18 m^2, and the experiment was organized in three repetitions, randomized. The 2020 – 2021 agricultural year was considered.

At physiological maturity, BBCH 9 code, Senescence [29], samples were collected to determine biological yield (g m^{-2}).

To evaluate the efficiency of nitrogen use from the mineral fertilizer applied on the soil, associated with foliar fertilization, the Agronomic Efficiency – AE [15, 17], relationship (1), and Partial Factor Productivity – PFP [17], relationship (2), were calculated.

$$AE = (BY - BY_0)/F \quad (1)$$

where: AE – Agronomic Efficiency;
BY – biological yield at each dose of N, and each SF level;
BY_0 – biological yield in the control variant (N0), on each SF level;
F – the dose of N corresponding to the biological yield (BY).

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

where: PFP – Partial Factor Productivity;
BY – biological yield at each dose of N, and each SF level;
F – the dose of N corresponding to the biological yield BY.

The PAST software [18], the Wolfram Alpha software [40], and mathematical module in EXCEL (Office package) were used for the analysis and mathematical and statistical processing of the data, and for the graphs generated.

RESULTS AND DISCUSSIONS

The study quantified the level of biological yield (BY, g m^{-2}) in wheat, the 'Alex' cultivar, under the influence of mineral fertilization with nitrogen (ammonium nitrate) associated with foliar fertilization with the Super Fifty product (SF).

The values recorded for biological yield, in relation to the two factors (N, SF) are presented in Table 1.

The increase in biological yield in relation to nitrogen (N) was found, up to around the dose of 150 kg ha^{-1} N a.s. Also, the increasing variation of biological yield was found in relation to the Super Fifty product, up to the SF3 variant (3 L ha^{-1}, 1.2%).

The study investigated the variation of N use efficiency, associated with foliar treatments (SF) based on the recorded biological yield (BY, g m^{-2}).

Thus, the variation of biological yield (BY) generated by N, associated with the six levels of foliar treatments with the Super Fifty product (SF), was described by equations (3) – (8), under statistical safety conditions, Table 2; in the equations (3) - (8) *x* represents the doses of N.

Table 1. Values of biological yield in relation to N and SF, the 'Alex' wheat cultivar

Nitrogen (N)	Super Fifty (SF)					
	SF0	SF1	SF2	SF3	SF4	SF5
	Biological Yield (BY, g m^{-2})					
N0	1,139	1,207	1,238	1,372	1,443	1,409
N50	1,278	1,473	1,443	1,728	1,508	1,509
N100	1,339	1,479	1,490	1,733	1,530	1,527
N150	1,494	1,599	1,673	1,890	1,670	1,665
N200	1,379	1,548	1,667	1,763	1,658	1,604

Source: Original data from the experiment.

Table 2. The equations that describe the variation of BY in relation to N and foliar fertilization levels, the 'Alex' wheat cultivar

Foliar treatment	Equation	Equation number	R^2	p
SF0	$BY_{SF0} = -0.0118x^2 + 3.758x + 1{,}127$	(3)	0.886	0.114
SF1	$BY_{SF1} = -0.0148x^2 + 4.587x + 1{,}225$	(4)	0.924	0.076
SF2	$BY_{SF2} = -0.00817x^2 + 3.81x + 1{,}244$	(5)	0.957	0.042
SF3	$BY_{SF3} = -0.0233x^2 + 6.555x + 1{,}391$	(6)	0.913	0.087
SF4	$BY_{SF4} = -0.00103x^2 + 1.39x + 1{,}438$	(7)	0.901	0.098
SF5	$BY_{SF5} = -0.00577x^2 + 2.246x + 1{,}405$	(8)	0.862	0.138

Source: Original equations and values, based on experimental data.

In order to more precisely quantify the way in which the efficiency of nitrogen use changes, associated with foliar treatments (SF), were used two specific indicators regarding NUE, proposed by specialized literature, Agronomic Efficiency – AE [15, 17], and Partial Factor Productivity – PFP [17].

Agronomic Efficiency (AE) was calculated based on the relationship (1) for each experimental variant, in order to evaluate the efficiency of nitrogen (N) in the applied doses, associated with each foliar treatment (SF), in terms of biological yield (BY), and the values obtained are presented in Table 3.

Table 3. The values of the AE index on experimental variants, in relation to biological yield, the 'Alex' wheat cultivar

Trials	SF0	SF1	SF2	SF3	SF4	SF5
N0	-	-	-	-	-	-
N50	2.78	5.32	4.10	7.12	1.30	2.00
N100	2.00	2.72	2.52	3.61	0.87	1.18
N150	2.37	2.61	2.90	3.45	1.51	1.71
N200	1.20	1.71	2.15	1.96	1.08	0.98

Source: Original data obtained by calculation.

On each level of N, an increasing variation of AE associated with foliar treatments (SF) was found, up to the SF3 variant, after which a decrease in AE values followed.

Partial Factor Productivity (PFP) was calculated based on the relationship (2), and the recorded values are presented in Table 4.

Also in the case of this index, the increase of PFP values was found for each level of N associated with the foliar treatments up to variant SF3, after which followed a downward trend.

Table 4. The values of the PFP index on experimental variants, in relation to biological production, the 'Alex' wheat cultivar

Trials	SF0	SF1	SF2	SF3	SF4	SF5
N0	-	-	-	-	-	-
N50	25.56	29.46	28.86	34.56	30.16	30.18
N100	13.39	14.79	14.90	17.33	15.30	15.27
N150	9.96	10.66	11.15	12.60	11.13	11.10
N200	6.90	7.74	8.34	8.82	8.29	8.02

Source: Original data obtained by calculation.

In the case of both indices considered (AE, PFP), the degree of N utilization, based on biological yield (BY), recorded decreasing values with increasing doses of N, at each level of foliar fertilization (SF). At the same time, there was an increase in the degree of N use, respectively N efficiency in biological yield (BY), associated with foliar fertilization. The graphic representation in Figures 1 and 2, illustrates the variation of the AE index (Figure 1) and PFP index (Figure 2), in relation to nitrogen fertilizers (N) and the foliar biofertilizer Super Fifty (SF).

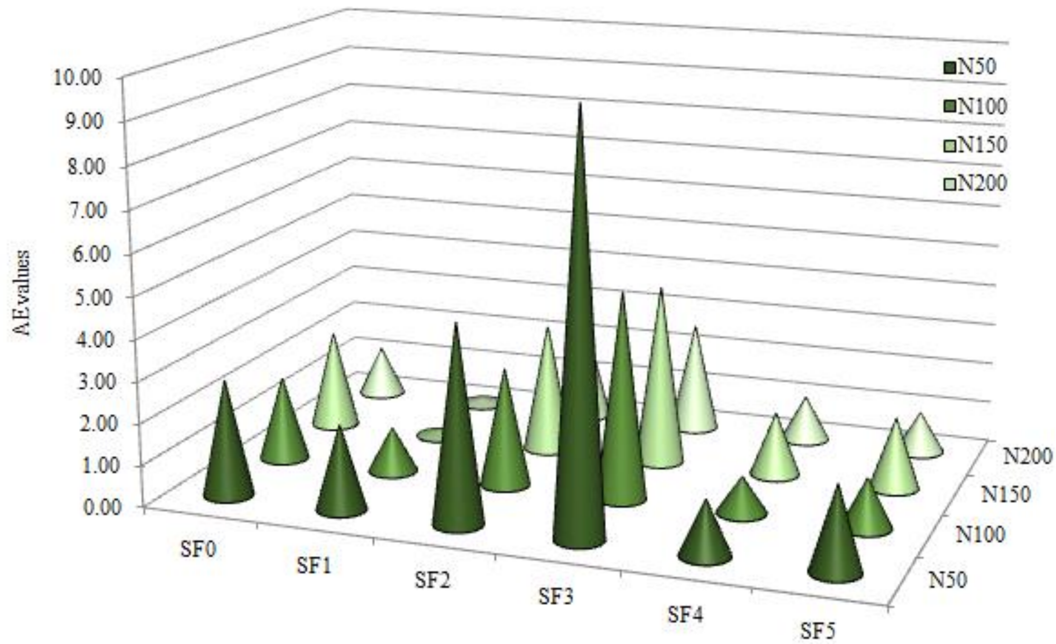

Fig. 1. The graphic distribution of the AE index values in relation to N and SF, the 'Alex' wheat cultivar
Source: original graphic based on calculated data.

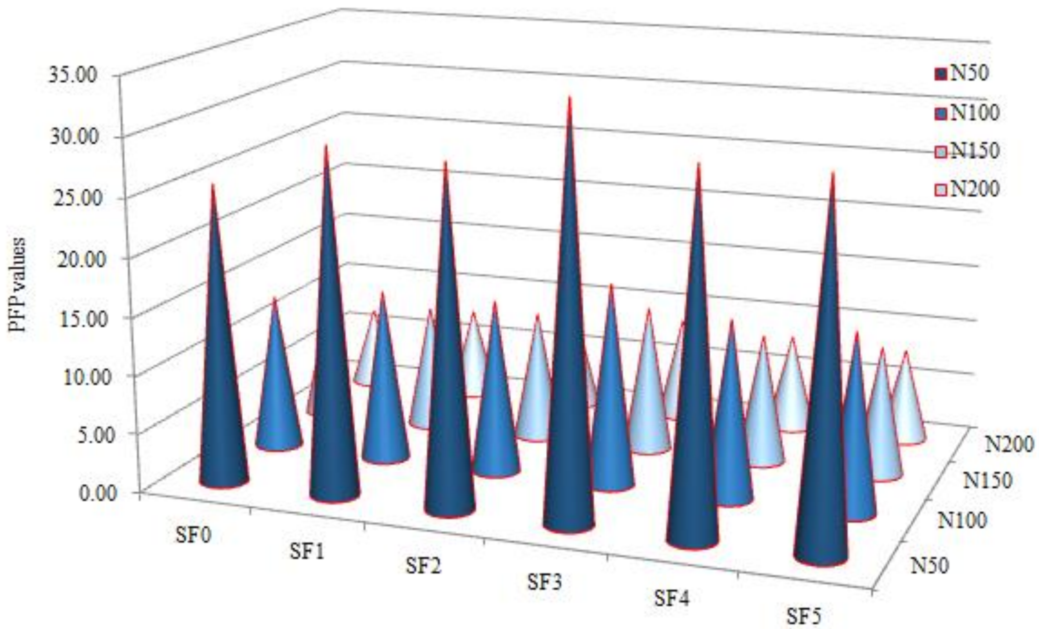

Fig. 2. Graphical distribution of the PFP index values in relation to N and SF, the 'Alex' wheat cultivar
Source: original graphic based on calculated data.

Based on the regression analysis, equation (9) was obtained that described the variation of biological yield (BY) in relation to nitrogen from mineral fertilizer (N), and foliar biofertilizer (SF), as a direct and interaction effect, under statistical safety conditions (R^2=0.957, p<0.001, F =113.92).

For high precision of the calculations, the values of the coefficients of equation (9) had up to 16 decimal places. The graphic distribution of biological yield (BY) values in relation to N and SF is presented in 3D form in figure 3, and in the form of isoquants in Figure 4.

The ANOVA test confirmed the safety for the parameters of equation (9); p=0.0191 for a, p=0.0046 for b, p<0.001 for c and d, respectively p=0.0011 for e.

$$BY = ax^2 + by^2 + cx + dy + exy + f \qquad (9)$$

where: BY – biological yield;
x – Nitrogen dozes (N, kg a.s. ha^{-1});
y – Super Fifty (SF, L ha^{-1});
a, b, c, d, e, f – coefficients of the equation (9);
a= -0.03527791;
b= -72.24608555;
c= 14.21481840;
d= 635.36592413;
e= -1.55564616;
f= 0

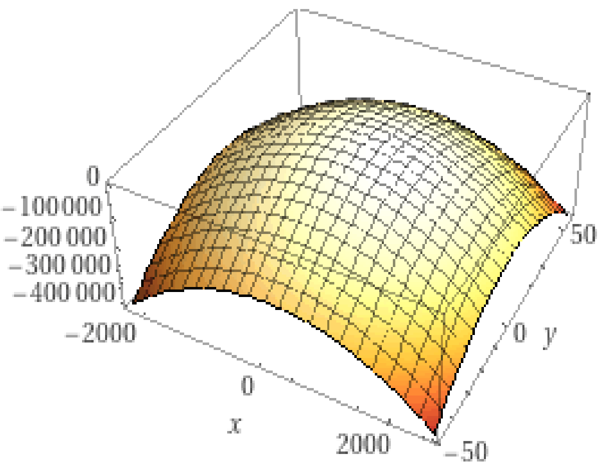

Fig. 3. 3D model of the BY variation in relation to the dose of nitrogen, N (x-axis) and SF (y-axis), the 'Alex' wheat cultivar
Source: Original graph.

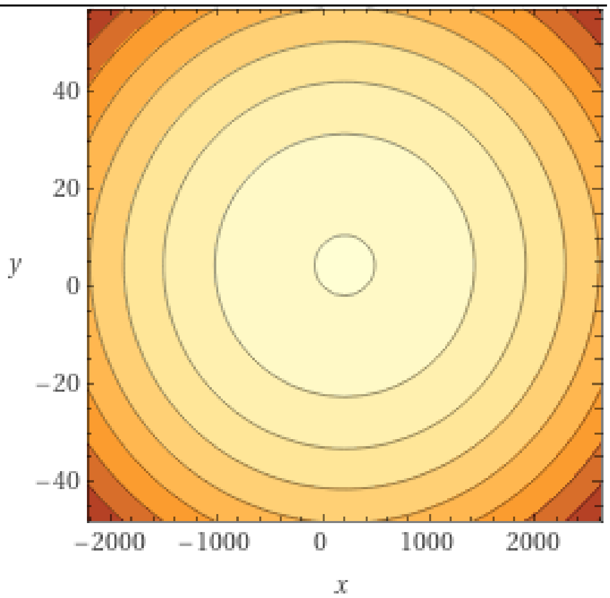

Fig. 4. Graphic representation in the form of isoquants, for the biological yield (BY) variation in relation to the dose of nitrogen, N (x-axis) and SF (y-axis), the 'Alex' wheat cultivar
Source: Original graph.

Based on the values of the coefficients of equation (9), the optimal doses for N and SF in relation to biological yield were calculated, and resulted the values x_{opt}=137.05 kg ha^{-1} N (a.s.) and y_{opt}=2.92 L ha^{-1} SF (concentration, 1.168 %).

To increase N efficiency, were studied different methods and techniques of fertilizer application [42], complex and alternative fertilization [5, 14], foliar fertilization with elements to potentiate N utilization [13], the use of performing genotypes [35], appropriate culture strategies and technologies [30] etc.

In the case of the present study, foliar fertilization with the Super Fifty product, based on algae extract, was taken into account, and the recorded results highlighted, based on the two indices (AE and PFP), the increasing variation of N use efficiency associated with SF.

The variation of p values, as a statistical safety parameter (Table 2), from p=0.114 in the case of SF0, to p=0.138 in the case of SF5, with the value of p=0.042 (p<0.05) in the SF2 variant, confirms the range of concentrations (SF2 to SF3 variants), where the optimal dose for SF was obtained, respectively y_{opt}=2.92 L ha^{-1}.

This value for SF led to the optimal utilization of N, in the experimental conditions, where

x_{opt}=137.05 kg ha^{-1} N (active substance).
The authors appreciate that the obtained results can contribute to the optimization of the fertilization system and to the improvement of wheat cultivation technology, in order to increase the efficiency of nitrogen use, with technological and environmental benefits.

CONCLUSIONS

Mineral fertilization with nitrogen led to the variation of biological yield (BY, g m^{-2}) in relation to the doses administered, in the range of 1,139 – 1,890 g m^{-2}.
Foliar administration of Super Fifty biofertilizer, at each nitrogen level, led to a corresponding variation in biological yield.
The efficiency of nitrogen use, provided by mineral fertilization, estimated based on biological yield, registered a positive variation associated with foliar fertilization with the Super Fifty product, aspect quantified based on the calculated indices (AE and PFP).
The regression analysis facilitated finding a mathematical model for the BY variation in relation to N and SF, and the optimal doses were calculated, x_{opt}=137.05 kg ha^{-1} N (a.s.), y_{opt}=2.92 L ha^{-1} SF.
The obtained results can be considered for the optimization of fertilization and wheat cultivation technology, with positive economic, ecological and social aspects.

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