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AGRONOMIC AND TECHNICAL EFFICIENCY OF THE PRODUCTIVITY OF OILSEED RAPE FROM COMBINATIONS OF SEVERAL NUTRIENTS

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ABSTRACT

The increase in yield per unit area in kg and the attained outcome from the usage of certain amounts of nutrients are measured by agronomic efficiency (AE). In terms of the sensible use of nutrients, the capacity and to determine technical efficiency is a contribution to this research. The findings are intended to aid in determining the efficacy of using the most essential nutrients (N, P_2O_5, K_2O, S and B) to determine their impact on productivity capacity. The purpose was to evaluate how varied levels of nitrogen, sulfur, and boron affected on potential of winter oilseed rape. For N was using quantities of 100 and 150 kg ha^{-1}, for S 30 and 70 kg ha^{-1}; and B 1 and 2 kg B ha-1. N (50 kg ha^{-1}) P and K (90 and 180 kg ha^{-1}) was also applied before sowing. The research was performed in vegetation years 2016 - 2018, with two genotypes: variety and hybrid, in 15 variants and 4 replications: 1: control 50 N kg ha^{-1}; 2: 100 N kg ha^{-1}; 3: 150 N kg ha^{-1}; 4: 130 N+S kg ha^{-1}; 5: 170 N+S kg ha^{-1}; 6: 180 N+S kg ha^{-1}; 7: 220 N+S kg ha^{-1}; 8: 131 N+S+B kg ha^{-1}; 9: 132 N+S+B kg ha^{-1}; 10: 171 N+S+B kg ha^{-1}; 11: 172 N+S+B kg ha^{-1}; 12: 181 N+S+B kg ha^{-1}; 13: 182 N+S+B kg ha^{-1}; 14: 221 N+S+B kg ha^{-1} и 15: 222 N+S+B kg ha^{-1}. The average agronomic efficiency of all variants was 4.66 kg for the variety and 2.99 kg for the hybrid. Technical efficiency showed constant efficiency in three variants, and increase tendency to other.

Key words: oilseed rape, N, S, B, AE, efficiency.

INTRODUCTION

Agrochemistry advancements have made it possible to increase fertilizer efficiency and achieve high yields with minimal investment. Science promotes the development and efficiency of the use of nutrients in production, as well as the best practices in their application (Fageria et al., 2008). The fertilizer industry's goal and challenge is to improve nutrient efficiency, with a focus on agriculture and directions for economic justification and environmental protection (Roberts, 2008). The use of N, S and B increases oilseed rape yields from 9.7 kg ha^{-1} to 13.7 kg ha^{-1} or 3-31% for each kg of N application, and increases early flowering by 10% with the foliar application of B. (Ma et al. 2015). The following are the most common methods for measuring nutrient use efficiency: partial factor efficiency, apparent efficiency, physiological efficiency, and agronomic efficiency. The increase in yield per unit area (kg) as a result of applied nutrients (kg) is referred to as agronomic efficiency (AE) (Mosier et al., 2004, Dobermann, 2007). The technical efficiency technique, determinating with data envelopment analysis, was used to determine the efficiency of the used fertilizer elements, which represents a significant contribution in terms of the rational use of mineral fertilizers. When there are multiple inputs and outputs, efficiency

measurement focuses on generating an efficient hypothetical number as well as a specified average of efficient units to allow comparison of inefficient units (Hoang &Alauddin 2012). The results of the technical efficiency analysis are expressed in percentages as well as on a return level or scale set as constant efficiency, which actually determines the significance and constancy in several interactions, most commonly input sums, increasing efficiency, and decreasing efficiency (Wang Y. et al. 2017, Wang, G., et al. 2018).

MATERIAL AND METHODS

Aim of the research is using two analytical methods agronomic efficiency and technical efficiency to compare multiple combinations of N, S and B in the production of oilseed rape.

The trial was conducted in three vegetation years 2016 - 2018, with two genotypes of oilseed rape (variety zorica) (hybrid rohan), in 15 variants and 4 replications: 1: control Ø; 2: N_{100}; 3: N_{150}; 4: $N_{100}+S_{30}$; 5: $N_{100}+S_{70}$; 6: $N_{150}+S_{30}$; 7: $N_{150}+S_{70}$; 8: $N_{100}+S_{30}+B_1$; 9: $N_{100}+S_{30}+B_2$; 10: $N_{100}+S_{70}+B_1$; 11: $N_{100}+S_{70}+B_2$; 12: $N_{150}+S_{30}+B_1$; 13: $N_{150}+S_{30}+B_2$; 14: $N_{150}+S_{70}+B_1$ и 15: $N_{150}+S_{70}+B_2$. From the fertilizers in the study, ammonium nitrate (NH_4NO_3) (34.4% N), ammonium sulfate ($(NH_4)2SO_4$) (21% N; 24% S), boron (8% liquid mineral fertilizer) and NPK 5:15:30 complex mineral fertilizer were used (P_2O_5 + K_2O total 270 kg ha^{-1}). To determine the efficiency of using N, S and B the agronomic efficiency (AE) was calculated according to the formula: $AE = Y_т - Y_∅ / F_т$ (Yt = yield (kg ha^{-1}) from of variant/treatment, Y yield (kg ha^{-1}) from control, Ft amount of element used in treatment (kg ha^{-1}) Murrell, 2009). To confirm the methodological framework and the used elements, doses and amounts, was used DEA Data Envelopment Analysis as a technique, comparing values from multiple inputs and outputs. The calculations to determine the efficiency are set as a ratio between the variants shown as inputs (area, sowing rate, doses/ha) and the outputs as yields. Excel (Office) and PSAW 17 and the Minitab 17 program are used for the statistical evaluation of the partial flows. The efficiency was calculated by Data Envelopment Analysis, using the framework data analysis platform.

RESULTS AND DISCUSSION

Agronomic Efficiency

The agronomic efficiency from the values obtained for seed yield with the combined use of N, S and B compared to the values of the control in variety (Zorica) was most pronounced in variants 11, 13 and 15 (28%). Individually according to elements, the agronomic efficiency from N-use is highest in variant 13 with an additional yield of 964 kg ha^{-1}, from S-use the highest efficiency and yield increase of 476.2 kg ha^{1} was determined variant 11, for which same variant to determine the highest efficiency from the use of B (13.6 kg ha^{-1}). The efficiency of applied nitrogen in oilseed rape cultivation is much higher when used in combination with S (Zhao et al. 1993).

The total amount of N, S and B of 172 kg ha^{-1}, that for variant 11 (N100+S70+B2) gave the highest agronomic efficiency of 6.80 kg, i.e. per kg fertilizer applied the yield increased by 6.80 kg (1 170 kg), thus the highest seed yield of 4 170 kg ha^{-1} (Table 1). AE increases when cultivating rapeseed with the use of small and medium amounts of N (25 and 50 kg N ha^{-1}) in contrast to the use of high amounts (100, 150 and 200 kg N ha^{-1}) (Holzapfel,2007). From the values for the seed yield when using N, S and C compared to the yield in the control in the hybrid (Rohan), the highest agronomic efficiency of 22% was determined in variant 13.

The agronomic efficiency for N depends on the use of different combinations and fertilizers ($N1BF_1Zn_1$), and increasing amounts decrease AE values (Hasanalideh et al. 2012). Individually, by elements, AE from the use of N is the highest in variant 13 with 18% participation in yield increase (874 kg ha^{-1}), from the use of S the highest agronomic efficiency of 8% was determined in variant 11 (350 kg ha^{-1}), and from the use of B, the highest AE was determined in variant 13 (11.6 kg ha^{-1}) (table 1).

The total amounts of N, S, and B of 182 kg ha^{-1} in variant 13 (N150+S30+B2) gave the highest agronomic efficiency, i.e. for each kg of fertilizer used, the yield increased by 5.82 kg, while from this variant realizes the highest seed yield of 4 810 kg ha^{-1}.

Table 1. Agronomic efficiency (AE), variety (Zorica) & hybrid (Rohan)

Treatment variants	Yield kg ha^{-1}	+ - од ø	Total N+S+B kg	AE (kg)	N		S		B		%			
					AE	+- kg	AE	+- kg	AE	+- kg	од ø	N	S	B
Variety (Zorica)														
1N50	3 000	Ø									ø			
2N100	3 450	450	100	4,50	4,50	450					13	13		
3N150	3 830	830	150	5,53	5,53	830					22	22		
4N100:S30	3 510	510	130	3,92	3,02	392	0,91	117,7			15	11	3	
5N100:S70	3 860	860	170	5,06	2,98	506	2,08	354,1			22	13	9	
6N150:S30	3 370	370	180	2,06	1,71	308	0,34	61,7			11	9	2	
7N150:S70	3 730	730	220	3,32	2,26	498	1,06	232,3			20	13	6	
8N100:S30:B1	3 860	860	131	6,56	5,01	656	1,50	196,9	0,05	6,6	22	17	5	0,2
9N100:S30:B2	3 500	500	132	3,79	2,87	379	0,86	113,6	0,06	7,6	14	11	3	0,2
10N100:S70:B1	3 650	650	171	3,80	2,22	380	1,56	266,1	0,02	3,8	18	10	7	0,1
11N100:S70:B2	4 170	1 170	172	6,80	3,95	680	2,77	476,2	0,08	13,6	28	16	11	0,3
12N150:S30:B1	3 960	960	181	5,30	4,40	796	0,88	159,1	0,03	5,3	24	20	4	0,1
13N150:S30:B2	4 170	1 170	182	6,43	5,30	964	1,06	192,9	0,07	12,9	28	23	5	0,3
14N150:S70:B1	3 680	680	221	3,08	2,09	462	0,97	215,4	0,01	3,1	18	13	6	0,1
15N150:S70:B2	4 140	1 140	222	5,14	3,47	770	1,62	359,5	0,05	10,3	28	19	9	0,2
			±	4,66	3,52	577	1,30	228,8	0,05	7,9	20.2	15,0	5.8	0,2
Hybrid (Rohan)														
1N50	3750	Ø									ø			
2N100	3900	150	100	1,50	1,50	100					4	4		
3N150	3800	50	150	0,33	0,22	50					1	1		
4N100:S30	3960	210	130	1,62	1,24	162	0,37	48,5			5	4	1	
5N100:S70	4110	360	170	2,12	1,25	212	0,87	148,2			9	5	4	
6N150:S30	4100	350	180	1,94	1,62	292	0,32	58,3			9	7	1	
7N150:S70	4050	300	220	1,36	0,93	205	0,43	95,5			7	5	2	
8N100:S30:B1	4690	940	131	7,18	5,48	718	1,64	215,3	0,05	7,2	20	15	5	0,2
9N100:S30:B2	4060	310	132	2,35	1,78	235	0,53	70,5	0,04	4,7	8	6	2	0,1
10N100:S70:B1	4200	450	171	2,63	1,54	263	1,08	184,2	0,02	2,6	11	6	4	0,1
11N100:S70:B2	4610	860	172	5,00	2,91	500	2,03	350,0	0,06	10,0	19	11	8	0,2
12N150:S30:B1	4380	630	181	3,48	2,88	522	0,58	104,4	0,02	3,5	14	12	2	0,1
13N150:S30:B2	4810	1060	182	5,82	4,80	874	0,96	174,7	0,06	11,6	22	18	4	0,2
14N150:S70:B1	4480	730	221	3,30	2,24	495	1,05	231,2	0,01	3,3	16	11	5	0,1
15N150:S70:B2	4450	700	222	3,15	2,13	473	0,99	220,7	0,03	6,3	16	11	5	0,1
			±	2,99	2,18	364	0,91	158,5	0,04	6,2	11.5	8.3	3.6	0,1

Measurement and analysis of technical efficiency

The expected research contribution also goes in the direction of determining the efficiency of the use of the main macro-elements (N, P_2O_5, K_2O, S) as well as a micro-element (B) to determine their effect (positive/negative) on the Production potential of oilseed rape - *Brassica napus* L.

In the three-year study, if the production area, the amount of sowing and the impact of the total doses of the fertilizer combinations are taken as the basic production inputs and compared with the yield achieved as a result or output in the process, the real effectiveness can be determined from the research results (Table 2).

Table 2. Efficiency between production area, sowing rate and dosages compared to the yields obtained

Variants	Inputs area m^2	Inputs seed rate kg/ha	Inputs total doses ha	Output yield ha	Efficiency	in-scale on return -efficiency
1N50 control	10000	8,0	320	3,58	100%	Constant
2N100	10000	8,0	370	3,70	95%	Increase
3N150	10000	8,0	420	3,69	88%	Increase
4N100:S30	10000	8,0	400	3,74	92%	Increase
5N100:S70	10000	8,0	440	4,00	93%	Increase
6N150:S30	10000	8,0	450	3,63	84%	Increase
7N150:S70	10000	8,0	490	3,95	90%	Increase
8N100:S30:B1	10000	8,0	401	4,09	100%	Constant
9N100:S30:B2	10000	8,0	402	3,67	90%	Increase
10N100:S70:B1	10000	8,0	441	3,93	92%	Increase
11N100:S70:B2	10000	8,0	442	4,23	98%	Increase
12N150:S30:B1	10000	8,0	451	4,15	96%	Increase
13N150:S30:B2	10000	8,0	452	4,35	100%	Constant
14N150:S70:B1	10000	8,0	491	3,98	91%	Increase
15N150:S70:B2	10000	8,0	492	4,37	100%	Constant

From the analysis it can be seen that the control variant Variant 8 ($N_1PK+S_1+B_1$), Variant 13 and Variant 15 show constant or significant efficacy. Achieving constant efficiency with the lowest realized yield (output) in the control variant is the result of the lowest applied fertilizer quantities (input). While the constant efficiency of variants 8 (N100:S30: B1), 13 (N150:S30: B2) and 15 lies in the high yield (output) achieved compared to all input combinations.

Analysis of the efficiency of all other variants in terms of set inputs and realized yield as output show an increase in the efficiency scale and none of them has a decreased efficiency (Table 2). Framework analysis (DEA) also compares input efficiency as a goal with output efficiency as an output goal. The set inputs and the efficiency measured from them result in the differences in achieving the constant efficiency or the yield achieved as the output target (Table 3). The efficiency for area as a target and yield as a performance target Variant 6 (N_2PK+S_1) shows the largest difference at 1636 m^2, so the yield achieved can be achieved on a smaller area of (8364 m^2). Other variants with a high difference are variants 3 (N150) and 9 (N100:S30: B2) or on 1187 m^2 and 1038 m^2 area it is less possible to realize the realized yield of these variants. In terms of sowing rate efficiency, the same variants 6 (N150:S30), 3 (N150) and 9 (N100:S30: B2) give the greatest difference in the yield obtained, or differences of 1.3 kg/ha and 0, 9 kg/ha more seed quantity used to achieve yields. In variant 6 (N150:S30) with 74 kg, variant 3 (N150) with 50 kg and variant 7 (N150:S70) with 47 kg, higher amounts of fertilizer than the yield actually achieved were

determined, with a clear difference also being obtained in the variants 14 (N150:S70: B1) and 9 (N100:S30: B2) 44 kg and 42 kg applied amounts of more total fertilizer

Table 3. Differences between the effectiveness of target inputs and effectiveness of yield as an output target

	Efficiency of inputs as a target									output
variants	area m^2			seed rate kg/ha			total doses kg/ha			yield/ha
1N50 control	10000	10000	0	8,0	8,0	0,0	320	320	0	3,58
2N100	10000	9499	501	8,0	7,6	0,4	370	351	19	3,70
3N150	10000	8813	1187	8,0	7,1	0,9	420	370	50	3,69
4N100:S30	10000	9158	842	8,0	7,3	0,7	400	366	34	3,74
5N100:S70	10000	9326	674	8,0	7,5	0,5	440	410	30	4,00
6N150:S30	10000	8364	1636	8,0	6,7	1,3	450	376	74	3,63
7N150:S70	10000	9041	959	8,0	7,2	0,8	490	443	47	3,95
8N100:S30:B1	10000	10000	0	8,0	8,0	0,0	401	401	0	4,09
9N100:S30:B2	10000	8962	1038	8,0	7,1	0,9	402	360	42	3,67
10N100:S70:B1	10000	9152	848	8,0	7,3	0,7	441	403	38	3,93
11N100:S70:B2	10000	9839	161	8,0	7,9	0,1	442	435	7	4,23
12N150:S30:B1	10000	9551	449	8,0	7,6	0,4	451	431	20	4,15
13N150:S30:B2	10000	10000	0	8,0	8,0	0,0	452	452	0	4,35
14N150:S70:B1	10000	9108	892	8,0	7,3	0,7	491	447	44	3,98
15N150:S70:B2	10000	10000	0	8,0	8,0	0,0	492	492	0	4,37

CONCLUSION

The analysis of AE in the variety the total amounts of N100+S70+B2 172 kg ha^{-1} gave highest agronomic efficiency of 6.80 kg, or for each kg of fertilizer used the yield increased by 6.80 kg (1 170 kg), as well as the highest seed yield of 4 170 kg ha^{-1} was determined, while in hydrid, the total amounts of N150+S30+B2 182 kg ha^{-1} gave the highest agronomic efficiency, or for each kg of fertilizer used, the yield increased by 5.82 kg, thus the highest seed yield of 4 810 kg ha^{-1}. The control variant, variant 8 (N100:S30:B1), variant 13 and variant 15 have constant or significant efficiency, according to the technical analysis, or combinations of N100:S30:B1, N150:S30:B2 and N150:S70:B2 have a constant efficiency in the achieved high yield (output) against all input combinations. For the efficiency of input total doses expressed in kg/ha, a greater number of variants with differences greater than 40 kg/ha^{-1} of applied fertilizer were used to achieve the targeted yield like combination of N150:S30 74 kg (variant 6), N2PK 50 kg (variant 3), N2PK+S2 47 kg (variant 7), N150:S70:B1 44 kg (variant 14) and N100:S30:B2 42 kg (variant 9) quantities of applied total fertilizers more.

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