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MATHEMATICAL MODELS, TABLES AND NOMOGRAMS TO SETTLE THE TECHNICALLY OPTIMAL RATES (TOR) OF N, P_2O_5 AND K_2O IN CORN

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Abstract

This is the second paper from the series concerning the field crops. The presented mathematical models and agrochemical tables and nomograms serve to settle the Technically Optimal Rates (TOR) of N, P_2O_5 and K_2O in corn as function of maximum expected yield, Y_m, and the specific soil agrochemical indexes (nitrogen index: IN; mobile phosphorous: P_{ALc}; mobile potassium: K_{AL}). The TOR of a nutrient is independent of the unitary price of the fertilizer (UPF) and unitary price of the yield (UPY), while the Economically Optimal Rates (EOR) is strongly dependent of UPF and UPY, EOR decreasing with the decrease of UPY/UPF ratio. The advantage of TOR versus EOR is that TOR always allows to obtain the maximum yield in a given condition of soil nutrient supply, while EOR allows this only in the particular rare case when UPY/UPF = 1. TOR system uses the same equations for nutrients action coefficients and soil nutrient supply as the EOR system. The Fertexpert software has been used for TOR calculations. The agrochemical tables and nomograms in corn will be accessible online on a specific website.

INTRODUCTION

To establish the TOR, which allow obtain the maximum yield in given soil nutrient supply conditions, is essential for crop technologies.

TOR can be assured form manure, chemical fertilizers and other sources, excepting the soil.

Unfortunately, many authors [6, 7, 8, 9, 10] published erroneous mathematical models which give absurd results, for example more than 25000 kg P_2O_5/ha in winter wheat, which means 29 trucks of 5 t with simple superphosphate/ha, some models give negative nutrient rates, for example around – 21000 kg P_2O_5/ha, as demonstrated in another paper [5] published in this Proceedings.

Other erroneous model [9] give nutrient rates one hundred times smaller than normal, that means 1 kg instead of 100 kg.

This paper brings, for the first time, reasonable solutions in settling TOR of N, P_2O_5 and K_2O in corn depending on the yield level and relevant soil agrochemical indexes.

MATERIAL AND METHODS

The TOR system for N, P_2O_5 and K_2O [3] is partially based on the EOR system [1]: the equations for nutrient action coefficients, c_a, and soil nutrient supply, S_n, have the same coefficients; the TOR mathematical model [3] is different from the EOR model [1]. A new version, number 3, of FERTEXPERT software [2] have been developed by author in order to incorporate the TOR model and to use the specific coefficients of the c_a and S_n equations for corn. FERTEXPERT has then been used for TOR calculations.

Based on calculated TOR, specific useful agrochemical tables and nomograms have been built.

RESULTS AND DISCUSSION

1. Specific results and discussion concerning the TOR in corn. The TOR mathematical model is [3, 5]:

$$\textbf{TOR, kg N, } \mathbf{P_2O_5, K_2O/ha} = [\log(2.3 \cdot c_a \cdot Y_m)]/c_a - S_n$$

(condition: if $[\log(2.3 \cdot c_a \cdot Y_m)]/c_a - S_n < 0$, then TOR = 0)

where:

Y_m = maximum expected yield, kg/ha, established on the basis of the site evaluation studies; the level of Y_m depend on the variety and on the levels of all vegetation factors;

c_a = action coefficient of N, P, K, unique for the considered nutrient from fertilizer and soil (potentially available form);

S_n = soil nutrient supply, potentially available form, kg N, P_2O_5 or K_2O/ha, calculated based on the specific agrochemical analyses (IN, P_{ALc}, K_{AL}) and Y_m.

The TOR system use the same computing equations for c_a and S_n as the EOR system [1]:

For nitrogen: $c_a = 0.003 + 25.2/Y_m$; $S_n = 115(1\text{-}10^{-0.13IN}) + 0.003Y_m$

For phosphorous: $c_a = 0.005 + 15/Y_m$; $S_n = 28 + 105(1\text{-}10^{-0.0136P_{ALc}}) + 0.004Y_m$

For potassium: $c_a = 0.0035 + 20/Y_m$; $S_n = 1.02K_{AL} - 0.000957(K_{AL})^2 + 0.004Y_m$

In these equations: IN = soil nitrogen index; P_{ALc} = soil mobile P content, ppm P, corrected with a reaction factor, FR [1]; K_{AL} = soil mobile K content, ppm K.

The results concerning the variation of TOR values depending on the soil agrochemical indexes (IN, P_{ALc}, K_{AL}) and maximum expected yield, Y_m, are presented in two-sided tables (tables 1, 2, 3) and in 3 nomograms (figure 1).

These practical agrochemical tables and the nomograms allow the farmers to operative estimate the TOR. The TOR mathematical model has to be used when the exact values of TOR are desired and and Y_m, IN, P_{ALc} and K_{AL} are not exactly those from the tables or nomograms.

Table 1

Technically optimal rates (TOR) of N (kg/ha) in corn as function of the maximum expected yield (Y_m) and soil nitrogen index (IN)

Y_m (kg/ha)	IN								
	0.5	**1.0**	**1.5**	**2.0**	**2.5**	**3.0**	**3.5**	**4.0**	**4.5**
2000	97	83	71	61	52	44	38	32	27
3000	141	127	115	105	96	89	82	77	72
4000	179	166	154	144	135	127	121	115	110
5000	213	199	187	177	169	161	154	149	144
6000	243	229	217	207	198	191	184	179	174
7000	270	256	244	234	225	217	211	205	201
8000	294	280	268	258	249	241	235	229	224

Table 2

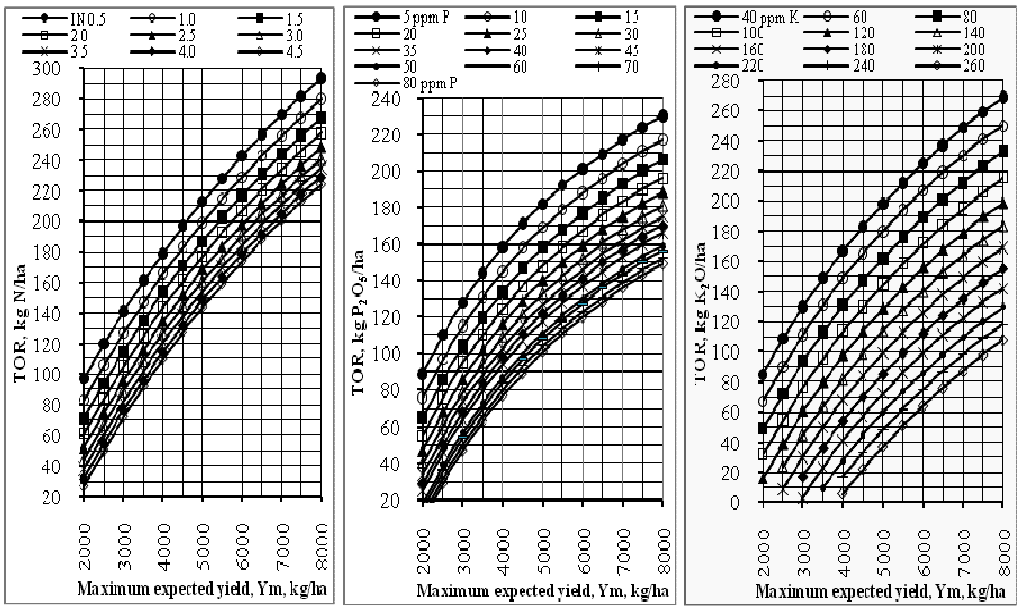
Technically optimal rates of P_2O_5 (kg/ha) in corn as function of the maximum expected yield (Y_m) and soil mobile P content (P_{ALc})

Y_m (kg/ha)	ppm P												
	5	**10**	**15**	**20**	**25**	**30**	**35**	**40**	**45**	**50**	**60**	**70**	**80**
2000	89	76	65	55	47	40	34	29	25	18	15	11	8
3000	128	115	104	95	86	79	74	68	64	57	54	50	47
4000	158	145	134	124	116	109	103	98	94	87	84	80	77
5000	182	169	158	148	140	133	127	122	118	111	108	104	101
6000	201	188	177	167	159	152	146	141	137	130	127	123	120
7000	217	204	193	183	175	168	162	157	153	146	143	139	136
8000	230	217	206	196	188	181	175	170	166	159	156	152	149

Table 3

Technically optimal rates of K_2O (kg/ha) in corn as function of the maximum expected yield (Y_m) and soil mobile K content (K_{AL})

Y_m (kg/ha)	ppm K											
	40	**60**	**80**	**100**	**120**	**140**	**160**	**180**	**200**	**220**	**240**	**260**
2000	85	67	49	32	16	0	0	0	0	0	0	0
3000	130	111	94	77	61	45	30	17	3	0	0	0
4000	167	149	131	114	98	82	68	54	41	28	17	6
5000	198	180	162	145	129	114	99	85	72	60	48	37
6000	225	207	189	172	156	140	126	112	99	86	75	64
7000	249	230	212	195	179	164	149	135	122	110	98	87
8000	269	250	233	216	199	184	169	155	142	130	118	108



a) b) c)

Fig. 1. Nomograms for TOR of N (a), P_2O_5 (b) and K_2O (c) in corn as function of maximum yield (Y_m) and soil nitrogen index (IN), mobile P content (P_{ALc}) and mobile K content (K_{AL}) respectively

The elaborated tables and the nomograms in corn, published for the first time in this paper, will be accessible on a specific website through an online Decision Support System (DSS) which will be built.

2. A short comparison between TOR and EOR and mistakes in the use of EOR model, tables and nomograms, avoided in the TOR system.

The advantage of the TOR tables and nomograms, as compared with those for EOR [1], is that those of TOR are stable, because TOR are independent of the changing unitary price of the yield (UPY, lei/kg) and unitary price of the fertilizer (UPF, lei/kg active substance) on the market, while EOR strongly depend on the UPY/UPF ratio.

This is the reason why each of the EOR published tables and nomograms [1], as „service solutions", is valid only for the ratio UPY/UPF given by the UPY and UPF values mentioned by authors, which were practically constant in the state controlled economy before 1989 in Romania, but is only a particular case on the free market economy after 1989.

In corn, for example, the published nomogram for EOR of N [1, pp. 44] is valid only for the ratio UPY/UPF = 0.8/2.942 = 0.272; for any other ratio, the nomogram is not valid. Unfortunately, today many use the EOR tables and nomograms no

matter the UPY and UPF are on the market, which is a gross mistake. In the use of TOR tables and nomograms, it is not possible such a mistake, because TOR do not depend on UPY/UPF ratio.

Not knowing the essential aspects of the EOR system, some authors [8] recently published EOR in 7 field crops, corn included, without any explanation on EOR system, on EOR model, on the fact that EOR are valid only for the particular UPY/UPF ratio they have been established in 1982 [1]; from their book, the reader (farmer, student etc.) understand, as the authors did, that the EOR rate are valid no mater the UPY and UPF values in the market, which is false, because the EOR rates can decrease even more than 50 % depending on UPY/UPF ratio. The scientific confusion of these authors [8] is so great that they put in the EOR table the values in apple and in grapevine that are in fact Experimental Optimal Rates (ExpOR), so they realized a very wrong "mixtum compositum". There are great difference between ExpOR [1] and EOR model [1], and of course, between their values. Other authors [7] confound the EOR with TOR: in a chapter with the syntagma "Economically Optimal Rates" in title they present a mathematical model that in fact calculates TOR.

The more the UPY/UPF ratio decreases, the more the EOR decreases in constant soil agrochemical index and expected yield level and becomes smaller than TOR [4], that means smaller than the optimal physiological nutrient needs. TOR are always higher than EOR, except the particular case UPY/UPF = 1, when EOR = TOR. Many use today the EOR model for calculations when UPY/UPF > 1, which is a gross mistake, as it was proved by a recent research [4]; in the use of TOR model, it is not possible such a mistake.

CONCLUSIONS

1. For the first time, useful agrochemical tables and nomograms have been elaborated, based on the TOR mathematical model, which can be used to settle the TOR of N, P_2O_5 and K_2O in corn depending on the maximum expected yield, Y_m, and on the specific soil agrochemical indexes: IN, P_{ALc}, K_{AL}.
2. The TOR mathematical model has to be used when exact values are desired; the agrochemical tables and nomograms can be used when operative settle of TOR are needed.
3. When maximum expected yields have to be obtained, the crops have to be fertilized in TOR. When maximum net revenue has to be obtained, the crops have to be fertilized in EOR; in this case, the maximum expected yield can be obtained only in the particular rare case when UPY/UPF = 1. It is wrong to calculate EOR when UPY/UPF > 1; in this case, only TOR has to be calculated.

4. Proving great scientific confusions and errors on the optimization of the nutrient rates, some authors [7], [8], [9], [10] published erroneous mathematical models and/or confound TOR with EOR, EOR with ExpOR etc. Some authors [7] confound TOR with EOR and presented TOR as being EOR. Other authors [8] presented the ExpOR as EOR or presented EOR in a wrong way. Such models and such books, that give absurd nutrient rates and induce great confusions, must not to be used in practice and in universities.

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