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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 WINTER WHEAT. COMPARISONS WITH SOME WRONG MODELS PUBLISHED BY D. AND V. DAVIDESCU, R. MADJAR, G. NEAȚĂ

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Abstract

This is the first paper from the series concerning the field crops. The mathematical models and agrochemical tables and nomograms in winter wheat are presented and these serve to settle the Technically Optimal Rates (TOR) of N, P_2O_5 and K_2O as function of maximum expected yield, Y_m, and the specific soil agrochemical indexes, AI (nitrogen index: IN; mobile phosphorous: P_{ALc}; mobile potassium: K_{AL}). The TOR of a nutrient, N for example, is that rate which allows to obtain the maximum yield in given conditions concerning the soil supply with the regarded nutrient, and allow a sustainable agriculture. The TOR system uses the same equations for nutrients action coefficients and soil nutrient supply as the Economically Optimal Rate (EOR) system. Fertexpert software version 3 has been used for TOR calculations. When the exact values of TOR are desired, the mathematical model have to be used; when operative settle of TOR are desired, the practical agrochemical tables or nomograms can be used by the farmers. The paper presents comparison between the nutrient rates calculated with TOR model and the absurd rates calculated with some published erroneous models.

INTRODUCTION

The TOR of N, P_2O_5 or K_2O are those rates that allow to obtain the maximum yield in given conditions concerning the soil supply with the considered nutrient, while the Economically Optimal Rates, EOR, allow to obtain the maximum net revenue/ha. The advantages and disadvantages of TOR system [3] versus EOR system [1] have been recently presented in another paper [4]. To can establish TOR is of crucial importance for the crop technologies. Unfortunately, many published mathematical models are wrong and give absurd nutrient rates [6, 7, 8, 9, 10]. This paper brings, for the first time, reasonable solutions in settling TOR in winter wheat depending on the yield level and relevant soil agrochemical indexes.

MATERIAL AND METHODS

A new version of FERTEXPERT software [2], the 3-rd, have been developed by author in order to incorporate the mathematical TOR model [3] and to use the

specific parameters for winter wheat. The mathematical models used by software for TOR, nutrient action coefficients, c_a, and soil nutrient supply, S_n, are presented below; the equations for c_a and S_n have the same coefficients as those used for the EOR of N, P_2O_5 and K_2O [1]. FERTEXPERT has then been used for TOR calculations. The specific practical agrochemical tables and nomograms (graphs) have been built based on the calculated TOR.

RESULTS AND DISCUSSION

1. Specific results and discussion concerning the TOR in winter wheat. The mathematical model, logically derived from the modified Mitscherlich response function [3], which can be used in order to calculate the TOR, is:

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

(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 (temperature, water etc.); c_a = action coefficient of N, P, K, unique for the nutrient from fertilizer and for the nutrient from soil (potentially available form), calculated with specific models; 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 logical deduction of the TOR mathematical model has been demonstrated by author in another paper [3].

The same equations and coefficients as those of EOR system [1] are used in order to compute c_a and S_n in TOR system; these equations are [1]:

For nitrogen: $c_a = 0.006 + 12/Y_m$; $S_n = 24.5IN - 2.41(IN)^2 + 0.0015Y_m$

For phosphorous: $c_a = 0.004 + 14/Y_m$; $S_n = 137(1\text{-}10^{-0.018P_{ALc}}) + 0.0045Y_m$

For potassium: $c_a = 0.0047 + 17.5/Y_m$; $S_n = 180(1\text{-}10^{-0.00362K_{AL}}) + 0.003Y_m$

In these models: 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 calculated results concerning the TOR values depending on the relevant soil agrochemical indexes, AI (IN, P_{ALc}, K_{AL}) and on the maximum expected yield, Y_m, are presented in two-sided tables (tables 1, 2, 3) and in 3 nomograms (figure 1). These agrochemical tables and nomograms show that the TOR increase with the decrease of AI and with the increase of Y_m. When the exact values of TOR are desired, the TOR mathematical model has to be used. When operative settle of TOR are desired, the practical agrochemical tables or nomograms can be used by the farmers; in such cases, visual interpolations have to be done, if necessary, in the TOR estimations; when interpolations have to be done, the results are approximates. The interpolations using a nomogram are more precise than those using a table. The agrochemical tables and nomograms in winter wheat, published

for the first time in this paper, will be accessible on a specific website through an online Decision Support System (DSS).

Table 1

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

Y_m	IN								
(kg/ha)	**0.5**	**1.0**	**1.5**	**2.0**	**2.5**	**3.0**	**3.5**	**4.0**	**4.5**
2000	130	120	110	102	96	90	85	82	80
3000	167	157	148	140	133	127	123	120	117
4000	195	185	175	167	160	155	150	147	145
5000	217	206	197	189	182	177	172	169	167
6000	234	224	215	207	200	194	190	187	184
7000	249	238	229	221	214	209	204	201	199

Table 2

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

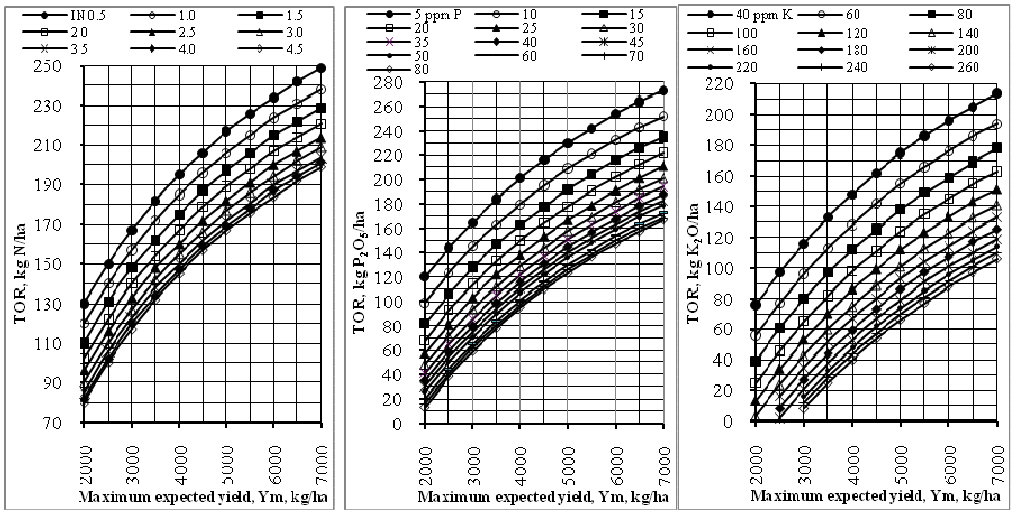
Y_m	ppm P												
(kg/ha)	**5**	**10**	**15**	**20**	**25**	**30**	**35**	**40**	**45**	**50**	**60**	**70**	**80**
2000	120	99	82	68	57	48	41	35	30	26	20	16	13
3000	165	145	128	114	103	94	86	80	75	71	65	62	59
4000	201	180	163	150	138	129	122	116	111	107	101	97	95
5000	230	209	192	178	167	158	151	145	140	136	130	126	123
6000	254	233	216	202	191	182	174	168	163	159	154	150	147
7000	273	252	235	222	211	201	194	188	183	179	173	169	167

Table 3

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

Y_m	ppm K											
(kg/ha)	**40**	**60**	**80**	**100**	**120**	**140**	**160**	**180**	**200**	**220**	**240**	**260**
2000	76	56	39	25	13	3	0	0	0	0	0	0
3000	116	96	80	65	53	43	35	27	21	16	12	8
4000	148	128	112	98	86	75	67	59	53	48	44	40
5000	175	155	138	124	112	101	93	86	79	74	70	66
6000	196	176	159	145	133	123	114	107	101	96	91	88
7000	214	194	178	163	151	141	133	125	119	114	110	106

2. Comparison between TOR and EOR and mistakes in the use of EOR model, tables and nomograms, avoided by TOR system. These aspects are presented in the complementary paper published by author in these Proceedings [5].



a) b) c)

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

3. Comparison between the macronutrient rates in winter wheat calculated with the above TOR mathematical and those calculated with the erroneous models elaborated and published by some authors [6], [7], published by other authors [8], [9], [10] with the same or new errors. In literature, the mathematical models wear in texts the names of the authors which elaborated and published them. This was not allowed me by the Scientific Committee of this Proceedings.

3.1. Reasonable nutrient rates given by the above TOR mathematical model. For example, on a soil with 35 ppm P, we have to apply 41 kg P_2O_5/ha for a 2000 kg/ha yield level and 122 kg P_2O_5/ha for a 4000 kg/ha yield level (table 2).

3.2. Absurd, huge nutrient rates given by the erroneous model

$$\text{"D, kg/ha} = (C_o - R_t) \cdot G_{sa} \cdot (1/C_u) \cdot k\text{"}$$

elaborated and published by some authors [6], [7], published also by others [9], [10], where: D = the rate to be applied (nitrogen, phosphorous, potassium), kg/ha, to reach the optimum content in soil; C_o = the optimum soil content which has to be attained in soil (nitrogen, phosphorous or potassium), ppm N, P, K (it is logic that C_o assure maximum yield/ha); R_t = total soil reserve of nitrogen, phosphorous or potassium (potentially available forms), in ppm; G_{sa} = weight of soil arable layer, t/ha; C_u = utilization coefficient of fertilizer, % (12-40 %); k = correction coefficient depending on soil organic matter content for N and K rates and on soil pH, texture and degree of gleization.

Some authors [9] published the above model even in a more absurd form, with Rt in t/ha, which means that we have to substract t/ha from ppm.

Example of calculation: for Co = 80 ppm P; Rt = 35 ppm P; Gsa = 3000 t/ha, Cu = 12 %, k = 1, kg P_2O_5 = kg P · 2.29, the rate is

D = (80-35)·3000·(1/12)·1 = 11250 kg P/ha = **25762 kg P_2O_5/ha** (absurd) ≡ **143125 kg** simple superphosphate**/ha** (with 18 % P_2O_5) ≡ **29 trucks** of 5 t**/ha** (absurd).

3.3. Huge, absurd, nonsense negative rates of P_2O_5 given by the wrong model

$$\textbf{"}D_{P\ (kg/ha)} = (P_{ex} - P_t \cdot 100) / C_u\textbf{"},$$

elaborated and published by some authors [6], published also by other authors [8], and published by another author [10] as

$$\textbf{"}D_{P\ (kg/ha)} = (P_{ex} - P_t)\ 100/\ C_u\textbf{"},$$

where P_{ex} = phosphorous extracted with the yield (Y), in kg/ha: $P_{ex} = Y \cdot C_{sp}$; C_{sp} = speciffic phosphorous consumption per tone of main yield: 15-18 kg P_2O_5/t [6]; C_u = utilization coefficient of fertilizer, %; Pt = total soil reserve of potentially available phosphorous, kg/ha, which, when we do not apply manure, is calculated with the equation "$P_t = G_{sa} \cdot P \cdot k_P \cdot CA_{pH} \cdot C_{Ag} \cdot 1/1000000$"; G_{sa} = weight of soil arable layer, kg/ha; P = mobile soil content, ppm P; k_P = coefficient of P assimilation from fertilizer (that means C_u); CA_{pH} = coefficient of assimilation depending on soil pH (in fact this is a correction factor of mobil soil P content with a reaction factor, FR [1], speciffic only for the AL method (extraction with ammonium acetate lactate), so the authors falsely consider this factor coefficient of P assimilation); C_{Ag} = coefficient of assimilation (0.6-1) depending on soil gleization degree.

Among other errors, the P_t equations do not contain the multiplication coefficient 2.29 in order to transform P in P_2O_5, which leads to wrong results; the D_P model use twice the coefficiant of P utilization form fertilizer, once as C_u and once as k_P, which also leads to wrong results.

Example of calculation:

If Y = 4 t/ha, C_{sp} = 18 kg P_2O_5/t, $P_{ex} = Y \cdot C_{sp}$ = 4·18= 72 kg P_2O_5/ha; G_{sa} = 3000000 kg/ha; P = 35 ppm P; k_P = 12 %, CA_{pH} = 0.9, C_{Ag} = 1, then

P_t = 3000000·35·12·0.9·1·(1/1000000) = 1134 kg P/ha= 2597 kg P_2O_5/ha (absurd)

$D_P = (72 - 2597 \cdot 100) / 12 = -21636$ kg P_2O_5/ha (absurd, nonsense)

With the other model [8], $D_P = (72 - 2597) \cdot 100/12 = -21042$ kg P_2O_5/ha (absurd).

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

The above erroneous models give absurd rates in all nutrients and all crops, not only in the exemplified P_2O_5 rate in winter wheat. Many other models published by these authors are incredible wrong.

CONCLUSIONS

1. Based on the TOR mathematical model, useful agrochemical tables and nomograms have been elaborated and published for the first time in order to operative settle the TOR of N, P_2O_5 and K_2O in winter wheat.
2. The agrochemical tables and nomograms can be used when operative settle of TOR are needed; the mathematical model has to be used when exact values of TOR are desired.
3. The erroneous models elaborated and published by some authors [6], [7], published also by other authors [8], [9], [10] with the same or new errors, give absurd rates in all nutrients and all crops. Such models and such books must not to be used in practice by farmers and in universities.

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