BUJOR MĂNESCU
N. LAGADIN

Using Econometric Calculation in Studying Fertilizer Utilization for Vegetables

"Maximum of efficiency with minimal expenses"

Among the factors of increasing farming output per unit area, a main part is played by mineral fertilizers. These have become an important factor, that determines the intensifying degree and the economic efficiency level in farming units. At present, it is admitted that the advanced-farming countries would not have attained the present-day profitableness of farming, gardening and wine-growing cultures without rationally applying chemical fertilizers.

It is worth emphasizing the fact that, in the after-war period, the weight of costs for fertilizers from the total production costs increases at a rapid pace, surpassing, for instance, more than twice the increasing of costs for the mechanization of the main farming works.

The production of ever increasing amounts of fertilizers and their utilization in an ever more various number of farming, gardening and viticultural cultivated plants makes it compulsory that the doses be made up rationally, by taking into account a series of factors, among which the most important are: the soil type, the soil fertilizing-substance storage, the cultivated breed and variety.

If one does not take into consideration the soil-type diversity, does not know the nutrient-elements storage in the soil, and does inadequately apply fertilizers, the latters' efficiency will be low, and the production increase by unit area will be reduced. This is why only an efficient calculation instrument could offer the possibility of establishing a rational dose, which might lead to obtaining high crops, of a high quality and with minimal costs.

Starting from this objective, we try in this paper to apply some mathematical models in establishing economic efficiency of fertilizers used in vegetable culture, as well as in determining an optimal schedule of distributing and dosing fertilizers.

I. ESTABLISHING OPTIMAL DOSES

As is known, fertilizers are a variable production factor, and this means that modifying fertilizer amount, by increasing or diminishing it, involves the modification of the level of the crop per unit area. As such, within the production process fertilizers can be used in lesser or larger amounts. Determining the optimal fertilizer amount per unit area can be done by taking into account the product's and fertilizer's costs, the physical production ratio, expressed through the marginal production, the establishing of the marginal substitution rate, and the blending of fertilizers.

The optimal fertilizer-dose level is, however, affected by zone-differentiations, assigned to several factors. Thus, the marginal fertilizer efficiency is higher in fertile soils, where higher amounts of these products are to be applied. Agrotechnical measures highly vary as concerns efficiency, and also contribute to differentiate marginal efficiency. One finds that, when applying identical technologies in various cultivating units or to various soils, the differentiation of fertilizer doses can be explained by the available funds of the unit in view of developing the production process.

In order to better understand the calculation mechanism of the economic efficiency, it is necessary to get acquinted with the possibilities of substituting fertilizers, i.e. the proportion of blending fertilizers with a view to diminishing production costs, and what amount of each fertilizer must be used on the cultivated grounds. The rational substitution starts from the determination of the marginal substitution ratio, and the optimal fertilizer combination (blending) is based upon the minimizing of production costs, with a view to obtaining the same production volume. Optimal combining conditions make it necessary that the marginal substitution rate be equal with the reverse costs ratio.

In view of emphasizing these principle elements, linked to the economic efficiency of chemical fertilizers utilization, we shall present the working procedure for determining optimal doses in early tomato culture. Similarly, doses for other cultures can be also established.

We present in table 1 the incorporated fertilizer doses according to the various soils cultivated with early tomatoes. When studying data in this table, it is difficult to draw significant conclusions as concerns the fertilizer utilization efficiency, given the great variability of production results as against the applied doses, in various soil and climate conditions. This is why, in a first investigation stage, the results in table 1 were grouped in terms of fertilizer kind, applied dose and soil type. To this end, the obtained outputs have been referred to the unfertilized reference soil, and they have been plotted in the diagrams in Fig. 1 and 2. For better understanding the effect of fertilizers upon various soil types, the diagram in Fig. 3 was plotted, where the crop increase per kg fertilizer is presented.

From the above-shown diagrams one can establish that the presented results are not concluding and the marked diversity of production factors does not allow to emphasize the experimented fertilizer efficiency, with a view to making some recommendations for the vegetable sector.

Table 1

Fertilizer doses on various soils cultivated with early tomatoes

Variations	Brown-reddish forest soil Băneasa	Degraded chernozem Miniș	Alluvional argillaceous sand soil Ciolpani	Alluvional loam sand soil		
				Buzău	Ișalnița	Ștefănești
Reference soil (unfertilized)	21.72	23.0	28.17	17.895	19.00	24.1
N_{40}	35.87	27.62	31.4	16.505	21.10	22.94
N_{80}	34.01	28.65	31.76	17.118	20.9	23.62
P_{40}	26.3	27.7	28.44	20.037	19.8	24.9
P_{80}	26.86	26.72	27.19	19.29	19.1	24.78
N_{80} P_{40}	27.42	32.6	27.32	22.096	24.2	25.54
N_{40} P_{80}	28.11	30.12	29.02	22.747	19.00	28.16
N_{80} P_{40}	30.7	34.97	28.46	21.361	21.3	25.72
N_{80} P_{80}	27.14	32.5	29.60	20.166	21.8	27.16

For keeping apart the fertilizers' influence from other factors' influences, we proceeded to arranging the series of data in table 1. To this end, we used linear regression of type

$$y = a + bx$$

By using the method of least squares, we determine the parameters:

$$a = \frac{\Sigma y \, \Sigma x^2 - \Sigma x \, \Sigma xy}{n \, \Sigma x^2 - \Sigma x \, \Sigma x} = 24.39; \quad b = \frac{n \, \Sigma xy - \Sigma x \, \Sigma y}{n \, \Sigma x^2 - \Sigma x \, \Sigma x} = 1.54$$

For the purpose of verifying the hypothesis concerning the linearity of the connection between the analysed variables, we resort to the criterion F, i.e. the ratio between variation of y characteristic values around the regression line (s_2^2) and the variation within the observation groups (s_1^2). Both dispersions are calculated as follows:

$$s_2^2 = \frac{\sum_{i=1}^{k} (y_i - \bar{y}_i)^2}{k-2} \quad \text{and} \quad s_1^2 = \frac{\sum_{i=1}^{k} \sum_{v=1}^{n_i} (y_{iv} - \overline{Y}_i)}{\sum_{i=1}^{k} n_i - k}$$

$$\text{where } \overline{Y}_i = \frac{\sum_{v=1}^{n_i} y_{iv}}{n_i} \quad \text{and} \quad Y_i = ax_i + b.$$

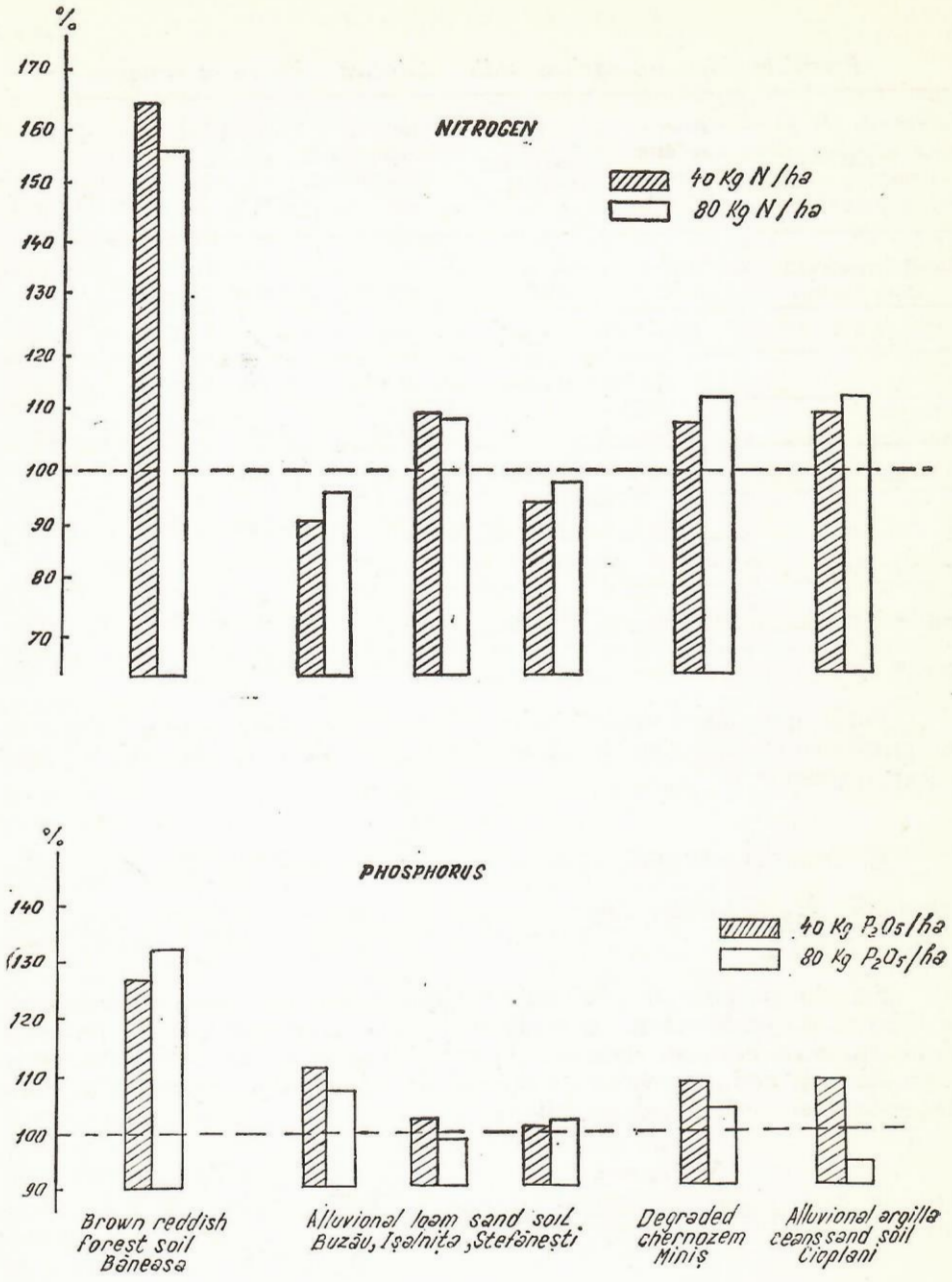


Fig. 1 Nitrogen and phosphorus containing fertilizers, in terms of soil type

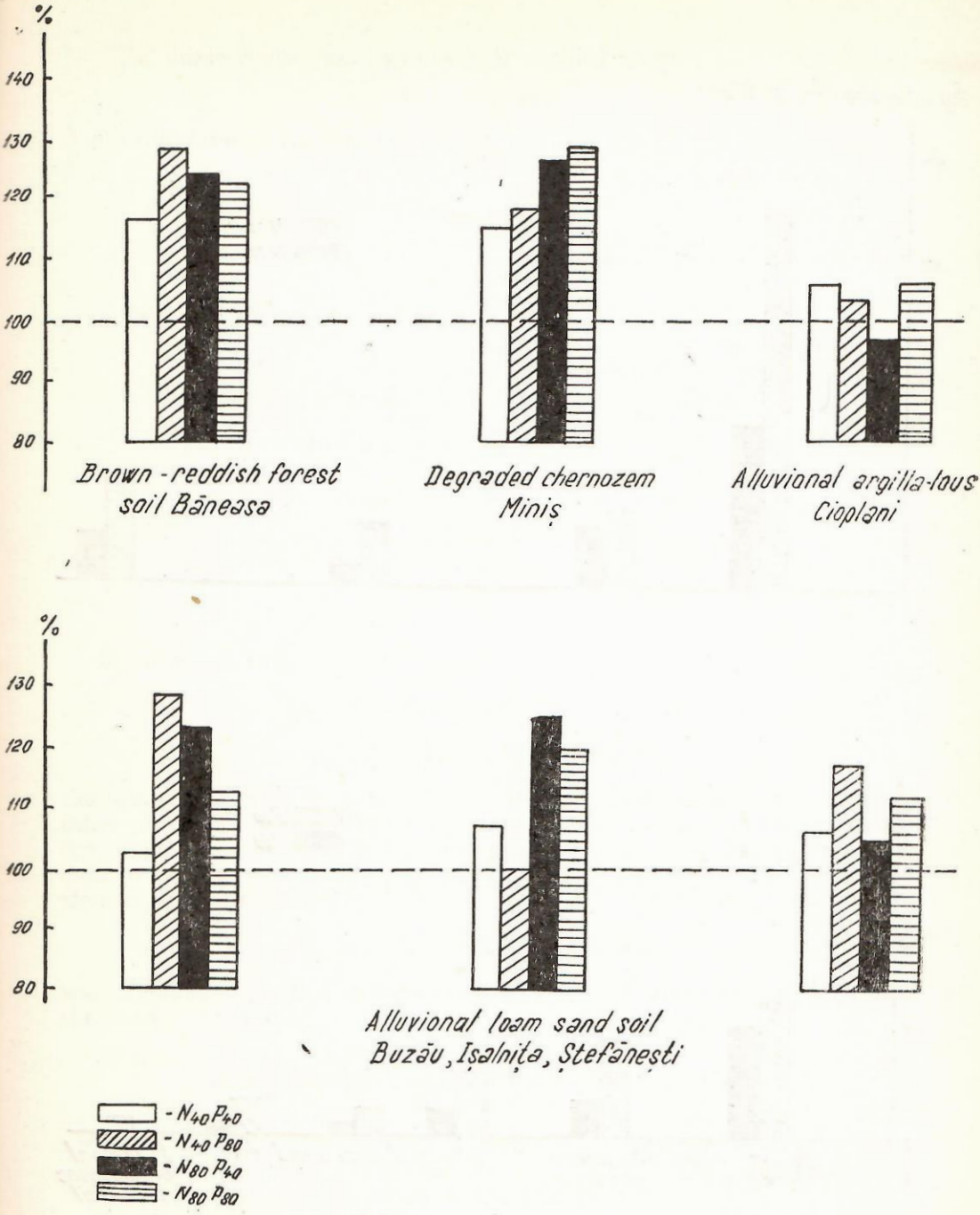


Fig. 2 - Efficience of combinations of nitrogen and phosphorus containing fertilizers, in terms of soil type

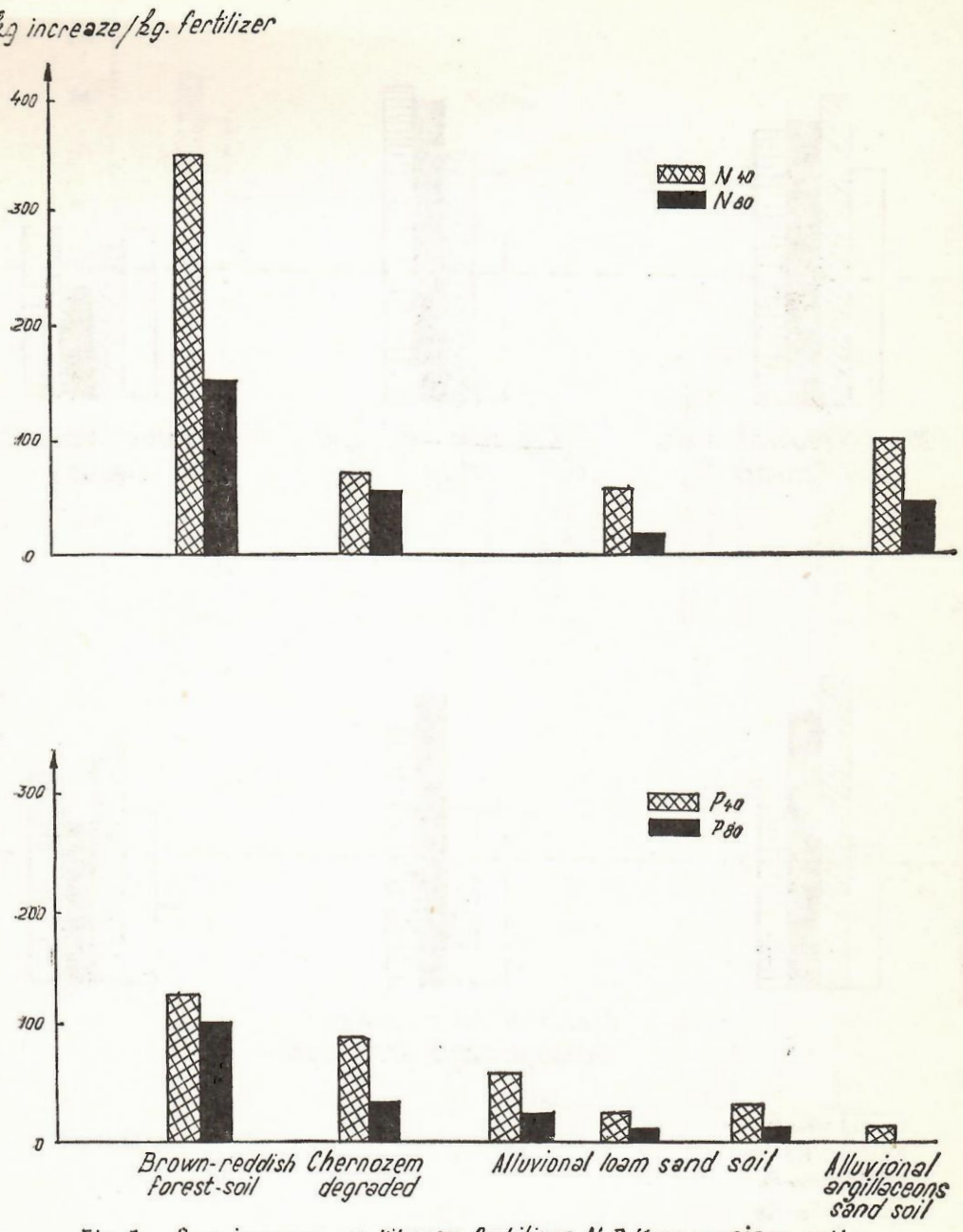


Fig. 3 - Crop increase per kilogram fertilizer N,P,K on various soil tipes

The linear connection hypothesis is verified when

$$Y_x \ldots F < F_{0.99}$$

A working table is made up (table 2).

Table 2

Working table

	Fertilizer amount	
	Variation between groups	Variation within groups
Sum of deviation square	75.8924	42.7213
Number of degrees of freedom	1	12
Dispersion	75.8924	3.5601
F	21.317	
$F_{0.99}$	9.33	
$F_{0.95}$	4.75	

Since in our case

$$Y_x \ldots F > F_{0.99} \ldots 21.317 > 9.33 \text{ and}$$

$$y_x \ldots F > F_{0.95} \ldots 21.317 > 4.75.$$

the linear connection hypothesis is not verified; it is necessary to look after other connection forms. The most frequently used ones are the curvilinear functions, especially the 2nd degree parabola. On using the experimental data in table 1, with the help of the method of least squares we determine thew regression equation:

$$\overline{Y}_x = 21.72 + 5.5311x - 0.4994\,x^2$$

whose graphical plotting is reproduced in Fig. 4. Further on, we determine the correlation ratio

$$\eta = \sqrt{\frac{a\Sigma y + b\Sigma xy + c\Sigma x^2 y - n\bar{y}^2}{\Sigma y^2 - n\bar{y}^2}} = 0.997$$

with respect to the linear correlation coefficient, which is only 0.799.

The fertilizer amount (N), corresponding to the crop's maximal level, is of 55.4 kg/hectare, and by annulling the first derivative

$$y' = \frac{b}{2c} = \frac{5.5311}{2 \cdot 0.4994}$$

For this fertilizer amount, the corresponding tomato crop is 37.035 kg/hectare. By applying the above-mentioned function, we calculated the marginal product for the early tomato culture, which is shown in table 3. It results, from the obtained data, that the maximal output lies around the quantity of 37

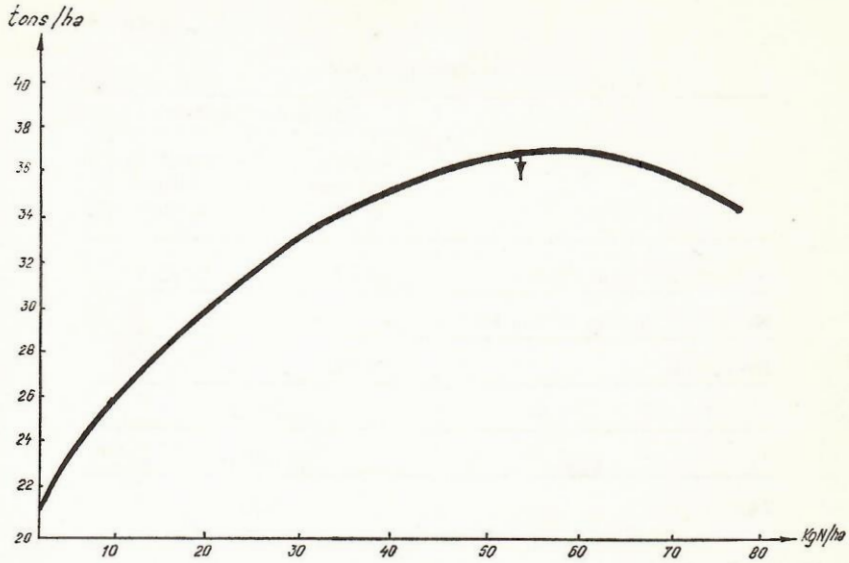


Fig. 4 - Output variation in term of the variation of nitrogen amount administered to 1 hectare of ground cultivated with early tomatoes

tons, which corresponds to a nitrogen doses of 55.4 kg/hectare or about 174 kg/hect. ammonium nitrate, active substance. The mean output is continuously diminishing and the marginal product has also a decreasing evolu-

Table 3

Marginal product calculation

kg N/ha X	Tomato crop (kg/ha) Y	Fixed-basis increase Y	Mean output Y/X	Chain-basis increase Y_{n-1}	Marginal product Y_{n-1}/X
0	21.715	—	—	—	—
10	26.752	5037	503.7	5037	503.7
20	30.785	9070	453.5	4033	201.6
30	33.819	12104	403,5	3034	101.1
400	35.854	14139	353.5	2035	50.9
50	36.890	15175	303.5	1036	20.7
60	36.928	15213	253.5	38	0.6
70	33.967	14252	203.6	—961	— 13.7
80	34.007	12292	153.6	—1960	— 24.5

tion. We can generally affirm that contribution's effect is rather limited, in the sense that the maximum increase is only 70.5% as against the reference soil, and the fertilizer amount which gives the maximal crop level is 55 kg/hectare.

We simultaneously analysed the main economic indicators, in terms of the fertilizer doses administered per unit area. It results, from the data in table 1, that the maximal early-tomato output is obtained with a nitrogen amount of about 60 kg//hectare. The optimal costs profit level corresponds to a lesser fertilizer amount. The crop increase is particularly economical and varies between 0.29 and 0.32 lei/kg tomatoes, and each "leu" spent for fertilizers brings a profit of 8.59 — 9.35 lei.

Table 4

Main economic indicators for various nitrogen doses applied to early tomatoes

N kg/ha	Crop (output) kg/ha	Expenses lei/ha	Returns lei/ha	Profits lei/ha	Costs lei/ha
0	21.715	60,000	65,145	5,145	2,763
10	26.752	61,460	80,256	18,796	2,297
20	30.287	62,640	92,355	29,715	2,035
30	33.819	63,539	101,457	37,918	1,879
40	35.854	64,159	107,562	43,403	1,789
50	36.890	64,499	110,773	46,274	1,748
60	36.928	64,559	110,784	46,225	1,749
70	35.967	64,341	107,901	43,560	1,789
80	34.007	63,842	102,021	38,176	1,877

We stated, in a first series of experiments, a great efficiency of nitrogen and phosphorus fertilizers on forest reddish soils, which clearly stand out among the other studied soil types. When fertilizer doses are made up of various rations of NP elements, better results are obtained on brown—reddish forest soils and degraded black earth (chernozem), in comparison with alluvial loam—sand soil.

II. OPTIMAL FERTILIZER-MANAGEMENT PLAN

The working out of an optimal plan of distributing and dosing fertilizers, from the economic viewpoint and that of crop increase, consists in three main stages: collecting the information material, the economic—mathematical matrix, and the computation proper.

Such a distribution plan is based upon comparing the economic efficiency obtained from each sown or planted plot after introducing mineral

fertilizers. The main economic efficiency criterion is the obtaining of the maximum posible profit from the administered fertilizer.

For drawing up the fertilizer administering plan it is first necessary to determine an information source, which would contain following data:

— total possible crop on the whole plot on which mineral fertilizers are applied;

— expected crop increase frcm the applied fertilizers (difference between total possible crop by applying fertilizers and the total probable crop from the same area);

— cost of fertilizers administered on the respective area;

— the crop increase calculated per one "leu" spent for fertilizers.

According to the experiments carried out in the Experimental Station-Buzău, a plan was worked out in order to distribute mineral fertilizers to three cultures: tomatoes, onions, headed cabbage. As a result of the application of the production functions, following efficiency categories for fertilizer were established:

Tomatoes:

$$y_{x_1x_2x_3} = 4.0114 + 2.6145\ x_1 - 1.1716\ x_1^2 + 1.5594\ x_2 - \\ - 0.3123\ x_2^2 + 2.5086\ x_3 - 1.1144\ x_3^2$$

Onions

$$y_{x_1x_2x_3} = 1.6005 + 0.1249\ x_1 - 0.0555\ x_1^2 + 0.4992\ x_2 - \\ - 0.3695\ x_2^2 + 8.8829\ x_3 - 12.3085\ x_3^2.$$

Cabbage

$$y_{x_1x_2x_3} = 3.6896 + 0.3511\ x_1 - 0.0151\ x_1^2 + 0.1825\ x_2 - \\ - 0.01\ x_2^2 + 0.7242\ x_3 - 0.0883\ x_3^2$$

The computed information material concerning the production increase, is presented in table 5.

With a view to solving the problem, an economic-mathematical model was drawn up where the efficiency function is the maximizing of profits by applying NPK fertilizers in optimal doses to the cultures:

$$Z_{max} = \sum_{i=1}^{n} \sum_{j=1}^{m} c_j x_{ij}$$

Restrictions are as follows:

— the area upon which fertilizers are applied cannot be greater than the area occupied by the three cultures

$$\Sigma\, a_{ij} \leqslant S;$$

— the fertilizer amount to be applied should not be higher than the available one

$$\Sigma\, x_{ij} \leqslant B\ ;$$

Table 5

Information material concerning production increase

Culture	Fertilizer type	Dose: kg/ha	Increase (kg)		Increase (lei)	
			for one kg fertilizer	by hectare	for one kg fertilizer	by hectare
Tomatoes	nitrogen	25	23.2	580	6.44	161.00
		50	20.3	1015	5.63	281.50
		75	17.4	1305	4.82	361.50
	phosphorus	25	14.6	365	5.55	138.75
		50	13.5	675	5.13	256.50
		75	12.5	937.5	4.75	356.25
	potassium	25	22.3	557.5	16.81	420.25
		50	19.5	975	14.70	735.00
		75	16.7	1252.5	12.59	944.25
Cabbage	nitrogen	25	31	775	3.73	93.25
		50	27	1350	3.25	162.50
		75	24	1800	2.89	216.75
	phosphorus	25	16	400	2.64	66.00
		50	13	650	2.14	107.00
		75	11	825	1.81	135.75
	potassium	25	5	125	1.63	40.75
Onions	nitrogen	25	11	275	4.78	119.50
		50	10	500	4.34	217.00
		75	9	675	3.90	292.50
	phosphorus	25	4.1	1025	2.44	61.00
		50	3.1	1550	1.84	92.00
	potassium	25	5.8	145	6.84	171.00

— a minimal production increase should be at least obtained, i.e.

$$\Sigma q_{ij} \geqslant Q ;$$

Table 6

Economic-mathematical matrix

	Tomatoes									Cabbage							Onions							
	N			P			K			N			P			K	N			P			K	
	x_1	x_2	x_3	x_4	x_5	x_6	x_7	x_8	x_9	x_{10}	x_{11}	x_{12}	x_{13}	x_{14}	x_{15}	x_{16}	x_{17}	x_{18}	x_{19}	x_{20}	x_{21}	x_{22}		
Tomato-sown area	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	$\leqslant$	40 ha
Cabbage area	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	0	0	0	0	0	0	$\leqslant$	35 ha
Onion area	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	$\leqslant$	5 ha
N-amount	25	50	75	0	0	0	0	0	0	25	50	75	0	0	0	25	50	75	0	0	0	0	$\leqslant$	5000 ha
P-amount	0	0	0	25	50	75	0	0	0	0	0	0	25	50	75	0	0	0	0	25	50	0	$\leqslant$	4100 ha
K-amount	0	0	0	0	0	0	25	50	75	0	0	0	0	0	0	25	0	0	0	0	0	25	$\leqslant$	3000 kg
Tomato increase	580	1015	1305	365	675	937.5	557.5	975	1252.5	0	0	0	0	0	0	0	0	0	0	0	0	0	$\geqslant$	92000 kg
Cabbage increase	0	0	0	0	0	0	0	0	0	775	1350	1800	400	650	825	125	0	0	0	0	0	0	$>$	47000 kg
Onion increase	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	275	500	675	1025	1550	145	$>$	30000 kg

Efficiency function (maximizing profit)

$$563\ x_1 + 960\ x_2 + 1190\ x_3 + 344\ x_4 + 625\ x_5 + 851\ x_6 + 603\ x_7 + 1045\ x_8 +$$
$$+ 1326\ x_9 + 284\ x_{10} + 468\ x_{11} + 589\ x_{12} + 124\ x_{13} + 174\ x_{14} + 186\ x_{15} + 24\ x_{16} +$$
$$+ 391\ x_{17} + 693\ x_{18} + 904\ x_{19} + 1769\ x_{20} + 2639\ x_{21} + 223\ x_{22} = max$$

The non-negativity condition is as follows:

$$x_{ij} \geqslant 0$$

Where:

x_{ij} — fertilizer amount j that can be applied to culture i;
c_j — profit that can be obtained by applying fertilizer j;
a_{ij} — area occupied by culture i which should be made fertile;
S — total area occupied by cultures i;
B — total fertilizer amount j;
q_{ij} — production increase obtained by applying various fertilizer amounts j to cultures i.
Q — Total production increase of each of the cultures i.

For the electronic computer, the economic-mathematical matrix in table 6 was worked out.

It results from the computation that the most economical doses, in the given conditions, are:

	N	P	K
Tomatoes	50	75	75
Cabbage	65	38	25
Onions	75	25	—

On the basis of the obtained results, the optimal solution (A) given by the computer is compared with the version of applying fertilizers in maximal doses (B). The existing fertilizer amounts — 5000 kg nitrogen, 4100 kg phosphorus, and 3000 kg potassium — can be used to make fertile the plot of land, bringing about following production increases:

Table 7

Crop increase by cultures (kg)

Culture	Optimal solution *A*	Version *B*	Difference
Tomatoes	117947	75414	+42533
Cabbage	47000	59447	—12447
Onions	42500	33957	+ 8543
Total	207447	168818	38629

The total vegetable increase is also reflected in the level of the technical-economic indicators. Thus, the costs (lei/t) are the most reduced for the optimal solution A, as compared to version B (table 8).

Table 8

Costs by cultures (lei/t)

Culture	Optimal solution *A*	Version *B*	Difference
Tomatoes	171	200	—29
Cabbage	159	221	—62
Onions	227	277	—50
Total	179	223	—44

Another indicator, which certifies the optimal solution efficiency, is the one denominated "expenses for 1000 lei production", exhibited in table 9.

Table 9

Expenses for 1000 lei production

Culture	Optimal solution *A*	Version *B*	Difference
Tomatoes	148	173	— 25
Cabbage	318	443	—125
Onions	126	154	— 28
Total	158	212	— 54

Finally, the highest profits from tomatoes and onions are obtained when adopting optimal solution; only for the cabbage culture is the profit higher with version *B* (table 10).

Table 10

Obtained profits (thousand lei)

Culture	Optimal solution *A*	Version *B*	Difference
Tomatoes	115.4	71.6	+33.8
Cabbage	15.1	17.6	— 2.5
Onions	66.3	53.5	+12.8
Total	196.8	142.7	+44.1

The results obtained by using the mathematical model in order to establish fertilizer doses, optimal from the economic viewpoint, are particularly concluding. Thus, for all analysed cultures, the production increases are high, the costs are low, and the profits increased.

REFERENCES

1. BISHOP C. E. TOUSSAINT W. D.: *Introduction to Agricultural Economic Analysis.* John Wiley & Sons, New York, 1963.
2. BOGUSLAWSKI E., SCHNEIDER B.: *Die dritte Annäherung des Ertragsgesetzes.* Zeitschrift für Acker und Pflanzenbau, 1964, vol. 119, nr. 1.
3. BUBLOT GEORGES: *L'exploitation agricole. Economie-Gestion-Analyse,* Nauwelaerts, Louvain-Paris, 1965.
4. COSTAN GH., RĂUȚĂ C., LAGADIN N.: *Unele aspecte ale aplicării îngrășămintelor în hortiviticultură* (Some Aspects of Applying Fertilizer in Garden and Wine-growing Cultures) Grădina, Via și Livada, nr. 8, 1964.
5. EZEKIEL MORDECAI, FOX KARL: *Methods of Correlation and Regression Analysis.* Ed. John Wiley & Sons, New York, 1966.
6. HEADY EARL, PESEK T. J., RAO J. V.: *Fertilizer Production Functions from Experimental Data with Associated Supply and Demand Relationships.*
7. HERA CR., VÎLCEANU GR.: *Corelații economice în folosirea rațională a îngrășămintelor* (Economic Correlations in Rational Usage of Fertilizers). Viața economică, nr. 8 and 11, 1963.
8. HOEPNER P. H., LÜTZ J. A.: *An application of multiple covariance analysis to the estimation of fertilizer response functions.* Agronomy Journal, vol. 58 nr. 1, 1966.
9. IONESCU C., IORDACHE V., MOINEAGU C., POSTELNICU V., SCHATTELES T.: *Metode statistice de cercetare a corelațiilor în economie.* (Statistical Methods of Investigating Correlations in Economy), Editura Academiei, București, 1967.
10. KRAVCENKO R.: *Optimalnîi plan respredelenia mineralnîh udobrenii.* Ekonomika selskogo hoziaistva, nr. 9, 1966.
11. KUVȘINOV S. I., LOVKOV A. I., MERZLOV V. K.: *Rasciot effecktivnosti mineralnîh udobrenii.* Ekonomika selskogo hoziaistva, nr, nr. 8, 1964.
12. MIHOC GH., NĂDEJDE ILEANA: *Programarea matematică,* vol. I—II (Mathematical Programming, vol. I—II), Editura Științifică, 1966.
13. OBOLENSKI K.: *Ekonomiceskie problemî ispolzovania udobrenii.* Ekonomika selskogo hoziaistva, nr. 6, 1964.
14. SCHADEREIT G.: *Die Anwendung der Produktionsfunktionsanalyse zur Bestimmung des Nutzens der Umlaufmittel, dargestellt an der Stikstoffdüngung.*
15. SKRIPKA A.: *Modelirovanie zadaci optimalnogo ispolzovania udobrenii.* Ekonomika selskogo hoziaistva, nr. 4, 1963.
16. STOICESCU MARIA, PĂUNEL I.: *Stabilirea dozelor de îngrășăminte minerale pentru îngrășarea tomatelor, cepei de apă și verzei de toamnă.* (Establishing Mineral Fertilizer Doses for Fertilizing Early Tomatoes, Onions and Autumn Cabbages). Lucrări științifice I.C.H.V., 1963—1964 vol. VII.

L'UTILISATION DU CALCUL ECONOMETRIQUE DANS L'ETUDE DE L'UTILISATION DES ENGRAIS POUR LES LEGUMES

Parmi les principaux facteurs de l'accroissement de l'efficience économique de la culture des légumes, un rôle particulier revient à l'application des engrais. L'utilisation des doses optimales dépend du prix des produits, du coût des engrais et de leur efficience différentielle (marginale).

Les auteurs présentent les résultats de certaines expériences faites avec des engrais chimiques appliqués aux cultures de tomates précoces, pour l'obtention d'une production aussi grande et économique que possible, en tenant compte des types de sol, du climat et de la teneur du sol en éléments nutritifs. Les graphiques présentés montrent que les résultats obtenus (les données primaires) ne sont pas concluants et c'est pour cela qu'on a calculé la fonction de production linéaire; puisque l'hypothèse de linéarité ne s'est pas vérifie, on a recours à l'ajustement curviligne avec des fonctions du II-me degré. L'équation de régression permet de calculer la dose optimale d'azote, qui mène à la production maximale de tomates, aussi bien qu'à l'augmentation la plus économique.

On montre ensuite comment on peut établir un plan optimal de répartition et de dosage des engrais, en prenant en considération trois cultures légumicoles (choux, tomates, oignons). On a élaboré la matrice économique-mathématique du plan optimal et on a calculé le programme optimal sur un calculateur électronique.

On démontre que la solution optimale est bien plus avantageuse, fait qui plaide en faveur de l'extension des méthodes et des modèles d'optimisation à l'aide de la technique électronique de calcul.

ПРИМЕНЕНИЕ ЭКОНОМЕТРИЧЕСКОГО РАСЧЕТА ПРИ ИЗУЧЕНИИ ИСПОЛЬЗОВАНИЯ УДОБРЕНИЙ В ОВОЩЕВОДСТВЕ

Среди важнейших факторов роста экономической эффективности овощеводства особую роль играет использование удобрений. Применение оптимальных доз связано с ценой продуктов, со стоимостью удобрений и с их дифференцированной (конечной) эффективностью.

Авторы указывают результаты некоторых опытов с химическими удобрениями, использованными для культур ранних помидоров в целях получения как можно большей и экономичной продукции с учетом типов почвы, климата и содержания питательных элементов в почве. Из приведенных графиков видно, что достигнутые результаты (первичные данные) не являются убедительными и поэтому была рассчитана линейная функция производства; поскольку не была проверена гипотеза линейности, было произведено криволинейное приближение при помощи функций II степени. Уравнение регрессий позволяет рассчитывать оптимальную дозу азота, что обеспечивает наибольшую продукцию помидоров, а также наиболее экономичное увеличение продукции.

Затем указывается, как можно установить оптимальный план распределения и дозирования удобрений с учетом трех видов овощных культур (капусты, помидоров и лука). Была разработана экономико-математическая матрица оптимального плана и рассчитана оптимальная программа на электронной вычислительной машине.

Указывается, что оптимальное решение представляется гораздо более выгодным, что является аргументом в пользу распространения методов и моделей оптимизации при помощи электронной техники расчета.