MODEL TO DESCRIBE THE INFLUENCE OF N AND PK FERTILIZERS IN THE VARIATION OF RAPESEED PRODUCTION

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Abstract

The production variation in relation to fertilizers with N and PK was analyzed. The study was conducted on rapeseed. Four levels of fertilization with PK (0, 80, 100 and 120 kg a.s. ha^{-1}) and three levels of fertilization with N were performed (0, 70, 140 kg a.s. ha^{-1}). The combination of doses resulted in 12 experimental variants, which ensured the differentiated nutrition of the plants. Production ranged from 986.88 kg ha^{-1} (V1), and 3,167.33 kg ha^{-1} (V9). The variation of production was described by a function of type Y = f (N, PK), in conditions of statistical certainty (R^2=0.976, p<0.001). From the analysis of the values of the production increase given by N and PK, it was found that, with the increase of N doses, in the studied interval, the contribution of PK to the production increase was more and higher. Regarding PCA, PC1 explained 99.244% of variance, and PC2 explained 0.65613% of variance. The PCA diagram highlighted the distribution of the considered variants, in relation to the attributes of the experiment, N, PK and Y. The cluster analysis facilitated the grouping of variants based on Euclidean distances, in conditions of statistical safety, Coph. corr. = 0.762. Based on similarity and distance indices (SDI) the highest degree of similarity was identified between variants V2 and V12 (SDI = 11.49), followed by variants V8 and V11 (SDI = 31.71), and variants V6 and V7, respectively (SDI = 100.6).

Key words: *experimental attributes, model, NPK, PCA, similarity distance indices, yield*

INTRODUCTION

The production of crop plants is dependent on inputs and factors, and their sizing requires a permanent adaptation and adjustment in order to optimization [23], [49].

Fertilizers represent important inputs in plant production, and dose sizing is a particularly important technical aspect, in relation to the agricultural system, soil and climatic conditions, production and its quality [32], [43], [48].

Macronutrients (NPK) represent the highest consumption of mineral elements for crops. Harmonization of the doses of these elements is important for crop plants. Nitrogen is a nutrient that quantitatively defines plant growth, biomass production and agricultural production, in general [18], [44], [51]. Phosphorus and potassium are macro elements with major influence in fruiting, production quality, and plant tolerance to certain vegetation conditions [54], [11], [6].

Various studies have addressed the influence of nutrients (macro- and microelements) in order to analyze and model the variation of production and quality at crop plants, in relation to them [17], [4], [16], [25], [5].

Optimization problems are permanent, in relation to agricultural systems [12], [26], [37], in relation to crop plants and the production potential of cultivated genotypes [24], [3], [7], with the spatial and temporal variability of soil fertility [29], [50], [22], with the variation of market requirements for agricultural products [38], [39], with climatic conditions variations [14], [47], with crops technologies [2], [42], or facilities offered by related fields, remote sensing, GIS, smart agriculture [13], [19], [20], [8], [10], [30].

The present study analyzed the variation of rapeseed production in relation to different doses of nitrogen (N) and phosphorus and potassium (PK) considered together, in order to estimate by models the response of rapeseed plant crop, and the production increase.

MATERIALS AND METHODS

The study looked at the influence and contribution of nitrogen (N), phosphorus and potassium (PK) on rapeseed production.
The study was carried out in the Zadareni - Arad area, in chernozem type soil conditions.
The biological material was represented by rapeseed (*Brassica napus* L.).
Differentiated nutrition was provided to the plants by fertilization with nitrogen (N) and phosphorus and potassium (PK).
Four levels of PK fertilization (0, 80, 100 and 120 kg a.s. ha^{-1}) were performed. On each level of PK fertilization, three levels of nitrogen fertilization were performed (0, 70, 140 kg a.s. ha^{-1}). From the combination of the two types of fertilizers (N and PK), 12 experimental variants resulted.
The influence of fertilization on rapeseed production was analyzed, in terms of the two types of fertilizers used.
The analysis of the experimental data was done with EXCEL and PAST software [15].
The graphical distribution of the production values according to N and PK fertilizer was made with Wolfram alpha software [46].
Variance analysis, correlation analysis, regression analysis, PCA and cluster analysis were used.
As a statistical safety parameters the regression coefficient (R^2), the correlation coefficient (r), the Cophenetic coefficient (Coph. corr.), similarity and distance indices (SDI), the p parameter and the F test, respectively, were used.

RESULTS AND DISCUSSIONS

The study analyzed the influence of N and PK on rapeseed production and hypothesized the finding of models to describe the variation and distribution, based on similarity, of the experimental variants.
Under differentiated nitrogen (N) and PK fertilization conditions, rapeseed production ranged from 986.88 kg ha^{-1} (V1) to 3,167.33 kg ha^{-1} (V9) (Table 1).
Nitrogen fertilization, on the four levels of fertilization with PK led to the variation of production between 986.88 kg ha^{-1} (V1) and 1,796.52 kg ha^{-1} (V3), in PK0 conditions; 1,537.99 kg ha^{-1} (V4) and 2,734.53 kg ha^{-1} (V5) in PK80 conditions; 2,156.50 kg ha^{-1} (V7) and 3,167.33 kg ha^{-1} (V9) in PK100 conditions; 2,378.00 kg ha^{-1} (V10) and 2,964.98 kg ha^{-1} (V11) in PK120 conditions, respectively. Graphic representation is presented in Figure 1.

Table 1. Rapeseed production, under the influence of N and PK fertilization

Fertilizer doses (kg active substance ha^{-1})		Experimental variant	Yield
N	PK	Trial	Kg ha^{-1}
0	0	V1	986.88^{ooo}
70	0	V2	$1,345.87^{ooo}$
140	0	V3	$1,796.52^{ooo}$
0	80	V4	1537.99^{ooo}
70	80	V5	2,734.53
140	80	V6	$2,055.90^{***}$
0	100	V7	$2,156.50^{ooo}$
70	100	V8	$2,933.27^{*}$
140	100	V9	$3,167.33^{***}$
0	120	V10	$2,378.00^{ooo}$
70	120	V11	$2,964.98^{**}$
140	120	V12	2,746.02
Limits of Significance of Differences (LSD) Interpretation was made compared to V5			LSD5% = 162.690 LSD1%=221.636 LSD0.1%=297.873

Source: Own data from the experiment.

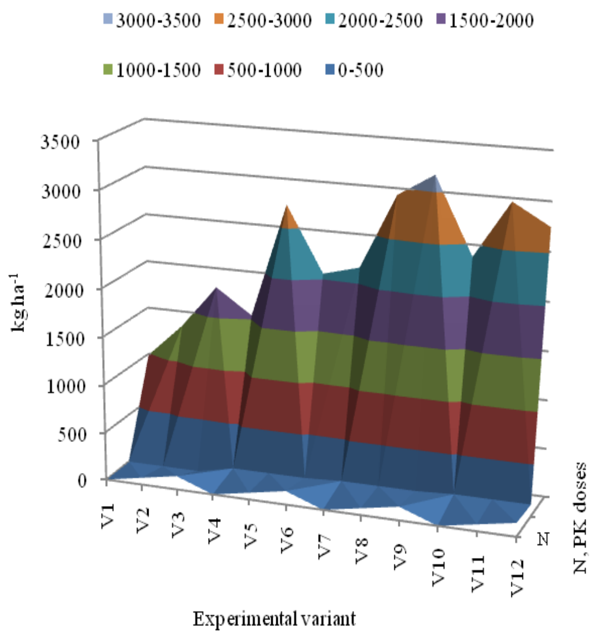

Fig. 1. Graphic distribution of production in relation to experimental variants
Source: Original graph, based on experimental data.

The variation of rapeseed production (Y), depending on the doses of N and PK was described by equation (1), in statistical safety conditions, according to R^2=0.976, p<0.001, F=59.0258. For high accuracy, the values of the coefficients of equation (1) were used to 16 digits.
The 3D distribution of production, depending on N and PK, is shown in Figure 2, and the distribution in the form of isoquants is shown in Figure 3.

$$Y = ax^2 + by^2 + cx + dy + exy + f \qquad (1)$$

where: Y – rapeseed production;
x – N fertilizer (kg a.s. ha^{-1});
y – PK fertilizers (kg a.s. ha^{-1});
a, b, c, d, e, f - the equation (1) coefficients;
a= -0.1049769;
b= -0.0137494;
c= 27.0952100;
d= 21.6663994;
e= -0.0774712;
f= 0.

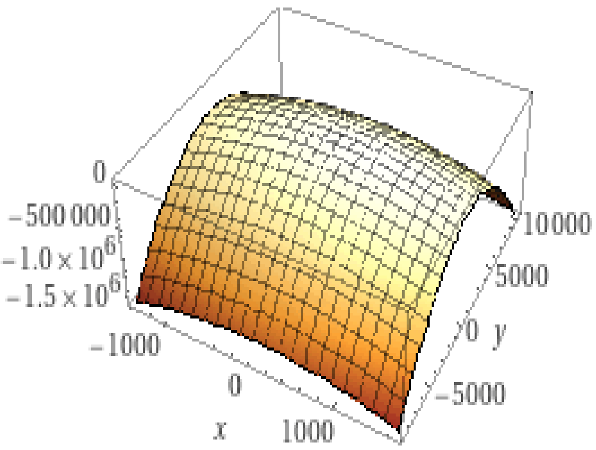

Fig. 2. 3D graphical distribution of Y values in relation to N (x-axis) and PK (y-axis)
Source: original graph based on experimental data, generated with Wolfram Alpha [46].

The 3D graphical distribution shows a much wider variation of rapeseed production in relation to PK, compared to the variation depending on N.
The production increase generated by N and PK for rapeseed is shown graphically in Figure 4.
From the analysis of the values of the production increase given by N and PK, it was found that the PK contribution to the production increase was higher compared to the N contribution, under the study conditions.

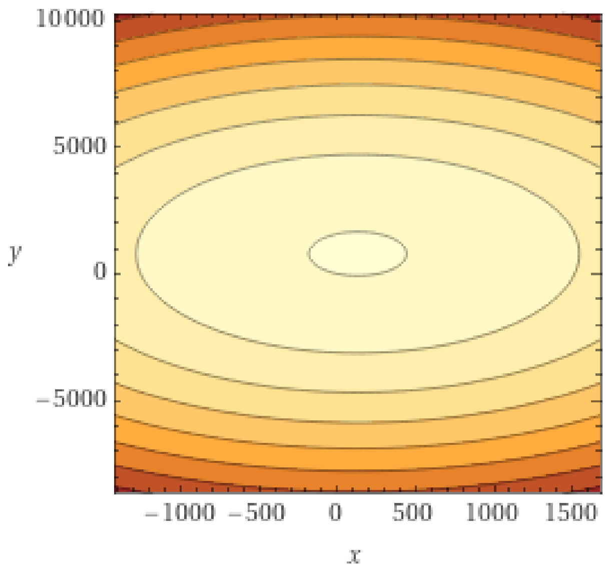

Fig. 3. Graphic distribution in the form of isoquants of Y values in relation to N (x-axis) and PK (y-axis)
Source: original graph based on experimental data, generated with Wolfram Alpha [46].

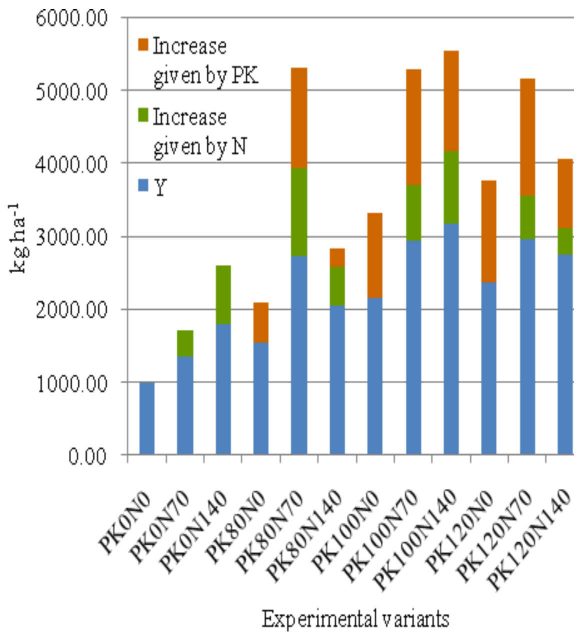

Fig. 4. Graphical representation of the production increase generated by N and PK fertilization in rapeseed
Source: original graphic generated based on experimental data.

The results are consistent with other research on the relationship between N and PK for plant nutrition. With the increase of N doses through fertilization, there is an increase in the need for P, respectively K of plants, and nutrition and production relationships have been studied to different crops, such as wheat, corn, sunflower, rapeseed etc. [21], [36], [27], [1], [31].

Principal Component Analysis led to the diagram in Figure 5. PC1 explained 99.244% of variance, and PC2 explained 0.65613% of variance.

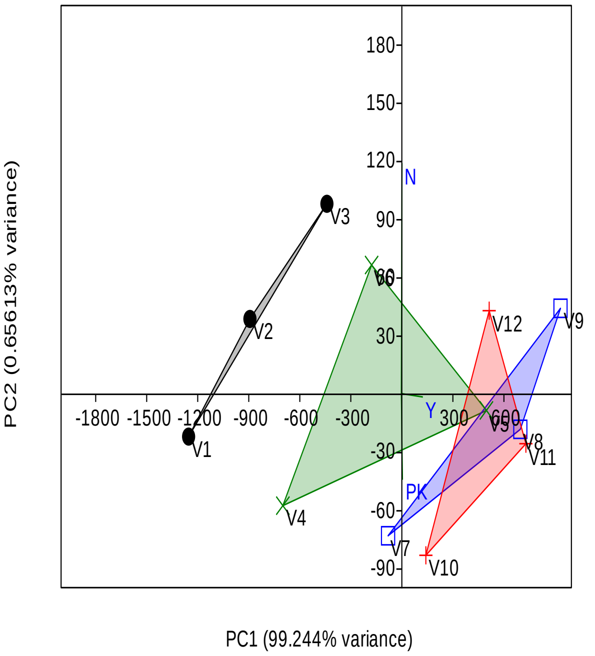

Fig. 5. PCA variant distribution diagram
Source: original figure, generated based on experimental data

From the analysis of the PCA diagram, it was found the independent placement of the first three variants (single fertilization with N). Associated PK biplot were placed variants V4, V7 and V10 (fertilization with PK 80, 100 and 120 kg ha^{-1}, and N0).

In relation to the attributes of the experiment (Y, N, PK), associated with the Y biplot, the variants V5, V8, V9, V11 and V12 were registered, which ensured high production levels.

Cluster analysis facilitated the grouping of variants based on Euclidean distances, figure 6, in statistical safety conditions, Coph corr. = 0.762.

Two distinct clusters were obtained. A cluster C1 comprises variants V1 - V4, with V1 on a separate position, V2 and V4 with values of the similarity index SDI = 192.12, to which variant V3 is associated.

Cluster C2 comprises two sub clusters (C2-1 and C2-2), each grouping several variants. Cluster C2-1 comprises three variants (V6, V7) for which SDI = 100.6, and V10 which is affiliated to this group. Cluster C2-2 comprises five variants. The V9 variant was positioned on a distinct position, which generated the best production results. Variants V5 and V12 were associated and had the best value on the similarity index (SDI = 11.49). V8 and V11 variants were also associated, for which SDI = 31.71 (Table 2).

Within the C1 cluster, the framed variants generated products between 986.88 kg ha^{-1} (V1) and 1,796.52 kg ha^{-1} (V3). The variants from cluster C2-1 generated productions between 2,055.90 kg ha^{-1} (V6) and 2,378.00 kg ha^{-1} (V10). The variants within the C2-2 cluster generated productions between 2734.53 kg ha^{-1} (V5) and 3167.33 kg ha^{-1} (V7).

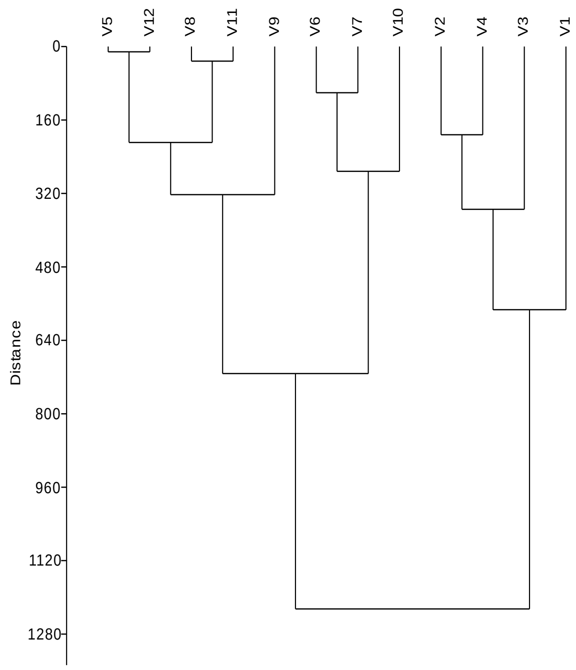

Fig. 6. Cluster diagram of grouping variants based on Euclidean distances
Source: original diagram based on experimental data.

Within each cluster, different fertilization options have led to similar results, which provide important information for agricultural practice. It is possible to opt for certain fertilization, in relation to the production interval in which it is desired to obtain the results, and different fertilizations have different costs. Thus, the production and costs of fertilization can be taken into account to choose an appropriate fertilization option.

Table 2. Values for similarity and distance indices (SDI), depending on the rapeseed production influenced by N, PK fertilization

	V1	V2	V3	V4	V5	V6	V7	V8	V9	V10	V11	V12
V1		358.99	809.64	551.11	1,747.7	1,069	1,169.6	1,946.4	2,180.4	1,391.1	1,978.1	1,759.1
V2	358.99		450.65	192.12	1,388.7	710.03	810.63	1,587.4	1,821.5	1,032.1	1,619.1	1,400.2
V3	809.64	450.65		258.53	938.01	259.38	359.98	1,136.8	1,370.8	581.48	1,168.5	949.5
V4	551.11	192.12	258.53		1,196.5	517.91	618.51	1,395.3	1,629.3	840.01	1,427	1,208
V5	1,747.7	1,388.7	938.01	1,196.5		678.63	578.03	198.74	432.8	356.53	230.45	11.49
V6	1,069	710.03	259.38	517.91	678.63		100.6	877.37	1,111.4	322.1	909.08	690.12
V7	1,169.6	810.63	359.98	618.51	578.03	100.6		776.77	1,010.8	221.5	808.48	589.52
V8	1,946.4	1,587.4	1,136.8	1,395.3	198.74	877.37	776.77		234.06	555.27	31.71	187.25
V9	2,180.4	1,821.5	1,370.8	1,629.3	432.8	1,111.4	1,010.8	234.06		789.33	202.35	421.31
V10	1,391.1	1,032.1	581.48	840.01	356.53	322.1	221.5	555.27	789.33		586.98	368.02
V11	1,978.1	1,619.1	1,168.5	1,427	230.45	909.08	808.48	31.71	202.35	586.98		218.96
V12	1,759.1	1,400.2	949.5	1,208	11.49	690.12	589.52	187.25	421.31	368.02	218.96	

Source: Original data, resulting from the analysis of experimental values.

It is obvious that for a high level of production, a balanced fertilization is necessary, a consistent contribution of PK to production being registered also by the present study.

The analysis of the obtained results shows the differentiated contribution of the two categories of mineral elements (N and PK) on the production, in the case of the present study of rapeseed production.

Under the conditions of the singular application of N, the harvest had an increasing trend, in the range of the studied fertilizer doses.

A relatively balanced share of the two categories, N and PK in production generation, was recorded in the case of variant V5 (N80, PK70).

As the dose of PK increases, the level of production increases, associated with N, and the share of the two types of fertilizers, N and PK, in the production increase was changed, in the context of experimental conditions.

A higher value of the production increase was associated with PK fertilizers, compared to N.

PCA method explained the source of the variance in the experimental data set, and the cluster analysis facilitated the grouping of the variants in relation to the experimental attributes. Within each of the three clusters, different fertilization variants, in the range of studied doses, led to similar productions, under the experimental conditions.

This model of grouping and presentation of variants offers the possibility to choose a certain experimental variant depending on the expected level of production afferent to a certain level of input, in the form of fertilizer allocation

PCA is a very objective method in the analysis, evaluation and differentiation of variants in relation to different performance or benchmarks [33], [34].

Cluster analysis is also a very useful method in analysis and sorting - classification of results, especially in the case of a large number of variants, for the analysis and understanding of variability and degree of similarity, as an effect under different influencing factors [40], [28], [53], [35].

The results obtained are consistent with other studies, which reported similar results on the analysis and classification of the effect of some mineral elements on different plants of interest [41], [52], [45], [9].

CONCLUSIONS

N and PK fertilizers have differentiated the influence of rapeseed production. With the increase of the doses of PK fertilizers, a higher production increase was registered and associated with a better capitalization of N.

The mathematical model described in statistical safety conditions the variation of the production in relation to the two categories of fertilizers, N and PK.

PCA and cluster analysis facilitated the identification and evaluation of variance and the grouping of fertilization variants in relation to the degree of affinity and similarity to the main attributes.

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