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PRODUCTION AND PRODUCTIVITY ELEMENTS IN FIELD PEAS IN RELATION TO MINERAL FERTILIZATION

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Abstract

Legumes represent crops with multiple values at the farm level, from an economic and ecological point of view. The study evaluated the variation of biological yield, grain production and some productivity elements in field peas. The research took place in ARDS Lovrin, Romania. The experiment was organized under the conditions of a cambic chernoziom type soil, in a non-irrigated system. The 'Boxer' pea cultivar was cultivated. Fertilization was done with phosphorus, applied in autumn, in five concentrations (0, 40, 80, 120 and 160 kg ha^{-1} a.s.; a.s. – active substance). On each phosphorus level, nitrogen was applied in spring in five doses (0, 25, 50, 75 and 100 kg ha^{-1} a.s.). The combination of the two fertilizers resulted in 25 experimental variants, in four repetitions. Biological yield recorded values BY=0.800 – 1.640±0.046 kg m^{-2}. Pea grains production recorded values PgP=0.091 – 0.604±0.031 kg m^{-2}. Pea stalks varied between PS=0.584 – 1.026±0.026 kg m^{-2}. Secondary pea production varied between PsP=0.659 – 1.127±0.027 kg m^{-2}. Correlation of variable intensity was recorded between determined parameters. Based on PCA, PC1 explained 72.664% of variance, and PC2 explained 27.217% of variance.

Key words: *biological production, field peas, grain production, mineral fertilizers, multivalent crop*

INTRODUCTION

Leguminous crops are highly important for the production of vegetable proteins, intended for human consumption, fodder and industrialization [21, 28, 29, 35].
Along with the protein production they provide, legumes are also very important from an ecological perspective for agricultural ecosystems, in accordance with the concept of sustainability [7, 9, 30].
Some studies have associated leguminous crops with sustainable development, with sustainability, with the principles of the circular economy, respectively with circular agriculture [18, 24, 25].
The authors of this study, communicated in a previous study, the concept of "ESE triangle", (Economy - Society - Environment), as a pillar of the circular economy [15], and within this concept, legumes occupy important role in the agricultural ecosystems.
Legumes have an important role in the structure of crops and in crop rotation, with ecosystem benefits for the soil, but also economic benefits through nitrogen fixation, the positive influence on the regime of some nutrients and the reduction of doses of nitrogen fertilizers for successive crops [4, 10, 37].
Legumes are very good precursor plants for cereal crops, especially for wheat [5, 20, 36].
The complex approach to leguminous crops, including field peas, highlights the potential of these crops, in terms of grain production, nitrogen fixation in the soil, beneficial ecosystem influence over time [3, 26, 30].
The one-sided approach, only through the lens of grain production, makes the profitability to be only partially surprised, and some studies communicated that the efficiency of leguminous crops was much increased with a complex, economic and ecological approach [2].
The presence of legumes in mid- and long-term crop rotation is important, to ensure the sustainable use of agricultural land, with the support of soil fertility [1, 16].
Although they fix nitrogen during the vegetation period, leguminous crops respond

to fertilization and technological practices, depending on soil conditions and vegetation factors [6, 8, 12, 13, 17]. Within leguminous crops, peas have high importance [22, 34].

The present study evaluated the influence of mineral fertilization with nitrogen and phosphorus on some elements of productivity, biological yield in the field pea crop, and to formulate crop response models in relation to the doses of fertilizers.

MATERIALS AND METHODS

The study took place in the specific conditions of the Western Plain of Romania, within the ARDS Lovrin. The pea crop, the 'Boxer' cultivar, was placed under the conditions of a chernozem type soil. The crop was established in the spring of 2023, in a non-irrigated system.

Adequate vegetation conditions were ensured through the crop technology. In relation to the objectives of the study, fertilization was the factor that generated the response variation of the pea crop to the experimental variants.

In the autumn of 2022, phosphorus fertilizers were applied, in five doses: 0, 40, 80, 120 and 160 kg ha^{-1} active substance (a.s.). On each level of phosphorus fertilization, nitrogen fertilizers were applied in the spring of 2023, in doses: 0, 25, 50, 75 and 100 kg ha^{-1} a.s. From the combination of the two fertilizers, 25 experimental variants resulted, placed in four repetitions.

In relation to the specifics of the pea crop, and the purpose of the study, a series of parameters were analyzed to quantify the way in which the field pea crop capitalized on the applied fertilization.

At the stage of physiological maturity (BBCH 99) [19] the pea crop was harvested and plant samples were taken from the experimental variants. The following were determined: Biological yield (BY, kg m^{-2}); Peas pod number (PpN); Pea pod weight (PpW); Pea pod shells (PpS); Pea stalks (PS); Pea grains production (PgP); Peas secondary production (PsP).

The experimental data were analyzed under the aspect of statistical certainty, the level of correlations between determined parameters. Multivariate analysis (PCA, CA) was used to evaluate the distribution of variants and their association mode, in relation to determined parameters.

The regression analysis was used to evaluate the variation of the main productivity parameters (BY, PgP, PsP) in relation to the applied fertilizers. Appropriate statistical parameters were used to confirm the reliability of the statistical analyzes and the results obtained (e.g. p, R^2, RMSE). Dedicated applications were used for the analysis of the experimental data and the generation of graphic representations [11, 14, 33].

RESULTS AND DISCUSSIONS

At the moment of physiological maturity (BBCH 99), samples were taken from the pea crop, on the experimental variants (25 variants in four repetitions).

Biological production (BY) varied between BY = 0.800 – 1.640±0.046 kg m^{-2}. Peas pod number (PpN) varied between PpN = 316.00 – 860.00±25.550 m^{-2}. Peas pod weight (PpW) varied between 0.130 – 0.778±0.036 kg m^{-2}. Pea pod shells (PpS) varied between 0.052 – 0.174±0.005 kg m^{-2}. Peas stalks (PS) varied between PS = 0.584 – 1.026±0.026 kg m^{-2}. Pea grains production (PgP) varied between 0.091 – 0.604±0.031 kg m^{-2}. Peas secondary production (PsP) varied between PsP = 0.659 – 1.127±0.027 kg m^{-2}. The resulting values based on the descriptive statistical analysis are presented in Table 1.

The correlation analysis led to the values presented in Table 2. Correlations were recorded in conditions of statistical certainty, but also correlations without statistical assurance.

Pea grain production (PgP) showed a very strong correlation with PpW (r=0.997***) and a strong correlation with the other analyzed parameters (BY, PpN, PpS), in conditions of statistical safety at the $p<0.001$ level. This shows the very high importance in the formation and normal development of pods.

Table 1. Descriptive statistics in the description of field pea parameters, the 'Boxer' cultivar

Statistical Parameters	BY	PpN	PpW	PpS	PS	PgP	PsP
Valid	25	25	25	25	25	25	25
Missing	0	0	0	0	0	0	0
Median	1.200	480.000	0.393	0.090	0.838	0.286	0.909
Mean	1.208	494.360	0.386	0.091	0.827	0.296	0.916
Std. Error of Mean	0.046	25.550	0.036	0.005	0.026	0.031	0.027
Std. Deviation	0.228	127.751	0.178	0.026	0.129	0.154	0.136
Minimum	0.800	316.000	0.130	0.052	0.584	0.091	0.659
Maximum	1.640	860.000	0.778	0.174	1.026	0.604	1.127
25th percentile	1.080	420.000	0.227	0.070	0.758	0.157	0.837
50th percentile	1.200	480.000	0.393	0.090	0.838	0.286	0.909
75th percentile	1.320	556.000	0.476	0.105	0.927	0.371	1.018

Source: Original data.

Table 2. Pearson’s Correlation

Variable		BY	PpN	PpW	PpS	PS	PgP	PsP
BY	Pearson's r	—						
	p-value	—						
PpN	Pearson's r	0.852***	—					
	p-value	< .001	—					
PpW	Pearson's r	0.821***	0.900***	—				
	p-value	< .001	< .001	—				
PpS	Pearson's r	0.818***	0.930***	0.910***	—			
	p-value	< .001	< .001	< .001	—			
PS	Pearson's r	0.577**	0.217	0.021	0.133	—		
	p-value	0.003	0.297	0.920	0.526	—		
PgP	Pearson's r	0.805***	0.878***	0.997***	0.878***	-0.002	—	
	p-value	< .001	< .001	< .001	< .001	0.991	—	
PsP	Pearson's r	0.726***	0.403*	0.214	0.339	0.976***	0.184	—
	p-value	< .001	0.046	0.305	0.097	< .001	0.377	—
* p < .05, ** p < .01, *** p < .001								

Source: Original data.

The multiparameter analysis (PCA) evaluated the way in which the experimental variants are associated with the main productivity elements, respectively with biological production (BY), pea production (PgP) and respectively secondary production (PsP). The result was the PCA diagram, represented in Figure 1. PC1 explained 72.664% of variance, and PC2 explained 27.217% of variance. The experimental variants were distributed within the diagram associated with the component for which they presented high values.

Cluster analysis, based on PgP data (the important parameter of crop productivity analysis) facilitated the grouping of variants, according to the dendrogram in Figure 2 (Coph. corr. = 0.769). Two distinct clusters resulted, with several sub-clusters.

The V18 variant had the highest level of the PgP parameter, and the V10, V11 and V25 variants were also associated in the respective sub-cluster based on similarity (marked in red).

The other variants in cluster 1 (left side of the dendrogram) generated values of the PgP parameter in the same major framing group. On the right side of the dendrogram, the variants with values of the PgP parameter below the average were grouped, also based on similarity.

The regression analysis was used to evaluate the variation of some parameters in relation to the doses of fertilizers (N, P) applied.

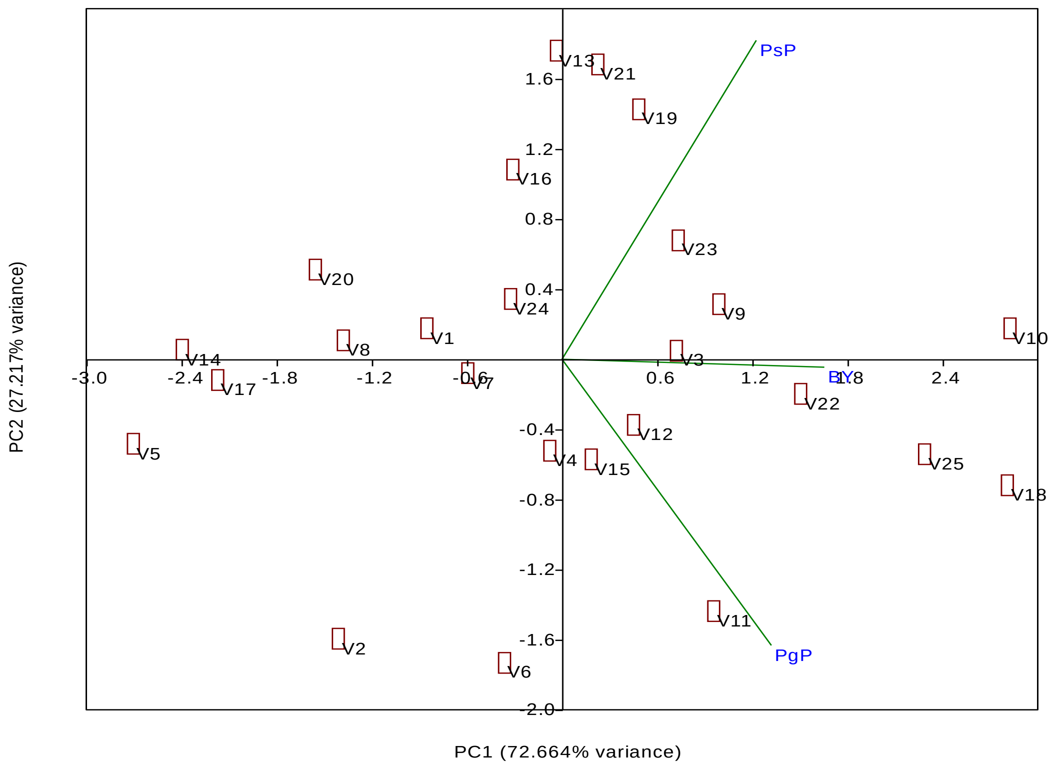

Fig. 1. PCA diagram, with the variants distribution in relation to parameters BY, Pg Psi PsP, 'Boxer' cultivar
Source: Original figure.

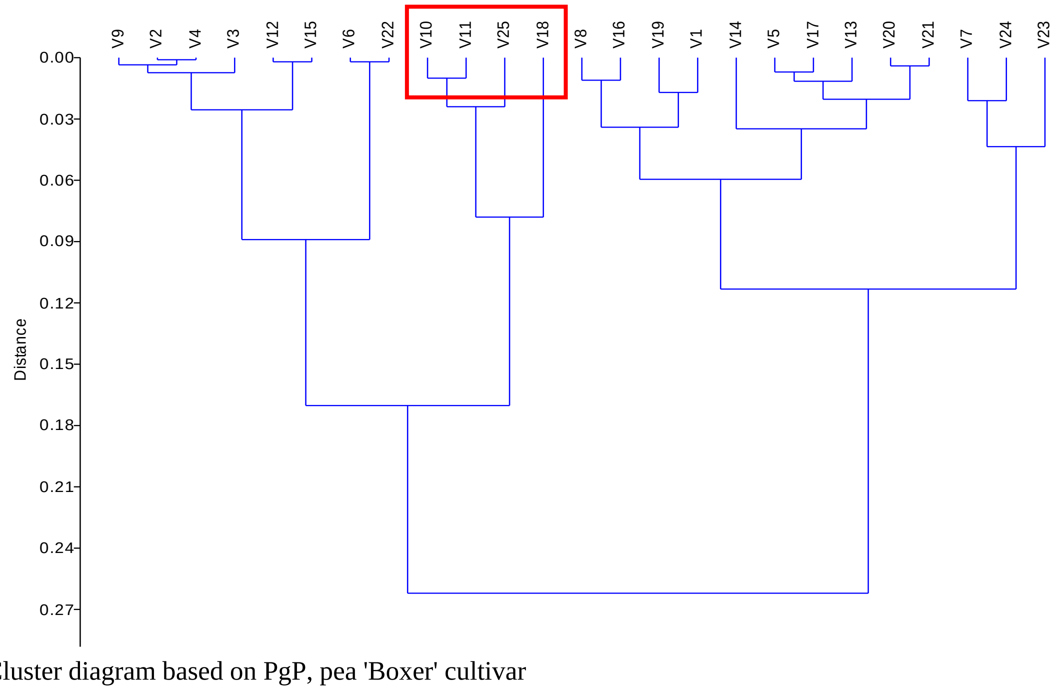

Fig. 2. Cluster diagram based on PgP, pea 'Boxer' cultivar
Source: Original figure.

Biological production (BY, t ha^{-1}) varied in relation to nitrogen and phosphorus doses, according to equation (1), under conditions of R^2 = 0.901, F = 36.4683, p<0.001. The graphic representation of the BY variation in relation to N and P is presented in Figures 3 and 4.

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

where: BY – biological yield (t ha^{-1}); x – nitrogen doses (kg ha^{-1}); y – phosphorus doses (kg ha^{-1});
a, b, c, d, e, f – coefficients of the equation (1); a= -0.00111399; b= -0.00039586; c= 0.22580929; d= 0.14384509; e= -0.00091874; f= 0.

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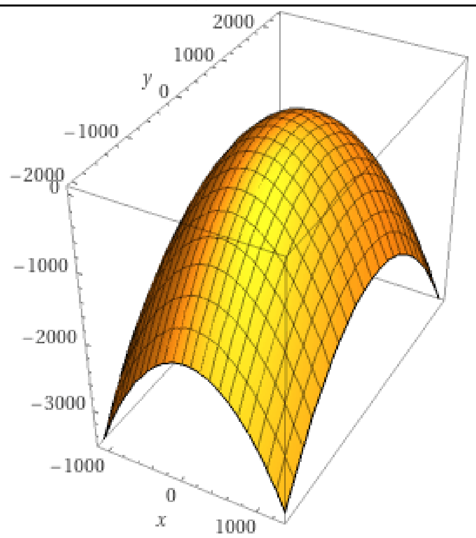

Fig. 3. 3D representation regarding the BY variation in relation to N (x-axis) and P (y-axis)
Source: Original figure.

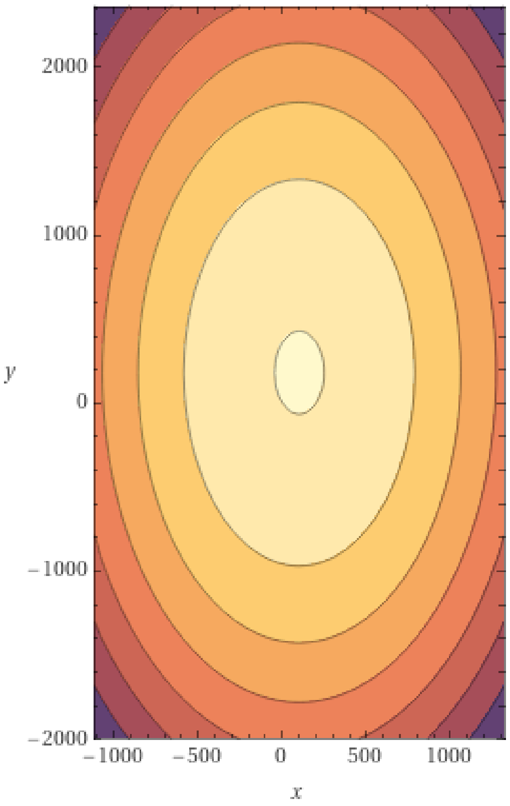

Fig. 4. Representation in isoquant format regarding the BY variation in relation to N (x-axis) and P (y-axis)
Source: Original figure.

The variation of peas grain production (PgP) in relation to N and P was described by equation (2) under conditions of $R^2 = 0.702$, $F = 9.4231$, $p = 0.00012$. The graphic distribution of PgP in relation to N and P is presented in Figure 5 and Figure 6.

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

where: PgP – Peas grains production (t ha^{-1}); x – nitrogen doses (kg ha^{-1}); y – phosphorus doses (kg ha^{-1}); a, b, c, d, e, f – coefficients of the equation (2);
a= -0.00022827; b= -0.00012425; c= 0.04953960; d= 0.03643154; e= -0.00017263; f= 0.

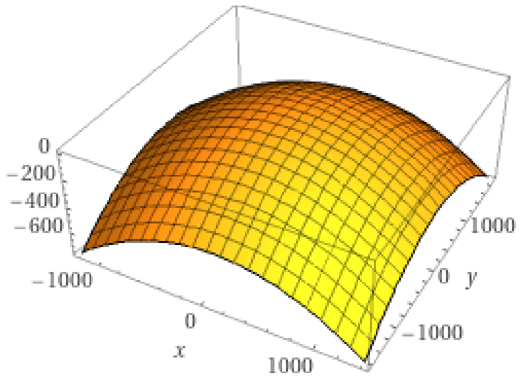

Fig. 5. 3D representation regarding the PgP variation in relation to N (x-axis) and P (y-axis)
Source: Original figure.

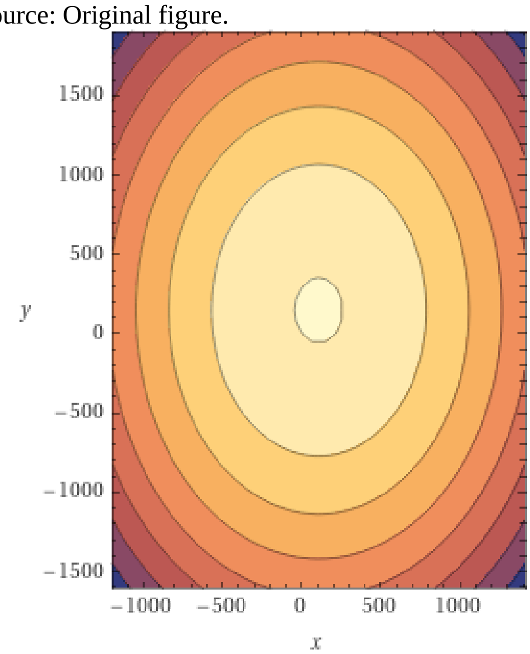

Fig. 6. Representation in isoquant format regarding the PgP variation in relation to N (x-axis) and P (y-axis)
Source: Original figure.

The variation of peas secondary production (PsP) in relation to N and P was described by equation (3) under conditions of $R^2 = 0.930$, $F = 53.2414$, $p<0.001$. The graphic distribution of the PsP distribution in relation to N and P is presented in Figure 7 and Figure 8.

$$PsP = ax^2 + by^2 + cx + dy + exy + f \qquad (3)$$

where: PsP – peas secondary production (t ha^{-1}); x – nitrogen doses (kg ha^{-1}); y – phosphorus doses (kg ha^{-1}); a, b, c, d, e, f – coefficients of the equation (3);
a= -0.00084637; b= -0.00028257; c= 0.17260235; d= 0.10881075; e= -0.00072867; f= 0.

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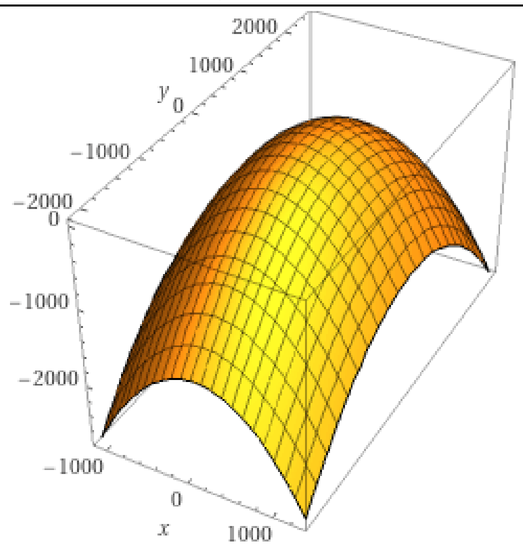

Fig. 7. 3D representation regarding the PsP variation in relation to N (x-axis) and P (y-axis)
Source: Original figure.

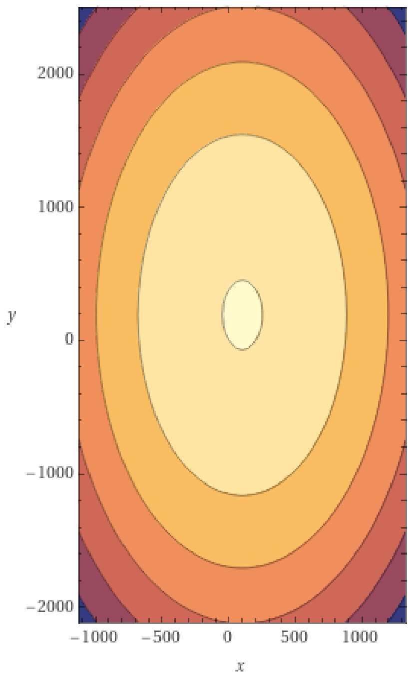

Fig. 8. Representation in isoquant format regarding the PsP variation in relation to N (x-axis) and P (y-axis)
Source: Original figure.

Within leguminous plants, field pea is a crop with multiple values. In addition to grain production, secondary production is of interest as organic matter that decomposes in the soil and contributes to balancing the balance of nutrients in the soil for the crop that follows in the agricultural rotation. Also, the nitrogen fixed during the vegetation makes the field pea crop of high interest in the total nitrogen balance.

The estimation of the production is of interest for organizing the harvesting process, for transport and storage, and of course for the capitalization of grain production on the market. In the conditions of the present study, the regression analysis facilitated the estimation of the parameters considered representative for the rape crop.

The biological yield (BY) was estimated by regression analysis, in relation to the applied fertilization, under conditions of R^2=0.901, p<0.001, and the calculated RMSE parameter presented the RMSE value = 3.8621. In the case of pea grain production (PgP), the regression analysis led to an estimate in relation to the N and P fertilizers applied, under conditions of R^2 = 0.702, p = 0.00012. The value of the RMSE parameter was RMSE = 1.8113. Grain production represents the marketable product, and respectively the element with the most important economic aspect [6, 23, 31].

In the case of the secondary production of peas (PsP), the regression analysis led to an estimate based on the doses of N and P applied, under conditions of R^2 = 0.930, p<0.001. The statistical parameter RMSE showed the value RMSE = 2.4479. The secondary production, represented by the vegetable remains left after harvesting, has medium and long-term interest in restoring soil fertility. By incorporating it into the soil, plant residues are decomposed by microorganisms and contribute to the restoration of soil fertility [27, 32].

Leguminous crops have always shown interest both for the main production (grain production - protein production), but also for the ecological benefits they bring to agricultural ecosystems [3, 30]. All the more now, leguminous crops are appreciated for their positive contribution to the sustainability of ecosystems and agricultural technologies. Associated with the costs of agricultural inputs, leguminous crops can contribute in a considerable proportion to balancing the nitrogen balance in the soil [10, 37].

The field pea crop also presents interest and advantages, associated with the climatic conditions and the threat of aridization by the fact that it is established in early spring, utilizes the soil moisture accumulated during autumn and winter, and reaches physiological maturity, and harvest, before by the dry periods from July to August.

According to the results of this study, the fertilization variants that ensured high productivity levels were differentiated based on the PgP values, and the regression analysis facilitated the estimation of the three important parameters in terms of statistical safety. The communicated results are important for agricultural practice, as well as for research, in order to optimize culture technologies for field peas.

CONCLUSIONS

The field pea crop, the 'Boxer' cultivar, responded differently to the mineral fertilization with nitrogen and phosphorus applied, in relation to the doses, the combinations of fertilizing elements, and the analyzed productivity parameters. The V18 variant generated the highest level of grain production (PgP) under studio conditions, and in the same sub-cluster, on the basis of similarity, the V10, V11 and V25 variants were associated, which have close production values of grains. The cluster analysis facilitated this classification, useful for choosing variants, depending on the results.

According to PCA, the distribution diagram of the variants also makes a selection of them, by associating them with the three important parameters considered, respectively BY, PgP and PsP.

The correlation analysis highlighted different levels of correlation, and of statistical certainty, in the set of parameters analyzed for the field pea crop. Information can be extracted regarding the parameters with which grain production (PgP) is correlated as the main element in crop profitability. There is also information regarding the correlation of secondary production with the pea crop (PsP), which will contribute to the restoration of soil fertility. Biological production (BY) is at levels of strong correlation with PgP ($r = 0.805^{***}$), and moderate correlation with secondary production ($r = 0.726^{***}$). These data confirm the importance of a successful culture, with a high biological production, and the elements of agricultural technology require adequate management, in order to ensure these objectives.

Last but not least, the regression analysis described the variation of the main productivity parameters (BY, PgP, PsP) in relation to the applied fertilization, under statistical safety conditions.

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