GRAINS MOISTURE VARIATION IN FIELD PEAS IN RELATION TO FERTILIZATION

Andreea Lidia JURJESCU[1], Florin SALA[1,2,*]
[1]Agricultural Research and Development Station Lovrin, Lovrin, 307250, Romania
[2]University of Life Sciences "King Mihai I" from Timisoara, Timisoara, Calea Aradului, 300645, Romania
**Corresponding author: florin_sala@usvt.ro*

Abstract. *The study evaluated the moisture content of field pea's grains at the time of harvest, in relation to mineral fertilization. The field researches took place within ARDS Lovrin. The field pea, 'Boxer' variety, was cultivated in non-irrigated conditions, on a chernozem type soil. Mineral fertilization was done with nitrogen (0, 25, 75 kg ha^{-1} a.s.; a.s. – active substance), phosphorus (0, 80 kg ha^{-1} a.s.) and potassium (0, 40, 80, 120 kg ha^{-1} a.s.). The combination of the three fertilizers resulted in 16 fertilization options (V1 to V16). At the moment of physiological maturity, BBCH code 9, the plants on the experimental variants were harvested. On pea grains samples, on the experimental variants, the humidity (M, %) was determined with the Wile 200 – Granit device. The moisture values varied between 13.70% (V3) and 17.90% (V13). The grain moisture values showed a normal distribution (r = 0.975). Compared to the average value (MAvg = 16.36%), higher values were recorded for variants V1, V4, V7, V9, V11, V12, V13, V14. The cluster analysis facilitated the generation of a dendrogram in which the variants were grouped based on Euclidean distances (Coph. corr. = 0.739). A cluster C1 included the variants with low moisture content, within which a high level of similarity was recorded between V5 and V8 (SDI = 0.00). Within cluster C2, the variants with higher moisture content were grouped, and a high level of similarity was recorded between variants V4 and V11 (SDI = 0.00). The model in the form of equations and graphic models resulted from the regression analysis, which described the variation of grain moisture depending on the applied fertilizers. Divergent action was recorded between nitrogen and phosphorus, respectively potassium in relation to grain moisture values.*

Keywords*: cluster analysis, field peas, mineral fertilization, models, peas grain moisture*

INTRODUCTION

The field pea is a crop plant of the genus Pisum (*Pisum sativum* L.). Along with other legumes, it is a crop plant with importance for human nutrition as well as forage (Powers and Thavarajah, 2019). It is a crop plant that provides a share of the protein requirement (Ma et al., 2018).

The pea is important in the crop structure, through the symbiotic fixing of nitrogen and the contribution to restore soil fertility (French, 2016; Lake et al., 2021). It is a crop plant that, through its technological specificity, contributes to the management of weeds and some pathogens, with positive effects on other crops in the rotation (French, 2016).

Field pea production potential was communicated up to 7 t ha^{-1}, depending on the genotype, environmental conditions and culture technology. The research on field pea yield aims to solve some aspects of adaptation to environmental conditions (especially to drought and thermal stress), and to increase the quality of the seeds (Lake et al., 2021).

Field pea crop technology was studied as a whole, as well as on technological segments, in order to formulate appropriate solutions for the purpose of high yields (French, 2016).

Pea culture was analyzed in relation to soil and nutrients, especially in relation to phosphorus, an important nutrient for the formation of grain yield (Powers and Thavarajah, 2019). The authors of the study also evaluated the benefits of the pea crop for organic agriculture.

Pea cultivation, pea yield and its use in human food and animal feed has been studied in relation to different European culture systems (Karkanis et al., 2016). The authors of the study highlighted the importance of field peas in crop systems, by fixing nitrogen, contributing to the restoration of soil fertility, to the realization of sustainable agricultural systems.

Field peas were studied from the perspective of ecological importance, in nitrogen fixation, as well as the relationship with nutrients (especially phosphorus) needed in the nodulation process (Powers and Thavarajah, 2019). The authors of the study analyzed the contribution of peas to sustainable agriculture, ecological and biological plant production systems, in order to formulate strategies for food safety.

The pea yield was analyzed in relation to the climatic conditions (dry or rainy periods, specific to temperate zones). Wilczewski et al. (2023) studied the influence of sowing depth on emergence, vegetation dynamics and pea yield, correlated with climatic conditions. The authors of the study quantified the way in which the pea capitalized the vegetation conditions with high precipitation conditions, through the yield values, and the seeding method did not influence the yield in the study conditions.

In the conditions of small farms, peas presented a series of advantages both through the production achieved and through the favorable effect on soil fertility (Gufi et al., 2022). The authors studied different agricultural households (a number of 168 households) and analyzed different cultivated varieties, and based on some parameters and indices (eg Shannon) they were able to select the varieties with the highest frequency of being cultivated, therefore more important ecologically and economic for the study area under Ethiopian conditions.

The pea crop yield was studied in relation to the vegetation conditions and in particular to different pathogens (Semaškienė et al., 2022). The authors of the study recorded the yield variation of six pea genotypes depending on the tolerance to the attack of some pathogens, in relation to the climatic conditions. The results recorded were considered important for improvement programs, as well as for agricultural practice in order to adapt culture technologies.

The present study analyzed the humidity of pea grains at the time of harvest in relation to mineral fertilization, an important aspect in relation to the preservation, storage and utilization of field pea yield.

MATERIAL AND METHODS

The study analyzed the variation of the moisture content of field peas at the time of harvest, depending on the applied fertilization. The field experiment took place within ARDS Lovrin (Agricultural Research and Development Station Lovrin).

A mineral fertilization was applied, with three nutritional elements. Phosphorus and potassium were applied in the fall and incorporated into the soil with the basic works. Nitrogen was applied in the spring.

Phosphorus was applied in doses of 0 and 80 kg ha^{-1} a.s. (active substance). Potassium was applied in doses of 0, 40, 80 and 120 kg ha^{-1} a.s. Nitrogen was applied in doses of 0, 25 and 75 kg ha^{-1} a.s.

The pea crop was sown in the spring, and the 'Boxer' variety was cultivated.

Culture technology ensured optimal conditions for plant growth, in a non-irrigated system.

At the moment of physiological maturity, BBCH code 9 (Meier, 2001), plant samples were collected and the yield on the experimental variants.

The moisture content of the grains (M, %) was determined with the Wile 200 - Granit device, on grain samples of the experimental variants.

The data were analyzed and processed statistically to find the average value of moisture (M, %), the situation of moisture by variants in relation to the average value.

The moisture variation was analyzed in relation to the applied fertilizers, considered in different combinations, and analyzed as an independent influence, but also as an interaction effect.

Models were obtained in the form of equations and graphic models (3D, isoquants), and established parameters were used for statistical safety, $p < 0.05$, R^2, Coph.corr., RMSE, equation (1).

$$RMSE = \sqrt{\frac{1}{n}\sum_{j=1}^{n}\left(y_j - \hat{y}_j\right)^2} \quad (1)$$

The mathematical calculation module in EXCEL, but also other appropriate mathematical tools were used, in relation to the proposed purpose (Hammer et al., 2001; Wolfram Alpha, 2020).

RESULTS AND DISCUSSIONS

From the analysis of grain samples, for the field pea crop, under the study conditions, on the experimental variants and repetitions, the experimental data on moisture (M, %) and the calculated average values, which are presented in table 1, resulted.

It was found that the moisture varied between 13.70%, recorded in the V3 version, and 17.90% recorded in the V13 version. According to the graphic representation in figure 1, the moisture values of the grains, field peas, the 'Boxer' variety, presented a normal distribution ($r = 0.975$).

The graphic representation of the moisture values of the pea grains (M, %) compared to the average calculated on the experimental variants (Mavg = 16.36%), is presented in figure 2.

Compared to the calculated average value (MAvg), higher values were recorded for variants V1, V4, V7, V9, V11, V12, V13, V14, and very close to the average for V16.

At the level of the calculated average value of humidity, on the experimental variants, and in the study conditions, the V15 variant was placed. The other variants presented grain moisture values, field peas, below the calculated average value.

Table 1. Grain moisture in field peas, 'Boxer' variety, in relation to mineral fertilization

Experimental variants			Trial code	Peas grains moisture (M)
Fertilizer doses				
N	P	K		
	(kg ha^{-1} a.s.)			(%)
0	0	0	V1	17.30
0	0	40	V2	15.50
0	0	80	V3	13.70
0	0	120	V4	17.20
25	0	0	V5	15.40
25	0	40	V6	14.60
25	0	80	V7	17.60
25	0	120	V8	15.40
25	80	0	V9	16.60
25	80	40	V10	16.00
25	80	80	V11	17.20
25	80	120	V12	17.80
75	80	0	V13	17.90
75	80	40	V14	16.80
75	80	80	V15	16.30
75	80	120	V16	16.40
SE				±0.29

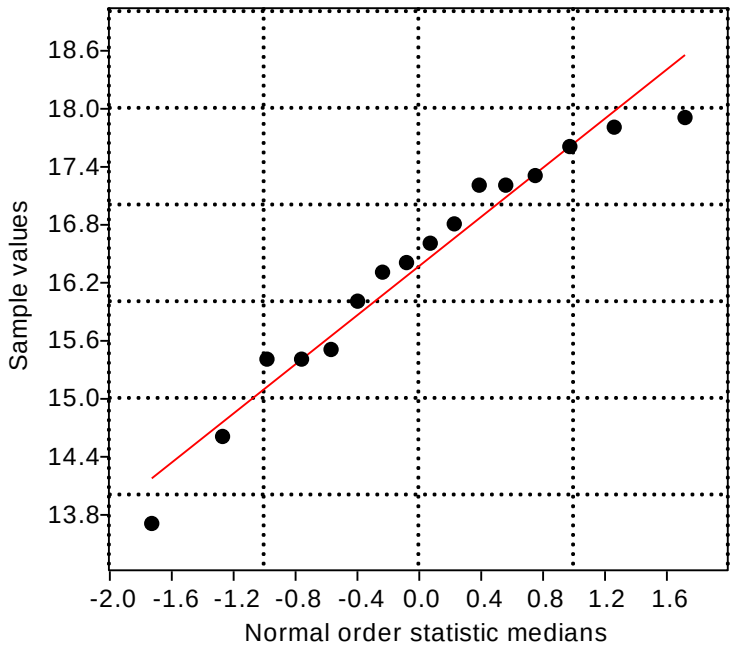


Figure 1. Normal probability plot for the moisture values of field peas grains, the 'Boxer' variety

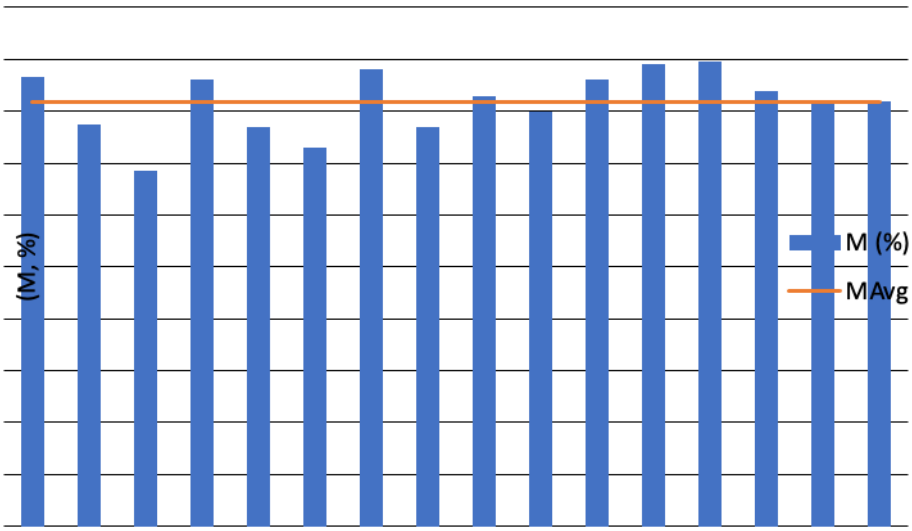


Figure 2. The graphic distribution of the moisture values of the pea grains on experimental variants, compared to the average value, the 'Boxer' pea variety

The cluster analysis facilitated the generation of the dendrogram in figure 3, based on Euclidean distances. Within the dendrogram, the experimental variants were associated on the basis of similarity according to the moisture values of the grains (M, %), in conditions of statistical safety (Coph.corr. = 0.739). Two distinct clusters resulted, with several sub-clusters each.

A C1 cluster included the variants with lower moisture content, within which the V3 variant was positioned independently (M = 13.70%), and the highest level of similarity was recorded between the V5 and V8 variants (SDI = 0.00; table 2).

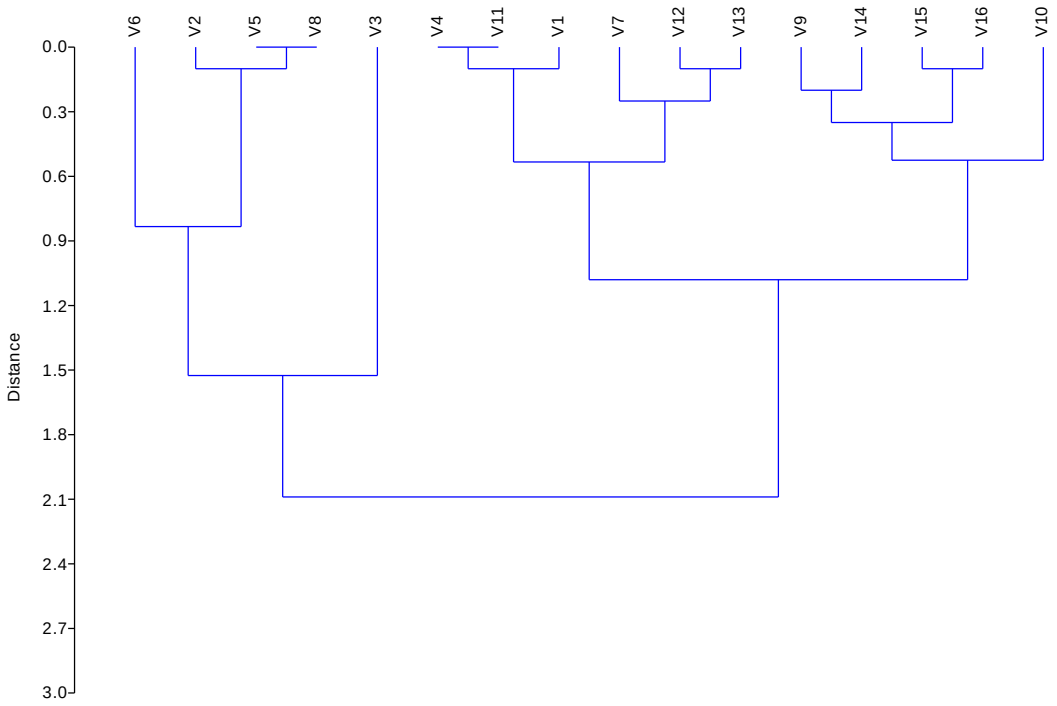


Figure 3. Dendrogram of cluster grouping of variants based on Euclidean distances in relation to the M values (%) in field peas grains, 'Boxer' variety

The variants with a higher moisture content in the grains were included in the C2 cluster. Within this cluster, a high level of similarity was recorded between variants V4 and V11 (SDI = 0.00, table 2).

Table 2. SDI values in the case of field pea grain moisture, 'Boxer' variety, in relation to the experimental variants

	V1	V2	V3	V4	V5	V6	V7	V8	V9	V10	V11	V12	V13	V14	V15	V16
V1	0.00	1.80	3.60	0.10	1.90	2.70	0.30	1.90	0.70	1.30	0.10	0.50	0.60	0.50	1.00	0.90
V2	1.80	0.00	1.80	1.70	0.10	0.90	2.10	0.10	1.10	0.50	1.70	2.30	2.40	1.30	0.80	0.90
V3	3.60	1.80	0.00	3.50	1.70	0.90	3.90	1.70	2.90	2.30	3.50	4.10	4.20	3.10	2.60	2.70
V4	0.10	1.70	3.50	0.00	1.80	2.60	0.40	1.80	0.60	1.20	0.00	0.60	0.70	0.40	0.90	0.80
V5	1.90	0.10	1.70	1.80	0.00	0.80	2.20	0.00	1.20	0.60	1.80	2.40	2.50	1.40	0.90	1.00
V6	2.70	0.90	0.90	2.60	0.80	0.00	3.00	0.80	2.00	1.40	2.60	3.20	3.30	2.20	1.70	1.80
V7	0.30	2.10	3.90	0.40	2.20	3.00	0.00	2.20	1.00	1.60	0.40	0.20	0.30	0.80	1.30	1.20
V8	1.90	0.10	1.70	1.80	0.00	0.80	2.20	0.00	1.20	0.60	1.80	2.40	2.50	1.40	0.90	1.00
V9	0.70	1.10	2.90	0.60	1.20	2.00	1.00	1.20	0.00	0.60	0.60	1.20	1.30	0.20	0.30	0.20
V10	1.30	0.50	2.30	1.20	0.60	1.40	1.60	0.60	0.60	0.00	1.20	1.80	1.90	0.80	0.30	0.40
V11	0.10	1.70	3.50	0.00	1.80	2.60	0.40	1.80	0.60	1.20	0.00	0.60	0.70	0.40	0.90	0.80
V12	0.50	2.30	4.10	0.60	2.40	3.20	0.20	2.40	1.20	1.80	0.60	0.00	0.10	1.00	1.50	1.40
V13	0.60	2.40	4.20	0.70	2.50	3.30	0.30	2.50	1.30	1.90	0.70	0.10	0.00	1.10	1.60	1.50
V14	0.50	1.30	3.10	0.40	1.40	2.20	0.80	1.40	0.20	0.80	0.40	1.00	1.10	0.00	0.50	0.40
V15	1.00	0.80	2.60	0.90	0.90	1.70	1.30	0.90	0.30	0.30	0.90	1.50	1.60	0.50	0.00	0.10
V16	0.90	0.90	2.70	0.80	1.00	1.80	1.20	1.00	0.20	0.40	0.80	1.40	1.50	0.40	0.10	0.00

Regression analysis was used to evaluate the variation of M values (%) depending on the applied fertilizers.

Equation (2) was obtained that described the variation of humidity (M, %) depending on the three fertilizers applied.

$$M(\%) = 15.8387 - 0.0022 \cdot N + 0.014 \cdot P + 0.000437 \cdot K \quad (2)$$

The regression analysis regarding the variation of M (%) in relation to the applied fertilizers, as a direct relationship and interaction effect, led to equation (3), as a description model, with the values of the coefficients in table 3, depending on the combinations of fertilizers considered .

The graphic distribution of the moisture variation of field peas, the 'Boxer' variety (M, %) according to different combinations of fertilizers considered in the analysis, is presented in figure 4 based on the NP combination, in figure 5 based on the NK combination, in figure 6 based on the PK combination and in figure 7 based on the N,PK combination (PK considered together).

When it was considered nitrogen (N) with phosphorus (P), figure 4, or nitrogen (N) with potassium (K), figure 5, the divergent action of nitrogen (N) with each of the two elements (P and K) in defining the humidity value, in the study conditions.

When phosphorus and potassium were considered in the analysis, figure 6, it was found that the much stronger contribution of potassium (K, y-axis) in the grain moisture value.

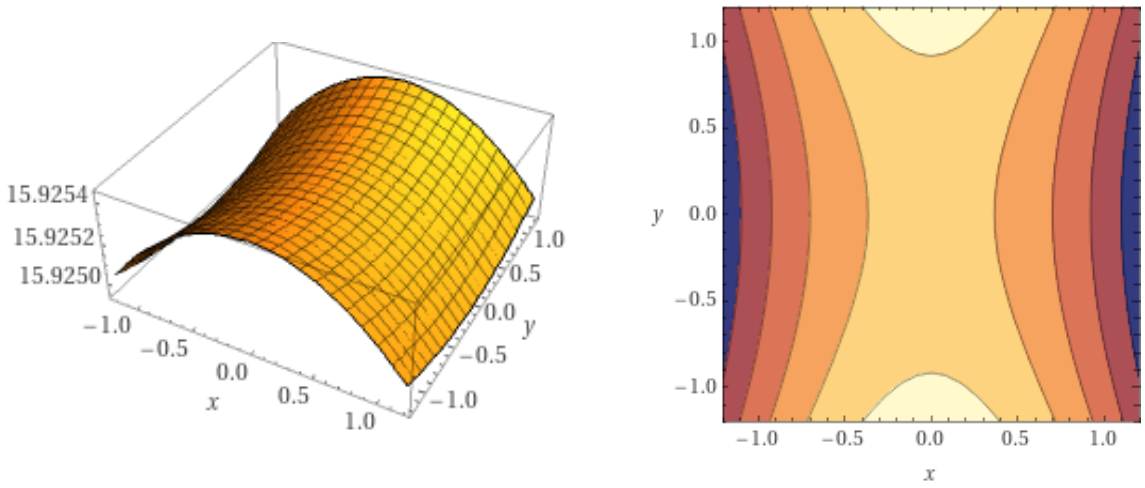
When nitrogen (N, x-axis) and phosphorus and potassium together (PK, y-axis) were considered, figure 7, a convergent action of the two categories of nutrient elements from fertilizers was found, in defining the moisture of pea grains, at the time of harvest.

$$M(\%) = ax^2 + by^2 + cx + dy + exy + f \quad (3)$$

where: M(%) – field pea grain moisture (%);
x, y – considered fertilizers (table 3);
a, b, c, d, e, f – coefficients of the equation (3), table 3.

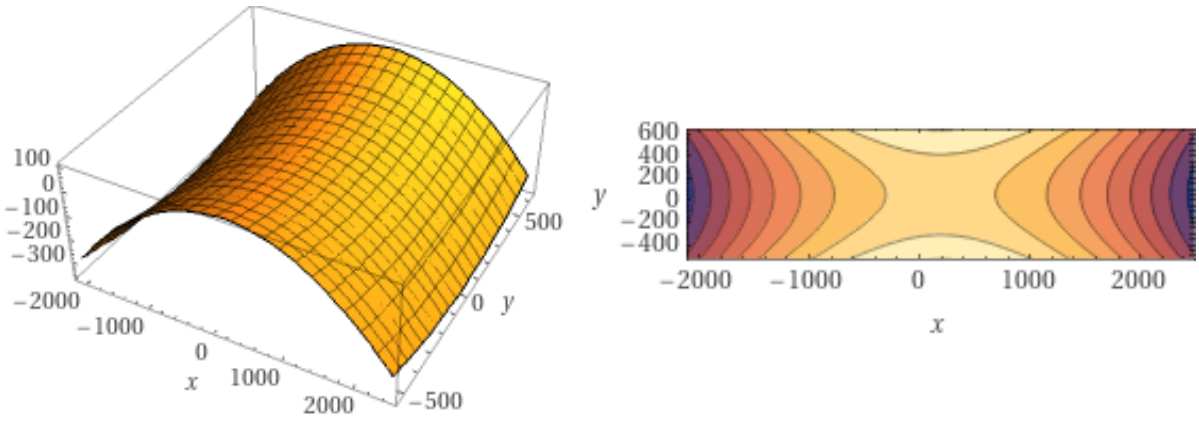
Table 3. Values of the coefficients of equation (3) for the description of the moisture variation of the pea grains in relation to fertilizers

Considered fertilizers	The coefficients of the equation (3)						Statistical parameter
	a	b	c	d	e	f	RMSE
x=N y=P	-0.000280	0.000074	0.000000	0.000000	0.000337	15.925000	1.0322
x=N y=K	-0.000073	0.000246	0.028033	-0.023781	-0.000170	15.973750	1.0161
x=P y=K	0.000175	0.000246	0.000000	-0.028406	-0.000017	16.163750	0.9556
x=N y=PK	0.000462	0.000119	0.020544	-0.006559	-0.000438	15.649447	0.9907



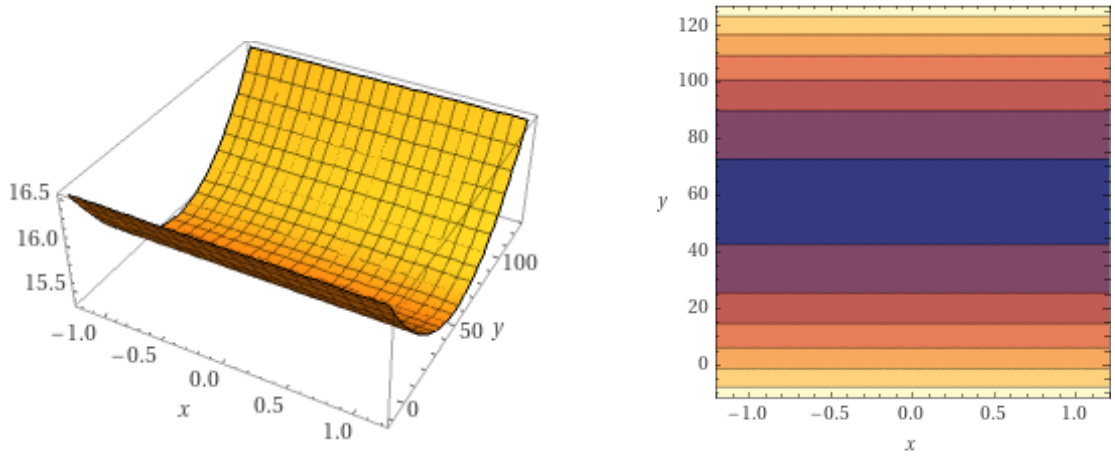
(a) **(b)**

Figura 4. Graphical distribution of moisture values (M, %) in relation to N (x-axis) and P (y-axis), field peas, 'Boxer' variety



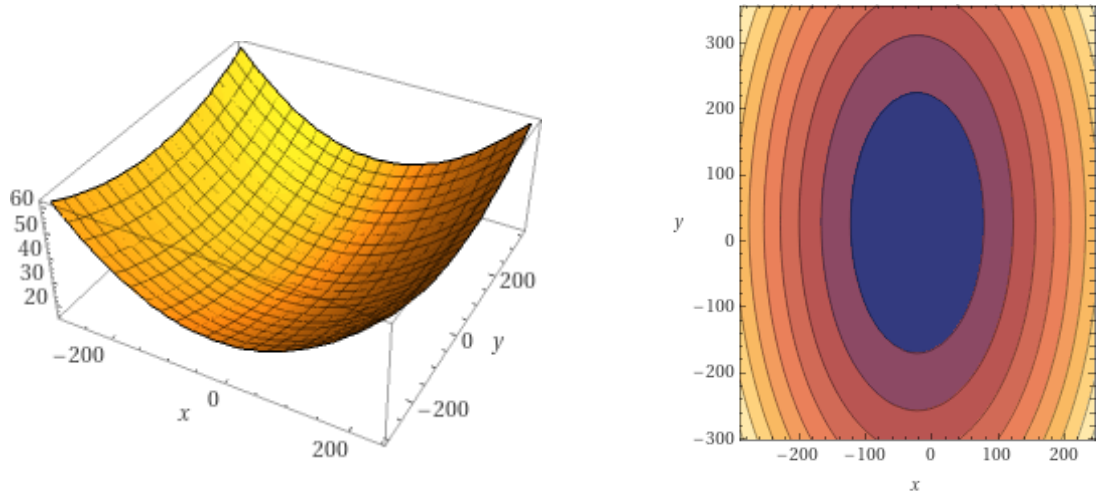
(a) **(b)**

Figura 5. Graphical distribution of moisture values (M, %) in relation to N (x-axis) and K (y-axis), field peas grains, 'Boxer' variety



(a) **(b)**

Figura 6. Graphical distribution of moisture values (M, %) in relation to P (x-axis) and K (y-axis), field peas grains, 'Boxer' variety



(a) **(b)**

Figura 7. Graphical distribution of moisture values (M, %) in relation to N (x-axis) and PK (y-axis), field peas grains, 'Boxer' variety

Moisture content in different categories of agricultural products at harvest is important in relation to the optimal time of harvesting, conditioning, storage and utilization of yield. Scariot et al. (2017) studied the moisture of the beans at harvest for black beans ('BRS Campeiro' variety) and the drying conditions and how these factors influenced quality indices of the bean yield. The authors of the study found that high values of the drying temperature influenced the physical quality and physiological properties of the seeds (physiological performance). The moisture of the grains of different leguminous species was analyzed in relation to the storage conditions, with the aim of optimal storage conditions, the improvement of some monitoring and control methods, and the reduction of storage losses (Abay and Tolesa, 2023; Bhattarai et al., 2023).

Dadlani et al. (2023) studied the storage conditions in relation to the humidity of the grains to ensure optimal storage conditions and ensure the quality indices of the seeds for sowing.

The production of crop plants is the result of the "genotype x environment x technology" interaction. Within the crop technologies, the relationship of the culture plants with the soil and fertilizers occupies an important role. The differential influence of nitrogen, phosphorus and potassium in the formation of agricultural production has been studied and analyzed for different crop plants, in order to evaluate yields and optimize the doses of fertilizers (Sala and Boldea, 2011; Sala et al., 2015; Powers and Thavarajah, 2019).

In the present study, the divergent influence of nitrogen in relation to phosphorus or potassium (considered independently) was found in the moisture values of field peas, the 'Boxer' variety. The study explained the variation of the humidity of the field pea grains in relation to the applied mineral fertilization, and contributes to the specialized literature with useful information regarding the influence of fertilization on the humidity of the grains at the time of harvest.

CONCLUSIONS

Mineral fertilization differentially influenced the moisture content of field peas at the time of harvest, in relation to the combination of fertilizers and the dose in which they were applied. The series of data on grain moisture presented a normal distribution (r = 0.975).

The cluster analysis facilitated the grouping of the experimental variants into two clusters, with different sub-clusters, based on Euclidean distances, in relation to the level of similarity for grain moisture values (M, %). From the analysis of the SDI values, as well as from the resulting dendrogram, the variants with a high level of similarity were identified.

The regression analysis led to equation-type models and graphic models that described and represented the variation of the humidity of field peas, the 'Boxer' variety, in relation to the applied fertilizers. The divergent effect of nitrogen in relation to phosphorus and potassium (considered independently) in the level of humidity values was found.

ACKNOWLEDGMENTS

The authors thank ARDS Lovrin for facilitating this study.

REFERENCES

1. Abay M.M., Tolesa G.N. - Effects of storage temperature and relative humidity on cooking time and moisture uptake of selected common bean (*Phaseolus vulgaris* L.) varieties grown in Ethiopia. Cogent Food & Agriculture, 2023, 9(1), 2163577.
2. Bhattarai B., Walker C.K., Wallace A.J., Nuttall J.G., Hepworth G., Panozzo J.F., Partington D.L., Fitzgerald G.J. - Storage temperature and grain moisture effects on market and end use properties of red lentil. Agronomy, 2023, 13, 2261.
3. Dadlani M., Gupta A., Sinha S.N., Kavali R. - Seed storage and packaging. Seed Science and Technology, 2023, 239-266.
4. French R.J. - Field pea: Agronomy. Reference Module in Food Science, 2016, https://doi.org/10.1016/B978-0-08-100596-5.00196-7
5. Gufi Y., Tsegay A., Ruelle M.L., Teka K., Tewolde-Berhan S., Power A.G. - Field pea diversity and its contribution to farmers' livelihoods in northern Ethiopia. Legume Science, 2022, 4(4), e141.
6. Hammer Ø., Harper D.A.T., Ryan P.D. - PAST: Paleontological Statistics software package for education and data analysis. Palaeontologia Electronica, 2001, 4(1), 1-9.
7. Karkanis A., Ntatsi G., Kontopoulou C.-K., Pristeri A., Bilalis D., Savvas D. - Field pea in european cropping systems: Adaptability, biological nitrogen fixation and cultivation practices. Notulae Botanicae Horti Agrobotanici, 2016, 44(2), 325-336.
8. Lake L., Guilioni L., French B., Sadras V.O. - Chapter 9 - Field pea. Crop Physiology Case Histories for Major Crops, 2021, 320-341.
9. Ma Z., Boye J.I., Hu X. - Nutritional quality and techno-functional changes in raw, germinated and fermented yellow field pea (*Pisum sativum* L.) upon pasteurization. LWT, 2018, 92, 147-154.
10. Meier U. - Growth stages of mono-and dicotyledonous plants e BBCH monograph, Federal Biological Research Centre for Agriculture and Forestry, 2001, 158 pp.
11. Powers S.E., Thavarajah D. - Checking agriculture's pulse: Field pea (*Pisum sativum* L.), sustainability, and phosphorus use efficiency. Frontiers in Plant Science, 2019, 10, 1489.
12. Sala F., Boldea M. - On the optimization of the doses of chemical fertilizers for crops. AIP Conference Proceedings, 2011, 1389(1), 1297-1300.
13. Sala F., Boldea M., Rawashdeh H., Nemet I. - Mathematical model for determining the optimal doses of mineral fertilizers for wheat crops. Pakistan Journal of Agricultural Sciences, 2015, 52(3), 609-617.
14. Scariot M.A., Tiburski G., Reichert F.W.J., Radünz L.L., Meneguzzo M.R.R. - Moisture content at harvest and drying temperature on bean seed quality. Pesquisa Agropecuaria Tropical, Goiânia, 2017, 47(1), 93-101.
15. Semaškienė R., Jonavičienė A., Razbadauskienė K., Deveikytė I., Sabeckis A., Supronienė S., Šarūnaitė L., Kadžiulienė Ž. - The response to crop health and productivity of field pea (*Pisum sativum* L.) at different growing conditions. Acta Agriculturae Scandinavica, Section B - Soil & Plant Science, 2022, 72(1), 923-930.
16. Wilczewski E., Sokół B., Nowicki R., Jug I., Pietrzykowski K., Gałęzewski, L. - Response of field pea and common vetch, grown as a catch crop, on the sowing method. Agriculture, 2023, 13, 3.
17. Wolfram Alpha, Research, Inc., Mathematica, Version 12.1, Champaign, IL (2020).