

Characterization of Wheat Plants based on Morphological Parameters and Productivity Elements at the Ear – Case Study

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Abstract. The study aimed to characterize wheat plants based on morphological parameters and describe through mathematical models the variation of some productivity elements in the wheat ear. The field experiments were located within the ARDS Lovrin, agricultural year 2024 - 2025. The biological material was represented by the 'Dacic' wheat variety sown at a density of 280 kg/ha. The culture was in a non-irrigated system. Conventional cultivation technology was provided, with fertilization at the level 30 kg a.s./ha nitrogen (ammonium nitrate, applied in spring, in two doses; a.s. active substance) and 120 kg a.s./ha phosphorus (concentrated superphosphate, applied in autumn). At crop maturity, 20 plants were randomly sampled. Plant height (PH, cm), spike length (EL, cm), spikelet number (SpkN), grain number per spike (GNE), spike weight (EW, g) and grain weight per spike (EGW, g) were determined. Moderate variability was recorded for the EGW parameter ($CV_{EGW} = 21.32$) and low variability for the other parameters. The variation of the GNE parameter was evaluated in relation to PH, EL and SpkN, and the variation of EGW was analyzed in relation to EL, SpkN and GNE, considered as variables in different combinations. The quadratic regression analysis generated mathematical models that described the variation of GNE under conditions of $R^2 = 0.587$, $p = 0.019$ (based on PH, EL), $R^2 = 0.682$, $p = 0.004$ (based on PH, SpkN), respectively $R^2 = 0.677$, $p = 0.004$ (based on EL, SpkN). In the case of the EGW parameter, the regression analysis led to mathematical models with $R^2 = 0.760$, $p = 0.001$ (based on SpkN, GNE), $R^2 = 0.351$, $p = 0.247$ (based on EL, SpkN), and respectively $R^2 = 0.695$, $p = 0.003$ (based on EL, GNE). 3D graphical models and isoquant format described the distribution of GNE and EGW in relation to the considered parameters. Statistical reliability was recorded for the obtained models, except for the variation of EGW in relation to EL and SpkN. Based on the moderate and low values of the regression coefficient, it can be appreciated that under the study conditions, the variation and interdependence of the parameters considered at the level of the wheat ear, the 'Dacic' variety, was influenced to a considerable extent by environmental factors.

Keywords: agronomic parameters, mathematical model, morphological parameters, regression analysis, wheat crop

INTRODUCTION

Wheat is one of the main crops worldwide, with a major role in food safety and security (Curtis and Halford, 2014; Lidwell-Durnin and Laphorn, 2020; Bentley et al., 2022).

The specific content of wheat grains makes wheat used primarily for human consumption, but also for industrialization and animal feed (Shewry and Hey, 2015; Hourston et al., 2017; Gooding and Shewry, 2022; Sigalas et al., 2024; Khan et al., 2025).

Wheat is a plant with high ecological plasticity, it is cultivated in all agricultural areas of the world with different pedoclimatic conditions (Elazab et al., 2025; Singh Sangha et al., 2025). In the structure of crop plants, wheat occupies a high share, and is cultivated in different agricultural systems (e.g. intensive, organic, subsistence, etc.) (Lai et al., 2023; Carr, 2024; Krause et al., 2024; Singh et al., 2024; Adil et al., 2025).

Wheat is a plant adaptable to crop technologies and responds positively to the inputs allocated (Mahmood et al., 2019; Girma et al., 2024; Liu et al., 2025; Ren et al., 2025). In relation to nutrition, wheat has high requirements for soil nutrients and responds well to fertilizer application, through increased yield and seed quality indices (Feyisa et al., 2024; Agapie et al., 2025; Qiang et al., 2025).

Morphological parameters of wheat plants were studied in relation to different environmental and technological influencing factors (Shan and Osborne, 2024; Chen et al., 2025a).

Wheat plant height is genetically defined, but varies in relation to environmental and technological factors (Chen et al., 2025b). Nitrogen causes wheat plants to grow taller, while phosphorus and potassium contribute to strengthening the stem of wheat plants and ensure the sustainability of high nitrogen fertilization levels (Li et al., 2023; Chen et al., 2024; Andrzejewska et al., 2025). Wheat ear productivity elements are important in breeding programs for yield formation and vary in relation to genetic, environmental and technological factors (Li et al., 2021; Shimoda et al., 2022; Kovalov, 2025). Evaluation of wheat ear parameters is important in relation to crop technology and yield estimation (Xu et al., 2020; Wu et al., 2023; Vicentin et al., 2024).

This study aimed to evaluate the morphological parameters of wheat plants, the 'Dacic' variety, through

statistical analysis and the description of the variation of some productivity elements in the ear through mathematical models.

MATERIAL AND METHODS

The field experiment was located within the Lovrin ARDS, in the pedoclimatic conditions specific to the Western Plain of Romania.

The wheat crop, the 'Dacie' variety, was placed in plot 3, with cambic chernozem soil, with medium fertilization, in a non-irrigated cropping system. The soil was prepared by plowing and harrowing.

In the fall, concentrated superphosphate was applied (120 kg a.s./ha; a.s. – active substance), and in the spring, ammonium nitrate was applied, in two doses, with a total dose of 30 kg a.s./ha. Sowing was done on October 14, 2024, with a seed rate of 280 kg/ha. The experiment was carried out in the agricultural year 2024 – 2025, with the climatic conditions presented in Figure 1. Compared to the multiannual average, higher temperatures were recorded, except for May.

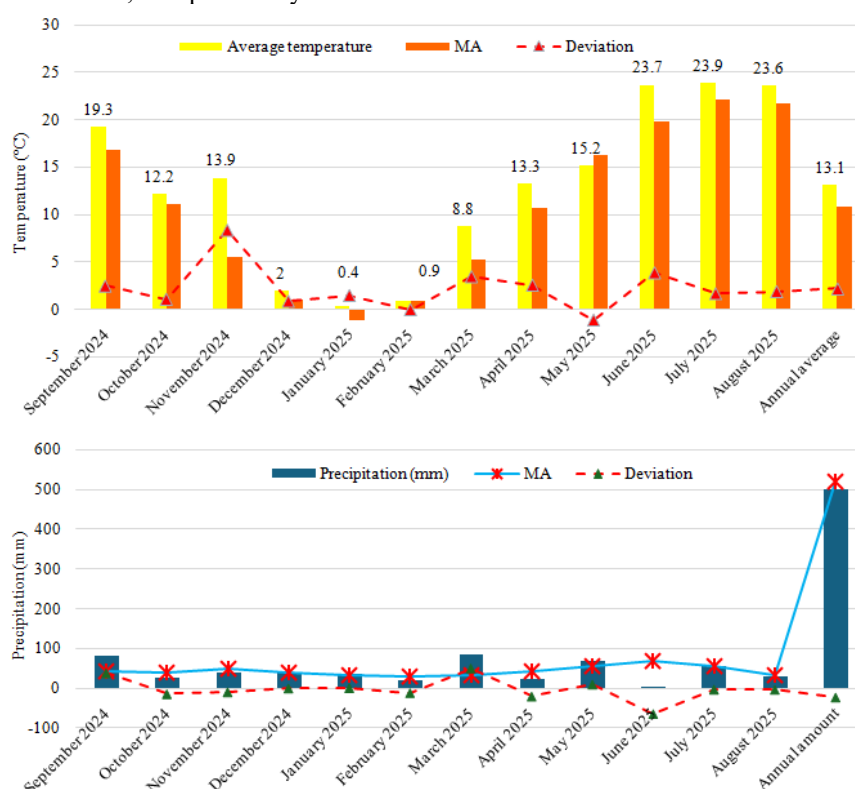


Figure 1. Climatic data during the experimental period

Through technological works, the protection of the wheat crop was ensured through treatments with the herbicide Orius (2L/ha), insecticide Cyperguard (2 L/ha). The harvest was done at physiological maturity, on July 24.

In relation to the purpose of the study, 20 plant samples were harvested, randomly arranged in the experimental plots. Measurements and determinations were made for plant parameters and productivity elements at the spike. The plant height (PH, cm) was measured. At the spike, the spike length (EL, cm) was measured and the number of spikelets in the spike (SpkN), the number of grains in the spike (GNE), the weight of the spike EW, g) and the weight of grains in the spike (EGW, g) were determined.

Descriptive statistical analysis was used for the general evaluation of the experimental data. The variation of the parameters grain number per spike (GNE) and grain weight per spike (EGW) was evaluated in relation to morphological parameters of the plants and spike. Regression analysis was used to evaluate the variation of GNE and EGW, and the reliability of the results was assessed based on established statistical parameters (R^2 , p , F test). Mathematical models in the form of equations, and graphical models described the variation of the two parameters.

The calculation module in EXCEL, the PAST software (Hammer et al., 2001) and the Mathematica (2024) software were used for data analysis and graph generation.

RESULTS AND DISCUSSIONS

Randomly taken plant samples, at the physiological maturity stage of wheat plants, were analyzed to find out the values of biometric parameters. The data series were statistically analyzed, and the values of the statistical parameters are presented in Table 1. For plant height (PH), the values recorded were $PH = 78.80 - 96.10 \pm 1.15$ cm. Spike length (EL) recorded values ranging from $EL = 6.30 \pm 0.17$ cm to $EL = 9.10 \pm 0.17$ cm. The number of spikelets in the spike (SpkN) recorded values ranging from $SpkN = 13.00 \pm 0.38$ and $SpkN = 19.00 \pm 0.38$. The number of grains in the spike (GNE) recorded values ranging from $GNE = 25.00 \pm 1.21$ and $GNE = 43.00 \pm 1.21$. The ear weight (EW) recorded values between $EW = 1.30 \pm 0.008$ g and $EW = 2.70 \pm 0.008$ g. The grain weight in the ear (EGW) recorded values between $EGW = 0.90 \pm 0.07$ g and $EGW = 2.00 \pm 0.07$ g.

Table 1. Results of Descriptive Statistical Analysis for wheat plant parameters, 'Dacic' variety

Statistical Parameters	Wheat plant parameters					
	PH	EL	SpkN	GNE	EW	EGW
N	20	20	20	20	20	20
Min	78.80	6.30	13.00	25.00	1.30	0.90
Max	96.10	9.10	19.00	43.00	2.70	2.00
Sum	1750.10	152.50	330.00	746.00	39.70	29.60
Mean	87.51	7.63	16.50	37.30	1.99	1.48
Std. error	1.15	0.17	0.38	1.21	0.08	0.07
Variance	26.47	0.57	2.89	29.06	0.12	0.10
Stand. dev	5.14	0.76	1.70	5.39	0.35	0.32
Median	86.75	7.55	17.00	38.50	1.90	1.50
25 prcntil	83.45	6.98	15.00	33.50	1.73	1.23
75 prcntil	91.83	8.18	17.00	42.75	2.28	1.78
Skewness	-0.01	0.06	-0.04	-0.75	0.25	-0.21
Kurtosis	-1.04	-0.67	-0.59	-0.17	-0.30	-0.94
Geom. mean	87.36	7.59	16.42	36.90	1.96	1.45
Coeff. var	5.88	9.93	10.31	14.45	17.70	21.32

Based on the coefficient of variation (CV) values, low variability was assessed for the PH, EL, SpkN, GNE and EW parameters, and moderate variability for the EGW parameter, with the diversity profile represented in Figure 2.

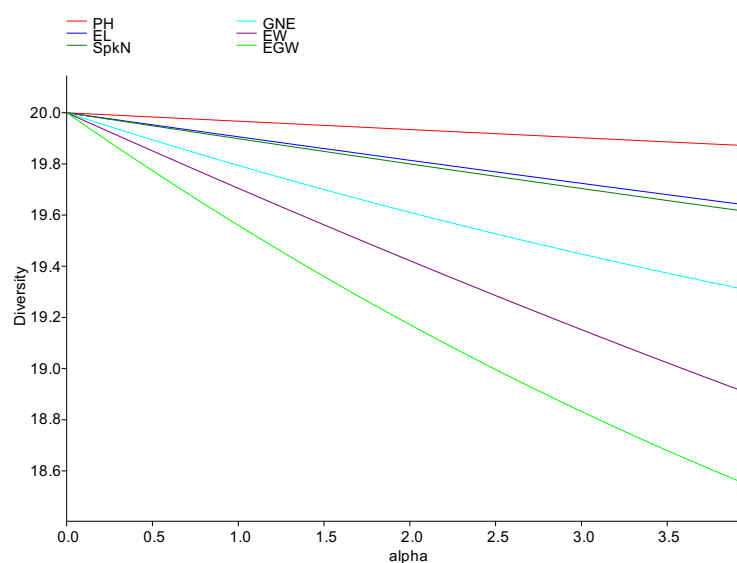


Figure 2. Diversity profile of biometric parameters in wheat plants

The number of grains per ear (GNE) and the weight of grains per ear (EGW) are important parameters in relation to yield formation in wheat crops.

The variation of the number of grains per spike (GNE) in relation to PH, EL and SpkN, in different combinations, was described by equation (1), according to the regression analysis, with the values of the coefficients and statistical safety parameters in Table 2. The graphical distribution of the variation of GNE in relation to the parameters of equation (1) is presented in Figure 3 (according to PH, EL), in Figure 4 (according to PH, SpkN), and in Figure 5 (according to EL, SpkN).

$$\text{GNE} = ax^2 + by^2 + cx + dy + exy + f \quad (1)$$

where: GNE – grains number in ear; x, y – the variables of equation (1), according to Table 2; a, b, c, d, e, f – the coefficients of equation (1), according to Table 2

Table 2. The values of the coefficients and parameters related to equation (1)

Spike parameter	Variable	Coefficients of equation (1)						Statistical parameters		
		a	b	c	d	e	f	R ²	F	p
GNE	x = PH, y = EL	-0.004293	-3.100562	2.157779	68.809589	-0.187444	-336.580319	0.587	3.975	0.019
	x = PH, y = SpkN	-0.014058	-0.546346	4.010763	28.135775	-0.084062	-398.773160	0.682	6.027	0.004
	x = EL, y = SpkN	-3.768209	-0.865013	17.086125	11.528008	2.505620	-142.151819	0.677	5.884	0.004

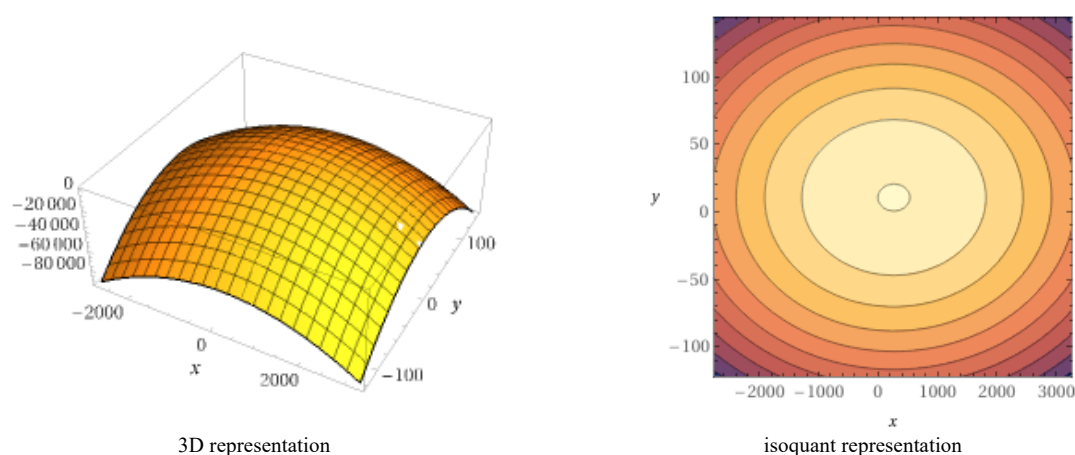


Figure 3. Graphical representation of GNE values in relation to PH and EL parameters in wheat, 'Dacic' variety

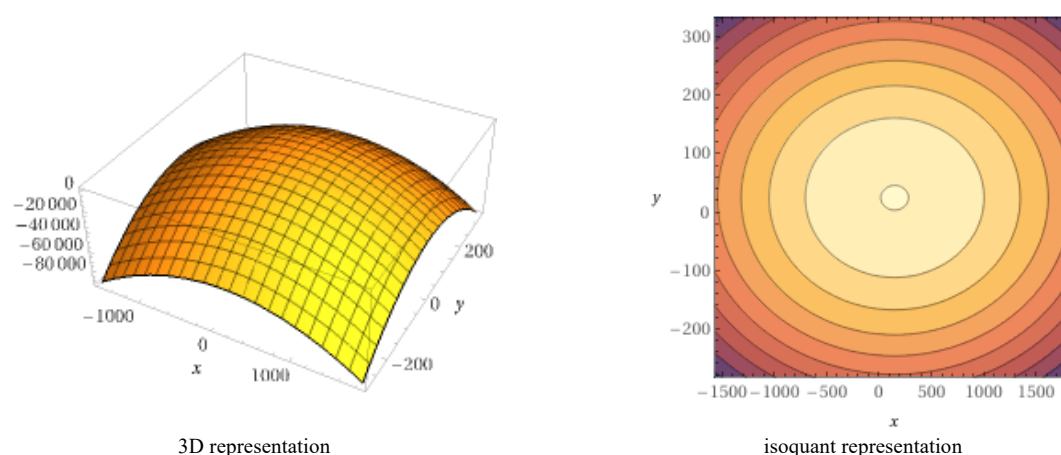


Figure 4. Graphical representation of GNE values in relation to PH and SpkN parameters in wheat, 'Dacic' variety

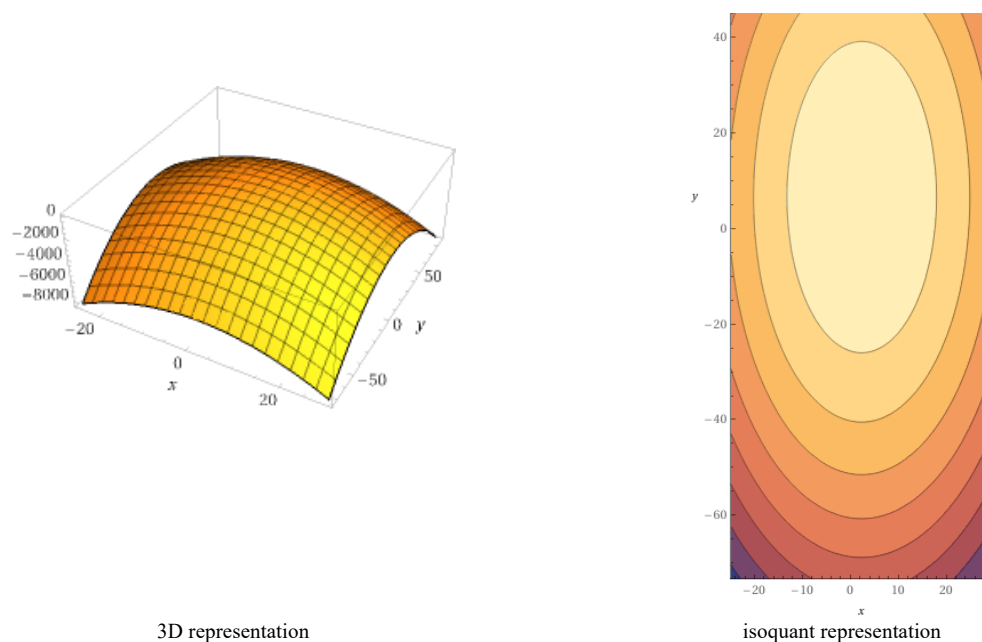


Figure 5. Graphical representation of GNE values in relation to EL and SpkN parameters in wheat, 'Dacic' variety

The variation of grain weight in ear (EGW) in relation to EL, SpkN and GNE, in different combinations, was described by equation (2), according to the regression analysis, with the values of the coefficients and statistical safety parameters in Table 3. The graphical distribution of the variation of EGW in relation to the parameters of equation (2) is presented in Figure 6 (based on SpkN, GNE), in Figure 7 (based on EL, SpkN), and in Figure 8 (based on EL, GNE).

$$EGW = ax^2 + by^2 + cx + dy + exy + f \quad (2)$$

where: EGW – ear grains weight; x, y – the variables of equation (2), according to Table 3; a, b, c, d, e, f – the coefficients of equation (2), according to Table 3

Table 3. The values of the coefficients and parameters related to equation (2)

Parameter	Variable	Coefficients of equation (2)						Statistical parameters		
		a	b	c	d	e	f	R ²	F	p
WA8	x = SpkN, y = GNE	-0.048077	-0.000230	0.899934	-0.199193	0.017075	-3.016172	0.760	8.890	0.001
WA6	x = EL, y = SpkN	-0.137637	-0.086891	-1.093729	1.440046	0.196368	-6.888727	0.351	1.516	0.247
WA7	x = EL, y = GNE	0.026385	0.001021	-0.660105	-0.042196	0.003919	3.965129	0.695	6.395	0.003

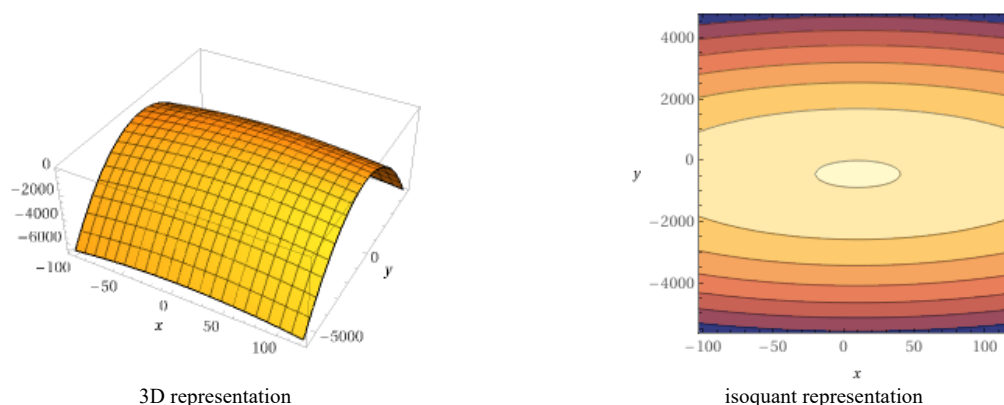


Figure 6. Graphical representation of EGW values in relation to SpkN and GNE parameters in wheat, 'Dacic' variety

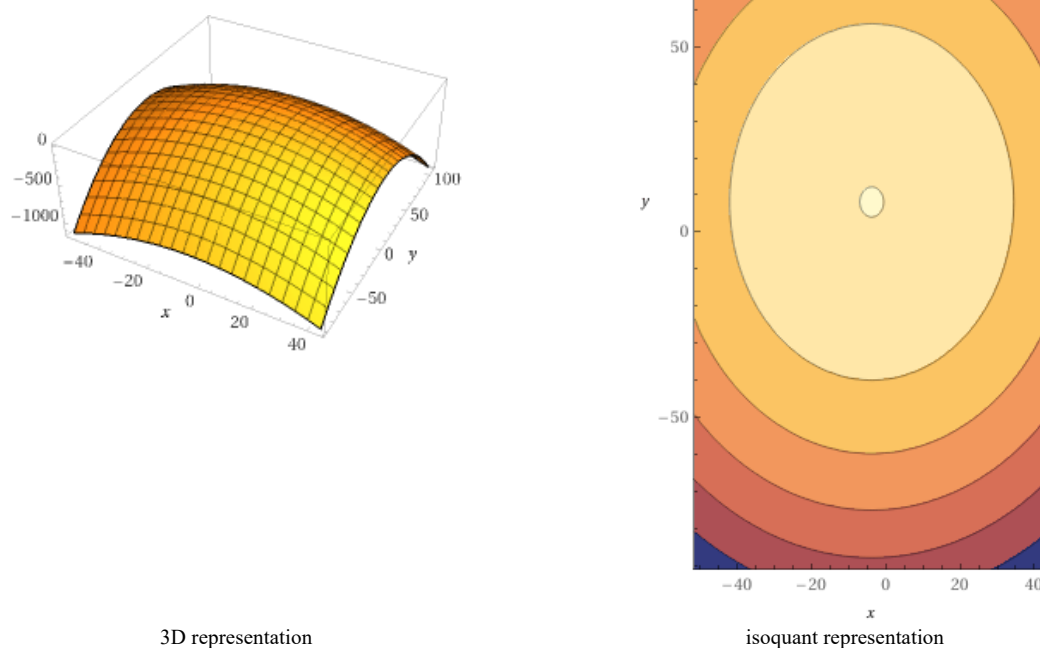


Figure 7. Graphical representation of EGW values in relation to EL and SpkN parameters in wheat, 'Dacic' variety

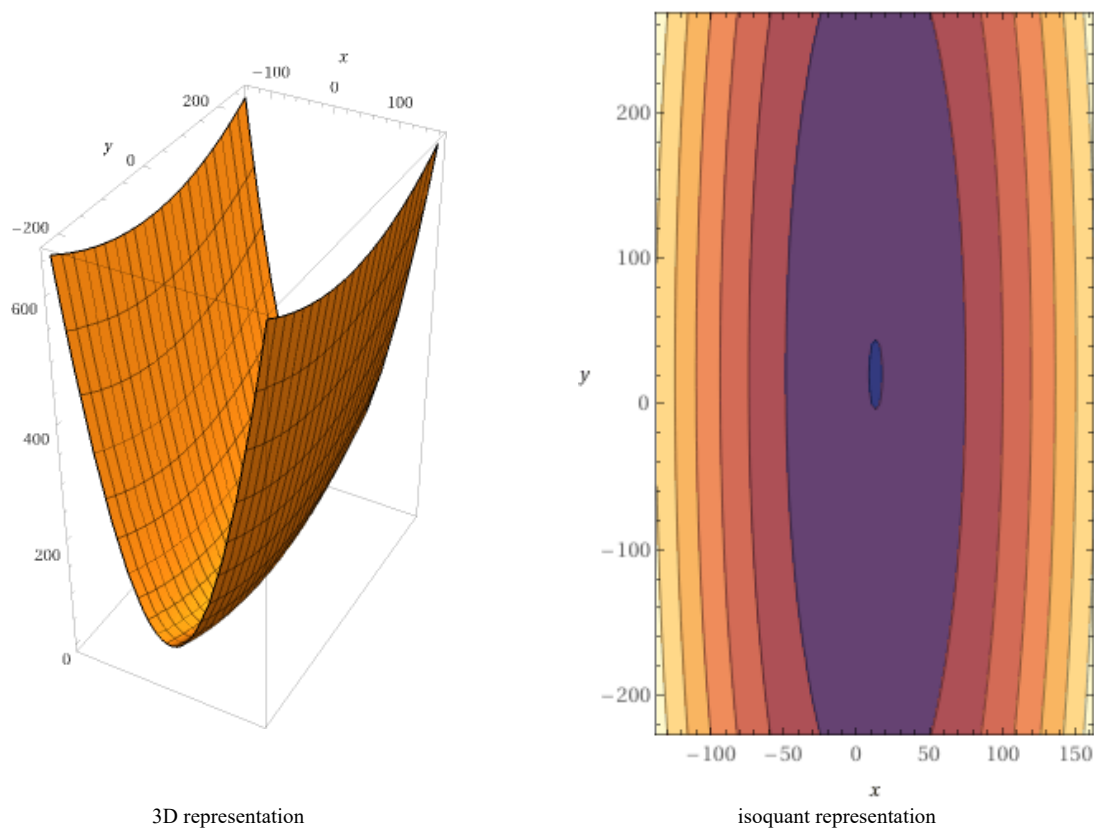


Figure 8. Graphical representation of EGW values in relation to EL and GNE parameters in wheat, 'Dacic' variety

Fertilizers are important for wheat cultivation and many studies have analyzed the impact of fertilizers in relation to agronomic parameters, yield and quality indices in wheat (Li et al., 2023; Chen et al., 2024; Adil et al., 2025; Agapie et al., 2025).

Various models (mathematical models in the form of equations as well as graphical models) were communicated for estimating agronomic parameters, physiological indices, crop yields and quality indices, for optimizing fertilization in relation to certain economic indicators, fertilizer categories and crop systems (Boldea and Sala, 2010; Constantinescu et al., 2018; Liu et al., 2024; Hou et al., 2025).

Under the study conditions, the height of the planes (PH) recorded low variability, which showed the uniformity of the wheat crop in the experiment. The ear parameters recorded low variability, but differentially increasing, respectively $CV_{EL} = 9.93$, $CV_{SpkN} = 10.31$, $CV_{GNE} = 14.45$, and $CV_{EW} = 17.70$. These values show changes in the parameters at the ear level, with increased variability even if within the limits of low variability. The EGW parameter probably accumulated the effects of the other parameters at the ear level, so that it fell into moderate variability, $CV_{EGW} = 21.32$.

The variation of GNE in relation to PH, EL and SpkN parameters was described by regression analysis under statistical safety conditions at the level of $p = 0.019$ (*) based on PH and EL, and at the level of $p = 0.004$ (**) in the case of the other parameters considered as independent variables, respectively PH with SpkN, and EL with SpkN. The estimation precision was at a moderate - low level, based on the R^2 values.

The values of the coefficients of equation (1), Table 2, as well as the 3D and isoquant graphic models showed a convergent contribution of the variables to the formation of the GNE parameter values, but with a differentiated weight. Thus, the variables PH and EL (Figure 3) and the variables PH and SpkN (Figure 4) presented a proportional contribution to the formation of the GNE parameter values. In the case of EL and SpkN variables (Figure 5), the contribution of SpkN registered a much wider variation, compared to EL variables. This shows the higher variability of SpkN values at the spike level, under similar conditions of EL values, a fact confirmed by the coefficient of variation (Table 1).

The variation of EGW in relation to EL, SpkN and GNE parameters was described by regression analysis under conditions of statistical safety at the level of $p = 0.001$ (**) based on SpkN and GNE, and at the level of $p = 0.247$ (ns) based on EL and SpkN, respectively at the level of $p = 0.003$ (**) based on EL and GNE. The estimation precision was at a moderate level in relation to SpkN and GNE, at a low level in relation to EL and GNE, and without statistical significance in relation to EL and SpkN, based on the R^2 values.

The values of the coefficients of equation (2), Table 3, as well as the 3D graphical models and isoquant format showed convergent contribution of the variables to the formation of the EGW parameter values, but with differentiated weight. Thus, in the case of the SpkN and GNE variables (Figure 6) low variation of EGW in relation to SpkN and a wide variation in relation to GNE was observed. This result showed that there was variability in the number of grains in spikelets, associated with flower fertilization under the study conditions, while the number of spikelets varied much less. In the case of the variables EL and SpkN (Figure 7) a wider variation of EGW was observed in relation to SpkN than with EL. In the case of the variables EL and GNE (Figure 8), a reduced variation of EGW was observed in relation to EL and a very wide variation in relation to GNE.

CONCLUSIONS

The results showed increasing variation in the contribution of EL, SpkN and GNE to EGW formation in wheat, 'Dacic' variety, under the study conditions, as a result of variability in the respective parameters. According to the values of the coefficient of variation (CV) for the considered parameters, it showed increasing levels of variability ($CV_{EL} = 9.93$; $CV_{SpkN} = 10.31$; $CV_{GNE} = 14.45$).

Therefore, by using the morphological parameters considered, in different combinations, as variables in the regression analysis, a convergent contribution was recorded in the formation of the GNE and EGW productivity elements at the level of wheat ears. Regarding the direct and interaction effects of the parameters considered, the recorded results showed their differentiated contribution to the formation of the GNE and EGW productivity elements in wheat ears, under the study conditions.

The results are important both for scientific research, from a physiological aspect, and for agricultural practice, with useful information in the formation of productivity elements at the ear level and in the formation of yield in wheat crops. The information can also be useful for wheat breeding programs, in view of the stability of morphological parameters in relation to environmental conditions and stress factors during the vegetation period.

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