JOURNAL of Horticulture, Forestry and Biotechnology
Volume 28(2), 2024, 86-91
https://jhfb.ro/index.php/jhfb
Print ISSN: 2066-1797
Online ISSN: 3045-1876

Variation models of maize ear production in relation to morphological elements

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Manuscript received: 18 October 2024; revised: 15 November 2024; accepted: 16 November 2024

Abstract
The variation in the weight of maize ears was analyzed in relation to certain morphological parameters. The experiment was carried out within ARDS Lovrin. The biological material was represented by 20 corn hybrids obtained at ARDS Suceava. In the framework of the experiment and the study, the hybrids were named SV1 to SV20. The ear length (EL), the number of rows per ear (RN), the number of grains per row (GNR) and the weight of the ear sample (EW) were determined. Variable values of the considered parameters were recorded, EL = 16.00 – 20.30±0.29 cm, RN = 12.00 – 17.00±0.29, GNR = 23.50 – 46.00±1.09, and EW = 0.543 – 1.304±0.048 kg. Low variability was recorded in the case of EL (CV = 7.5504), RN (CV = 9.0508) and GNR (CV = 13.2078) parameters, and moderate variability was recorded in the case of EW (CV = 23.6016). The variation of EW was described by equations and graphic models under conditions of statistical safety. Morphological parameters EL and GNR facilitated the estimation of EW variation under higher statistical safety conditions, compared to other parameters considered in the study. In the case of the variation models based on EL and GNR, statistical safety parameters p = 0.0023, and RMSE = 0.1146 resulted, in comparison with the other analyzed parameters (RMSE = 0.1860 in the case of EL with RN; RMSE = 0.1197 in the case of RN with GNR).

Keywords: biometric parameters, maize ears, maize hybrids, variation models

Introduction

The value of the maize ear, through specific morphological parameters, was considered and analyzed as a potential yield indicator [9]. In the formation of maize yield, the morphology of the ears has an essential role [16], [19], but it was found that studies of the classical traits associated with ears are no longer sufficient for breeding programs [16]. The authors used high-throughput methods and systems for phenotypic determination of a number of twenty ears traits in over 400 inbred maize lines, grown in two different locations.

Morphological parameters and defining elements of the maize ear were analyzed and studied by classical and imaging methods, based on image acquisition platforms, neural relationships and image analysis algorithms [1], [4], [12]. Aspects of abnormal development of maize ears have been reported by different studies [11]. Based on an extensive review, the authors analyzed causes, influencing factors, symptoms and stages of vegetation in which aspects of abnormal development of ears were manifested. Several types of genetic symptoms were identified, and the explanation of aspects of abnormal development as interactions between "genetics x environment x management practices".

For the formation and increase of the corn yield, the number of grains on the ear was considered as a main factor [14]. Under favorable conditions, the number of grains per ear correlates (varies) positively with (with) the features of the ear. The authors of the study considered it important to analyze the variation of this parameter in conditions of manifestation of some limiting factors, such as the pluviometric regime. In a comparative study, a different response of modern hybrids was recorded, compared to old hybrids, regarding the number of grains per ear and the yield of grains per ear, in relation to the environmental conditions and adaptive functionalities of the two categories of hybrids [14].

In order to understand the formation and development of maize inflorescences, genetic analysis techniques based on omic sequencing were used in some studies [17]. The authors identified certain types of meristems, genes and mechanisms involved in the formation of different types of tissues.

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Morphological parameters, productivity elements and aspects of resistance to pathogens and stress factors were analyzed for the characterization of ears in corn hybrids found in different collections and comparative cultures [1], [2], [6], [14].

This study analyzed the variation of maize ears weight in relation to defining morphological elements of the ear, in corn hybrids created by ARDS Suceava, being tested under the specific conditions of ARDS Lovrin.

Material and Method

The researches were organized within the Maize Breeding Laboratory, ARDS Lovrin, in the 2023-2024 agricultural year. The experiments were located in conditions of chernozem soil, medium fertility, non-irrigated system. The biological material was represented by a collection of 20 maize hybrids under test, hybrids produced by ARDS Suceava. Maize hybrids were named SV1 to SV20 in the study. The plot area for each hybrid was 6.7 m^2, in repetitions. The climatic conditions during the study period, average monthly temperatures and monthly precipitation, are presented in table 1, respectively in table 2.

Table 1. Mean temperature values, agricultural year 2023 – 2024

Temperature	Period												Mean 2023-2024
	2023				2024								
	IX	X	XI	XII	I	Ii	III	IV	V	VI	VII	VIII	
Monthly mean	21.3	15.3	6.7	3.4	1.6	7.9	9.6	13.8	18.1	23.6	26.8	26.9	14.6
Multiannual mean	16.8	11.1	5.5	1.1	-1.1	0.9	5.3	10.7	16.3	19.8	22.2	21.7	10.9
Deviation	4.5	4.2	1.2	2.3	2.7	7.0	4.3	3.1	1.8	3.8	4.6	5.2	3.7

Table 2. Rainfall values, agricultural year 2023 - 2024

Rainfall	Period												Amount 2023-2024
	2023				2024								
	IX	X	XI	XII	I	II	III	IV	V	VI	VII	VIII	
Monthly amount	79	23.2	63.8	49.4	38	7.4	35	23	15.4	24.4	33.8	25	417.4
Multiannual mean	42.4	40.5	48	39.7	32.7	29.6	32.3	42.7	57.3	68.1	55.8	32.3	521.4
Deviation	36.6	-17.3	15.8	9.7	5.3	-22.2	2.7	-19.7	-41.9	-43.7	-22	-7.3	-104

In the fall, the land was prepared by weeding (Lemken disc), followed by plowing to a depth of 30 cm. In the first decade of February, soil preparation work was done with the combine. Complex fertilizers (15:15:15; 300 kg ha^{-1}) were applied in March. Sowing was done on April 8, 2024. Weed control was done by pre-emergent weeding, and weeding during the vegetation period, mechanical weeding (the first decade of May), associated with manual weeding in a row. Fertilization in vegetation was done with ammonium nitrate, 200 kg ha^{-1}.Under the conditions of the 2023-2024 agricultural year, harvesting was done on August 29, at physiological maturity, BBCH code 99 [8]. According to the purpose of the study, ear samples were taken within each hybrid. In the ear samples, determinations of the biometric elements were made. The ear length (EL, cm), the number of rows per ear (RN), the number of grains per row (GNR), and ear weight (EW, kg/e.s.; e.s. – ear sample) were determined.

In order to evaluate the variation of parameters at the level of corn cobs, appropriate mathematical and statistical analysis methods were used [3], [18].

Results and Discussion

For the characterization of maize ear, ear length (EL), number of rows per ear (RN), number of grains per ear (GNR), and ear weight (EW) were considered. The determinations made on the maize ear samples led to the values presented in table 3. The calculated standard error (SE) is presented for each parameter. The ANOVA test (Alpha = 0.001) certified the safety of the data, and the existence of variance in the set of experimental data, table 4.

Table 3. The values of the parameters analyzed in the tested corn hybrids

Maize hybrids	EL	RN	GNR	EW
	(cm)	(no)	(no)	(kg/e.s.)
SV1	17.30	14	43.50	1.304
SV2	16.00	14	34.50	0.543
SV3	17.80	14	39.00	0.837
SV4	16.50	16	36.00	1.115
SV5	16.80	15	35.00	0.832
SV6	16.00	13	23.50	0.587
SV7	18.50	14	43.00	1.115
SV8	18.00	14	41.00	1.037
SV9	17.00	14	38.50	0.971
SV10	16.50	15	35.00	0.743
SV11	20.30	15	39.00	0.952
SV12	18.00	16	35.50	0.829
SV13	20.30	15	46.00	1.254
SV14	17.50	12	32.00	0.682
SV15	17.30	16	35.50	0.971
SV16	16.00	16	40.50	0.992
SV17	19.30	14	34.50	0.918
SV18	16.30	12	37.00	1.077
SV19	16.50	17	32.50	0.554
SV20	16.80	15	36.50	0.958
SE	±0.29	±0.29	±1.09	±0.048

Table 4. ANOVA Test, maize ears biometric data

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	13203.34	3	4401.113	645.6498	5.8E-54	6.003174
Within Groups	518.0588	76	6.816563			
Total	13721.4	79				

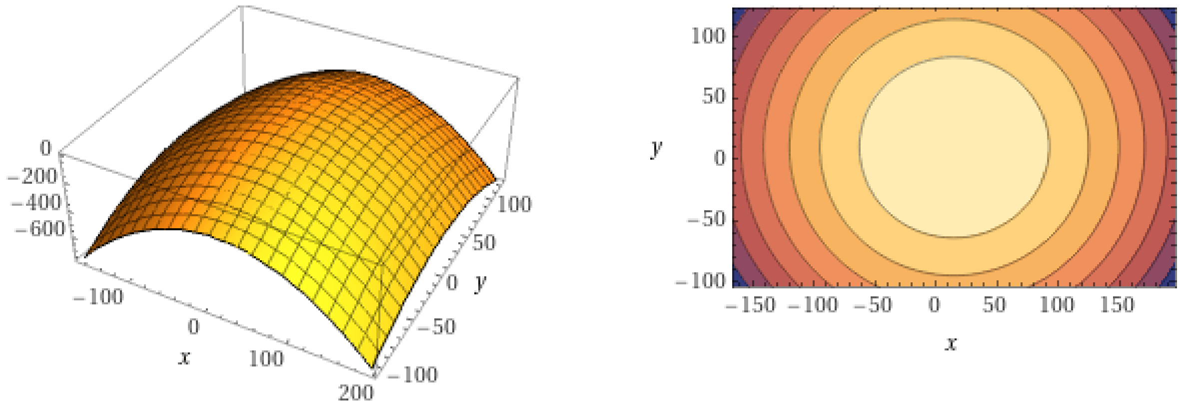
The weight of the ear (EW) is an important parameter in the formation of the yield in the corn crop, and it is the cumulative result of some defining elements at the ear level, such as the length of the ear, the diameter, the number of rows, the number of grains, the weight of the grains, etc. [1], [5], [16], [13].

The variation of ear weight (EW) was analyzed in relation to determined biometric parameters (EL, RN, and GNR). Regression analysis was used to evaluate the variation of the EW parameter.

The variation of ear weight (EW) in relation to EL and RN was described by equation (1), under conditions of Multiple R = 0.465, RMSE = 0.1860. The graphic representation is presented in figure 1 (a) and (b), in 3D, respectively isoquants format.

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

where: EW – ear weight (kg/e.s.); x – EL (ear length, cm); y – RN (rows number); a, b, c, d, e, f – coefficients of the equation (1); a = -0.01640238; b = -0.01813004; c = 0.49402841; d = 0.34547362; e = 0.01063536; f = -6.54363756.



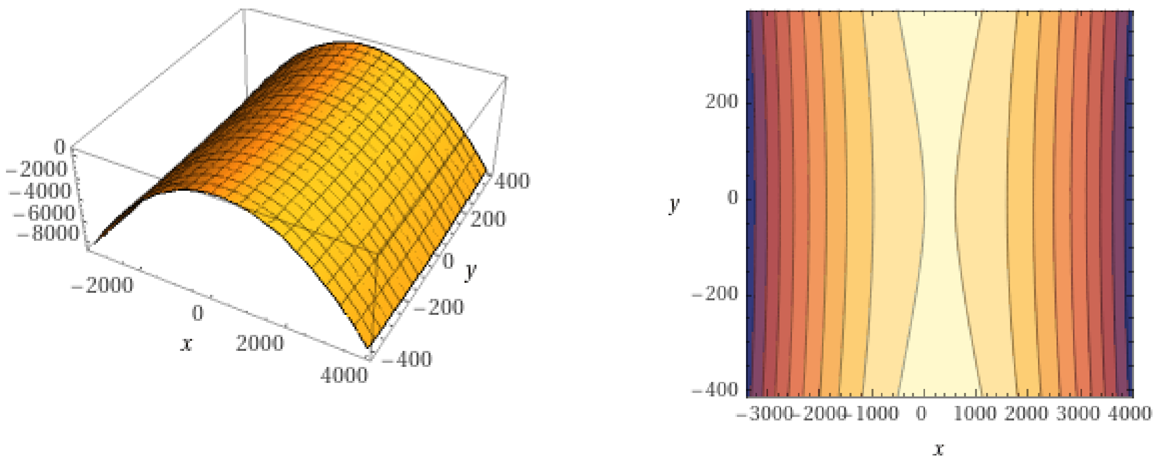
(a) (b)

Figure 1. Graphic representation of the EW variation in relation to EL and RN

The variation of ear weight (EW) in relation to EL and GNR was described by equation (2), under conditions of R^2 = 0.702, p = <0.01, RMSE = 0.1146. The graphic representation is presented in figure 2 (a) and (b), in 3D, respectively isoquants format.

$$\mathrm{EW} = ax^2 + by^2 + cx + dy + exy + f \quad (2)$$

where: EW – ear weight (kg/e.s.); *x* – EL (ear length, cm); *y* – GNR (grains number on row); a, b, c, d, e, f – coefficients of the equation (2); a = -0.00064416; b = 0.00226278; c = 0.39682660; d = 0.04352121; e = -0.00978107; f = -4.22412657



(a) (b)

Figure 2. Graphic representation of the EW variation in relation to EL and GNR

The variation of cob weight (EW) in relation to RN and GNR was described by equation (3), under conditions of R^2 = 0.675, p = <0.01, RMSE = 0.1197. The graphic representation is presented in figure 3 (a) and (b), in 3D, respectively isoquants format.

$$\mathrm{EW} = ax^2 + by^2 + cx + dy + exy + f \quad (3)$$

where: EW – ear weight (kg/e.s.); *x* – RN (row number); *y* – GNR (grains number on row); a, b, c, d, e, f – coefficients of the equation (3); a = 0.00496608; b = 0.00064930; c = -0.23111453; d = -0.04017665; e = 0.00220301; f = 2.61589826

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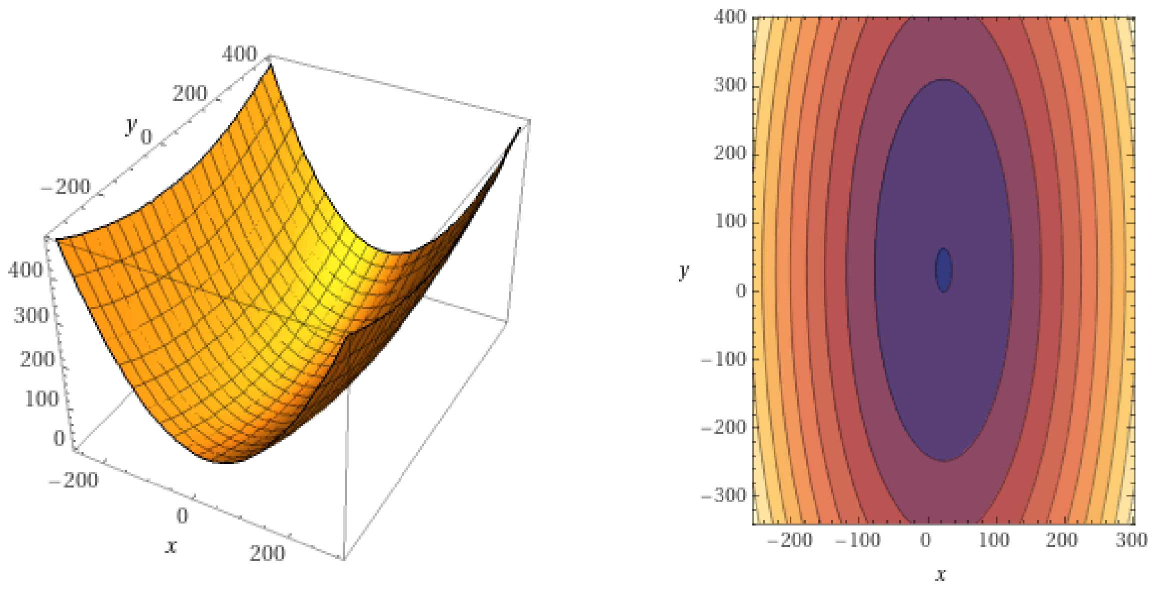

(a) (b)

Figure 3. Graphic representation of the EW variation in relation to RN and GNR

Relationships of interdependence and variation of corn ear parameters were communicated in other studies, as a result of their importance in yield formation [1], [7], [10]. At the same time, the maize yield was analyzed in relation to technological factors and environmental factors in order to optimize certain technological sequences [15].

Under the study conditions, the twenty maize hybrids generated specific values for morphological parameters of the ear. The EL parameter varied between 16.00 - 20.30 cm, the RN parameter varied between 12.00 - 17.00, the GNR parameter varied between 23.50 - 46.00 and the EW parameter varied between 0.543 - 1.304 kg per ears sample. Low variability was recorded in the case of EL, RN and GNR parameters, and moderate variability was recorded in the case of EW. Based on the recorded morphological parameter values, the EW variation was described by equations and graphic models under conditions of statistical safety. EL and GNR parameters facilitated the estimation of EW variation under high statistical confidence conditions ($p = 0.0023$, RMSE = 0.1146), in comparison with the other analyzed parameters.

Conclusions

The maize hybrids, produced at ARDS Suceava, presented specific values for the morphological parameters of the ears, under the study conditions. Low variability was recorded for EL parameters (CV = 7.5504), RN (CV = 9.0508), GNR (CV = 13.2078) and moderate variability in the case of EW (CV = 23.6016).

The regression analysis showed the variation of the EW parameter depending on the values of the EL, RN, and GNR parameters. The combination of EL and RN parameters led to the estimation of EW under conditions of RMSE = 0.1860. The combination of EL and GNR parameters led to the estimation of EW under conditions of RMSE = 0.1146. The combination of RN and GNR parameters led to the estimation of EW under conditions of RMSE = 0.1197.

Based on RMSE values, morphological parameters EL and GNR facilitated the estimation of EW variation with high precision. The values of the coefficients of equation (2) that described the variation of EW in relation to EL and GNR, as well as the graphic models (figure 2 (b)) showed the divergent variation of the two parameters in the formation of EW, under the study conditions. This showed that the two morphological parameters had a different manifestation in the study conditions. The number of grains per row (GNR) registered a different manifestation in relation to EL, although theoretically, GNR would depend closely on the EL value. It is possible that the vegetation conditions had an influence on the manifestation of the morphological parameters, and the approach to the two morphological parameters requires attention in the EW evaluation of the maize hybrids studied.

Acknowledgements

The present data were generated following the implementation of the ADER 2.1.2 project. Publishing of this journal is supported by the Institute for Plant Biotechnology of the University of Life Sciences "King Mihai I" from Timisoara.

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