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WHEAT PRODUCTION VARIATION ANALYSIS IN RELATION TO THE EARS DENSITY AND CATEGORY AT HARVEST

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Abstract

The study evaluated the variation of wheat production in relation to the ears density and category at harvest moment. The study was conducted at the Didactic and Experimental Resort (DER), Banat University of Agricultural Sciences and Veterinary Medicine "King Michael I of Romania" from Timisoara, Timis County, Romania (BUASVM).. The 'Solehio' wheat variety was cultivated in non-irrigated technology conditions, on a chernozem type soil. At the harvest moment, determinations of ears density and category were made in 10 random locations within the crop plot. Three ears categories were identified, in relation to the main stem and tillering, on which they formed: main stem ear (MSE), tiller stem 1 ear (TS1E), tiller stem 2 ears (TS2E). The average wheat production (Y) was 5,247 kg ha^{-1}. Weak correlations were found between TS2E and MSE, in statistical safety conditions ($r=-0.634^*$, $^*p<0.05$). High variability was recorded in the case of the TS2E ears category ($CV_{TS2E} = 3.2478$), intermediate variability was recorded in the case of the TS1E ears category ($CV_{TS1E} = 3.0096$), and in the case of the MSE ears category the lowest variability was recorded ($CV_{MSE} = 1.2538$). From the analysis of the ears categories identified at harvest, the 'Solehio' wheat variety, a ratio of about 7:2:1 was found. The regression analysis facilitated the obtaining of equations that described the production variation in relation to the categories of recorded ears, in conditions of statistical safety ($R^2=0.999$, $p<0.001$). The variation of wheat production (Y) and production increase (ΔY) was simulated based on the increase of the MSE ears density at harvest. Thus, by increasing the density of ears in the MSE category between 10 - 40%, production increases (ΔY) between 371.98 kg ha^{-1} and 1,487.94 kg ha^{-1} would be possible, under the conditions of an adequate cultivation technology.

Key words: *main stem ear, model, plant population density, tillering, wheat ear categories, wheat production*

INTRODUCTION

Wheat is one of the main agricultural crops that provide important resources for human nutrition, for animal feed, for various industries, the importance of wheat being highlighted in numerous studies and research [20, 21, 40].

Due to the great diversity of genotypes, with different ecological plasticity, wheat is cultivated in different areas and agricultural production systems, with pedoclimatic conditions and specific socio-economic particularities [7, 10, 23, 30, 48].

Wheat production was studied in relation to economic profitability, agricultural product markets, marketing aspects, prices, and different influencing factors [13, 15, 17, 34, 35].

Wheat cultivation technologies are constantly improved in relation to eco-climatic conditions, agricultural systems, cultivated genotypes, inputs categories, yield level and quality, influencing factors [3, 4, 6, 37, 42].

The density of the plants population is important in capitalizing on technological inputs, environmental conditions, the formation of productivity elements and agricultural production, as well as the profitability of the wheat crop [5, 27, 28].

Wheat is a plant with variable tillering capacity in relation to the genotype, so that from a germinated grain a variable number of plants is formed (eg 3 - 5 plants), of which 2 -

3 plants are fertile [5, 41]. The importance of the density of the plant population, respectively of the ears, was studied and highlighted in the formation of wheat production [31]. Wheat tillering capacity has been studied both in terms of plant breeding and genotype production, as well as in terms of crop technologies and crop management [24, 41, 45].

At the same time, it is known that the ear in tillers is smaller compared to the ear formed on the main plant, and contributes differently to the formation of wheat grain production, in the context of wheat plants vegetations conditions [14, 16, 19]. In the context of different wheat crop technologies, fertilization optimization is important in relation to genotype, plant density, with different categories of fertilizers, methods and application techniques, ecological crop conditions, production and quality indices estimated [12, 18, 28, 38, 46]. The present study evaluated the way in which wheat production was formed in relation to the density of ears and in relation to the ears categories, depending on the main stem or tillers (tillers stem order 1 or 2), on which were formed.

MATERIALS AND METHODS

The study was conducted at Didactic and Experimental Resort (DER), BUASVM Timisoara, Timis County, Romania. The 'Solehio' autumn wheat variety was cultivated in the conditions of a chernozem type soil, in an unirrigated system. The agricultural year 2021 - 2022 was taken into account.

In relation to the purpose of the study, the density of ears at harvest was evaluated (ears number m^{-2}), as well as the ears number by categories, depending on the main stem or secondary stems (tillers of the 1^{st} or 2^{nd} order), on which the ears were formed. Determinations of ears density were made, in random 10 positions on the wheat plot, Figure 1. The ears samples were collected, and evaluated by categories: ears formed on the main plant (main stem ear - MSE), ears formed on plants resulting from tillering, respectively ears formed on grade 1 tiller stem (TS1E) and ears formed on grade 2 tillers stem (TS2E), Figure 1(b).

(a) (b)

Fig. 1. Image from wheat crop, 'Solehio' variety; (a) ears density at harvest; (b) ears categories: MSE - left side; TS1E middle position; TS2E - right side
Source: Original figure, photos of the author.

The harvest was made mechanized, and the value of production was used in the study, in relation to the purpose considered.

The ANOVA test was used for the general analysis of the recorded results. In relation to the purpose of the study, appropriate mathematical and statistical analyses were used (descriptive statistics, correlation analysis, regression analysis). Appropriate statistical safety parameters were used to confirm the safety of the results (p, correlation and regression coefficients r, R^2). The EXCEL calculation module (Microsoft Office), the PAST software [22], the Wolfram Alpha software (2020) [43], and the JASP software (2022) [25] were used for the mathematical and statistical processing and analysis of the recorded data.

RESULTS AND DISCUSSIONS

From the analysis of the ears density at harvest moment, figure 1, three types of ears were found, in relation to the type of plants on which they formed (main stem, and tillers stems).

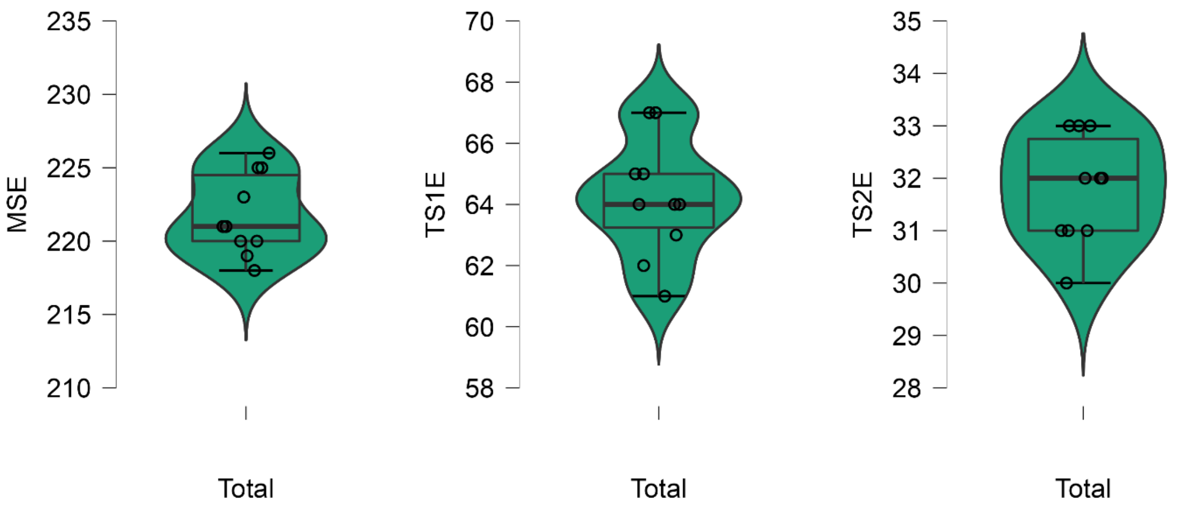
Thus, were found ears formed on the main stem (MSE), ears formed on plants resulting from tillering, respectively ears formed on tiller stem 1 (TS1E), and ears formed on tillers stem 2 (TS2E). The data recorded in the 10 samples, accompanied by the calculated standard error (SE) are presented in Table 1.

The values distribution, on the wheat ears categories determined, is presented graphically in Figure 2, in the form of a boxplot, with the marking of the recorded values in the variation interval.

Table 1. Values regarding the number of ears at harvest moment, 'Solehio' wheat cultivar

Trial	Wheat ear categories		
	MSE	TS1E	TS2E
T1	220	64	32
T2	225	63	31
T3	221	64	33
T4	226	65	30
T5	221	64	32
T6	219	62	31
T7	220	67	33
T8	225	61	32
T9	223	67	31
T10	218	65	33
SE	±0.88	±0.61	±0.33

Source: Original data, from the study determinations.



(a) (b) (c)

Fig. 2. Graphic distribution of the values of the ears number, 'Solehio' wheat variety; (a) MSE category, (b) TS1E category; (c) TS2E category

Source: original figure generated based on the recorded data.

Weak correlations were found between TS2E and MSE, in statistical safety conditions ($r = -0.634^*$, $^*p < 0.05$).

According to the coefficient of variation (CV), the three categories of registered wheat ears showed different variability. High variability was recorded in the case of TS2E category (CV_{TS2E} = 3.2478), intermediate variability was recorded in the case of TS1E category (CV_{TS1E} = 3.0096), and in the case of MSE category the lowest variability was recorded (CV_{MSE} = 1.2538).

The regression analysis facilitated the description of the relationship of wheat production (Y) with the three categories of wheat ears, which contributed to its formation. Equation (1) was obtained, which described the variation of production (Y) in relation to the three categories of wheat ears (MSE, TS1E and TS2E), in statistical safety conditions, $R^2 = 0.999$, $p < 0.001$.

$$Y = 0 + 16.77116\,x + 6.413926\,y + 35.06729\,z \qquad (1)$$

where: Y – wheat production (kg ha^{-1});
x – ears MSE category;
y – ears TS1E category;
z – ears TS2E category.

Regression analysis was used to find the wheat production variation in relation to the three categories of wheat ears found, as a direct and interaction effect.

Thus, the variation of production (Y) in relation to MSE and TS1E was described by equation (2), in statistical safety conditions (R^2=0.999, p<0.001). The distribution of the production variation in relation to MSE and TS1E is shown in a 3D model (Figure 3), and in isoquants (Figure 4).

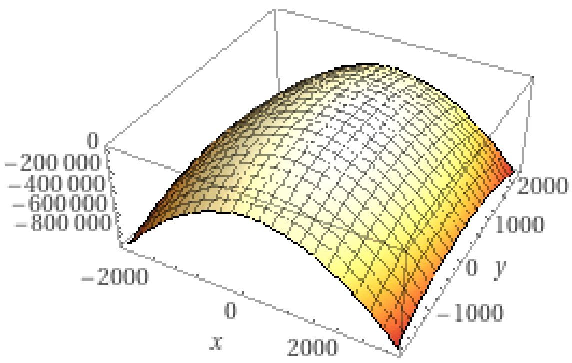


Fig. 3. 3D graphic distribution of wheat production (Y) according to MSE (x-axis) and TS1E (y-axis), 'Solehio' wheat variety
Source: original graph, based on calculated data.

The values of the equation (2) coefficients show the high weight of the MSE ears category in the wheat production formation, compared to the TS1E ears category (Fig. 3).

$$Y_{(MSE,TS1E)} = ax^2 + by^2 + cx + dy + exy + f \qquad (2)$$

where: $Y_{(MSE,TS1E)}$ – wheat production according to MSE and TS1E;
x – MSE, main stem ear;
y – TS1E, tiller stem 1 ear;
a, b, c, d, e, f – coefficients of the equation (2);
a = -0.08629274; b = -0.05729065;
c = 41.73967959; d = 19.08367872;
e = -0.05294840; f = 0

Also, from the analysis of the 3D graphic model (Figure 3), it was found the same.

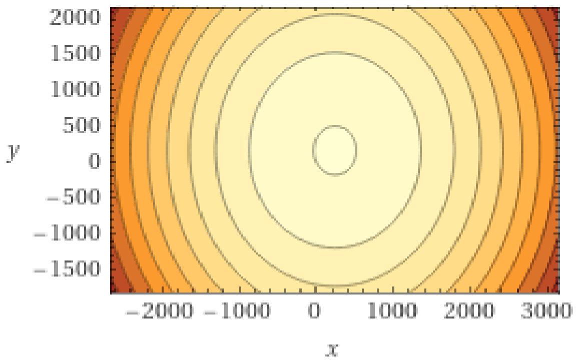


Fig. 4. Graphic distribution in the form of isoquants of wheat production (Y) according to MSE (x-axis) and TS1E (y-axis), 'Solehio' wheat variety
Source: original graph, based on calculated data.

Based on the values of the equation (2) coefficients, the optimal values were found for the two ears categories (MSE, TS1E) in the contribution of wheat production formation, 'Solehio' variety, under the study conditions. Thus, the values x_{opt} = 222.26 (MSE), y_{opt} = 63.84 (TS1E) were found.

The variation of wheat production (Y) in relation to the MSE and TS2E ears categories was described by equation (3), in statistical safety conditions (R^2=0.999, p<0.001). The graphical distribution of the production variation in relation to MSE and TS2E is presented in the form of a 3D model, Figure 5, and in the form of isoquants, Figure 6.

$$Y_{(MSE,TS2E)} = ax^2 + by^2 + cx + dy + exy + f \qquad (3)$$

where: $Y_{(MSE,TS2E)}$ – wheat production according to MSE and TS2E;
x – MSE, main stem ear;
y – TS2E, tiller stem 2 ear;
a, b, c, d, e, f – coefficients of the equation (3);
a = -0.07281554; b = -0.26985877;
c = 38.60225596; d = 61.13963681;
e = -0.19901650; f = 0

The values of the equation (3) coefficients were used to find the optimal values for the two ears categories (MSE, TS2E), in the contribution of wheat production formation, 'Solehio' wheat variety, under the study conditions. Thus, the values x_{opt} = 222.26 (MSE), and y_{opt} = 31.32 (TS2E) were found.

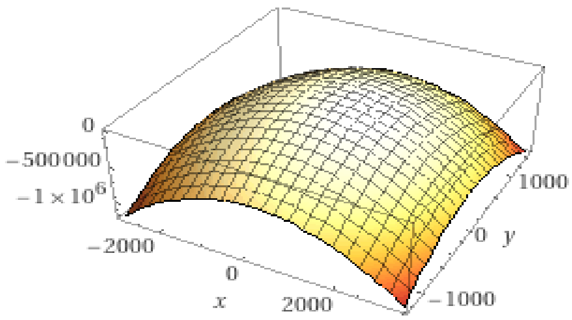


Fig. 5. 3D graphic distribution of wheat production (Y) according to MSE (x-axis) and TS2E (y-axis), 'Solehio' wheat variety
Source: original graph, based on calculated data.

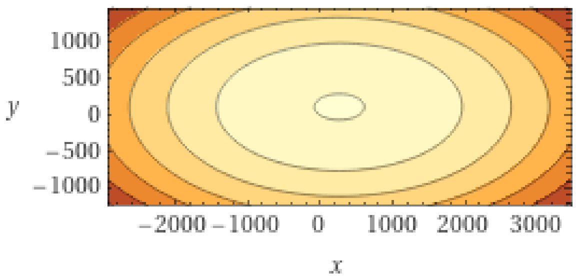


Fig. 6. Graphic distribution in the form of isoquants of wheat production (Y) according to MSE (x-axis) and TS2E (y-axis), 'Solehio' wheat variety
Source: original graph, based on calculated data.

The variation of wheat production (Y) in relation to the TS1E and TS2E ears categories was described by equation (4), in statistical safety conditions, (R^2=0.999, $p<0.001$). The graphical distribution of the wheat production (Y) variation in relation to TS1E and TS2E is shown in the form of a 3D model, Figure 7, and in the form of isoquants, Figure 8. Based on the values of the equation (4) coefficients, the optimal values were found for the two ears categories (TS1E, TS2E) in the formation of wheat production, 'Solehio' variety, under the study conditions. Thus, the values x_{opt} = 64.85 (TS1E), y_{opt} = 31.69 (TS2E) were found.

$$Y_{(TS1E,TS2E)} = ax^2 + by^2 + cx + dy + exy + f \qquad (4)$$

where: $Y_{(TS1E,TS2E)}$ – wheat production according to TS1E and TS2E;
x – TS1E, tiller stem 1 ear;
y – TS2E, tiller stem 2 ear;
a, b, c, d, e, f – coefficients of the equation (4);
a = -0.36778330; b = -1.82027964;
c = 76.62719589; d = 174.55860413;
e = -0.91284031; f = 0

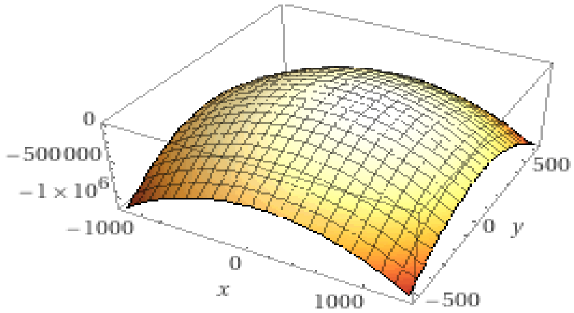


Fig. 7. 3D graphic distribution of wheat production (Y) according to TS1E (x-axis) and TS2E (y-axis), 'Solehio' wheat variety
Source: original graph, based on calculated data

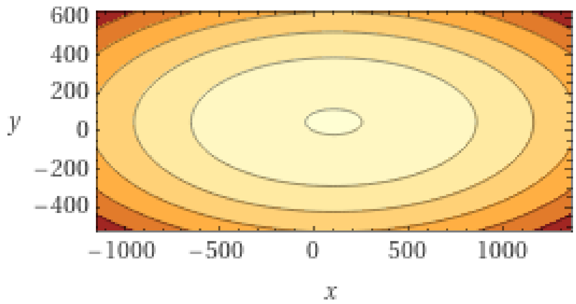


Fig. 8. Graphic distribution in the form of isoquants of wheat production (Y) according to TS1E (x-axis) and TS2E (y-axis), 'Solehio' wheat variety
Source: original graph, based on calculated data.

From the analysis of the ears categories identified at harvest in the case of the wheat crop studied, the 'Solehio' variety, a ratio of about 7:2:1 was found between the ears categories (MSE:TS1E:TS2E).

Starting from equation (1), the variation of production (Y) and the corresponded production increase (ΔY) were simulated based on the increase of the MSE category ears density at harvest. Ensuring a higher density of the MSE ears category at harvest can be achieved through a higher density of germinable seeds at sowing. Thus, keeping unchanged the other two categories of ears, TS1E and TS2E, an increase in production was obtained ΔY_I = 371.98 kg ha^{-1}, when increasing by 10% the category of MSE ears at harvest; an increase in production ΔY_{II} =

743.97 kg ha^{-1} at a 20% increase in the MSE category at harvest; an increase in production ΔY_{III} = 1,115.95 kg ha^{-1} at a 30% increase of the MSE category at harvest; an increase in production ΔY_{IV} = 1,487.94 kg ha^{-1} at a 40% increase in the MSE category at harvest.

The density of ears at harvest can be ensured from the time of sowing by the density of germinable seeds m^{-2} (eg 750 germinable seeds m^{-2}), and in this way the respective ears will be in the MSE category, so with the highest grain production ear^{-1}. This requires an appropriate cultivation technology, to control the growth of plants in height (eg growth regulators), to prevent the lodging phenomenon, and quantitative and qualitative depreciation of production [9, 11, 33, 36]. It is also necessary to adapt and optimize fertilization, in relation to the specific consumption of the cultivated genotype and the expected production, in the technological conditions of the agricultural system [8, 26, 46, 47, 49].

Monitoring and overall management need to be adequate for such wheat crop technology [29, 32]. This model of wheat technology involves certain costs related to the population of higher density plants since sowing (eg higher quantity of seed for sowing, different supplementary treatments), but predictably the technology is for a high production.

Alternatively, at more affordable costs, it is the way to for crop with a standard seed norm (in relation to the cultivated genotype, sowing season, etc.) and through the tillering capacity, can be ensure a certain density of ears at harvest [44, 50]. The wheat plants tillering, and the formation of ears, in relation to the plants categories (main stem or tillers) depends on several factors of influence during the vegetation period, so that the consideration of tillers for the production formation presents certain risks or uncertainties, with decreases in production [1, 2]. Thus, Abid et al. [1] observed the effect of water stress on wheat plant tillering (6 - 16%), and stem elongation (15-24%), with major implications on reducing wheat crop yield (72%).

In order to improve the values of the productivity elements at the wheat ear, 'Alex' variety, and production, Rawashdeh and Sala [39], used the foliar fertilization with boron and iron (on the background of mineral fertilization in the soil), and the obtained results were in statistical safety conditions ($p < 0.05$).

Considering the difference between the ears grain production capacity, in relation to the categories of plants (main stem, tillers stems), respectively the ears related to these categories of stems (MSE, TS1E, TS2E), it can be easily appreciated that a part of the technological level provided for wheat crop will be capitalized by a part of plants with a lower production capacity (about 30.21% in the present study) in relation to the main plants and the ears formed on the main plants (MSE).

The main plant will better capitalize on all production factors (most importantly inputs, with related costs), in relation to the plants resulting from tillering, including stressors and this will be reflected in the production of wheat grains, respectively in production at surface unit.

CONCLUSIONS

The population density of wheat plants and ears at harvest was an important factor in the quantitative formation of production in the context of the present study. The ears categories, in relation to the type of plant (main stem, tillers plants) are also an essential factor in the formation of wheat production. The ears numbers, by ear categories (MSE, TS1E, TS2E), depends on the cultivation technology, the germinable seeds density at sowing, and influencing factors.

Under the study conditions, a density of ears with an average ratio of 7:2:1 between ears categories (MSE:TS1E:TS2E) ensured an average production of 5,247 kg ha^{-1}. The production formation, in relation to the ears categories, and the density of ears, was described by different equations, in statistical safety conditions. The simulation of some higher densities of the MSE ear category at harvest moment, (considered possible through the density of seeds at sowing), led to production increases (ΔY) between 371.98 kg ha^{-1} and 1,487.94 kg ha^{-1}, under the conditions of an adequate technology.

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