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RESEARCH ON SOME MORPHOLOGICAL, BIOCHEMICAL, AND PRODUCTIVITY INDICES OF FOUR OAT (*AVENA SATIVA* L.) GENOTYPES UNDER SOIL AND CLIMATIC CONDITIONS OF THE CRIȘURILOR PLAIN (ROMANIA)

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Abstract: Oats (*Avena sativa* L.) are one of the most important cereal crops, grown globally as a source of energy, food, and feed. It is highly resistant to environmental conditions, nutrient-poor soils, and low temperatures while contributing to the improvement of the soil's physical characteristics and maintaining humus content. The oat grain is a rich source of fiber, in particular beta-glucan, avenanthramide, protein, vitamins, and bioactive compounds, but also has a low gluten content, and is used in various economic sectors, notably in the feeding of infants, people with illnesses, as animal feed and in biofuel production. In this study, 4 genotypes of spring oats were evaluated under soil and climatic conditions specific to the area of the Crișurilor Plain, Arad County, Romania, to assess the possibility of expanding this crop and to select an optimal variety for the soil and climatic conditions of the study area. The single-factor experiment was carried out in 4 repetitions, using as experimental variants the spring oat varieties V1 – 'Lovrin' 1; V2 – 'Mureșana'; V3 – 'Ovidiu'; V4 – 'Jeremy', and as control, the average of the 4 varieties taken in the study. The studied parameters include growing season, plant height, number of branches per panicle, number of caryopses per panicle, the mass of 1000 grains, hectoliter mass, seed yield, the percentage content of protein, fat, starch, cellulose, and ash in grains and economic efficiency. The results show good adaptability of the studied genotypes to the soil and climatic conditions of the Crișurilor Plain. The best results in terms of grain production and profit were obtained for the Ovidiu variety. The Jeremy variety had the highest content of proteins and starch, while the Mureșana variety had the highest content of fats and cellulose. The quality indices evaluated support the use of these varieties in the food industry as well as in the starch industry or as animal feed.

Keywords: oat, *Avena sativa* L., morphology, biochemistry, productivity

INTRODUCTION

Cereals are plants of the *Poaceae* (*Gramineae*) family, widely cultivated globally as a source of energy and food for both humans and animals (Francis Raguindin *et al*., 2021; Rasane *et al*., 2015). The main crops are wheat, rice, and maize, followed by barley and sorghum. Oats, however, remain an important crop, maintaining their position as the world's 6th largest crop for the last 30 years in terms of global production (Ma *et al*., 2021; Rasane et al., 2015). The most cultivated oat species is *Avena sativa* L. (Francis Raguindin et al., 2021; Rasane et al., 2015).

Compared to other cereal crops, oats have increased resistance to environmental conditions, wet climates, and acidic soils, along with a higher concentration of certain bioactive compounds and nutrients (Francis Raguindin et al., 2021; Grundy et al., 2018). Oat crops are more versatile, adapting more readily to different soil types and conditions, including nutrient-poor soil, low rainfall, and temperature levels (Ma et al., 2022).

An increasing number of health benefits are associated with oat consumption, including reduced risk of cancer, diabetes, obesity, and cardiovascular disease (Borneo & León, 2012; Francis Raguindin et al., 2021; Rasane et al., 2015). The content of bioactive compounds provides oats with antioxidant, antimicrobial, antihypertensive, antihyperlipidemic, immunomodulatory, and cardioprotective properties, in addition to those already mentioned (Tang et al., 2022). Due to the reported health benefits, oats have entered the functional food category, and there are prospects of developing products for the prevention and treatment of diabetes (Tang et al., 2022).

The health benefits are associated with the composition of macro, micro, and phytonutrients. Oats contain fibers, notably beta-glucans in significant amounts, proteins, essential fatty acids, vitamins (B1, B2, B3), minerals (Ca, Fe), phenolic compounds, avenanthramides and saponins (Francis Raguindin et al., 2021; Rasane et al., 2015). By 2020, more than 113 phytocompounds and metabolites have been reported in oats, mainly avenanthramides (alkaloids) and beta-glucans (polysaccharides), but also phytosterols, polyphenols, tocols (Vitamin E), flavonoids, and saponins (Francis Raguindin et al., 2021). The low gluten content is particularly important, with oats being

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recommended for people with gluten sensitivity (Arendt & Zannini, 2013; Francis Raguindin et al., 2021).

In the human diet, oats are introduced in various forms, from infant food to bakery and pastry products, probiotic drinks, fermented non-dairy yogurt, pasta, whole grains, and cereal flakes, as a fat substitute in various products, stabilizer for ice cream (Rasane et al., 2015). From a clinical perspective, oats are introduced in the gluten-free diet of sensitive individuals, for cholesterol-lowering and anti-cancer effects (Rasane et al., 2015). Due to its pharmacological and nutritional properties, *A. sativa* is also a potential nutraceutical and therapeutic agent (extracts, tinctures) (Connor et al., 2011; Singh et al., 2012). Industrially, oats are used for biofuel production (Rasane et al., 2015; Silva et al., 2022).

Oat cultivation, both as a monocrop and mixed with legumes or Brassicaceae has a beneficial effect on soil health, contributing to an increase in the abundance of microbial flora, fungi, and enzymatic activities important in the carbon and nitrogen cycle under semi-arid conditions (Thapa et al., 2020). Besides helping to control soil erosion and capture nutrients, oats are a good source of nutrient-rich green manure or fodder (Ma et al., 2022). The study by Silva et al. (2022) also shows the potential for phytoremediation of soil contaminated with herbicide residues (diclosulam), without affecting the physiological properties, yield, or glucose content of oats. Moreover, the phytoremediation potential is doubled by the ability to produce lignocellulosic ethanol, contributing to bioethanol production and sustainable agriculture. In the context of climate change and anticipated impacts, it is expected to favor the cultivation of crops, including oats, on larger areas to increase biomass production and soil carbon in autumn (Huang et al., 2020; Ma et al., 2022).

A. sativa L. is cultivated mainly in the northern hemisphere, between the parallels of 40° and 60° N (Murariu & Plăcintă, 2017). The most favorable growing areas for oats in Romania are the Western Plain, the Transylvanian Plain, the Moldavian Plain, the Someș and Oltului valleys, the Jijia Depression and the upper valley of the Siret, the Banat Plain, and south-western Oltenia (Mogârzan, 2012).

In 2020/2021 world oat production was about 25.5 million metric tons (Shahbandeh, 2022). Russia, known as the global leader in oat production, ranked second after the European Union in 2020 (Shahbandeh, 2022). In the EU, the leaders in oat production in 2019 were Poland, Finland, the United Kingdom, Spain, Sweden, and Germany, with large differences in yield (e.g. Poland 2.5 tons/ha, UK 6 tons/ha for the year 2019) (Somerville, 2020). In Romania, between 2017-2019, the area cultivated with oats was between 161-166 thousand ha, with yields between 361-408 thousand tons, registering a decrease in 2020-2021 (Tempo Online database, INS).

Considering the importance of *A. sativa* L. species, the prospects of increasing consumption and expansion of oat crops, the need for resistant species and varieties in the context of climate change with the maintenance of satisfactory productivity indices, coupled with the lack of recent comparative research on oat varieties, we proposed a comparative study of 4 varieties of oats (*A. sativa* L.) in the soil and climatic conditions characteristic of the area of the Crișurilor Plain, Arad County, Romania. We have chosen a series of varieties developed by the Lovrin Agricultural Research and Development Station, with the aim of better adaptability to the climate and soil conditions of the western part of the country and efficient exploitation of the production potential. A series of morphological indices considered relevant (plant height, number of branches, number of caryopses, caryopsis mass) (Kapoor et al., 2018), biochemical indices (protein, lipid, starch, cellulose, ash content), and productivity indices (seed yield, economic efficiency) were evaluated. The study aims to assess the possibility of oat crop expansion, and the selection of optimal variety for the pedo-climatic conditions of the study area.

MATERIALS AND METHODS

The following materials were used in the experiments:

- Alluvial soil with the following characteristics: pH = 7.0 - 7.5; Humus = 3.6 - 3.93 %; Clay = 33-35 %; Depth to groundwater = 60 - 70 cm; Mobile Phosphorus = 12.6 - 17.7 mg/100g soil; Total Nitrogen = 0.16 - 0.18 mg/100g soil (Data provided by The Development and Research Center for Cattle Breeding from Arad).
- Plots of 20 m^2 area, L = 10 m, W = 2m, 3 m wide buffer zone, 2 m between repetitions, and 0.5 m between variants.
- spring oat seed of the varieties: 'Lovrin 1', 'Mureșana', Ovidiu, and Jeremy.

Soil tillage consisted of:

- Autumn plowing at 20-22 cm depth, leveled and kept free of weeds until sowing;
- disking with harrow, and seedbed preparation with the combine at 3-4 cm depth;
- sowing in March, 3-4 cm deep;
- specific care work throughout the growing season, keeping the plots free of weeds
- harvesting - when the moisture content of the caryopses has fallen below 20%;
- economic calculation according to specific methodology (Brezuleanu, 2009; Săndoiu, 2012; Jităreanu et al., 2020). The economic efficiency was calculated by subtracting the production costs from the profits obtained from production sales.

Fertilization was carried out when preparing the seedbed with NPK complex fertilizer as follows: N = 80 kg/ha, P = 60 kg/ha, and K = 50 kg/ha.

A monofactorial experiment was conducted with four spring oat varieties under normal technology conditions in 4 replications.

The spring oat varieties used as experimental variants were V1 – 'Lovrin1'; V2 - Mureșana; V3 - Ovidiu; and V4 - Jeremy. The control variant is represented by the average of the four varieties taken into the study (ISTIS Official Catalog, 2020).

The experiment was performed at The Development and Research Center for Cattle Breeding from Arad.

RESULTS AND DISCUSSIONS

Oat cultures are suitable for wet climates with cool summers but present better adaptability to dry conditions than other similar crops. It prefers temperatures between 5° and 26°C, and precipitations over 500 mm, with a minimum germination temperature of 2-3°C, although young plants resist as low as -7°C (Duda et al., 2021). Spring oats are recommended for Romania's climatic conditions (Duda et al., 2021). Analyzing the climatic conditions in 2021, it can be said that they were favorable for growing oats in good conditions (Figure 1). The differences in temperature, precipitation, cloudiness, and relative humidity were insignificant compared to the multi-year average (Meteoblue database, Arad Weather Archive). Temperatures during the oat-growing period, i.e. March to July, were slightly higher than usual but did not significantly influence plant growth and development. Precipitation was overall sufficient during most of the growing season, with a small deficit in March and July and a surplus in April and May.

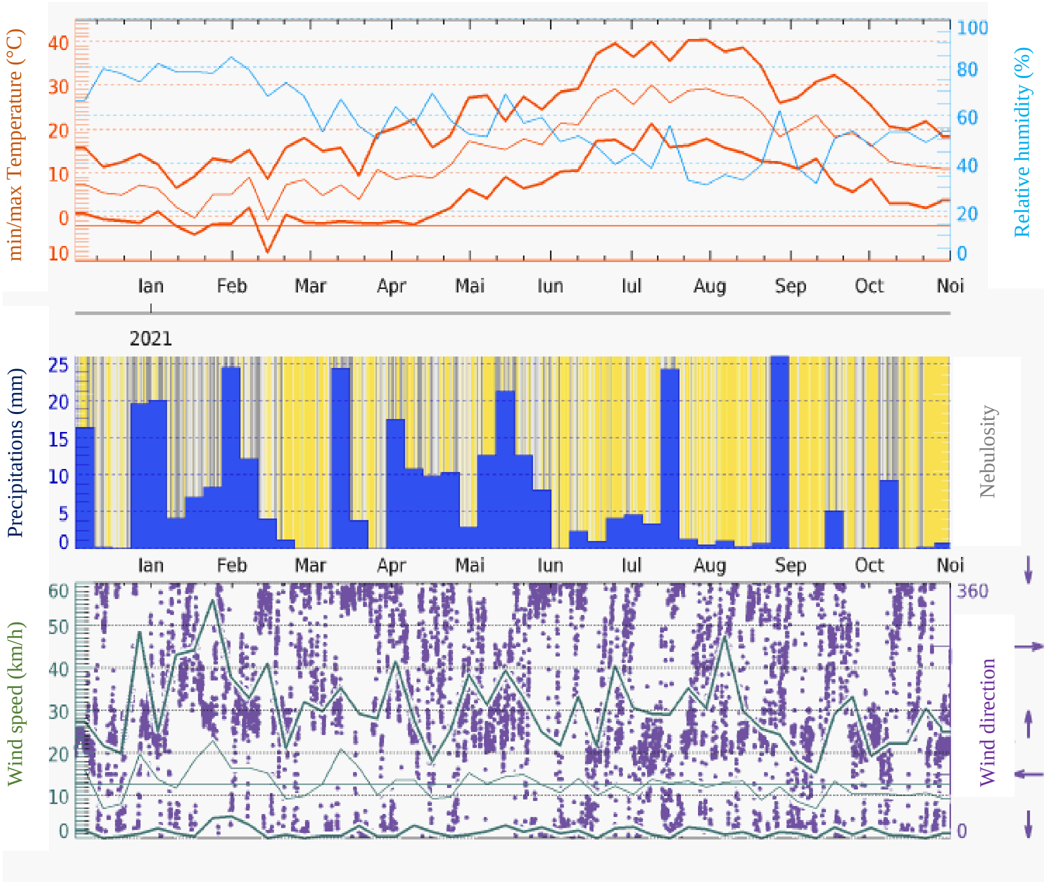

Fig. 1. Average temperature and precipitation values: January-November 2021 in Arad. Source: https://www.meteoblue.com Weather Archive Arad.

Spring oats (*Avena sativa* L.) are an annual plant with a short vegetation period, an average of 135 days (Duda et al., 2021). The growing period of the varieties analyzed averaged 105 days, reaching a maximum of 109 days in Mureșana and a minimum of 101 days in Lovrin 1. Ovidiu and Jeremy had a growing season of 107 days and 103 days respectively (Table 1).

Table 1.

Influence of soil and climatic conditions on the growing season in oats

No. crt.	Variety	Vegetation period (days)	Difference (days)
1	Lovrin 1	101	-4
2	Mureșana	109	4
3	Ovidiu	107	2
4	Jeremy	103	-2
5	Control	105	0

A valuable plant in terms of size, *A. sativa* provides great advantages in terms of physical stability when strong winds, heavy rains, storms, or gales occur at certain stages of the production process. The application of a cultivation technology recommended by specialists for spring oat cultivation revealed normal growth in the four genotypes studied (Duda et al., 2021; PepsiCo, 2019).

The genotypes analyzed had an average plant height of 95 cm. The shortest plants were found in the Lovrin 1 variety with a height of 87 cm, and the tallest plants were found in the Mureșana variety where the plant height was 102 cm (Table 2).

The number of panicle branches in the genotypes studied ranged from 6 to 7, with an average of 6.5. The smallest inflorescences were found in Lovrin 1 and Jeremy and the largest inflorescences pertained to the Ovidiu and Mureșana varieties (Table 3).

Table 2.

Plant height in oats

No. crt.	Variety	Plant size (cm)	Difference (cm)
1	Lovrin 1	87	-8
2	Mureșana	102	7
3	Ovidiu	98	3
4	Jeremy	93	-2
5	Control	95	0

Table 3.

The number of branches in the panicle of oats

No. crt.	Variety	Number of branches/panicle (piece)	Difference (piece)
1	Lovrin 1	6	-0,5
2	Mureșana	7	0,5
3	Ovidiu	7	0,5
4	Jeremy	6	-0,5
5	Control	6,5	0

The number of caryopses in the panicle is itself a function of the number of fertile sprouts per unit area as a consequence of the sowing rate (Duda et al., 2021). The lowest number of caryopses per panicle for the varieties analyzed was 90 per inflorescence and the highest was 93. The varieties Ovidiu stood out with 93 grains/panicle and Lovrin 1 with 92 grains/panicle, values that exceeded the control by 1.5 and 0.5 caryopses per panicle respectively. The lowest number of fruits per inflorescence was obtained in the cultivars Mureșana and Jeremy where the values were 90 grains/panicle and 91 grains/panicle respectively (Table 4).

Table 4.

The number of caryopses in the panicle of oats

No. crt.	Variant	Number of caryopses/panicle (piece)	Difference (piece)
1	Lovrin 1	92	0,5
2	Mureșana	90	-1,5
3	Ovidiu	93	1.5
4	Jeremy	91	-0,5
5	Control	91,5	0

The mass of 1000 grains (TSM) was influenced by the characteristics of the varieties studied and by the soil, climatic, and technological conditions, ranging from 32 g for Lovrin 1 to 38 g for Ovidiu. All oat genotypes studied reacted well to the given conditions, with an average 1000-grain mass of 34.5 g (Table 5).

Table 5.

Influence of pedo-climatic conditions on TSM in oats

No. crt.	Variant	TSM (g)	Difference (g)
1	Lovrin 1	32	-2,5
2	Mureșana	35	0,5
3	Ovidiu	38	3,5
4	Jeremy	33	-1,5
5	Control	34,5	0

In the case of oat cultivation, hectolitre weight (HW) is of great importance, being one of the parameters traders take into account when setting the buy-sell price (Manley et al., 2009; Burke et al., 2001). The hectolitre weight gives details about the quality of the oats, directing them either for use in animal feed or for use in the human segment if that is the purpose for which they were cultivated (Manley et al., 2009; Burke et al., 2001).

In the research conducted, the genotypes studied had a hectolitre mass ranging from 46 kg for Lovrin 1 to 47.5 kg for Ovidiu and Jeremy varieties. With an average of 47 kg, the varieties analyzed recorded a good hectolitre mass (Table 6).

Table 6.

Influence of soil and climatic conditions on hectolitre weight (HW) of oats

No. crt.	Variant	HW (kg)	Difference (kg)
1	Lovrin 1	46	-1
2	Mureșana	47	0
3	Ovidiu	47,5	0,5
4	Jeremy	47,5	0,5
5	Control	47	0

Harvesting of oats, used for food and feed, takes place when the plant has reached maturity, when the moisture level of the seeds is 16-18%, or when the oats are fully ripe, (moisture of 14-16%) (GRDC, 2016).

In this study, the growth and development of the oat plants proceeded normally, resulting in a high caryopsis yield per unit area, averaging 4530 kg/ha. The best-adapted varieties were Ovidiu and Jeremy with yields of 4840 kg/ha and 4510 kg/ha respectively. Lovrin 1 and Mureșana had the lowest grain yields, achieving 4350 kg/ha and 4420 kg/ha respectively, but overall the results are good (Table 7).

Table 7.

Influence of soil and climatic conditions on caryopsis production of oats

No. crt.	Variety	Caryopsis production (kg/ha)	Difference (kg/ha)
1	Lovrin 1	4350	-180
2	Mureșana	4420	-110
3	Ovidiu	4840	310
4	Jeremy	4510	-20
5	Control	4530	0

The quality indicators followed in oat breeding include the protein content of the caryopsis (Mut et al., 2018). Genotypes, climatic conditions, and cultivation technology during the growing season have a major impact on the protein content (Mut et al., 2018).

The average protein content of oat kernels ranged from 14.1% in Mureșana to 14.8% in Jeremy. Also noteworthy are the varieties Ovidiu, with a protein content of 14.3%, and Lovrin where the protein percentage in caryopses was 14.4% (Table 8).

Table 8.

Protein percentage in caryopses of oats

No. crt.	Variety	Proteins (%)	Difference (%)
1	Lovrin 1	14,4	0
2	Mureșana	14,1	-0,3
3	Ovidiu	14,3	-0,1
4	Jeremy	14,8	0,4
5	Control	14,4	0

As with other cereal grains, the oil content of oat kernels is quite low but higher than for barley and wheat. In this study, the oil content ranged between 4.6% and 5.2%.

From the chemical analysis of the oat caryopses, it can be seen that the average content of the cultivated variants was 4.9% (Table 9).

The starch content of oat caryopses was suitable for both animal feed and the food industry. The genotypes analyzed had an average starch content of 49.3%, with a maximum in Jeremy (66.5%) and a minimum in Mureșana (63.5%) (Table 10).

Table 9.

Fat percentage in caryopses of oats

No. crt.	Variant	Fats (%)	Difference (%)
1	Lovrin 1	4,8	-0,1
2	Mureșana	5,2	0,3
3	Ovidiu	5,0	0,1
4	Jeremy	4.6	-0,3
5	Control	4,9	0

Table 10.

Starch content in caryopses of oats

No. crt.	Variant	Starch (%)	Difference (%)
1	Lovrin 1	49,5	0,2
2	Mureșana	48,7	- 0,6
3	Ovidiu	49,1	-0,2
4	Jeremy	49,9	0,6
5	Control	49,3	0

The percentage of cellulose in oat caryopses showed a very similar value for all genotypes analyzed, ranging from 1.15% to 1.25%. Lovrin 1 and Ovidiu had the same value of cellulose content as the control, i.e. 1.2% (Table 11).

Table 11.

The percentage of cellulose in caryopses of oats

No. crt.	Variant	Cellulose (%)	Difference (%)
1	Lovrin 1	1,20	0
2	Mureșana	1,25	0,05
3	Ovidiu	1,20	0
4	Jeremy	1,15	-0,05
6	Control	1,20	0

The ash content of oat caryopses averaged 2.1%, with a plus for Mureșana (2.2%) and Lovrin 1 (2.15%) and a minus for Jeremy (2.0%) and Ovidiu (2.05%) (Table 12).

Table 12.

Ash percentage in caryopses of oats

No. crt.	Variety	Ash content (%)	Difference (%)
1	Lovrin 1	2.15	0,05
2	Mureșana	2,20	0,10
3	Ovidiu	2,05	- 0,05
4	Jeremy	2,00	-0,1
6	Control	2,10	0

Analyzing from an economic point of view the behavior of the four varieties of oats, in the pedo-climatic conditions of the Arad area, they can be considered efficient, with profits ranging between 2165 lei/ha (Lovrin 1) and 2674 lei/ha (Ovidiu). Good results were also obtained for the variants cultivated with the Jeremy genotypes with a profit of 2311 lei/ha and Mureșana where the profit was 2212 lei/ha (Table 13).

Table 13.

The economic efficiency of oats

No. crt.	Variety	Grain production (kg/ha)	Grain production value (RON/ha)	Profit (RON/ha)	Difference (RON/ha)
1	Lovrin 1	4350	4785	2165	-175
2	Mureșana	4420	4862	2212	-98
3	Ovidiu	4840	5324	2674	364
4	Jeremy	4510	4961	2311	1
6	Control	4530	4961	2310	0

1 kg oats = 1,1 RON; Production cost = 2650 RON/ha

CONCLUSIONS

The cultivation of the four varieties of oats (*Avena sativa* L.), namely, Lovrin 1, Mureșana, Ovidiu, and Jeremy, in the climate and soil conditions of Crișurilor Plain (Arad county) resulted in the achievement of optimal morphological, biochemical and production traits in all the variants tested.

The morphological characters evaluated show good adaptability of the experimental oat variants to the soil and climatic conditions of the study area. The average height of the oat plants was 95 cm and the number of branches per panicle averaged 6.5. The number of grains in the panicle was also good, ranging from 90 to 93 pieces.

High yields were obtained in all varieties with a plus for the variety Ovidiu, where the amount of caryopses per unit area was 4840 kg/ha. The contents of protein (14.4%) and fat (4.9%) were within the normal range for all varieties studied. The starch percentage found in oat caryopses recommends the studied cultivars for macro-scale use in animal feed, the starch industry, and the food industry.

The best results from an economic point of view were obtained for the Ovidiu variety, with a total production value of 4840 lei/ha and a profit of 2674 lei/ha. In second place was the Jeremy variety, with a total production value of 4510 lei/ha and a profit of 2311 lei/ha.

AUTHORS CONTRIBUTIONS

Conceptualization, O.C.U., I.O.S. and V.T; methodology, O.C.U., I.O.S. and V.T.; data collection F.C.M, E.U.; data validation, F.C.M., I.O.S. and E.U., V.T; data processing F.C.M., E.U., O.C.U.; writing—original draft preparation, O.C.U and V.B.B.; writing—review and editing, V.B.B.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

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