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ENVIRONMENT AND DIGESTATE AFFECT ON THE OATS QUALITY AND YIELD PARAMETERS

SUMMARY

Oats are of great economic importance thanks to the high nutritional value of the grain. In this study, the productivity of oats was analyzed in two varieties: control (variants without digestate) and in the variant with digestate, during 2021-2022. The following parameters were tested: plant height, number of grains per panicle, grain yield per hectare and protein content. Highly significant positive correlation coefficients were found between grain yield and number of grains per plants (r=0.68**) and grain yield and plant height (r=0.59*). The results showed that year and digestate had no statistically significant effect on oat grain yield. The obtained values for grain yield were statistically significantly higher in the variant with digestate compared to the control variant. The digestate had a significant effect on the increase of oat yield and yield parameters, therefore its application in the oat crop is recommended.

Keywords: oats, year, digestate, yield components, protein content

INTRODUCTION

Oats (*Avena sativa* L.) is a real cereal that is of great economic importance due to the grain that has a high nutritional value, which is why it has been declared a functional food. Oat grain is desirable in the diet because it is responsible for numerous health benefits (Burić *et al.*, 2023). In human nutrition, peeled oat grain is used in the form of oatmeal, semolina and oat flour, which is

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mixed with wheat to make bread and other bakery products (Figure 1a-c). Oat grain has 8.18% of digestible proteins and it has a higher nutritional value than maize (Glamočlija *et al.*, 2015; Rajičić and Terzić, 2022; Burić *et al.*, 2023; Popović *et al.*, 2023). In Serbia, more it is grown as a forage plant in mixtures with legumes, and less for grain. In the world, the area under oats is decreasing at the expense of more productive grains, and according to FAO data, in 2022, it was grown on 9,562,497 ha. The average grain yield was 2,360 kg ha^{-1}, and the total production was 22,571,618 tons. The largest areas under oats by continent were in Europe (5,390,227 ha or 56.37%) and America (2,387,873 ha or 24.97%). The highest average grain yield of 2,526 kg ha^{-1} and a total production of 13,614,876 tons were recorded In Europe. In Serbia, oats was grown on 14,503 on which 44,176 tons of oat grains were produced. The average grain yields of 3,046 kg ha^{-1} are 20.58% above the average of European countries, i.e. about 30% higher than the world's average yields (Popović *et al*., 2023).

These types of soils are characterized by different properties (chemical, physical, and physical-mechanical, productive). The agrotechnical and meliorative measures are determined based on the properties of the various soil types in the target of improving their productive capacity and agricultural production (Markoski *et al*., 2018; 2021a; 2021b; Boitumelo Mohlala *et al*., 2022; Dugalić *et al*., 2022; Stevanović *et al.*, 2023; Sekulić *et al.*, 2023). For most types of soil in Serbia conditions, to achieve high yield and good grain quality, on average, 60-90 kg ha^{-1} of N, 60-90 kg ha^{-1} of P_2O_5 and 40-60 kg ha^{-1} of K_2O pure nutrients should be applied. Phosphorus and potassium fertilizers are introduced in winter oats 50% in the basic tillage and 50% before sowing, while in spring oats all phosphorus and potassium quantities are introduced in autumn under basic tillage. In more humid regions, the amount of nitrogen for fertilization is added early in the spring during intense tillering (the first fertilization with half of the anticipated amount) and the second fertilization at the beginning of stem elongation with the remaining amount of nitrogen. In the case of spring oats in arid regions, the entire amount of nitrogen is given before basic treatment or pre-sowing preparation, i.e. without top dressing (Rajičić *et al.*, 2020; 2021; Popović *et al*., 2023). The aim of this study was to investigate the effect of digestate on grain yield, productivity parameters and protein content of oat grain, over a two-year period.

MATERIAL AND METHODS

Study area

Experiments with spring oat variety NS Dunav carried out in Kovin, Pančevo municipality during 2021 and 2022, on chernozem soil in three repetitions. The oats pre-crop was soybean. For trial, an elementary plot of 25 m^2 was sown. Soil cultivation was carried out according to the varietal standard growing technology for the tested spring oat variety. Digestate was used as supplement. The experiment was performed in two variants: 1) control variant

without digestate and 2) variant with digestate. The entire amount of digestate is given during the pre-sowing preparation. Sowing was done in mid-February, Harvesting was done in early August with a harvester for experiments. The following parameters were analyzed: plant height (cm), number of grains per panicle, grain yield per hectare (t ha^{-1}) and protein content (%). The yield was measured after harvest and recalculated to 14% moisture.

After harvesting, oat grains are stored in silos and dried to 14-15% humidity. Oat grain with a higher percentage of water after harvest is dried in dryers or directly poured into a silo that has an innovative mixing propeller that works with the help of SMART-THINGS, i.e. with the help of sensors as shown in Figures 1a and 1b. The sensors monitor the humidity of the oat grains, report to the central sensor that directly with the help of the aggregate automatically blows moist or dry air, depending on the need in order to maintain optimal conditions for storing oat seeds (Popović *et al.*, 2023).

a) Oats Panicle

b) Oats grain

c)Storage oats silo

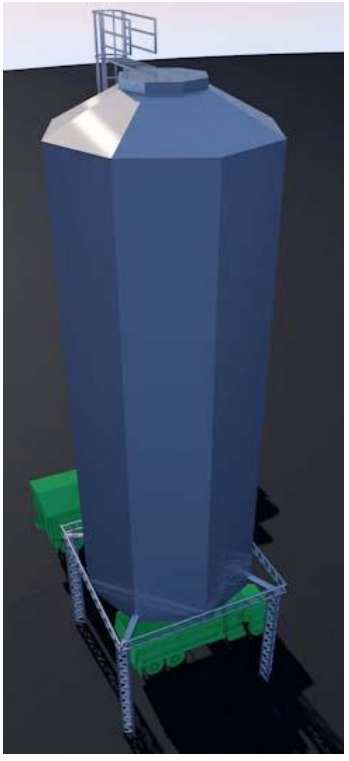


Figure 1. Oats panicle (a.), grain (b.), Storage silo (c.), Designed by (Ristić & Popović, 2023)

Meteorological Conditions

The meteorological conditions, monthly precipitation and air temperatures for 2021 and 2022 during the trial were taken from the Hydro-meteorological service of Republic of Serbia, Pancevo (Table 1).

Table 1. Average monthly temperatures and total precipitation for the oats vegetation period in 2021 and 2022, in Pančevo

Parameter	2021	2022
Average Temperature (˚C)	19.25	19.03
Total Precipitation (mm)	328.4	351.4

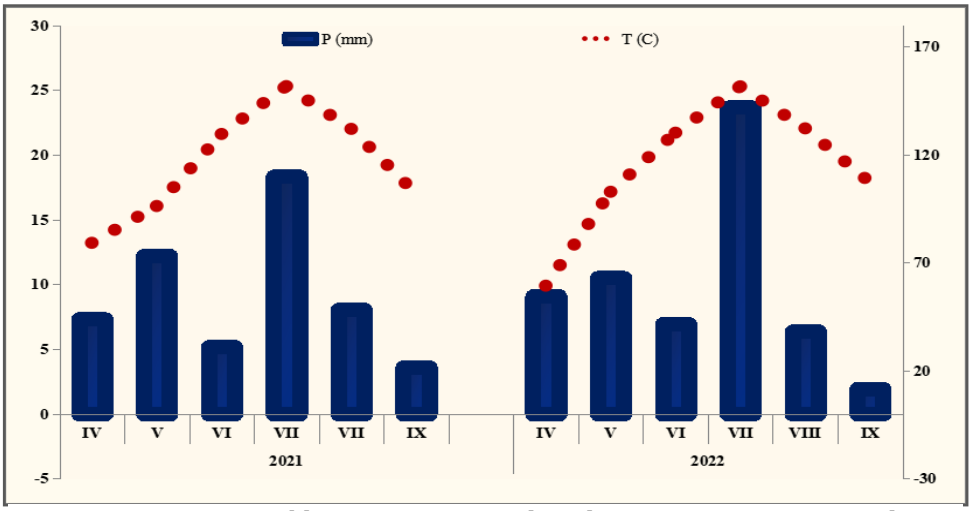


Figure 1. Average monthly temperatures and total precipitation in 2021 and 2022

Precipitation have a decisive influence on the yield components (Howarth *et al*., 2021; Lakić *et al*., 2021; 2022a; 2022b; Ljubičić *et al*., 2021; 2023; Nikolić *et al*., 2022; Dražić *et al*., 2022; Rakaščan *et al*., 2021; Dimitrijević *et al*., 2022; Filipović *et al*., 2022; Milunović *et al*., 2022; Popović *et al*., 2011; 2020a-b; 2022; Kosev *et al*., 2022). Average temperatures in the growing season were 19.25°C in 2021. and 19.03°C in 2022., while total precipitation in 2022 was 351.4 mm and it was higher by 23 mm then in 2021, figure 1.

RESULTS AND DISCUSSION

Productive characteristics and protein content of oat in Serbia

The average value for the height of the plants was 138.5 cm. The values for plant height varied from 138.5 cm in the control variant to 159.20 cm in the variant with digestate. The variant and the Y×V interaction had a statistically significant effect on plant height values. The year had no statistical significance for the investigated factor, tables 2 and 3, figure 2a.

The average value for the parameter - number of grains per panicle - was 48.50. The values of the number of grains per panicle varied from 44.33 in the control variant to 52.66 in the variant with digestate. The variant and the interaction of the examined factors V×Y was statistically significant for the examined factor (tables 2 and 4, figure 2b). A more favorable year for the number of grains per panicle was 2022 compared to 2021. In 2022, the number of grains per panicle increased by 4.5%.

Table 2. Parameters of oat productivity in Pančevo, 2021 and 2022

Parameters	Variant	2021.	2022	Average	IV*
Plant height, cm	Kontrola	138.3±1.87	138.7±1.20	138.5±1.41	0.40
	Digestat	161.0±0.72	157.3±0.15	159.2±0.51	3.70
	Average	**149.7±1.77**	**148.0±1.28**	**148.8±1.48**	**1.70**
Number of grains per panicle	Kontrola	41.33±6.11	47.33±5.51	44.33±6.15	6.00
	Digestat	53.66±2.31	51.66±3.06	52.66±2.66	2.00
	Average	**47.50±7.92**	**49.50±4.64**	**48.50±6.27**	**2.00**
Grain yield, t ha^{-1}	Kontrola	2.73±0.23	3.28±3.29	3,01±0.41	0.55
	Digestat	3.69±0.09	3.81±0.19	3.75±0.15	0.12
	Average	**3.21±0.55**	**3.55±0.38**	**3.38±0.48**	**0.34**
Protein content, %	Kontrola	7.00±0.72	5.90±0.26	6.45±0.77	1.10
	Digestat	7.76±0.73	6.83±0.68	7.30±0.81	0.93
	Average	**7.38±0.77**	**6.37±0.68**	**6.87±0.88**	**1.01**

**IV- Interval of variation*

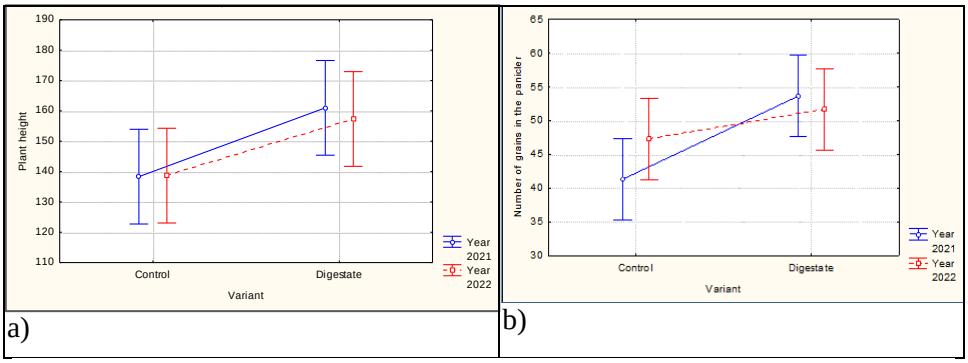
LSD	Plant height		Number of grain pp		Grain yield		Protein content	
	0.5	0.1	0.5	0.1	0.5	0.1	0.5	0.1
Year	1.559	2.269	6.040*	8.787	0,316	0.461	0.835	1.216
Variant	1.560	2.269	6.041*	8.789	0.317	0.461	0.836	1.216
YxV	2.206	3.209	8.542*	12.428	0.448	0.652	1.182	1.718

Table 3. Anova for plant height

Parameter	SS	Degr. of Fr.	MS	F	p
Intercept	265816.3	1	265816.3	193673.1	0.000000
Year	8.3	1	8.3	0.061	0.811572
Variant	1281.3	1	1281.3	9.336*	0.015691
Y x V	12.0	1	12.0	0.087*	0.774998
Error	1098.0	8	137.3		

Table 4. Anova for the number of grains per plant

Parameter	SS	Degr. of Freedom	MS	F	p
Intercept	28227.00	1	28227.00	1371.352	0.000000
Year	12.00	1	12.00	0.583	0.467058
Variant	208.33	1	208.33	10.121*	0.012970
Y x V	48.00	1	48.00	2.332*	0.165258
Error	164.67	8	20.58		



a) b)

Figure 2. Interaction Y×V for planth height (a) and number grain per panicle (b)

The average value for grain yield was 3.38 t ha^{-1} and varied from 3.01 t ha^{-1} in the control variant to 3.75 t ha^{-1} in the variant with digestate. Year, variant and interaction of the examined factors were statistically significant for the examined factor (tables 2 and 5, figure 3a). A more favorable year for grain yield was 2022 compared to 2021. In 2022, a statistically significantly higher grain yield was achieved, by 340 kg ha^{-1}, i.e. by 11.33% (tables 2 and 5).

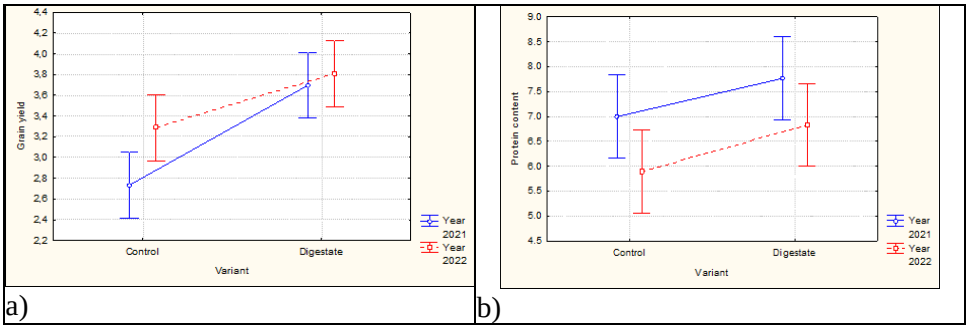
Tabela 5. Anova for grain yield

Parameter	SS	Degr. of Free.	MS	F	p
Intercept	137.2280	1	137.2280	2422.384	0.000000
Year*	0.3333	1	0.3333	5.884	0.041479
Variant*	1.6576	1	1.6576	29.261	0.000639
Y x V*	0.1452	1	0.1452	2.563	0.148051
Error	0.4532	8	0.0566		

The average value for protein content was 6.87% and varied from 6.45% in the control variant to 7.30% in the variant with digestate. The year, variant and interaction of the examined factors were statistically significant for the examined factor (table 2, figure 3b). The more favorable year for protein content was 2021 compared to 2022. In 2021, statistically significantly higher values were achieved for protein content, namely for 15, 85% (tables 2 and 6, figure 3b).

Tabela 6. Anova for oat grain protein content

Parameter	SS	Degr. of Freedom	MS	F	p
Intercept	567.1875	1	567.1875	1438.953	0.000000
Year*	3.1008	1	3.1008	7.867	0.023027
Variant*	2.1675	1	2.1675	5.499	0.047048
Y x V*	0.0208	1	0.0208	0.053	0.823939
Error	3.1533	8	0.3942		



a) b)

Figure 3. Interaction Y×V for grain yield (a) and protein content of oats grain (b)

Jordanovska *et al*. (2018) points out that the protein content of oat grains varied from 12-15%, fat content from 4-6.5% and crude fiber content from 12.2-12.5%.

Correlation analysis of the studied oat traits

Correlation coefficients based on all tested traits during 2021-2022 had positive values (Table 7). Genotypic correlation coefficients provide a measure of the genetic association among characters and give an indication of characters that could be useful so as to identify more important ones for a particular selection programme. Correlation studies were conducted to study the degree of interrelationship between grain yield and their major traits.

Table 7. Correlations between the analyzed traits

Traits	PH	NoG	GY	PC	Temp.	Prec.
Plant height - PH	1.00	0.16 ^{ns}	0.59*	0.24 ^{ns}	0.54*	0.76**
Number grain per panicle - NoG	0.16 ^{ns}	1.00	0.68*	0.14 ^{ns}	0.83*	0.66*
Grain yield-GY	0.59*	0.68*	1.00	0.04	0.76*	0.80**
Protein content-PC	0.24 ^{ns}	0.11 ^{ns}	0.04 ^{ns}	1.00	0.41 ^{ns}	0.52*
^{ns} - non significant; * significant at 0.05; **significant at 0.01						

Highly significant positive correlation coefficients were found between grain yield and number grains per plants (r=0.68**), grain yield and precipitaion (r=0.76*), grain yields and temperature (r=0.76*) and grain yield and planth height (r=0.59*). Significant positive correlations were found between number of

grains in panicle and precipitation (r=0.66*) and planth height and temperature (r=0.59*).

Protein content did not have a significant correlation with grain yield (Table 7). A strong positive correlation between small yields and grain weight has been found by many researchers (Terzic *et al*., 2018), medium (Đekić *et al.*, 2012; 2014; 2018; Güngör *et al.*, 2017), while weak positive dependence has been identified by Rajičić *et al.* (2020). Grain yield plant^{-1} exhibited significant and positive correlation coefficients with spike-lets panicle^{-1}, 1000 seed weight (g) but negative non-significant correlation with protein content (Ahmad *et al*., 2013). These results will be beneficial in devising a selection scheme for identifying best genotypes possessing higher forage yield, grain yield and better quality.

CONCLUSIONS

Oat grain is used for nutrition as a grain but also for non-food products and due to its unique grain quality, it is known as a functional food. The results showed that year and digestate had statistically significant effect on oat grain yield. Statistically significantly higher grain yield values were achieved in the variant with digestate compared to the control variant, which is why its application in the oat crop is justified. Highly significant positive correlation coefficients were found between grain yield and number of grains per plants (r=0.68**), grain yield and precipitation (r=0.76*), grain yields and temperature (r=0.76*) and grain yield and plant height (r=0.59*).

Big progress has already been achieved in breeding oats. Breeders of oats need to make available to the market higher yielding and higher grain quality cultivars. Therefore, it is necessary to optimize the strategies of selection of superior oats genotypes.

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