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Proceeding Paper

Yield, Morphological Traits, and Physiological Parameters of Organic and Pelleted *Avena sativa* L. Plants Under Different Fertilization Practices [†]

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Abstract: Oat (*Avena sativa* L.) is one of the most important self-fertilizing field plants belonging to the Poaceae family. It has no significant requirements regarding growing conditions but has a very good reaction to fertilization. The current research evaluated the significance of the effects of individual applications of mineral (NPK) and organo-mineral (OMF) fertilizers, as well as their individual combination with slaked lime (calcium hydroxide, $Ca(OH)_2$), on the yield, morphological traits [mean number of leaves per plant—MNLP, minimum leaf length (cm) per plant—MinLL, maximum leaf length (cm) per plant—MaxLL, number of ears per plant—NEP], and physiological parameters (nitrogen balance index—NBI, content of chlorophyll—Chl, flavonoids—Flv, anthocyanins—Ant) of organic and pelleted (graded) oat plants, comparing the treatments and in relation to the control. The experiment was performed in semi-controlled glasshouse conditions, in pots, from the fourth week of March to the fourth week of June 2024, using Vertisol soil. This soil is characterized as light clay with an acid reaction. Physiological parameters were measured using a Dualex leaf clip sensor. The results obtained showed that physiological parameters in both oat types significantly differed ($p < 0.05$) between the treatments applied and in relation to the control, whereas the morphological traits did not significantly differ ($p > 0.05$) between the treatments. Statistically significant differences ($p < 0.05$) in the yield of both oat types were most pronounced in the OMF + Slaked Lime treatment (organic: 4.49 g pot^{-1}; pelleted: 4.61 g pot^{-1}) in relation to the control (organic: 2.48 g pot^{-1}; pelleted: 2.63 g pot^{-1}). The pelleted oats showed slightly better results for the effects of different treatments across all tested parameters compared to organic oats. In conclusion, the best results were obtained with the use of OMF + Slaked Lime, which could be proposed as the optimal fertilization treatment for pelleted and organic oat cultivation based on this research.

Keywords: oats; mineral and organo-mineral fertilizer; slaked lime; Vertisol; growth parameters; yield

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1. Introduction

Oat (*Avena sativa* L.) is one of the most important self-fertilizing cereal crops belonging to the Poaceae family, primarily cultivated for cattle feed but also for human consumption, as it contains high concentrations of fermentable carbohydrates and amino acids [1–4].

Other authors [5,6] have reported new possibilities for using oat grains as an industrial plant for energy production. In terms of growing conditions, oats have no significant requirements, tolerating negative environmental conditions and less fertile soils, but at the same time, they show a strong reaction to increased fertilization and soil *amendments* [7]. Vertisol is a soil with a heavy mechanical composition (high clay content) and a generally low pH value [8,9]. Although plant nutrients are present at high levels, due to soil high clay content, they are not well suited to cultivation without effective management [10]. Due to the long-term improper application of mineral fertilizers, their acidity further increases [11]. This necessitates expanded efforts to promote the more rational use of mineral fertilizers to maximize their positive functions [12] and to contemporaneously adopt organic and organo-mineral fertilization. In addition to their fertilization effect, organic fertilizers often have a greater impact on improving the water, air, thermal, and biological regimes of the soil [13], indirectly affecting the complex mineral nutrition of plants, which is not the case with the application of many mineral nutrients. Nevertheless, only a small part of the basic plant nutrients in these fertilizers can be found in the form of mineral compounds. As a mixture of organic and mineral fertilizers, organo-mineral fertilizers retain all the aforementioned properties of organic fertilizers but provide a significantly more favorable plant nutrition regime, ensuring plant nutrition for a longer period of time. It is considered that the application of these fertilizers increases yield by 2–10% compared to the application of equivalent amounts of pure mineral fertilizers [14]. Apart from the plant nutrients, there are materials that when supplied to acid soil as liming materials (such as calcite and slaked lime), also promote plant growth without participating in the construction of plant material, thus improving the environmental conditions of the plant in so far as they involve the soil. In practice, efforts should be made to combine fertilizers and soil improvers since they complement each other [15]. The current study was carried out to evaluate the fertilization variants that can be used to improve the yield, morphological traits, and physiological parameters in growing organic and pelleted oat plants.

2. Materials and Methods

This research was performed under greenhouse vegetative conditions at the Institute of Soil Science, using plastic pots, from the 4th week of March to the 4th week of June 2024. Each pot was filled with 1.4 kg pot^{-1} of homogenized Vertisol-type soil [16], sourced from a field located in the Mala Ivanča settlement, Sopot Municipality (grid reference: 44°35′ N, 20°36′ E), about 35 km from Belgrade in Serbia. The soil properties were determined in our previous study [17], and accordingly, the soil was found to have a high clay fraction, an acidic reaction, high available K, very low available P, and medium total N and SOM supply. In every plastic pot, ten organic and ten pelleted oat seeds were sown on 27 March. Both oat types were grown according to standard growing methods, including watering and regular manual weed control. No plant protection products were used during the growth of the plants. The following five designed treatments were carried out in three replications: Mineral Fertilizer (NPK, 15:15:15); Oregano-Mineral Fertilizer (OMF); NPK + Slaked Lime; OMF + Slaked Lime; and Control (Ø, non-fertilized soil). Mineral fertilizer was applied as urea with 46% N, monoammonium phosphate with 52% P_2O_5 and 11% N, and potassium chloride with 40% K_2O. Commercial organo-mineral fertilizer was applied as a solid nutrient with 3.90% total N, 2.90% P_2O_5, and 2.65% K_2O. Before sowing, the rates of soil amendments were recalculated per 1 kg of soil and mixed with it as follows: NPK = 0.17 g kg^{-1}; OMF = 0.06 g kg^{-1}; slaked lime = 1.36 g kg^{-1}. Morphological traits (mean number of leaves per plant—MNLP; minimum leaf length per plant—Mill, in cm; maximum leaf length per plant—Mall, in cm; number of ears per plant—NEP) were manually measured and counted. Physiological parameters [content of chlorophyll—Chl, flavonoids—Flv, anthocyanins—Ant, nitrogen balance index (Chl/Flv Ratio)—NBI] were determined using a portable Dualex optical leaf clip sensor (FORCE-A, Orsay, France). The aerial biomass at the stage of the plants' total ear formation was taken, air-dried, and measured for the yield of oats and expressed in g pot^{-1}. Analysis of variance was used to statistically analyze the data relevant to the treatment effects on plant yield, as well as morphological and physiological parameters. The Excel program was used to provide a graphical data presentation comparing the organic and pelleted oats by treatments.

3. Results and Discussion

3.1. Yield, Morphological Traits, and Physiological Parameters

The obtained study results (Tables 1–3) revealed a slightly noticeable but insignificant effect ($p > 0.05$) of all fertilization treatments on the morphological traits of both oat aerial biomass. However, the physiological parameters in both oat types significantly differed ($p < 0.05$) between the treatments applied and in relation to the control.

Table 1. Effect of the fertilization treatments on the tested growth parameters [1] of organic oats.

Fertilization Treatment [2]	Morphological Parameters				Physiological Parameters			
	MNLP	MinLL (cm)	MaxLL (cm)	NEP	NBI	Chl (μ cm^{-2})	Flv (μ cm^{-2})	Ant (μ cm^{-2})
NPK	4.6 ± 0.47	9.2 ± 1.15	30.2 ± 1.53	4.3 ± 1.15	35.33 ± 4.51	23.06 ± 2.30	0.63 ± 0.06	0.13 ± 0.02
OMF	5.6 ± 1.53	8.7 ± 0.87	30.1 ± 1.62	4.7 ± 0.58	34.27 ± 6.45	22.96 ± 1.87	0.54 ± 0.08	0.12 ± 0.02
NPK + Slaked Lime	4.6 ± 0.47	9.7 ± 0.97	30.6 ± 1.75	4.3 ± 0.58	38.16 ± 3.99	29.40 ± 3.22	0.73 ± 0.11	0.15 ± 0.01
OMF + Slaked Lime	5.3 ± 0.94	9.6 ± 0.65	31.2 ± 2.74	5.3 ± 1.53	41.33 ± 6.80	32.43 ± 3.92	0.90 ± 0.17	0.19 ± 0.02
Ø, non-fertilized	4.6 ± 0.94	9.2 ± 0.76	28.6 ± 1.75	5.3 ± 1.15	24.48 ± 3.19	19.90 ± 5.54	0.49 ± 0.10	0.11 ± 0.02
Statistical analyses	Source of variation							
	Fertilization treatment							
p value	NSD	NSD	NSD	NSD	***	***	***	***
LSD (0.05)	1.506	3.082	1.202	0.622	1.112	1.442	0.134	0.039

[1] Average ± standard deviation; [2] Fertilization treatments and their labels are given in Section 2; LSD—least significant differences at $p = 0.05$; NSD indicates no significant difference; *** indicates statistically significant differences.

Table 2. Effect of the fertilization treatments on the tested growth parameters [1] of pelleted oats.

Fertilization Treatment [2]	Morphological Parameters				Physiological Parameters			
	MNLP	MinLL (cm)	MaxLL (cm)	NEP	NBI	Chl (μ cm^{-2})	Flv (μ cm^{-2})	Ant (μ cm^{-2})
NPK	5.3 ± 0.47	9.2 ± 1.76	31.2 ± 1.76	4.3 ± 0.56	36.08 ± 3.12	25.04 ± 1.24	0.87 ± 0.16	0.17 ± 0.01
OMF	5.6 ± 0.57	9.2 ± 0.75	30.7 ± 1.42	4.7 ± 0.58	35.99 ± 5.43	24.99 ± 3.40	0.80 ± 0.02	0.16 ± 0.01
NPK + Slaked Lime	5.3 ± 0.94	9.6 ± 0.97	32.1 ± 3.33	4.3 ± 1.15	39.33 ± 3.97	30.89 ± 4.51	0.91 ± 0.12	0.19 ± 0.01
OMF + Slaked Lime	5.6 ± 0.94	9.9 ± 1.02	32.8 ± 2.57	5.1 ± 0.58	42.89 ± 6.98	33.09 ± 3.69	1.10 ± 1.06	0.21 ± 0.04
Ø, non-fertilized	5.0 ± 0.82	9.1 ± 1.55	30.5 ± 1.65	4.3 ± 1.15	25.63 ± 4.46	21.85 ± 2.27	0.64 ± 0.13	0.13 ± 0.02
Statistical analyses	Source of variation							
	Fertilization treatment							
p value	NSD	NSD	NSD	NSD	***	***	***	***
LSD (0.05)	1.506	3.082	1.202	0.622	1.112	1.442	0.134	0.039

[1] Average ± standard deviation; [2] Fertilization treatments and their labels are given in Section 2; LSD—least significant differences at $p = 0.05$; NSD indicates no significant difference; *** indicates statistically significant differences.

The stimulative impact of all the tested physiological parameters was mostly observed in the combined organo-mineral and slaked lime treatment (OMF + Slaked Lime), followed by the combined mineral and slaked lime treatment (NPK + Slaked Lime). A statistically significant difference ($p < 0.05$) was observed in the mutual effects of the treatments and in relation to the control regarding the yield of both oat types. The most pronounced significant differences ($p < 0.05$) in yield were determined between the OMF + Slaked Lime treatment (organic: 4.49 g pot^{-1}; pelleted: 4.61 g pot^{-1}) and the control (organic: 2.48 g pot^{-1}; pelleted: 2.63 g pot^{-1}). The results obtained are in accordance with those obtained by Iren et al. [18] regarding pumpkin plants, where combined lime and OMF treatments resulted in a higher yield and number of leaves per plant relative to the control, as well as higher values than their individual applications.

Table 3. Effect of different fertilization treatments on the yield of oats' aerial biomass.

Fertilization Treatment [1]	Yield (g pot^{-1}, Air-Dried Biomass) [2]	
	Organic Oat	**Pelleted Oat**
NPK	3.14 ± 0.44	3.36 ± 1.16
OMF	3.38 ± 0.75	3.44 ± 0.97
NPK + Slaked Lime	3.55 ± 0.89	3.71 ± 0.72
OMF + Slaked Lime	4.49 ± 1.98	4.61 ± 2.05
Ø, non-fertilized	2.48 ± 0.93	2.63 ± 0.88
Statistical analyses	Source of variation	
	Fertilization treatment	
p value	***	***
LSD (0.05)	2.143	1.219

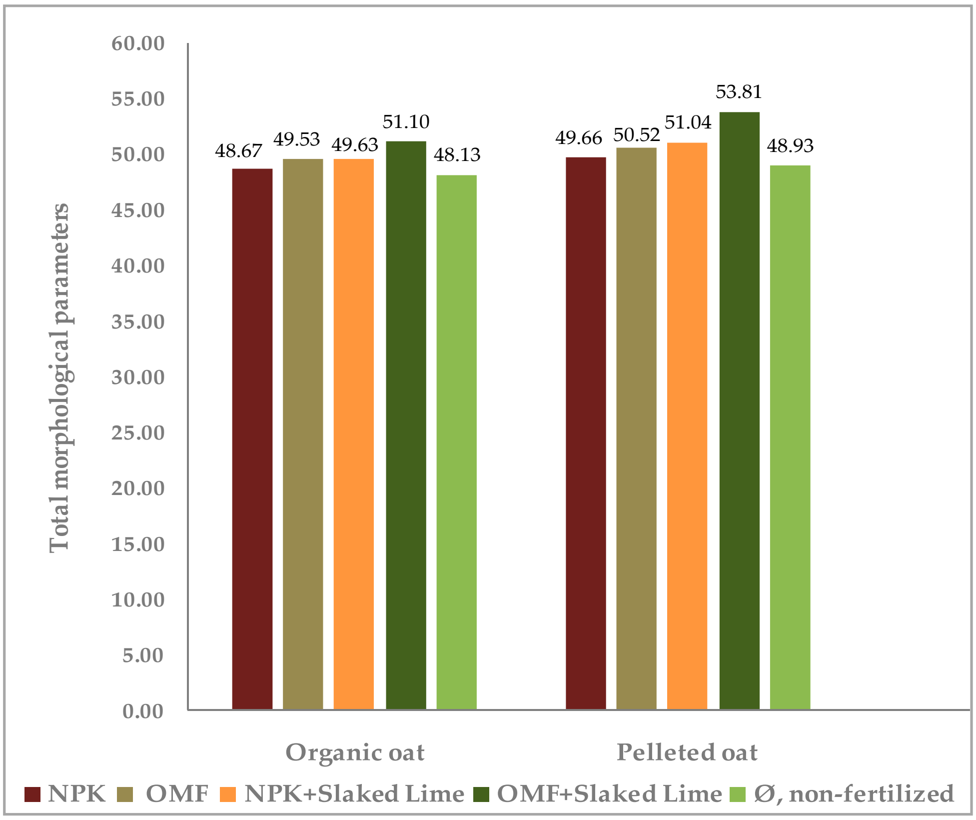
[1] Fertilization treatments and their labels are given in Section 2; [2] Average ± standard deviation; LSD—least significant differences at $p = 0.05$; *** indicates statistically significant differences.

The data regarding the superiority of the combined OMF and lime treatment may be due to increased microbial activity and the availability of major plant nutrients as a result of the soil acidity reduction [19,20], which led to better soil conditions, plant nutrient uptake, development, and quality. Also, research by Yildiz and Dizikisa [21] has shown that organo-mineral fertilizers can improve plant growth parameters to a greater degree than the use of chemical fertilizers or fertilizers alone. Furthermore, the plant's photosynthetic activity and nutrient assimilation were positively affected by the different formulations of organo-mineral fertilizers [22]. Rajičić et al. [23] stated the importance of the combined use of lime and rational doses of chemical fertilizers in reducing soil acidity, increasing yield and yield components of oats, and improving soil quality.

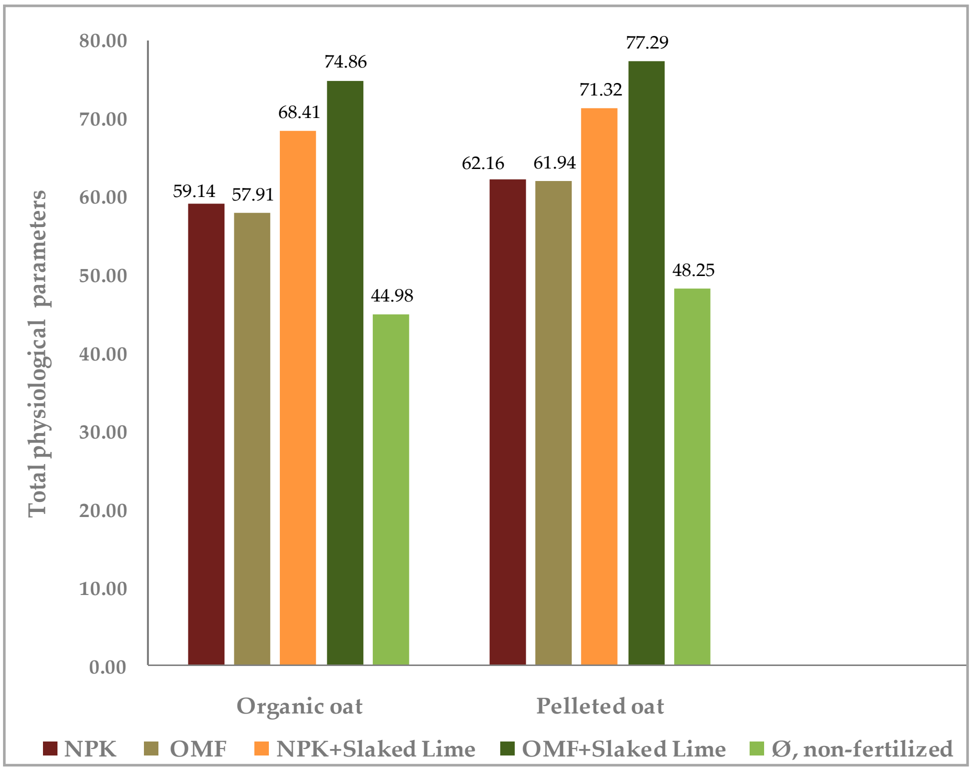
3.2. Effect of Treatments on Plant Parameters Depending on Oat Type

The obtained experimental data indicated that the differences in the tested parameters between organic and pelleted oats, depending on the treatment applied, were not pronounced. Nevertheless, slightly better results for all the tested parameters were observed for pelleted oats in relation to organic oats (Figure 1).

Pelleted seeds are believed to have higher germination rates and emergence energy than untreated seeds [24], such as the organic ones in this research, which can potentially enhance the growth and development of the plant. The present results are not completely in accordance with those obtained by Ćurčić et al. [25] on lettuce plants, where very high seed germination energy was established in pelleted seeds in relation to non-pelleted seeds, but not in organic oat seeds, which is the subject of this research. However, there is very little or no available information regarding the differences in the tested parameters between organic and pelleted oat, particularly as it relates to nutrient management.

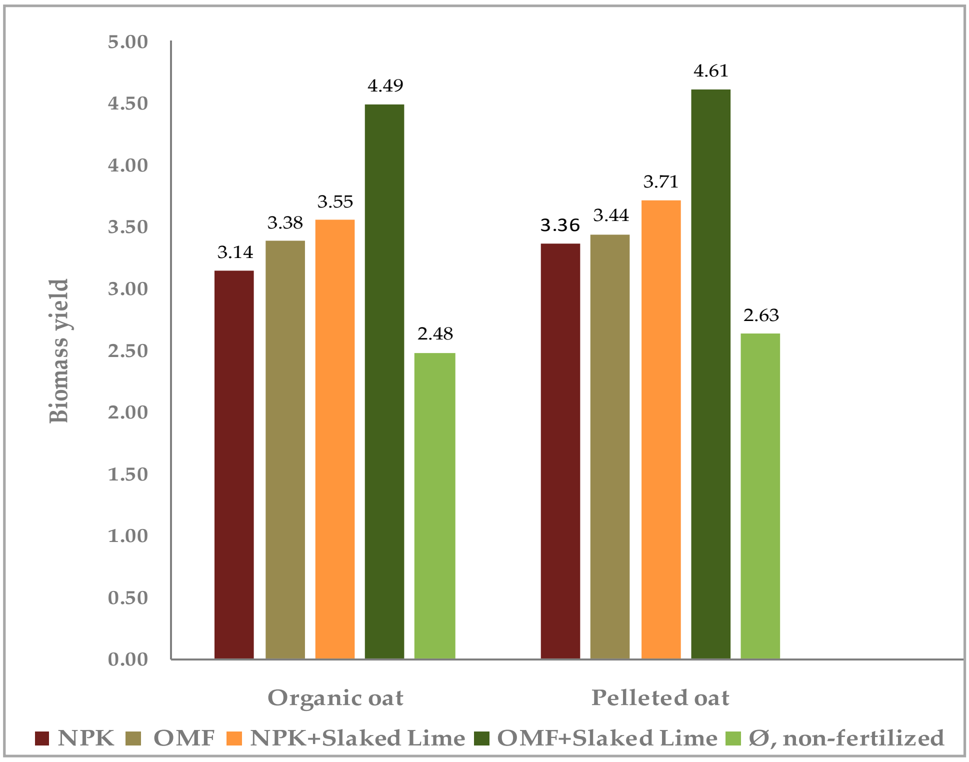


(**a**)



(**b**)

Figure 1. *Cont.*



(**c**)

Figure 1. Effect of fertilization treatments on the tested plant growth parameters, depending on the type of oat: (**a**) Effect on the total sum of the morphological parameters' average values; (**b**) Effect on the total sum of the physiological parameters' average values; (**c**) Effect on the yield of aerial oat biomass; Fertilization treatments and their labels are given in Section 2.

4. Conclusions

This study evaluated the effectiveness of different fertilization practices in the growth of organic and pelleted oats under greenhouse vegetative conditions. The values of the tested morphological parameters (mean number of leaves per plant, minimum leaf length per plant, maximum leaf length per plant, and number of ears per plant) did not significantly differ between the treatments for both oat types. In contrast to these results, the data obtained on the physiological parameter values (NBI, chlorophyll, flavonoids, and anthocyanins) showed significant effects of all the tested treatments in both oat types, particularly in relation to untreated soil, which was also found for yield. The pelleted oats showed less noticeable differences in the effects of different treatments on all tested parameters in relation to organic oats. The best results were obtained with the use of OMF + Slaked Lime treatment, which could be proposed as the optimal fertilization treatment for pelleted and organic oat cultivation based on this research.

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Abbreviations

The following abbreviations are used in this manuscript:

NPK	Mineral fertilizer
OMF	Organo-mineral fertilizer
Ø	Control
MNLP	Mean number of leaves per plant
MinLL	Minimum leaf length per plant
MaxLL	Maximum leaf length per plant
NEP	Number of ears per plant
NBI	Nitrogen balance index
Chl	Chlorophyll
Flv	Flavonoids
Ant	Anthocyanins
SOM	Soil organic matter

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