Article

Yield Performance of Spring Oats Varieties as a Response to Fertilization and Sowing Distance

Marcel Duda ¹ , Nicolae Tritean ^{2,*}, Ionuț Racț ^{2,3,*}, Rozalia Kadar ², Florin Russu ², Avram Fițiu ⁴, Edward Muntean ^{2,5} and Anamaria Vâtcă ⁶

- ¹ Department of Plant Culture, Faculty of Agriculture, University of Agricultural Sciences and Veterinary Medicine Cluj-Napoca, Calea Mănăștur 3-5, 400372 Cluj-Napoca, Romania; marcel.duda@usamvcluj.ro
- ² Agricultural Research Development Station Turda, 401100 Turda, Romania; rodica.kadar@scdaturda.ro (R.K.); florin.russu@scdaturda.ro (F.R.); emuntean@usamvcluj.ro (E.M.)
- ³ Department of Genetics, Faculty of Agriculture, University of Agricultural Sciences and Veterinary Medicine Cluj-Napoca, Calea Mănăștur 3-5, 400372 Cluj-Napoca, Romania
- ⁴ Department of Ecology, Faculty of Agriculture, University of Agricultural Sciences and Veterinary Medicine Cluj-Napoca, 3-5 Mănăștur St., 400372 Cluj-Napoca, Romania; avram.fitiu@usamvcluj.ro
- ⁵ Department of Food Science, Faculty of Food Science and Technology, University of Agricultural Sciences and Veterinary Medicine Cluj-Napoca, 3-5 Mănăștur St., 400372 Cluj-Napoca, Romania
- ⁶ Department of Management and Economics, Faculty of Animal Science and Biotechnologies, University of Agricultural Sciences and Veterinary Medicine Cluj-Napoca, Calea Mănăștur 3-5, 400372 Cluj-Napoca, Romania; anamaria.vatca@usamvcluj.ro
- * Correspondence: nicu.tritean@scdaturda.ro (N.T.); ionut.racz@usamvcluj.ro (I.R.)

Citation: Duda, M.; Tritean, N.; Racț, I.; Kadar, R.; Russu, F.; Fițiu, A.; Muntean, E.; Vâtcă, A. Yield Performance of Spring Oats Varieties as a Response to Fertilization and Sowing Distance. *Agronomy* **2021**, *11*, 815. <https://doi.org/10.3390/agronomy11050815>

Academic Editor: Scott Boden

Received: 26 March 2021

Accepted: 18 April 2021

Published: 21 April 2021

Publisher's Note: MDPI stays neutral with regard to jurisdictional claims in published maps and institutional affiliations.

Copyright: © 2021 by the authors. Licensee MDPI, Basel, Switzerland. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (<https://creativecommons.org/licenses/by/4.0/>).

Abstract: The main objective of this paper is to evaluate the yield potential of 25 different varieties of oat as a reaction to seeding distance and fertilization for improvement of crop technology and identification of the most adapted varieties. Based ANOVA test, the main influence on yield is due to climate, followed by the amount of fertilizers. The sowing distance reveals its influence when combined with the fertilization, this aspect pointing out the differences between studied varieties. The triple interactions gradually reduce the influence of the factors, their combination being very significant in the case year X sowing distance X variety. The spatial comparative analysis of the three experimental years presents an overlap in the median area of the PCA ordering of the 12.5 cm sowing distance, fertilized with N₅₀P₅₀ with the 25 cm sowing distance fertilized with N₁₀₀P₅₀. There are differences between the oat varieties regarding the reaction to the nitrogen fertilization, highlighting especially the Mureșana variety where comparable yields are obtained on both levels of fertilization: 5.18 t ha⁻¹ (N₅₀P₅₀) and 5.59 t ha⁻¹ (N₁₀₀P₅₀).

Keywords: spring oats; production; stability; clusters; fertilization; sowing distance

1. Introduction

Oat plants are cultivated up to an altitude of 1100 m and can reach mountainous, relatively humid, and cool areas located in the countries and the southern areas of Europe, USA, and Canada. Oat was cultivated in 2019 over a global area of 9.42 million hectares, with greater surfaces in the Russian Federation (2.43 million hectares), Canada (1.17 million hectares), Poland (495,000 hectares), Spain (453,000 hectares), Brazil (448,000 hectares), USA (334,000 hectares), etc. [1]. In Romania, spring oats are cultivated on an area that exceeds 160,000 hectares every year and sometimes even exceed 200,000 hectares, as it was the case in 2007–2009. Oat is found mostly between 45–65° latitude N and 20–46° latitude S [2]. The autumn oats crop is sensitive during winter and the warm dry weather before the kernel formation. Because autumn oats crop is sensitive during winter conditions, spring oat is preferable. However, oat performs better than other cereals on clay soils, tolerating also acid and low fertile soils, with a pH between 4.5 and 8.6. Oat is tolerant when it comes to

soil salinity. In the tropical areas it is cultivated at greater altitudes, in Ethiopia and Kenya reaching 1600 m, being able to surpass 2000 m [3,4].

Oat is used more and more in humans' diets under different forms: bread, biscuits, flakes, beverages, pasta, milk, yogurt made from oat milk, as a fat substitute, stabilizer for ice-cream, and the raw material used is different based on the result. The nutritional value of oat is mainly sustained by dietary fibers (DF), which represent an essential part of the human diet. DF are comprised of several substances of plant origin, which are not digested in the human upper gastrointestinal tract. These include polysaccharides such as β -glucans in cereals, arabinoxylans, and cellulose. DF are located in the cellular walls of the grain. The outer layers, respectively the seed coat and the pericarp of the cereal grains have the highest content of DF. Carbon hydrates are represented by starch, sucrose, and phytic acid. The fatty acids found in oat grains are: myristic, palmitic, stearic, palmitoleic, oleic, linoleic, and linolenic. The grains also contains the vitamins: B1 (thiamine), B2 (riboflavin), B3 (niacin, also called PP from pellagra preventers), B5 (pantothenic acid), B6 (pyridoxine), B8 (biotin), B9 (folic acid), E, K, and traces of vitamin D. Among minerals, they are: sodium, potassium, magnesium, calcium, manganese, iron, cobalt, copper, zinc, nickel, chromium, molybdenum, phosphorus, chlorine, fluorine, iodine, boron, and selenium. Oat has a more fatty acids' content compared to that of other cereals from the same temperate area (wheat, rye, and barley), these being located in the embryo [4,5].

Oat has a bipolar germination and usually forms three embryo roots, afterwards the coronary roots appear, growing until the efflorescence. The root system of oats is well developed, surpassing that of wheat, rye, and barley. The roots run deep and have a high solubilizing power for nutrients. Thus, oats are less pretentious when it comes to soil, utilizing nutritional elements from less soluble forms. Oats are autogamous plants, but cases of allogamy are quite common. Because of this it is quite frequent for hybrids between cultivated oat and common wild oat to appear. This can cause biological impurities, thus making it necessary for the seed to be renewed.

Oat is a plant typical for regions with a wet climate and cool summers, but it resists better than other plants in dry conditions. Oat grows on a great variety of soils, with temperatures between 5 and 26 °C and in regions with precipitations over 500 mm [6,7]. The minimum germination temperature is 2–3 °C and the young plants resist to temperatures as low as –7 °C. Autumn oat species resist at –12 °C without a layer of snow. In the first period of the vegetation period, oat grows and develops well at temperatures between 5 and 12 °C (for the development of organogenesis) and afterwards at 12–15 °C. Temperatures of 15–17 °C are favorable for flowering and fecundation while for the maturation 17–20 °C are favorable. The sum of the temperatures for the total period of vegetation is 1700–2000 °C. Spring oats represents an alternative that is to be considered for Romania given the climatic changes when in the years with dry and hot autumns the land cannot be prepared for sowing or we are dealing with an excess of moisture in the soil due to the rains of October and November.

As can be seen in the reported results, the sowing distance represents an extremely important technological element for spring oat in the years where drought is present in the growth period and that of the filling of the grain (June–July). In favorable years for spring oats, as it was 2017, we can reduce the amount of seed by half. A seed quantity of 150 and 180 kg ha^{–1}, based on the TKW, is used for a distance of 12.5 cm in between rows and for a distance of 25 cm the quantity of seed that is used is reduced in half, respectively, 70–90 kg ha^{–1}, the number of grains that germinate ha^{–1} being 5 million for 12.5 cm and 2.5 million for 25 cm. The rates of seeding in oat vary depending on the location and the purpose for which the crop is cultivated and seed rates of about 125 to 175 kg ha^{–1} are normal for the sowing [8].

Due to its short vegetation period of 120–140 days it is usually sown in the first week of March and it is harvested at the latest at the end of July. Oats have a high demand for water, having the highest transpiration coefficient of all cereals from the temperate climate (400–600). The maximum water usage is when the straw is elongated and during

efflorescence-flowering. Soil requirements for oats are low because of its deep root system and the great power of roots to solubilize nutrients. It prefers chernozem and brown soils. It does not give a good yield on compact, non-aerated soils, and on sands from the dry area it suffers from lack of moisture. It succeeds better than wheat, rye, or barley on acid soils.

In some varieties, nitrogen fertilization caused a much greater increase in production compared to the number of seeded seeds m^{-1} , ranging between 0.36 and 1.48 $t\ ha^{-1}$ [9–12]. Moreover, additional fertilization with nitrogen determines an increase in oat production similar to other small grain cereals [13–15].

The main research objective is to improve the technology for cultivating spring oats in the Transylvanian Plain, an area that is very favorable for this crop. This objective will be achieved by accumulating new knowledge aimed at providing a scientific and practice basis for using the best varieties in cultures and as this is correlated with the sowing distance and a rational fertilization it would lead to improved yields, taking into account the economic efficiency and the protection of the environment.

2. Materials and Methods

The production capacity of 25 varieties and lines of spring oats, of local and foreign origins, were studied (Table 1). The experiment was conducted on a chernozem argic soil [16] from ARDS Turda ($46^{\circ}34'57.5538''$ N and $23^{\circ}47'15.7158''$ E), Cluj county, Romania. Based on their origin, the varieties were divided in 4 categories: 7 varieties and lines created at ARDS Turda (RoTd), 6 lines created at ARDS Lovrin (RoLo), 7 varieties from Western Europe (WEu) and 5 varieties from Central and Eastern Europe (CEEu). As presented in the literature, knowledge of genotype-environment interaction is very important for the application of appropriate technology [17–20]. All varieties belong to the oat collection from ARDS Turda, and they are used for research and plant breeding programs.

Table 1. The biological material used in the experiment.

Variety	Name	Source	Region
V1	Someșan	Romania ARDS Turda	RoTd
V2	Mureș	Romania ARDS Turda	RoTd
V3	Mureșana	Romania ARDS Turda	RoTd
V4	T. 90-81 M	Romania ARDS Turda	RoTd
V5	T. 21-81 M	Romania ARDS Turda	RoTd
V6	T. 38-81 M	Romania ARDS Turda	RoTd
V7	T. 44-81 M	Romania ARDS Turda	RoTd
V8	LV. 4324-86	Romania ARDS Lovrin	RoLo
V9	LV. 4325-86	Romania ARDS Lovrin	RoLo
V10	LV. 4362-86	Romania ARDS Lovrin	RoLo
V11	LV. 4363-86	Romania ARDS Lovrin	RoLo
V12	LV. 8644-82	Romania ARDS Lovrin	RoLo
V13	LV. 7478-82	Romania ARDS Lovrin	RoLo
V14	Solidor	Germany	WEu
V15	Romulus	Germany	WEu
V16	Gramena	Germany	WEu
V17	Jumbo	Germany	WEu
V18	Cory	France	WEu
V19	Avalanche	France	WEu
V20	Integrale	France	WEu
V21	Rumak	Poland	CEEu
V22	Bug	Belarus	CEEu
V23	Skakum	Russia	CEEu
V24	Fucs	Letonia	CEEu
V25	Pan	Czech Republic	CEEu

The experiment is a four-factor type [21], organized according to the method of subdivided plots, in 3 repetitions. The factors that were considered are: year with 3 graduations—

2015, 2016, and 2017; sowing distance with 2 graduations—12.5 (D1) and 25.0 (D2) cm between rows, fertilization with 2 graduations— $N_{100}P_{50}$ (F1) and $N_{50}P_{50}$ (F20), respectively 25 spring oat varieties. The sowing was done every year with the Wintersteiger plot machine, around 15th of March; the sown plot had 9 m² and the harvested 7.5 m². Fertilization was carried out in two phases, one in autumn with fertilizer 20:20:0, using a quantity of 250 kg ha⁻¹ to provide 50 kg ha⁻¹ nitrogen and phosphorus active substance (a.s.), and second in the spring with fertilizers based only on nitrogen for ensure 50 kg ha⁻¹ nitrogen a.s.

Data analysis was conducted with R Studio [22]. Statistical analysis was elaborated based on the formulas from the “psych” [23] package. The ANOVA tests and the least significant difference (LSD) from the “agricolae” package [24,25] were used. The entire set of observation was transformed using the Euclidean method, the stats package available in R [26], before being analyzed with the cluster method from the “ape” package [27]. In order to completely explore the experimental data, the redundancy analysis (RDA) ordination from the “vegan” package [28] was applied, a method that allows spatial grouping.

3. Results

The vegetation period of spring oats is, in average, of 135 days and lasts from sowing of the crop in the field (usually sown in the first decade of March) until the harvest (end of July). Tables 2 and 3 show the characteristic of the months: March, April, May, June, and July from the point of view of temperatures and precipitations, and climate data recorded by the Turda weather station.

Table 2. ARDS Turda thermal regime (°C) during 2015–2017.

Month	Monthly Average	58 Years Average	Characteristic	Monthly Average	59 Years Average	Characteristic	Monthly Average	60 Years Average	Characteristic
March	5.5	4.1	Warm	5.9	4.5	Warm	8.4	4.7	Warm
April	9.6	9.8	Normal	12.4	9.9	Warm	9.9	9.9	Normal
May	15.8	14.7	Warm	14.3	15.0	Normal	15.7	15.0	Normal
June	19.4	17.7	Warm	19.8	17.8	Warm	20.7	17.9	Warm
July	22.3	19.6	Warm	20.5	19.7	Normal	20.3	19.7	Normal

Table 3. ARDS Turda rainfall (mm) during 2015–2017.

Month	Monthly Average	58 Years Average	Characteristic	Monthly Average	59 Years Average	Characteristic	Monthly Average	60 Years Average	Characteristic
March	12.8	23.1	Very droughty	47.0	21.3	Excessively rainy	46.1	23.6	Excessively rainy
April	32.2	44.7	Droughty	62.2	44.4	Very rainy	65.2	45.9	Very rainy
May	66.0	67.7	Normal	90.4	67.1	Very rainy	65.4	68.7	Normal
June	115.7	84.5	Very rainy	123.2	83.4	Very rainy	30.6	84.8	Excessively droughty
July	52.2	76.7	Very droughty	124.9	72.9	Excessively rainy	110.2	77.1	Very rainy
March–July amount	278.9	296.7	−17.8	447.7	289.1	+160.6	317.5	300.1	+17.4

The year 2015 was characterized by the month of May being more droughty but preceded by the month of February that was balanced from the point of view of precipitations, a fact that led to the emergence of spring oats 10 days after sowing, followed by a lower vegetative development in the first phenophases, given also that the month of April that followed was also dry, with a minus of 12.5 mm compared to the multiannual average. The period of vegetation for spring oats in 2015 happened on a background of higher-than-normal temperatures from the month of March until the month of July, with the exception of April, and an excess of humidity in the month of June, when the phenophases of flowering and, partially, growth and filling grain took place. If we analyze the year 2015 in terms of favorability for spring oats we can say that it was “favorable”, the productions being lowered by the drought in April (−12.5 mm of rainfall) and July (−24.5 mm of rainfall).

The year 2016 was less favorable for the spring oats culture, although an excess of rain of 160.6 mm was recorded in the vegetation period, thus in the organized experiments the smallest productions in the three experimental years series were recorded. The abundant

rains in the months of June and July have caused the plants to lodge, diminishing the production, but the Mureșana variety especially stood out, being less affected by this phenomenon. The year 2017 was the most favorable year for the spring oats, particularly due to the balanced spread of the precipitation during the vegetation period of the oats. The analysis of the data presented in Table 3, regarding the precipitation, corroborated with the 2017 yield, allows us to elaborate an important conclusion, namely that for the vegetation period of the spring oats (March–July), given the conditions from the Transylvanian plain, approximately 300 mm of rain are needed.

An ideal distribution of rainfall for the spring oat culture would mean: 8% (24 mm) in March, 16% (48 mm) in April, 23% (69 mm) in May, 28% (84 mm) in June, and 25% (75 mm) in July. With regards to this distribution of rainfall during the spring oat's vegetation period, 2017 almost achieved this, with the exception of June that was excessively dry but followed a balanced month from this point of view.

The production of spring oats is subject to both the singular impact of experimental factors as well as that of their combined influence (Table 4). At the singular level, weather conditions of the crop year (Y) has the greatest influence, followed by fertilization and sowing distance. All the experimental factors that were studied have a very significant influence over production and the value of the Fisher test for the variety factor (V) shows that there are genetic differences in between them with regards to the production capacity. The two factor interactions point out the very significant impact of the crop year combine with sowing distance, fertilization X variety. The sowing distance reveals its influence when combined with the fertilization and the variety, this aspect pointing out the differences between studied varieties. The triple interactions gradually reduce the influence of the factors, their combination being very significant in the case year X sowing distance X variety. The year and the fertilization have a significant impact in combination with the sowing distance or the variety. This aspect supports the idea of the necessity of optimizing the technologic resources separately for each variety. The origin of the oat spring varieties that were tested is visible in reducing the significance of the ternary combinations (DxFxV) and quaternary (YxDxFxV), in both cases test F was insignificant.

Table 4. The impact of the experimental factors on the production of spring oats.

Factors	F Value	p Value	Double Interactions	F Value	p Value	Triple and Quadruple Interactions	F Value	p Value
Y	4422.73	$p < 0.001$	Y × D	92.93	$p < 0.001$	Y × D × F	5.46	0.004
D	667.58	$p < 0.001$	Y × F	12.86	$p < 0.001$	Y × D × V	2.16	$p < 0.001$
F	784.63	$p < 0.001$	D × F	6.48	0.011	Y × F × V	1.70	0.003
V	36.94	$p < 0.001$	Y × V	20.15	$p < 0.001$	D × F × V	0.69	0.866
			D × V	1.75	0.015	Y × D × F × V	0.63	0.978
			F × V	2.22	0.001			

Note: Y—Year; D—Density of sowing; F—Fertilization; V—Variety. Origin of varieties is provided in Table 1. F.val and p.val are according to ANOVA test. Significance levels: Significance levels: $p < 0.001$ ***, $p < 0.01$ **, $p < 0.05$ *, $p > 0.05$ n.s.

3.1. The Influence of the Year on the Production Capacity of Spring Oats

The production capacity of spring oats is closely connected with the origin of the varieties (Figure 1), this leading to significant differences between the tested genotypes. The best performing variety is Mureșana, created at ARDS Turda (approved in 2012) and adapted to the climate conditions of this area. Compared to the production potential of this variety, only the lines T. 38-81 M and LV. 4363-86 have registered insignificant differences. This group of three genotypes significantly surpass the majority of the other varieties that were tested. From the foreign varieties only Rumak (Poland) is present in the top of the fourth place, but with small differences when compared to the other varieties. Two local varieties (Mureș and T. 44-81 M) have productions similar to Skakum (Russia) and Fucs (Latvia) proving that they have similar climate needs. A group of eight varieties: V1, V5, V9,

V15, V17, V18, V19, V25, on the graph (c d e f g) have close productions in the experimental conditions, which suggests an identical reaction to the environmental conditions. Two varieties from Germany (Romulus and Gramena), one from France (Integrale) and the variety from Belarus (Bug) record productions close to 5 t ha^{-1} and surpass insignificantly LV. 4362-86, a variety of Romanian origin. Variant 3 Mureșana is on the first place, clearly detaching from the others.

Figure 1. Specific yield performance of spring oat variety (Different letters between cultivars denote significant differences Post-hoc LSD test, $p < 0.05$). V1—Someșan; V2—Mureș; V3—Mureșana; V4—T. 90-81 M; V5—T. 21-81 M; V6—T. 38-81 M; V7—T. 44-81 M; V8—LV. 4324-86; V9—LV. 4325-86; V10—LV. 4362-86; V11—LV. 4363-86; V12—LV. 8644-82; V13—LV. 7478-82; V14—Solidor; V15—Romulus; V16—Gramena; V17—Jumbo; V18—Cory; V19—Avalanche; V20—Integrale; V21—Rumak; V22—Bug; V23—Skakum; V24—Fucs; V25—Pan. A full descriptions of varieties is provided in Table 1.

For the year 2015 (Figure 2a), the variation explained by principal component analysis (PCA) is 95.38%, with a greater importance of the first principal component (PC) (88.44%). At a sowing distance of 25 cm, one starts seeing the differences in performance between the studied varieties with regards to the production capacity. The greatest dispersions are recorded at the variants fertilized with $N_{100}P_{50}$ (F1), that strongly separates the varieties along PC 2 (variance = 6.95%). In the case of fertilization with equal doses of nitrogen and phosphorous (F2), the dispersion of the production values is homogenous, grouping the data in different quadrants of the PCA graph. The variations in production that were recorded in 2015 group the varieties in five well-defined clusters (Figure 2b), independent of their origin. The production average in cluster 1 is 5.31 t ha^{-1} , with similar margins, the Mureș variety (5.38 t ha^{-1}), respectively Bug with 5.35 t ha^{-1} . The second and third clusters have a reduced number of variants, but show great differences when it comes to the average production. The heterogeneity of cluster two sets the average production at a level of 5.14 t ha^{-1} , with identical margins as production of 5.12 t ha^{-1} . In cluster 3 there are only lines of oats created at Lovrin and varieties from Western Europe. The average of this cluster is the highest for 2015, respectively 5.88 t ha^{-1} . Cluster 4 brings together six genotypes, with a production average of 5.60 t ha^{-1} , but with two variation

directions in the production of marginal varieties being from CEE Rumak (5.55 t ha^{-1}) and Fucs (5.65 t ha^{-1}). In the last cluster an increase of the productions can be observed, from 5.37 t ha^{-1} (Someșan) up to 5.61 t ha^{-1} (Cory).

For the second experimental year (2016), the placement of the variants in the PCA plan has an impact on explaining the major variance on PC 1 (96.42%) and of only 2.06% on PC 2 (Figure 2c). A very large dispersion of the variants due to the fertilizations applied at the distance of 12.5 cm in between rows can be noticed. The best combination of technological variables is at a distance of 25 cm between rows and a moderate fertilization ($N_{50}P_{50}$). The fertilization $N_{100}P_{50}$ overlapped over a distance of 12.5 cm has a standard deviation that is almost circular and a median position on the graphic, an aspect indicating the variation potential of the varieties production due to this combination of technological factors. The harvest obtained in this experimental year groups the oat genotypes in six clusters, with large differences between the registered average values (Figure 2d). Clusters 1, 2, and 3 have average productions below 4 t ha^{-1} , with a minimum of 3.10 t ha^{-1} for cluster 3. This group include varieties from WEu, CEEu, respectively an autochthonous variety. Cluster 4 contains 2 varieties from WEu and CEEu, respectively one from the Romanian research stations. Line LV. 4324-86 records productions of 4.18 t ha^{-1} , while the performer of the Solidor group attains 4.42 t ha^{-1} . Cluster 5 surpasses the average value of 4.5 t ha^{-1} , while the final cluster has the highest production, 5.28 t ha^{-1} including two Romanian varieties: T. 90-81 with 5.53 t ha^{-1} , respectively LV. 8644-82 with 5.63 t ha^{-1} .

Figure 2. Cont.

(c)

PCA 1 (%) 96.42 PCA 2 (%) 2.06

(d)

Total (%) 98.48

(e)

PCA 1 (%) 69.28 PCA 2 (%) 19.97

(f)

Total (%) 89.25

Figure 2. Cont.

Figure 2. PCA and cluster analysis of single-year and inter-annual profile for spring oat. Each point comprises the recorded values of yield in each of the three experimental years (a,b–2015, c,d–2016, e,f–2017) and all three experimental years (g,h), separated by the combination Density $\times$ Fertilization. Explained variance (%) is provide separately for each PCA axis. Ellipses represent the standard error within each group in a confidence interval of 95%. Density of sowing: A = 12.5 cm; B = 25.0 cm. Fertilization: F1 = N₁₀₀P₅₀; F2 = N₅₀P₅₀. V1—Someșan; V2—Mureș; V3—Mureșana; V4—T. 90-81 M; V5—T. 21-81 M; V6—T. 38-81 M; V7—T. 44-81 M; V8—LV. 4324-86; V9—LV. 4325-86; V10—LV. 4362-86; V11—LV. 4363-86; V12—LV. 8644-82; V13—LV. 7478-82; V14—Solidor; V15—Romulus; V16—Gramena; V17—Jumbo; V18—Cory; V19—Avalanche; V20—Integrale; V21—Rumak; V22—Bug; V23—Skakum; V24—Fucs; V25—Pan. Full description of varieties is provided in Table 1.

The evaluation of the production in the third experimental year (2017) indicates a clear separation between the technological factors that were studied: fertilization and sowing distance (Figure 2e). This detail is underlined also by a drop in the variation explained by PC 1 (69.28%), concomitantly with increasing the value of PC 2 (19.97%). The location of the centroid of each data group is in diagonally opposite quadrants, with an overlap of the N₅₀P₅₀ fertilization center on the edge of the N₁₀₀P₅₀ fertilization area. The dispersion of the data in the ordering plane is similar at the data grouped by the same sowing distance, for each variety there are two parallel vectors. The cluster analysis presents a strong separation of the varieties in seven unequal clusters (Figure 2f). Cluster 1 has an average production potential of 6.31 t ha⁻¹ and is composed of three varieties created at ARDS Turda and two west-European varieties. The cluster's marginal production potential is in the Avalanche (6.35 t ha⁻¹) and Integrale (6.42 t ha⁻¹) varieties, both with great differences in between repetitions. The second cluster had the highest average production (6.64 t ha⁻¹) and it includes two varieties created at ARDS Lovrin and one each from Turda, respectively, CEEu. The maximum production value in this cluster is encountered at the Lv. 7878-82 variety (6.77 t ha⁻¹). The two West-European varieties and the variety LV. 4324-86 from cluster 3 have an average production of 5.75 t ha⁻¹, surpassed by the varieties from clusters 4 and 5 with 5.93 t ha⁻¹, respectively, 5.99 t ha⁻¹. These three clusters comprise autochthonous varieties (ARDS Turda and ARDS Lovin), four varieties from WEu and the Rumak variety (6.05 t ha⁻¹) from CEEu. Clusters 6 and 7 are made up of two varieties, both with an average production potential of over 6 t ha⁻¹.

The spatial comparative analysis of the three experimental years (Figure 2g) presents an overlap in the median area of the PCA ordering of the 12.5 cm sowing distance, fertilized with N₅₀P₅₀ (AF2) with the 25 cm sowing distance fertilized with N₁₀₀P₅₀ (BF1). Both

groups of values present an orientation of the dispersion on the diagonal axis (−++) of the ordination. PCA explain a total variance of 82.05% (PC 1 64.81%, respectively PC 2 17.24%), an aspect indicating the graphical correction due to axis 2. The $N_{50}P_{50}$ fertilization and the sowing at a distance of 12.5 cm in between rows positions the center of the AF1 group in the upper left quadrant of the ordination (−+), opposed to BF2. The clustering shows an interaction annual normalization of the productions, with a strong reduction in the production potential and a reorganization of the varieties in groups (Figure 2h). Clusters 2 and 4 have an average production potential below 5 t ha^{-1} and include in majority Romanian varieties. One can observe at the level of cluster 1 a great gap between the autochthonous varieties and those from WEu and CEEu, all with productions of over 5 t ha^{-1} , while the Romulus variety (WEu) registers a production of just 4.92 t ha^{-1} . The fifth cluster records average productions of 5.35 t ha^{-1} , this group includes only the line LV. 4363-86, with an average production of 5.34 t ha^{-1} . The varieties with the highest productivity are included in cluster 3, with an average of 5.61 t ha^{-1} . The edges of this cluster have productions of 5.51 t ha^{-1} (LV. 4325-86), respectively 6.02 t ha^{-1} (LV. 864-82). The central area of cluster 6 is occupied by the Bug variety from Belarus, with an average production of 5.38 t ha^{-1} , also characterized by a strong fluctuation in the annual production.

3.2. The Influence of the Sowing Distance and of the Fertilization on the Production Performance of the Spring Oat

The analysis of the multiannual response of the spring oat genotypes to each experimental factor indicates significant differences specific for the fertilization or the sowing distance (Table 5). At a distance of 12.5 cm between rows, two autochthonous varieties have recorded the highest productions: Mureșana (RoTd, 6.30 t ha^{-1}), respectively, LV. 4363-86 (RoLo, 6.15 t ha^{-1}), with considerable difference compared to the other varieties. At the opposite end, the varieties Gramena (WEu, 5.10 t ha^{-1}), respectively LV. 4363-86 (RoLo, 5.02 t ha^{-1}), remain at a production of just 5 t ha^{-1} . Favorable climate conditions for the oat do not determine an increase in production by increasing the sowing distance in between rows to 25 cm. The classification of the varieties indicates once more the genotypes Mureșana and LV. 4363-86, as having the greatest production potential. Significant difference for the varieties considered in the study have been observed on the fertilization level $N_{50}P_{50}$. The two autochthonous varieties (Mureșana and LV. 4363-86) have productions of over 6 t ha^{-1} , with significant differences compared to the WEu varieties (Integrale and Gramena), respectively LV. 4362-86, and between the Bug (5.20 t ha^{-1}) and the T.44-81 M (5.89 t ha^{-1}) variety the difference is of 0.69 t ha^{-1} . The increase of the sowing distance and the increase of the nitrogen fertilizer dosage ($N_{100}P_{50}$) means that a group of nine varieties stands out, recording values of over 5 t ha^{-1} , with a maximum of 5.86 t ha^{-1} for the Mureșana variety and a minimum of 5.03 t ha^{-1} for the LV. 4325-86 variety, the difference in this group reaching 0.83 t ha^{-1} . In the group comprising the other varieties the production difference is just 0.35 t ha^{-1} , with a maximum for the Jumbo variety (4.95 t ha^{-1}), respectively a minimum for LV. 4362-86 (4.60 t ha^{-1}).

Table 5. Yield performance of spring oat varieties in different conditions of distance sowing and fertilization.

Variety	Distance		Fertilization	
	D1 = 12.5 cm	D2 = 25 cm	F1 = N ₁₀₀ P ₅₀	F2 = N ₅₀ P ₅₀
Someșan	5.38 ± 0.25c–g	4.93 ± 0.31bc	5.54 ± 0.26a–e	4.78 ± 0.27cd
Mureș	5.73 ± 0.16a–e	5.05 ± 0.24a–c	5.59 ± 0.2a–e	5.18 ± 0.23a–d
Mureșana	6.30 ± 0.1a	5.73 ± 0.19a	6.17 ± 0.16a	5.86 ± 0.16a
T. 90-81 M	5.28±0.28c–g	4.88±0.26bc	5.46±0.25b–e	4.70±0.27cd
T. 21-81 M	5.32±0.23c–g	4.96±0.26bc	5.47±0.22b–e	4.81±0.25b–d
T. 38-81 M	5.85±0.14a–c	5.31±0.21a–c	5.81±0.16a–d	5.35±0.2a–c
T. 44-81 M	5.71±0.19a–f	5.27±0.23a–c	5.89±0.2a–c	5.10±0.18b–d
LV. 4324-86	5.29±0.17c–g	4.76±0.22bc	5.34±0.18c–e	4.71±0.2cd
LV. 4325-86	5.60±0.24b–g	4.84±0.32bc	5.41±0.26c–e	5.03±0.32b–d
LV. 4362-86	5.02±0.31g	4.66±0.33c	5.08±0.31e	4.60±0.33d
LV. 4363-86	6.15±0.14ab	5.41 ± 0.23ab	6.06 ± 0.16ab	5.50 ± 0.24ab
LV. 8644-82	5.24 ± 0.19c–g	4.87 ± 0.2bc	5.23 ± 0.17de	4.88 ± 0.22b–d
LV. 7478-82	5.35 ± 0.19c–g	4.84 ± 0.28bc	5.40 ± 0.24c–e	4.79 ± 0.23cd
Solidor	5.26 ± 0.27c–g	4.92 ± 0.29bc	5.39 ± 0.28c–e	4.79 ± 0.27cd
Romulus	5.18 ± 0.18d–g	4.71 ± 0.18bc	5.20 ± 0.2de	4.68 ± 0.16cd
Gramena	5.10 ± 0.32fg	4.74 ± 0.35bc	5.08 ± 0.33e	4.75 ± 0.35cd
Jumbo	5.47 ± 0.2c–g	4.95 ± 0.24bc	5.47 ± 0.2b–e	4.95 ± 0.24b–d
Cory	5.44 ± 0.22c–g	4.95 ± 0.3bc	5.46 ± 0.26b–e	4.93 ± 0.27b–d
Avalanche	5.39 ± 0.19c–g	4.90 ± 0.22bc	5.45 ± 0.18b–e	4.84 ± 0.22b–d
Integrale	5.11 ± 0.34e–g	4.74 ± 0.34bc	5.14 ± 0.32e	4.72 ± 0.36cd
Rumak	5.77 ± 0.18a–d	5.26 ± 0.24a–c	5.66 ± 0.21a–e	5.36 ± 0.22a–c
Bug	5.17 ± 0.24d–g	4.74 ± 0.26bc	5.2 ± 0.22de	4.71 ± 0.28cd
Skakum	5.61 ± 0.17b–g	5.08 ± 0.19a–c	5.62 ± 0.17a–e	5.07 ± 0.19b–d
Fucs	5.65 ± 0.26b–f	5.10 ± 0.26a–c	5.6 ± 0.26a–e	5.15 ± 0.27a–d
Pan	5.24 ± 0.26c–g	5.00 ± 0.27bc	5.38 ± 0.25c–e	4.86 ± 0.27b–d

Note: Different letters between cultivars denote significant differences based on Post hoc LSD test, $p < 0.05$. D1–12.5 cm density of sowing; D2–25.0 cm density of sowing; F1—N₅₀P₅₀ kg ha^{−1}; F2—N₁₀₀P₅₀ kg ha^{−1}. V1—Someșan; V2—Mureș; V3—Mureșana; V4—T. 90-81 M; V5—T. 21-81 M; V6—T. 38-81 M; V7—T. 44-81 M; V8—LV. 4324-86; V9—LV. 4325-86; V10—LV. 4362-86; V11—LV. 4363-86; V12—LV. 8644-82; V13—LV. 7478-82; V14—Solidor; V15—Romulus; V16—Gramena; V17—Jumbo; V18—Cory; V19—Avalanche; V20—Integrale; V21—Rumak; V22—Bug; V23—Skakum; V24—Fucs; V25—Pan. A full description of experimental factors is provided in Table 1.

3.3. The Influence of the Source on the Production Stability of the Varieties Given Different Sowing and Fertilization Conditions

The realization of the bi-factorial experimental design for testing the spring oat genotypes allowed the evaluation of the response of each to the technological factors, fertilization and distance between rows (Figure 3a–d). In the sowing condition of 12.5 cm in between rows and a fertilization with N₅₀P₅₀ (Figure 3a) one notices a similar gradient for the varieties LV. 8644-82 (RoLo) and Bug (CEEu). Both varieties show a parallel movement, supported also by similar productions. Three of the genotypes created at ARDS Turda (Mureșana, T. 90-81 M and T. 44-81) have similar production in the third experimental year but with very significant differences in the second year, meaning a positioning in different areas of the ordination. The varieties Mureșana and LV. 4363-86 show a drop in production below 5 t ha^{−1} in the second experimental year (2016—less favorable for spring oats), but record productions of over 6 t ha^{−1} for years 1 and 3, positioning them in the same area of the ordination. The total variance explained by PCA is of 77.76% in the graphic plan one can notice a diagonal positioning of the Gramena variety compared with Rumak, the latter obtained in year 3 of the experiment (2017) productions greater with 2 t ha^{−1} when compared to year 2 (2016).

Figure 3. PCA of the source influence on spring oat in the interaction sowing density $\times$ fertilization within yield stability. Each point comprises the recorded values of yield in all of the three experimental years for each combination of Density $\times$ Fertilization: AF1 (a); AF2 (b); BF1 (c); BF2 (d). Density of sowing: A = 12.5 cm; B = 25.0 cm. Fertilization: F1 = N₁₀₀P₅₀; F2 = N₅₀P₅₀. Separation of data in PCA graph is based on the source. Explained variance (%) is provided separately for each PCA axis. Ellipses represent the standard error within each group in a confidence interval of 95%. V1—Someșan; V2—Mureș; V3—Mureșana; V4—T. 90–81 M; V5—T. 21–81 M; V6—T. 38–81 M; V7—T. 44–81 M; V8—LV. 4324–86; V9—LV. 4325–86; V10—LV. 4362–86; V11—LV. 4363–86; V12—LV. 8644–82; V13—LV. 7478–82; V14—Solidor; V15—Romulus; V16—Gramena; V17—Jumbo; V18—Cory; V19—Avalanche; V20—Integrale; V21—Rumak; V22—Bug; V23—Skakum; V24—Fucs; V25—Pan. RoTd—ARDS Turda Romania; RoLo—ARDS Lovrin Romania; WEu—Western Europe; CEEu—Central and Eastern Europe. Full description of experimental factors is provided in Table 1.

The increase of the fertilizer dosage at the same sowing distance in between rows (AF2—Figure 3b), leads to a strong dispersion of the tested genotypes. The variation explained by PC 1 is 66.71%, completed by PC 2 with 13.58%, which normalizes the dimension of the ordination quadrants. The varieties LV. 4362–86, Gramena, Integrale, and Fucs, generally give productions below 6 t ha^{−1}, with strong drops until 3 t ha^{−1} in

the second experimental year (2016). In the upper ordination quadrant, the varieties T. 44-81 M, LV. 4324-86 and Romulus present a greater stability of the productions, no matter the year, not dropping below 4 t ha^{-1} but also not reaching production over 6 t ha^{-1} . The varieties Mureșana and LV. 4363-86 record the highest productions and do not drop in any year below 5 t ha^{-1} , similar to the LV. 4325-86 variety, but where one can notice a drop in production to 4 t ha^{-1} given the conditions of the second experimental year.

The PCA evaluation for the 25 cm distance in between rows and the fertilization with $\text{N}_{50}\text{P}_{50}$ (Figure 3c), indicates a positioning of the centroids from the origin groups in the median area of the ordination. The variance explained by PC 1 is 74.52%, with an increase weight for PC 2 (17.75%). The varieties Mureșana and LV. 4363-86 are located in the same quadrant, because of their increased production potential. The varieties LV. 8644-82 and Romulus show the lowest production fluctuations in all the years that the experiment was conducted, their potential production being 5 t ha^{-1} . The difference in the production potential between the Gramena and Integrale varieties is 0.5 t ha^{-1} , in favor of Gramena for the first year of the experiment (2015), respectively in favor of Integrale in the third (2017). It is only in the second year of the experiment, 2016, a year that was less favorable for the spring oats culture, that both varieties had similar yields.

A clear separation between the Mureșana and Gramena as compared to the other varieties is easy to observe in the PCA ordination plan given a distance of 25 cm in between rows and a fertilization with $\text{N}_{100}\text{P}_{50}$ (Figure 3d). Both varieties register productions over 5.5 t ha^{-1} in the first year of the experiment, but the Mureșana variety takes the lead with 2 t ha^{-1} in the second year, respectively 1 t ha^{-1} in the third year, when compared to Gramena. The varieties LV. 4325-86 and Integrale suffer from a sharp reduction in production in the second experimental year, both recording productions below 3 t ha^{-1} . Two varieties of oat, LV. 4363-86 and Rumak, maintain their production potential in the limits of $4\text{--}5 \text{ t ha}^{-1}$ in the first two experimental years and register over 6 t ha^{-1} in the third. LV. 4362-86 has a special position in the right upper quadrant, because of the production fluctuations of 1.5 t ha^{-1} in the three experimental years.

4. Discussion

This paper presents the results of a complex study conducted in 2015, 2016, and 2017 on a batch of 25 spring oat varieties and lines, all from the *Avena sativa* L. species, all with yellow hull grains.

A clear observation that can be exposed without statistical analyses could be observed by comparing of the productions obtained in the three experimental years in Romania [25,29,30], with those registered in the conditions from Turda in the same period. We can state that there exists a positive relation between yields and sum of precipitations from the month of June and July that coincide with the growth and the filling of the grain phenophases. This observation might be contradicted by the period 1st of June–31 of July 2016 when an excess of rain with a deviation of +91.8 mm, as compared to the normal (156.3 mm) was observed, and the harvests were the lowest obtained given the conditions from Turda, due to the fact that the spread was not equal and there was no rain in the third decade of June and the first two days of July. In fact, the last rainfalls from June 2016 had a torrential character (28.8 mm) and as it is well-known this rain infiltrates slower, evaporating on the surface of the soil. In a study concerning the year 2005 [29], showed that the partitioning of the variance components of the environment factors is predictable for locations and unpredictable for the year and that they were an important source of variation.

The yields that were obtained for the spring oat genotypes, in the conditions of the Transylvanian Plain (Romania), are similar or even higher in the years with favorable climatic conditions. The average production in the 3 years of the experiment for the spring oat varieties was 5.22 t ha^{-1} , with an average of 5.48 t ha^{-1} for 2015, 4.04 t ha^{-1} in 2016, and 6.14 t ha^{-1} in 2017. Mut et al. [31] have done a study detailing harvests obtained in the experimental years 2012/2013 and 2013/2014 for 25 autumn oat varieties in the conditions

from Turkey ($39^{\circ}39' \text{ N}$, $34^{\circ}15' \text{ E}$ and 775 m a.s.l.), resulting an average production of 4.16 t ha^{-1} in 2012/2013 and 3.28 t ha^{-1} in 2013/2014, a single genotype having an average production in the two experimental years of 5.65 t ha^{-1} . Aydin et al. [32] showed that the sowing date had a great effect on hay yield and quality potential of oat genotypes.

Irfan et al. [33] determined the production of dry substance for autumn oat for fodder being greater at a distance of 12 cm; they are 18.4 t ha^{-1} in the season 2011–2012 and 23.4 t ha^{-1} in the season 2012/2013. The production of dry substance was with 20%, respectively 35% lower given a sowing distance of 24, respectively, 46 cm. Determining the forage potential for cultivation requires not only the dry matter yield, but also the nutritional value for animals [8,34]. Henson et al. [35] conducted a study following the influence of the seed norm on the production of oat grains, using for sowing 0.75, 1 and $1.25 \text{ million seeds acre}^{-1}$, corresponding to 1.85, 2.47, and $3.09 \text{ mill. grains ha}^{-1}$; the highest yield was obtained in the variant with the largest norm, of 3.31 t ha^{-1} . Gao et al. [12] revealed that increasing the planting density is an important factor for increasing the crop yield for oats. The increase in the seeded acreage of oats, yield potential with newer varieties and practices, causes an increase in demand on markets for these oats.

The consumption of nutrients for oat, per 100 kg of grains + returning straw (about 150 kg), is on average 2.72 kg N ; $1.34 \text{ kg P}_2\text{O}_5$; $2.74 \text{ kg K}_2\text{O}$; and 0.65 kg CaO . The absorption rhythm of these elements increases until the flowering. Oat reacts well to organic and chemical fertilizers on all the types of soil [36–38]. As noticed, the consumption of nitrogen in oats is twice as high as the consumption of phosphorous, thus researchers have studied more the influence that this element has on the production. Maral et al. [39] has studied the response that 6 varieties of autumn oats have on three graduations of the nitrogen dose (N_0 , N_{10} , and N_{20}), noting that the highest yield was obtained with the highest nitrogen concentration. In the study conducted at ARDS Turda, it was shown that an increase in the dose of nitrogen by 50 kg ha^{-1} a.s. on the level of fertilization $\text{N}_{100}\text{P}_{50}$ had led to an increase in the production of spring oats by 514 kg ha^{-1} . The study conducted by [40] led to results showing that an increase in the dose of nitrogen from 60 to 120 kg ha^{-1} a.s. causes an increase in the production of dry matter for oats with 70% in 2011–2012 and 53% in 2012–2013. Moreover, the data on the green fodder yield (t ha^{-1}) has showed that the green fodder yield varied significantly among the varieties [41]. Knowing the particularities of the reactions of spring oat varieties, Romanian and foreign, to the environmental conditions and to the technological inputs is important for their correct zoning in the territory but also for mentioning the place that they need to occupy in the structure of the varieties for each area [42]. The increase in the yield per surface unit can be achieved in two ways: by improving agronomic practices and by cultivating improved varieties with a superior genetic production potential, with an improved resistance to diseases and an increased tolerance to the poor environmental conditions. The introduction of the new breeds has led in many cases to reducing the vulnerability of the crops, by increasing biological diversity but also to improving the quality of the raw material for the manufacturing industry. The development of high yielding varieties of oats therefore, has assumed greater importance for the human consumption and the animal health and also Kashmir valley is ideally suitable for oats cultivation because of its temperate climate [43].

The results confirmed that there are genetic differences between varieties in terms of production capacity. It seems that newer cultivars are more responsive to environmental changes than their predecessors and this can also be explained with the help of the Mureșana variety (registered in 2012 in Romania), which is originally a more adapted selection from Mureș variety (realized in 1993). However, the yield potential seems positively associated with responsiveness to the environmental enhancement so that future increases for avoidance of losses in the yield stability would remain dependent upon management improvements like a better choice of the cultivated varieties, the rational use of nitrogen for fertilization, a more suitable sowing distance between rows. However, the decrease in production may also be due to climatic conditions, such as heavy rains in the last part of the oat vegetation period, which can cause the plants to lodging. Redaelli et al. [44] evaluate

the genetic progress of oats in Italy over the past 40 years using 14 cultivars from three different groups. Genetic gain was estimated to $3.6 \text{ g m}^{-2} \text{ y}^{-1}$. They found also that the yield increase is negatively correlated with the plant height and positively correlated with the test weight and the seed weight. It can be observed that most cereals have exhibited a trend for relatively low yield increases during much of the first half of the 20th century followed by a rapid rate of yield gains, due to both genetic and management improvement, during the second half.

In South Korea, on a mixture of sand and mud soil, the increase in sowing density led to a decrease in plant size and panicle length, due to a decrease in nutrition/plant space. Regarding the number of siblings/area unit, the differences were not significant between the different sowing densities. The effect of progressive nitrogen fertilization on plant height and panicle length was directly proportional to the applied dose, the maximum being $90 \text{ kg ha}^{-1} \text{ N s.a.}$ [43]. The size of the grains and their number/spike (the number of grains per spike area) has decreased when sowing density was increased [14,45]. Nitrogen fertilization positively influenced the hectoliter mass and mass of 1000 grains (liter and 1000-kernel weight) in oats. The production of kernels has significantly increased along with density. A negative effect of the increased nitrogen fertilizer dose is the increase in the unevenness in the ripe period, meaning a higher percentage in the insufficiently matured kernels. The seeding rate and nitrogen fertilization did not affect the emergence date and degree, and the lodging degree of oats [14,46].

In Romania, oats are the most cultivated spring cereal, but there are few studies on the chemical composition of the grain, although today we see a reversal in its use in human nutrition, especially in advanced countries, where it is used to produce functional foods, so-called nutraceuticals. Moreover, in Brazil oats remained an optional food item that appealed to a small section of the population until more recently, when consumption started to increase [46]. However, for Romania, spring oats are a very efficient crop, because they have a fairly easy cultivation technology and in a short period of up to 135 days (it is usually sown around March 15 and harvested at the latest at the end of July), important productions can be obtained.

Nitrogen fertilization had a greater impact on the oat composition than on milling characteristics and in many cases the effect of nitrogen was dependent on the location. Other results obtained during this research project has showed that the yield in flour is correlated with the hectoliter mass, the tested genotypes having on average 45% yield in flour. At sites where the residual nitrogen was low (less than 36 kg ha^{-1}), the fertilization resulted in increased levels of proteins and B-glucans (by as much as 4.4% and 1%, respectively), while oil decreased slightly (less than 1%) [47]. However, determining the forage potential for cultivars requires not only dry matter yield, but also the nutritional value for animals.

In the course of the project, “Avena genetic resources for quality in human consumption” co-funded by the European Commission (AGRI GENRES 061, Council regulation 870/2004), 658 European oat genotypes grown in different environments in 2008 or 2009, it was noticed that “indicated that the genotype had a major effect on the b-glucan content and suggested that the most favorable conditions for its accumulation were found both in Romania, which also presented the widest variation, and in Sweden in 2009, with climatic conditions regarded as normal for these environments and characterized by mild mean temperature and sufficient rainfall amounts during the period of the vegetative growth” [44].

According to Faostat (2019) in Europe, the largest cultivators, besides Poland and Spain that were mentioned already, are Finland with 298,000 ha (4 t ha^{-1}); Great Britain, with 182,000 ha (5.9 t ha^{-1}); Romania, 161,000 (2.2 t ha^{-1}); Sweden, 131,000 ha (4.8 t ha^{-1}); Germany with 126,000 ha (4.1 t ha^{-1}), Ireland, 107,500 ha (2.3 t ha^{-1}); Italy 103,800 ha (2.4 t ha^{-1}); France 87,500 ha (4.6 t ha^{-1}); Lithuania, 86,000 ha (2.1 t ha^{-1}); and in eastern Europe are the Russian Federation, 2,426,000 ha (1.8 t ha^{-1}); Ukraine with 181,000 ha (2.3 t ha^{-1}); and Belarus, 160,000 ha (2.3 t ha^{-1}). Sometimes spring oats are in competition

with spring barley in terms of cultivated areas in Romania, but not only here, so Leszczynska et al. [48] presents a study that benefits both species recommending covered barley + covered oats (160 seed number of barley and 300 seed number of oats), and the production obtained was 6.30 t ha^{-1} on albic luvisol.

5. Conclusions

For 2015, we point out especially the behavior of the Mureșana variety, where similar productions were obtained on both nitrogen fertilization levels, this is mostly due to their resistance to lodging due to their low height, as compared to the other genotypes that were tested. In 2016 the diminishing yields for spring oats was due to abundant rainfall in June and July, causing the plants to lodge, the Mureșana variety, that has a lower height, was less affected as compared to the other varieties. The year 2017 had an almost ideal distribution of precipitation during the vegetation period of spring oats in Turda, which is why the largest productions in the series of the three experimental years were obtained.

The resulting productions obtained at Turda show that three different years for the spring oats cultivation were included, the year 2017 was very favorable, the year 2015 was favorable and the year 2016 was less favorable, a fact that allowed the singling out of three genotypes where yields higher than the average yield for the experimental years were obtained and that showed yield stability, respectively: Mureșana, T. 38-81 M and LV.4363-86. The best distance between rows for spring oats is 12.5 cm, a distance where the average production was 5.46 t ha^{-1} , with 0.47 t ha^{-1} greater than the one obtained at a 25 cm sowing distance, for which a quantity of seed in between 150 and 180 kg per ha is used, based on the mass of 1000 grains. Given less favorable climatic conditions for the cultivation of spring oats, the increase in production due to the sowing distance is greater for some varieties, Mureșana is included, as compared to the increases determined by the nitrogen dose. There are differences between the oat varieties regarding the reaction to the nitrogen fertilization, highlighting especially the Mureșana variety where comparable yields are obtained on both levels of fertilization.

Author Contributions: Conceptualization, M.D., R.K., and F.R.; methodology, M.D., N.T., R.K., F.R., A.F., and E.M.; software, I.R. and A.V.; validation, M.D., N.T., I.R., A.F., and A.V.; formal analysis, M.D., I.R., R.K., and E.M.; investigation, R.K., F.R., and E.M.; resources, M.D. and N.T.; data curation, I.R. and R.K.; writing—original draft preparation, M.D., N.T., I.R., R.K., F.R., A.F., E.M., and A.V.; writing—review and editing, M.D., N.T., I.R., R.K., F.R., A.F., E.M., and A.V. First author (M.D.) and the corresponding authors (N.T.) and (I.R.) have contributed equally to this paper, all three being considered as first authors. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Data Availability Statement: The data presented in this study are available on request from the corresponding author.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Available online: <http://www.fao.org/faostat/en/#data/QC> (accessed on 15 February 2021).
2. Stevens, E.J.; Armstrong, K.W.; Bezar, H.J.; Griffin, W.B.; Hampton, J.G. Fodder Oats an Overview. *Fodder Oats: A World Overview*. **2004**, *33*, 11–18.
3. Suttie, J.M.; Reynolds, S.G. (Eds.) *Fodder Oats: A World Overview, Plant Production and Protection and Protection Series No. 33*; Food Agriculture Organization of the United Nations: Rome, Italy, 2004.
4. Sterna, V.; Zute, S.; Brunava, L. Oat grain composition and its nutrition benefice. *Agric. Agric. Sci. Procedia* **2016**, *8*, 252–256. [[CrossRef](#)]
5. Smulders, M.J.M.; van de Wiel, C.C.M.; van den Broeck, H.C.; van der Meer, I.M.; Israel-Hoevelaken, T.P.M.; Timmer, R.D.; van Dinter, B.J.; Braun, S.; Gilissen, L.J.W.J. Oats in healthy gluten-free and regular diets: A perspective. *Food Res. Int.* **2018**, *110*, 3–10. [[CrossRef](#)] [[PubMed](#)]

6. Assefa, G.; Feyissa, F.; Gebeyehu, A.; Minta, M. Characterization of Selected Oats Varieties for Their Important Production Traits in the Highlands of Ethiopia. In Proceedings of the 11th Annual Conference of the Ethiopian Society of Animal Production, Addis Ababa, Ethiopia, 28–30 August 2003; pp. 305–314.
7. Ecoport, 2013. Available online: <https://www.feedipedia.org/node/16585> (accessed on 15 February 2021).
8. Tiwari, V. Growth and Production of Oat and Rye. In *Encyclopedia of Life Support Systems. Food and Agricultural Sciences, Engineering and Technology Resources*; Verheye, W., Ed.; Rop Improvement Division, Directorate of Wheat Research (ICAR): Karnal, India, 2010; Volume 2.
9. Jelic, M.; Dugalic, G.; Milivojevic, J.; Djekic, V. Effect of liming and fertilization on yield and quality of oat (*Avena sativa* L.) On an acid luvisol soil. *Rom. Agric. Res.* **2013**, *30*, 249–258.
10. Huza, R.; Duda, M.; Kadar, R.; Racz, I. Results regarding the influence of technological factors on spring oat yields. *Res. J. Agric. Sci.* **2016**, *48*, 57–62.
11. Huza, R.; Duda, M.; Kadar, R.; Racz, I.; Ceclan, A. The influence of technological factors on yield and quality of spring oats at ARDS Turda. *Res. J. Agric. Sci.* **2017**, *49*, 80–84.
12. Gao, K.; Yu, Y.F.; Xia, Z.T.; Yang, G.; Xing, Z.L.; Qi, L.T.; Ling, L.Z. Response of height, dry matter accumulation and partitioning of oat (*Avena sativa* L.) to planting density and nitrogen in Horqin Sandy Land. *Sci. Rep.* **2019**, *9*, 7961. [CrossRef]
13. Kaur, G.; Goyal, M. Effect of growth stages and fertility levels on growth, yield and quality of fodder oats (*Avena sativa* L.). *J. Appl. Nat. Sci.* **2017**, *9*, 1287–1296. [CrossRef]
14. Tomple, B.M.; Hwan, J.I. Enhancing Seed Productivity and Feed Value of Oats (*Avena sativa* L.) with Different Seeding Rate and Nitrogen Fertilizing Levels in Gyeongbuk Area. *J. Agric. Life Sci.* **2018**, *52*, 61–72. [CrossRef]
15. Hausherr Lüder, R.M.; Qin, R.; Richner, W.; Stamp, P.; Noulas, C. Spatial variability of selected soil properties and its impact on the grain yield of oats (*Avena sativa* L.) in small fields. *J. Plant Nutr.* **2018**, *41*, 2446–2469. [CrossRef]
16. Florea, N.; Munteanu, I.; Rusu, C. *Sistemul Român de Taxonomie a Solurilor (SRTS). Sitech, Craiova; ***SRTS 2012; Romanian System of Soil Taxonomy*, Ed.; Estfalia: Bucharest, Romania, 2012.
17. Buerstmayr, H.; Krenn, N.; Stephan, U.; Grausgruber, H.; Zechner, E. Agronomic performance and quality of oat (*Avena sativa* L.) genotypes of worldwide origin produced under Central European growing conditions. *Field Crop. Res.* **2007**, *101*, 343–351. [CrossRef]
18. Hisir, Y.; Kara, R.; Dokuyucu, T. Evaluation of oat (*Avena sativa* L.) genotypes for grain yield and physiological traits. *Žemdirbystė Agric.* **2012**, *99*, 55–60.
19. Redaelli, R.; Del Frate, V.; Bellato, S.; Terracciano, G.; Ciccoritti, R.; Germeier, C.U.; De Stefanis, E.; Sgrulletta, D. Genetic and environmental variability in total and soluble β-glucan in European oat genotypes. *J. Cereal Sci.* **2013**, *57*, 193–199. [CrossRef]
20. Krishna, A.; Ahmed, S.; Pandey, H.C.; Kumar, V. Correlation, path and diversity analysis of oat (*Avena sativa* L.) Genotypes for grain and fodder yield. *J. Plant Sci. Res.* **2014**, *1*, 110.
21. Racz, I.; Kadar, R.; Varady, A.; Hirișcău, D.; Russu, F.; Tritcan, N.; Berindean, I.V. Agronomic performances of heterogeneously group of spring wheat genotypes. *Rom. Agric. Res.* **2021**, *38*, 1–7.
22. RStudio Team. *RStudio: Integrated Development Environment for R*; RStudio, Inc.: Boston, MA, USA, 2019.
23. Revelle, W. *Psych: Procedures for Psychological, Psychometric, and Personality Research*, R package version 1.9.12.; Northwestern University: Evanston, IL, USA, 2019.
24. De Mendiburu, F. *Agricolae: Statistical Procedures for Agricultural Research*, R package version 1.3-2.24; R Foundation Statistical Computing: Vienna, Austria, 2020.
25. Vidican, R.; Păcurar, F.; Vătcă, S.D.; Pleșa, A.; Stoian, V. Arbuscular Mycorrhizas Traits and Yield of Winter Wheat Profiled by Mineral Fertilization. *Agronomy* **2020**, *10*, 846. [CrossRef]
26. R Core Team. *R: A Language and Environment for Statistical Computing*; R Foundation for Statistical Computing: Vienna, Austria, 2020.
27. Paradis, E.; Schliep, K. Ape 5.0: An environment for modern phylogenetics and evolutionary analyses in R. *Bioinformatics* **2018**, *35*, 526–528. [CrossRef]
28. Oksanen, J.; Blanchet, F.G.; Friendly, M.; Kindt, R.; Legendre, P.; McGinn, D.; Minchin, P.R.; O'Hara, R.B.; Simpson, G.L.; Solymos, P.; et al. *Vegan: Community Ecology Package*, R package version 2.5-6; R Foundation for Statistical Computing: Vienna, Austria, 2019.
29. Croitoru, A.-E.; Man, T.C.; Vătcă, S.D.; Kobulniczky, B.; Stoian, V. Refining the Spatial Scale for Maize Crop Agro-Climatological Suitability Conditions in an Area with Complex Topography towards a Smart and Sustainable Agriculture. Case Study: Central Romania (Cluj County). *Sustainability* **2020**, *12*, 2783. [CrossRef]
30. Vidican, R.; Rotar, I.; Stoian, V.; Păcurar, F. Influence of Phosphorus and Nitrogen on Mycorrhizas in Winter Wheat. *Bull. Univ. Agric. Sci. Vet. Med. Cluj-Napoca Agric.* **2016**, *73*, 358–359. [CrossRef]
31. Mut, Z.; Erbaş Kose, Ö.D.; Akay, H. Grain yield and some quality traits of different oat (*Avena sativa* L.) genotypes. *Int. J. Environ. Agric. Res.* **2016**, *2*, 83–88.
32. Aydin, N.; Mut, Z.; Mut, H.; Ayan, İ. Effect of Autumn and Spring Sowing Dates on Hay Yield and Quality of Oat (*Avena sativa* L.) Genotypes. 2010. Available online: https://www.researchgate.net/publication/240828062_Effect_of_Autumn_and_Spring_Sowing_Dates_on_Hay_Yield_and_Quality_of_Oat_Avena_sativa_L_Genotypes (accessed on 10 February 2021).

33. Irfan, M.; Ansar, M.; Sher, A.; Wasaya, A.; Sattar, A. Improving Forage Yield and Morphology of Oat Varieties through Various Row Spacing and Nitrogen Application. *Japs J. Anim. Plant Sci.* **2016**, *26*, 1718–1724.
34. Neres, M.A.; Castagnara, D.D.; De Oliveira, P.S.R.; De Oliveira, E.; Jobim, C.C.; Tres, T.T.; Mesquita, E.E. IPR 126 White Oat Forage Potential under Free Growth, Cutting and Grazing at Two Management Heights. *Rev. Bras. Zootec.* **2012**, *41*, 889–897. [CrossRef]
35. Henson, B.; McMullen, M.; Schatz, B. Response of Oat Varieties to Seeding Rate and Nitrogen Fertilizer. 1999. Available online: www.ag.ndsu.edu/archive/carringt/99data/oat_seeding_rate.htm (accessed on 10 February 2021).
36. Muntean, L.S.; Cernea, S.; Morar, G.; Duda, M.M.; Vârban, D.; Muntean, S.; Moldovan, C. *Fitotehnie*, a III-a ed.; Editura Risoprint: Cluj-Napoca, Romania, 2014.
37. Mogârzan, A.; Morar, G.; Ștefan, M. *Fitotehnie*; Ion Ionescu de la Brad: Iași, Romania, 2004.
38. Roman, G.V.; Tabără, V.; Robu, T.; Pîrșan, P.; Ștefan, M.; Axinte, M.; Morar, G.; Cernea, S. *Fitotehnie Vol.1. Cereale și Leguminoase Pentru Boabe*; Editura Universitară: București, Romania, 2011.
39. Maral, H.; Dumlupinar, Z.; Dokuyucu, T.; Akkaya, A. Response of Six Oat (*Avena sativa* L.) Cultivars to Nitrogen Fertilization for Agronomical Traits. *Turk. J. Field Crop.* **2013**, *18*, 254–259.
40. Akcura, M.; Ceri, S.; Taner, S.; Kaya, Y.; Ozer, E.; Ayranci, R. Grain Yield Stability of Winter Oat (*Avena sativa* L.) Cultivars in the Central Anatolian Region of Turkey. *J. Cent. Eur. Agric.* **2005**, *6*, 203–210.
41. Ayub, M.; Shehzad, M.; Nadeem, M.A.; Pervez, M.; Nadeem, M.; Sarwar, N. Comparative study of forage yield and quality of different oat (*Avena sativa* L.) varieties under agroecological conditions of Faisalabad, Pakistan. *Afr. J. Agric. Res.* **2010**, *6*, 3388–3391.
42. Stoian, V.; Vidican, R.; Rotar, I.; Păcurar, F.; Șandor, M.; Buta, M. Mycorrhizas as a tool in mapping agricultural soils. *Sci. Pap. Ser. A Agron.* **2018**, *61*, 130–136.
43. Mushtaq, A.; Gul-Zaffar, Z.A.; Habib, M. A review on Oat (*Avena sativa* L.) as a dual-purpose crop. *Sci. Res. Essays* **2014**, *9*, 52–59. [CrossRef]
44. Redaelli, R.; Laganà, P.; Rizza, F.; Nicosia, O.L.D.; Cattivelli, L. Genetic Progress of Oats in Italy. *Euphytica* **2008**, *164*, 679–687. [CrossRef]
45. Li, P.; Mo, F.; Li, D.; Ma, B.-L.; Yan, W.; Xiong, Y. Exploring Agronomic Strategies to Improve Oat Productivity and Control Weeds: Leaf Type, Row Spacing, and Planting Density. *Can. J. Plant Sci.* **2018**, *98*, 1084–1093. [CrossRef]
46. De Francisco, A.; Federizzi, L.C.; Setti, T. Development of Oat Production in Brazil: Interaction between Agriculture, Academia, and Industry. *Cereal Foods World* **2019**, *64*, 1–3.
47. Rhymer, C.R. Effects of Nitrogen Fertilization, Genotype and Environment on the Quality of Oats (*Avena sativa*) Grown in Manitoba. 2002. Available online: <https://mspace.lib.umanitoba.ca/handle/1993/7809> (accessed on 18 March 2021).
48. Leszczynska, D.; Klimek-Kopyra, A.; Patkowski, K. Evaluation of the Productivity of New Spring Cereal Mixture to Optimize Cultivation under Different Soil Conditions. *Agriculture* **2020**, *10*, 344. [CrossRef]