

EFFECTS OF SOWING DENSITY, TILLAGE SYSTEM (PLOWING VERSUS SCARIFICATION), AND FERTILIZATION LEVEL ON THE PERFORMANCE OF WINTER OILSEED RAPE

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Abstract

The study evaluated the effects of sowing density, tillage system, and fertilization level on the performance of winter oilseed rape (Brassica napus L.). The research was conducted under field conditions at the Agricultural Research and Development Station (SCDA) Lovrin, Romania. A factorial experimental design was used, including two sowing densities, two tillage systems (plowing and scarification), and two fertilization levels, with emphasis on nitrogen input. The observations focused on the production components (thousand kernel weight and seed production). Sowing density significantly influenced plant architecture and yield formation, while the tillage system affected crop establishment and growth dynamics. Plowing generally ensured better early development, whereas scarification represented a suitable alternative depending on soil and climatic conditions. Higher fertilization levels led to increased yield performance, with responses varying according to sowing density and tillage practice. The interaction between experimental factors highlighted the importance of integrated crop management for optimizing winter oilseed rape productivity. The results contribute to improving cultivation strategies adapted to local pedoclimatic conditions in western Romania.

Key words: winter oilseed rape, sowing density, tillage system, nitrogen fertilization, yield.

INTRODUCTION

Winter oilseed rape (*Brassica napus* L.) is one of the most important oil crops worldwide, playing a key role in food, feed, and biofuel production (Suvet et al., 2024). In Europe, and particularly in Romania, rapeseed has become a strategic crop due to its high economic value, favorable place in crop rotations, and contribution to soil structure improvement (Gherasimescu et al., 2023). However, achieving stable and high yields remains challenging, as crop performance is strongly influenced by agronomic management practices and their interaction with local pedoclimatic conditions (Sitnicki et al., 2024).

Among the main agronomic factors affecting winter oilseed rape productivity, sowing density, soil tillage system, and fertilization – especially nitrogen application – are considered decisive (Li et al., 2014; Bouchet et al., 2016). Each of these factors influences plant establishment, canopy structure, nutrient uptake,

and yield components, and their combined effects often determine crop success or failure (Berry et al., 2010). Optimizing these practices is therefore essential to maximize yield while maintaining sustainable input use.

Sowing density plays a crucial role in shaping plant architecture and yield formation in oilseed rape (Bagheri et al., 2011; Lin et al., 2024). Previous studies have shown that low densities favor individual plant development through increased branching and silique number per plant, whereas higher densities enhance yield stability per unit area but may increase competition for resources (Ma et al., 2014; Ren et al., 2017; Kuai et al., 2016). The response of rapeseed to sowing density is also closely linked to nitrogen availability, as sufficient nitrogen supply can partially compensate for higher interplant competition by supporting biomass accumulation and reproductive development (Khan et al., 2017). Liu et al. (2019) demonstrated that inappropriate nitrogen management amplifies yield losses under

suboptimal plant densities, highlighting the importance of adjusting density to fertilization level.

Nitrogen fertilization remains the most influential nutrient factor in rapeseed cultivation due to its strong effect on vegetative growth, photosynthetic capacity, and yield components. Numerous studies have confirmed that increasing nitrogen rates generally leads to higher seed yield, up to an optimal threshold beyond which yield gains diminish and environmental risks increase (Ren et al., 2017; Yahbi et al., 2022). Moreover, recent research emphasizes the need for improving nitrogen use efficiency by adapting nitrogen rates to planting density and crop management systems, rather than relying on uniformly high inputs (Luo et al., 2024; Li et al., 2024). These interactions underline the importance of integrated nitrogen and stand management strategies.

Soil tillage system is another critical factor influencing winter oilseed rape performance, as it affects soil physical properties, root development, water availability, and nutrient dynamics. Conventional plowing has traditionally been favored for rapeseed due to its positive effects on seedbed quality and uniform crop establishment. However, alternative tillage practices, such as scarification or reduced tillage, have gained increasing attention as potential solutions for reducing fuel consumption, labor costs, and soil degradation. Rabiee et al. (2021) reported that different tillage systems interact significantly with nitrogen fertilization in determining yield and agronomic traits of oilseed rape, suggesting that reduced tillage methods can be viable under appropriate fertilization regimes. Similarly, Seepaul et al. (2023) showed that tillage system influences crop response to nitrogen by modifying soil moisture and nutrient availability.

Despite the extensive body of international research on individual effects of sowing density, nitrogen fertilization, and tillage systems, studies assessing their combined impact – particularly under the specific pedoclimatic conditions of Eastern Europe – remain limited (Ahmadi & Bahrani, 2009; Chițu et al., 2024). Romanian agroecosystems are characterized by high interannual climatic variability, which can significantly modify crop responses to

management practices. Consequently, region-specific research is essential to develop practical recommendations adapted to local conditions (Smuleac et al., 2020).

MATERIALS AND METHODS

The field experiment was conducted during the 2024-2025 agricultural season at the Lovrin Agricultural Research and Development Station (SCDA Lovrin), western Romania, on a chernozem soil characteristic of the Banat Plain. The experimental design was trifactorial, including three experimental factors arranged in a completely randomized design, with one observation per experimental unit:

Factor A - Soil tillage and fertilization system (4 levels):

a₁ – Scarification + NPK 10–20–0;

a₂ – Scarification + NPK 15–15–15;

a₃ – Ploughing + NPK 10–20–0;

a₄ – Ploughing + NPK 15–15–15.

For all fertilization variants included in Factor A, a uniform dose of 200 kg ha⁻¹ commercial fertilizer was applied, irrespective of the fertilizer type (NPK 10–20–0 or NPK 15–15–15). Factor B – Hybrid (33 levels): Thirty-three commercial winter oilseed rape (*Brassica napus* L.) hybrids (LID TEBO, CS CALCULATI CL, CS BESSITO, LID INVICTO, LDC 23135, LDC 23140, LID CALIENTO, GENEROSO, ES CAPELLO, DK EXCITED, DK EXUM, DK EXBURY, DK IMMORTAL CL, DK IMPRINT CL, DK EXPOSE, SY GLORIETTA, SY ROBOT CL, SY FLORETTA, PT 312, PT 315, PT 303, PT 314, NS RAS, NS PEK, NS VIR, NS VID, NS DIV, NS DUNAV, NS MARIN, ZLATNA, ANNA, ZORICA, ILIA).

Factor C – Plant density (2 levels):

c₁ – 35 plants m⁻²;

c₂ – 50 plants m⁻².

Sowing was performed in autumn under optimal agrotechnical conditions for the area. Crop management practices (weed, pest, and disease control) were applied uniformly across all experimental variants.

The thousand seed weight (TSW) was determined at harvest maturity, according to standard laboratory procedures. Data were subjected to analysis of variance (ANOVA) to assess the effects of the studied factors on TSW.

Mean comparisons were performed using the Duncan multiple range test, at a 5% significance level. The relative contribution of each experimental factor to TSW variation was also calculated. Statistical analyses were carried out using STATISTICA software.

RESULTS AND DISCUSSIONS

Effect of soil tillage and fertilization system on thousand seed weight (TSW)

The analysis of variance (ANOVA) for thousand seed weight (TSW) revealed a very significant effect ($p < 0.001$) of the soil tillage and fertilization system (Factor A), as shown in Table 1. The mean TSW values varied between 4.86 g and 4.43 g, indicating a clear differentiation among the four technological variants.

Table 1. Effect of soil tillage and fertilization system on thousand seed weight (TSW)

Soil tillage and fertilization system	TSW	Std. Err.	-95.00%	+95.00%
a1 – Scarification + NPK 10–20–0	4.86	0.045553	4.769025	4.950975
a2 – Scarification + NPK 15–15–15	4.63	0.045033	4.544911	4.724786
a3 – Ploughing + NPK 10–20–0	4.79	0.064097	4.663655	4.919678
a4 – Ploughing + NPK 15–15–15	4.43	0.045193	4.343834	4.524348

As illustrated in Figure 1, the highest TSW values were recorded under scarification combined with NPK 10–20–0 (a1: 4.86 g) and ploughing combined with NPK 10–20–0 (a3: 4.79 g). According to Duncan’s multiple range test (Table 2), both treatments were grouped in class A, showing statistically significant superiority compared with the other fertilization systems.

Conversely, the lowest TSW value (4.43 g) was obtained under ploughing combined with NPK 15–15–15 (a4), which formed a distinct statistical group (class C).

These results indicate that the fertilizer formulation (10–20–0) had a stronger influence on seed weight than the soil tillage system itself, as similar TSW values were obtained under both scarification and ploughing when this fertilizer was applied.

Influence of hybrid on thousand seed weight

Hybrid genotype (Factor B) exerted a highly significant influence on TSW ($p < 0.001$), as indicated in Table 3 and illustrated in Figure 2.

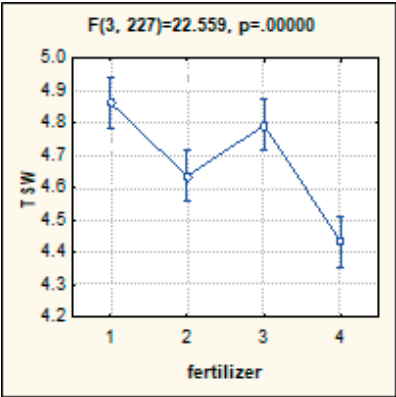


Figure 1. Variation TSW, factor A - test F

Table 2. DUNCAN TEST for factor A DL 5% = 0.11g

Original Date	Sorate Date
Mean 1 = 4.860 A	Mean 1 = 4.860 A
Mean 2 = 4.630 B	Mean 3 = 4.790 A
Mean 3 = 4.790 A	Mean 2 = 4.630 B
Mean 4 = 4.430 C	Mean 4 = 4.430 C

a1=scarified fat used: 10-20-0; a2=scarified fat used: 15-15-15
a3=fat ploughing used: 10-20-0; a4=fat ploughing used: 15-15-15

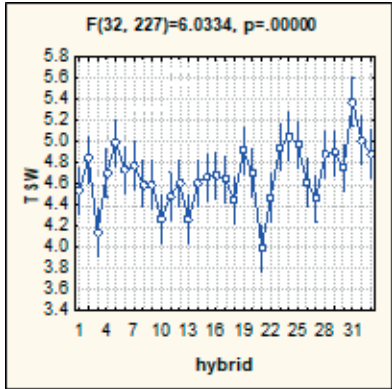


Figure 2. Variation TSW, factor B - test F

Substantial variability was observed among the 33 rapeseed hybrids, with mean TSW values ranging from 4.00 g to 5.37 g.

The highest TSW was recorded for hybrid ANNA (b31), which reached 5.37 g and was classified alone in Duncan class A (Table 4). Other hybrids exceeding 5.00 g included NS PEK (b24) and ZORICA (b32), confirming their superior seed development potential under the tested conditions.

In contrast, the lowest TSW values were obtained for PT 303 (b21: 4.00 g) and CS BESSITO (b3: 4.14 g), which were placed in the lowest statistical classes.

Table 3. Influence of hybrid on thousand seed weight

Hybrid	TSW	Std.Err.	-95.00%	+95.00%
LID TEBO	4.54	0.078848	4.351055	4.723945
CS CALCULATI CL	4.84	0.111515	4.572560	5.099940
CS BESSITO	4.14	0.181610	3.705561	4.564439
LID INVICTO	4.70	0.108447	4.443564	4.956436
LDC 23135	4.99	0.128521	4.689846	5.297654
LDC 23140	4.74	0.108595	4.478214	4.991786
LID CALIENTO	4.78	0.127692	4.476807	5.080693
GENEROSO	4.60	0.093052	4.378717	4.818783
ES CAPELLO	4.59	0.077982	4.403101	4.771899
DK EXCITED	4.28	0.129931	3.967761	4.582239
DK EXUM	4.49	0.079614	4.299243	4.675757
DK EXBURY	4.60	0.109739	4.344259	4.863241
DK IMMORTAL CL	4.26	0.116840	3.984968	4.537532
DK IMPRINT CL	4.61	0.056740	4.474581	4.742919
DK EXPOSE	4.66	0.060723	4.517663	4.804837
SY GLORIETTA	4.68	0.101941	4.436448	4.918552
SY ROBOT CL	4.65	0.124656	4.351486	4.941014
SY FLORETTA	4.45	0.093269	4.226954	4.668046
PT 312	4.91	0.240278	4.343082	5.479418
PT 315	4.70	0.132166	4.387477	5.012523
PT 303	4.00	0.186193	3.554723	4.435277
PT 314	4.46	0.196666	3.997458	4.927542
NS RAS	4.94	0.191915	4.488694	5.396306
NS PEK	5.04	0.054511	4.911102	5.168898
NS VIR	4.97	0.100694	4.726896	5.203104
NS VID	4.61	0.116258	4.333844	4.883656
NS DIV	4.46	0.114532	4.192924	4.734576
NS DUNAV	4.89	0.094130	4.663667	5.108833
NS MARIN	4.89	0.110023	4.631086	5.151414
ZLATNA	4.76	0.085670	4.552424	4.957576
ANNA	5.37	0.222999	4.842691	5.897309
ZORICA	5.01	0.126786	4.706448	5.306052
ILIA	4.88	0.136433	4.553636	5.198864

The wide range of Duncan groupings (A–O) highlights the predominant role of genetic factors in determining thousand seed weight, a finding consistent with previous reports on rapeseed yield components

Effect of plant density on thousand seed weight

Plant density (Factor C) did not significantly affect TSW ($p = 0.933$), as shown in Table 5 and Figure 3. The mean values were 4.682 g for 35 plants m^{-2} and 4.679 g for 50 plants m^{-2} , indicating almost identical seed weights.

Table 4. Table TEST DUNCAN for Factor B [hybrid]
DL 5% = 0.32 g

Original Date		Sorate Date	
Mean 1 = 4.540	IJKLM	Mean 31 = 5.370	A
Mean 2 = 4.840	BCDEFGHI	Mean 24 = 5.040	B
Mean 3 = 4.140	NO	Mean 32 = 5.010	BC
Mean 4 = 4.700	CDEFGHIJK	Mean 5 = 4.990	BCD
Mean 5 = 4.990	BCD	Mean 25 = 4.970	BCDE
Mean 6 = 4.740	BCDEFGHIJK	Mean 23 = 4.940	BCDEF
Mean 7 = 4.780	BCDEFGHIJ	Mean 19 = 4.910	BCDEFG
Mean 8 = 4.600	GHIJK	Mean 28 = 4.890	BCDEFGH
Mean 9 = 4.590	HIJKL	Mean 29 = 4.890	BCDEFGH
Mean 10 = 4.280	LMNO	Mean 33 = 4.880	BCDEFGH
Mean 11 = 4.490	JKLM	Mean 2 = 4.840	BCDEFGHI
Mean 12 = 4.600	GHIJK	Mean 7 = 4.780	BCDEFGHIJ
Mean 13 = 4.260	MNO	Mean 30 = 4.760	BCDEFGHIJ
Mean 14 = 4.610	GHIJK	Mean 6 = 4.740	BCDEFGHIJK
Mean 15 = 4.660	EFGHIJK	Mean 4 = 4.700	CDEFGHIJK
Mean 16 = 4.680	DEFGHIJK	Mean 20 = 4.700	CDEFGHIJK
Mean 17 = 4.650	FGHIJK	Mean 16 = 4.680	DEFGHIJK
Mean 18 = 4.450	KLMN	Mean 15 = 4.660	EFGHIJK
Mean 19 = 4.910	BCDEFG	Mean 17 = 4.650	FGHIJK
Mean 20 = 4.700	CDEFGHIJK	Mean 26 = 4.610	GHIJK
Mean 21 = 4.000	O	Mean 14 = 4.610	GHIJK
Mean 22 = 4.460	KLM	Mean 12 = 4.600	GHIJK
Mean 23 = 4.940	BCDEF	Mean 8 = 4.600	GHIJK
Mean 24 = 5.040	B	Mean 9 = 4.590	HIJKL
Mean 25 = 4.970	BCDE	Mean 1 = 4.540	IJKLM
Mean 26 = 4.610	GHIJK	Mean 11 = 4.490	JKLM
Mean 27 = 4.460	KLM	Mean 27 = 4.460	KLM
Mean 28 = 4.890	BCDEFGH	Mean 22 = 4.460	KLM
Mean 29 = 4.890	BCDEFGH	Mean 18 = 4.450	KLMN
Mean 30 = 4.760	BCDEFGHIJK	Mean 10 = 4.280	LMNO
Mean 31 = 5.370	A	Mean 13 = 4.260	MNO
Mean 32 = 5.010	BC	Mean 3 = 4.140	NO
Mean 33 = 4.880	BCDEFGH	Mean 21 = 4.000	O

Table 5. Effect of plant density on thousand seed weight

Density	TSW	Std.Err.	-95.00%	+95.00%
c1 – 35 pl/mp	4.6818	0.038083	4.606481	4.757155
c2 – 50 pl/mp	4.6785	0.038774	4.601781	4.755189

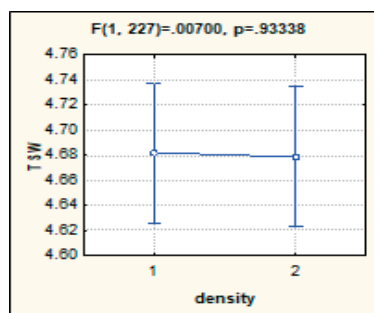


Figure 3. Variation TSW, factor C - test F

These results suggest that, within the tested density range, rapeseed plants compensated effectively through morphological and physiological adjustments, maintaining stable seed weight regardless of stand density.

Contribution of experimental factors to TSW variability

The relative contribution of the studied factors to TSW variability is presented in Figure 4. Hybrid (Factor B) accounted for the largest share (39.6%), followed by the soil tillage and fertilization system (Factor A) with 14%, while plant density contributed only 0.001%.

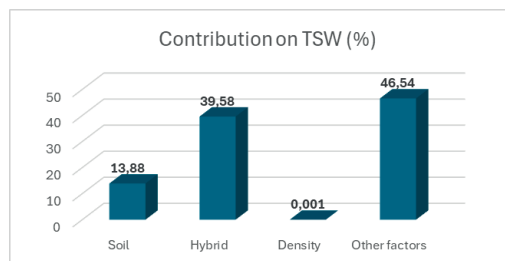


Figure 4. Contribution on TSW of factors A [Soil tillage and fertilization system], B [hybrid], C [density]

The three factors explained approximately 53% of the total TSW variation, indicating that environmental conditions and other unmeasured factors also played an important role in determining seed weight

Cluster analysis

Cluster analysis further supported the differentiation among treatments and hybrids. The dendrogram for the soil tillage and fertilization system (Figure 5) clearly separated treatments based on fertilizer type, while the dendrogram for hybrids (Figure 6) highlighted distinct genetic groupings associated with TSW performance.

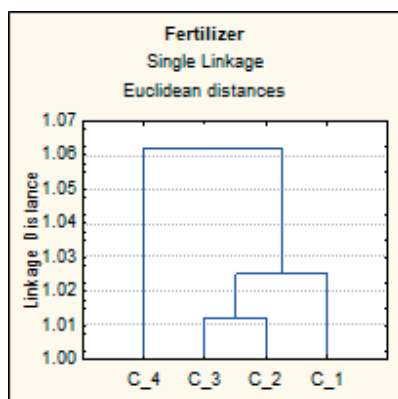


Figure 5. Dendrogram for the soil tillage and fertilization system

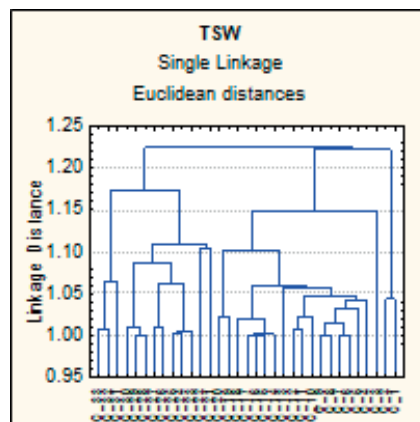


Figure 6. Dendrogram for hybrids

These results confirm the strong genetic control of thousand seed weight and the secondary, yet significant, influence of fertilization strategy.

Interpretation of Yield Results (kg ha^{-1})

The analysis of variance for seed yield (Table 6) showed that the soil tillage and fertilization system (Factor A) and hybrid (Factor B) had a highly significant effect on rapeseed yield ($p < 0.001$), whereas plant density (Factor C) had no statistically significant influence ($p > 0.05$). Therefore, the null hypothesis was rejected for Factors A and B but accepted for Factor C.

Effect of Soil Tillage and Fertilization System

As presented in Table 7, average yield values ranged from $3,221 \text{ kg ha}^{-1}$ under scarification combined with NPK 10–20–0 (a_1) to $4,913 \text{ kg ha}^{-1}$ under ploughing combined with NPK 15–15–15 (a_4).

Duncan's multiple range test classified treatment a_4 in the highest significance group (A), with yields significantly higher than all other treatments. Conversely, treatments a_1 (scarification + NPK 10–20–0) and a_3 (ploughing + NPK 10–20–0) were included in the lowest significance group (C), with yields around $3,200\text{--}3,400 \text{ kg ha}^{-1}$.

These results indicate that the balanced NPK 15–15–15 fertilizer significantly enhanced yield, regardless of the tillage method, while the NPK 10–20–0 formulation was less effective.

Table 6. The analysis of variance for seed yield

Source of variation	SSP [SP]	Weighted Sum of Squares [s ²]	Test F		Significance
			Value	p	
A[Soil tillage and fertilization system]	132812745.0	44270915.01	53.35	0.00000	***
B[Hybrid]	89668904.8	2802153.27	3.38	0.00000	***
C[Density]	2613666.0	2613666.00	3.15	0.07729	ns
Error	188382550.0	829879.07			
Total	413477865.8				

Table 7. Effect of factor A on rapeseed production

Factor A [Soil tillage and fertilization system]	Production kg/ha	Std.Err.	-95.00%	+95.00%
a ₁ – Scarification + NPK 10–20–0	3221	88.4415	3044.203	3397.463
a ₂ – Scarification + NPK 15–15–15	4520	160.1383	4200.560	4840.197
a ₃ – Ploughing + NPK 10–20–0	3449	86.9697	3275.082	3622.463
a ₄ – Ploughing + NPK 15–15–15	4913	156.1832	4600.884	5224.722

Effect of Hybrid

Significant yield differences were recorded among the 33 hybrids (Table 8). The highest average yield was obtained for hybrid PT 315 (b20), with approximately 5,523 kg ha⁻¹, which was significantly superior to all other hybrids. Other high-yielding hybrids included PT 303 (b21) and PT 314 (b22), with yields exceeding 5,200 kg ha⁻¹. In contrast, the lowest yield was recorded for SY ROBOT CL (b17), with approximately 2,821 kg ha⁻¹, significantly lower than the remaining hybrids.

Table 8. Effect of factor B on rapeseed production

Factor B (Hybrid)	Production kg/ha	Std.Err.	-95.00%	+95.00%
LID TEBO	3518	257.8950	2907.925	4127.575
CS CALCULATI CL	4171	363.3661	3311.776	5030.224
CS BESSITO	3713	276.2755	3060.087	4366.663
LID INVICTO	3742	217.7027	3226.965	4256.535
LDC 23135	4133	160.5304	3752.906	4512.094
LDC 23140	4393	169.3057	3992.906	4793.594
LID CALIENTO	3791	168.2138	3393.613	4189.137
GENEROSO	4151	177.0700	3732.296	4569.704
ES CAPELLO	4066	170.9087	3661.365	4469.635
DK EXCITED	3341	97.8788	3109.054	3571.946
DK EXUM	3493	139.7894	3162.201	3823.299
DK EXBURY	3520	206.0956	3032.411	4007.089
DK IMMORTAL CL	3522	191.5164	3069.136	3974.864
DK IMPRINT CL	3672	102.3671	3430.190	3914.310
DK EXPOSE	3915	102.5394	3672.033	4156.967

Factor B (Hybrid)	Production kg/ha	Std.Err.	-95.00%	+95.00%
SY GLORIETTA	2910	92.9942	2690.479	3130.271
SY ROBOT CL	2821	430.2410	1803.517	3838.233
SY FLORETTA	3817	534.2624	2553.295	5079.955
PT 312	4706	532.4656	3447.294	5965.456
PT 315	5523	694.1504	3881.470	7164.280
PT 303	5346	576.4453	3982.549	6708.701
PT 314	5206	512.8761	3993.366	6418.884
NS RAS	4291	539.1326	3016.529	5566.221
NS PEK	4075	476.4807	2948.177	5201.573
NS VIR	4079	525.8430	2835.579	5322.421
NS VID	3906	490.6645	2745.888	5066.362
NS DIV	3969	417.2657	2981.948	4955.302
NS DUNAV	4072	574.9981	2712.346	5431.654
NS MARIN	4319	530.5699	3063.902	5573.098
ZLATNA	4253	464.9040	3153.802	5352.448
ANNA	4165	606.7718	2729.838	5599.412
ZORICA	4500	679.5666	2893.080	6106.920
ILIA	3752	693.0147	2112.906	5390.344

Effect of Plant Density

Mean yields for the two plant densities were 3,926 kg ha⁻¹ at 35 plants m⁻² (c₁) and 4,125 kg ha⁻¹ at 50 plants m⁻² (c₂) (Table 9). However, the differences were not statistically significant (p = 0.077), indicating that both densities provided comparable yield levels under the experimental conditions.

Table 9. Effect of Plant Density

Factor C (Density)	Production kg/ha	Std.Err.	-95.00%	+95.00%
c ₁ – 35 pl/mp	3926	108.8473	3710.871	4141.523
c ₂ – 50 pl/mp	4125	109.1450	3909.282	4341.112

CONCLUSIONS

The results obtained under the pedoclimatic conditions of SCDA Lovrin highlight the differentiated influence of soil tillage and fertilization system, hybrid, and plant density on thousand seed weight (TSW) and seed yield of winter oilseed rape.

Thousand seed weight was significantly influenced by the soil tillage and fertilization system as well as by the hybrid factor, while plant density had no statistically significant effect. The highest TSW values were consistently associated with the fertilization variant based on NPK 10–20–0, regardless of

whether scarification or ploughing was applied. This indicates that phosphorus availability plays a key role in seed filling processes. Hybrid variability accounted for the largest proportion of TSW variation, confirming the strong genetic control over this trait and emphasizing the importance of hybrid selection in achieving superior seed quality.

Seed yield was significantly affected by both the soil tillage and fertilization system and the hybrid, whereas plant density showed no significant effect within the tested range. The highest yields were obtained under ploughing combined with balanced fertilization (NPK 15–15–15), suggesting that higher nitrogen input, together with adequate soil loosening, enhances biomass accumulation and yield formation. Yield differences among hybrids were substantial, reflecting contrasting genetic potential and adaptability to local conditions. The results demonstrate that hybrid choice and fertilization strategy are the main drivers of both yield and seed quality, while moderate variations in plant density exert a limited influence. These findings support the optimization of fertilization regimes and hybrid selection as key components for improving winter oilseed rape performance in western Romania.

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