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EFFECTS OF DIFFERENT SULPHUR RATES AND ROW SPACING ON OILSEED RAPE

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Abstract

Oilseed rape is an important crop for the 21st century, its oil being widely used for producing biodiesel, due to its effect on reducing exhaust emissions, as well as in human alimentation. Sulphur is a secondary macronutrient which is important in oilseed rape production as it is interacting strongly with nitrogen having a great impact on seed yield. Row spacing in oilseed rape cultivation is a key element due to its impact on plant architecture, as oilseed rape is a plant with high branching ability, especially in the case of newly created hybrids. Branching can help surpass plant population losses due to environmental factors, it having an important contribution to the seed yield establishment. A study on the interaction between sulphur fertilization rate and row spacing is important to finding the optimum of these elements of oilseed rape production technology, and our research aimed to identify them in the agro-climatic conditions of NE Romania over 3 years, in 2021-2023. Variant with 37.5 cm row spacing and sulphur fertilizer rate of 72 kg SO_3 per hectare generated the highest statistically significant yield of 3,689 kg per hectare compared to the control variant yield of 2,832 kg per hectare. The medium row spacing and high sulphur rate have resulted in higher yields associated with better development of yielding components such as number of branches per plant, number of siliques per plant, and number of seeds per plant, compared to variants with closer row spacing and low sulphur fertilizer rates.

Key words: *oilseed rape, sulphur fertilizer, row spacing, yielding components, seed yield.*

INTRODUCTION

Oilseed rape (*Brassica napus* ssp. *napus* L.) is an important crop for the 21st century, ranking the third place in world vegetable oil production, it being widely used for producing biodiesel, due to its effect on reducing exhaust emissions, as well as in human alimentation especially after development of low erucic acid content hybrids.

In addition to nitrogen (N), sulphur (S) fertilization is considered a critical factor in high yielding oilseed rape crops (Fismes et al., 2000), S deficiencies frequently restricting the yield at this important oil crop (Grant & Bailey, 1993).

Throughout decades of research on the effect of sulphur fertilization it has become evident that, this often-forgotten secondary macronutrient has a substantial impact in oilseed rape crop production.

Sulphur is a constituent of certain amino acids needed for protein synthesis in oilseed rape (Grant & Bailey, 1993; Ngezimana & Agenbag, 2014; Rameeh et al., 2021), such as methionine which is an essential amino acid, as well as cysteine which is a non-essential amino acid, these allowing the formation of disulfide bonds for protein structure and function (Brosnan & Brosnan, 2006). Chemical analysis of seeds obtained in field crops fertilized with high sulphur content showed a significant increase in napin and an important decrease in the level of cruciferin compounds (Poisson et al., 2019). Sulphur is a component of plant amino acids, proteins, vitamins, and enzyme (Varényiová et al., 2017; Ivanov & Harizanova, 2022).

Glucosinolates contain sulphur (Grant et al., 2012), and therefore S fertilization increased the glucosinolates content (Fismes et al., 2000), but their level is still well below the limit set for the canola standard (Hocking et al., 1996). Also, sulphur plays an essential role in the synthesis of chlorophyll and is also an important component for the synthesis of oil (Brennan & Bolland, 2008; Rehmanuh et al., 2013).

Sulphur is more important for reproductive development (grain yield and quality) than vegetative growth (dry matter production) (Ngezimana & Agenbag, 2014).

Sulphur fertilization contributes to improved N-use efficiency (Fismes et al., 2000; Rameeh et al., 2021). Nitrogen and sulphur applied should be balanced so that a limitation of one does not restrict yield response to the other (Malhi et al., 2005). The results of several of the studies focused on the optimization of nutrition of oilseed rape confirm that the highest seed yield was reached at treatments where nitrogen was applied in combination with sulphur (Mansoori, 2012; Jackson, 2000).

Nitrogen and sulphur nutrition during the growth are tightly linked, and their interactions, as reflected by plant uptake, are synergistic at optimum rates and antagonistic at excessive levels of one of the both (Schnug et al., 1993; Fismes et al., 2000; Poisson et al., 2019). Too much N combined with inadequate S can lead to a nutrient imbalance that can restrict protein synthesis and reduce rapeseed growth and seed yield (Grant et al., 2012). Sulphur deficiency mainly leads to a decrease in nitrogen uptake, which will suppress vegetative development of the plant with an important effect on yield components and finally decreasing seed yield (Schnug et al., 1993; Brennan and Bolland, 2008). The requirement of S for optimum seed yield and quality tends to increase with increasing amount of N applied, and should be considered when planning for S fertilization (Malhi et al., 2005). The ratio N:S should be between 5:1 and 7:1 when fertilizer N is applied (Karamanos et al., 2007; Ngezimana & Agenbag, 2014).

Lack of adequate sulphur sources for oilseed rape plants have directly impacted the pathogen resistance mechanism, weakening the plants resistance towards microbial and fungal infections produced by pathogens *Botrytis cinerea* and *Phytophthora brassicae* (Dubuis et al., 2005).

Sulfur deficiency of rapeseed is a major concern in many parts of the world as oilseed rape requires higher levels of S for optimum yield than do most other agronomic crops, and therefore effective S management is an important part of oilseed rape production (Grant et al., 2012).

Row spacing, an important element at seeding time and for plant phenotypical elements developments, has a significant impact on radiation usage efficiency and late stage crop lodging. Also, it is one of the most impactful elements in oilseed rape production technology with effects on plant architecture as it can unleash the plants genetic potential of production through branching.

Many scientists reported that narrow row spacing resulted in maximum seed yield (Hussain et al., 2020). So, research has highlighted that using 15 cm row spacing will increase radiation usage efficiency due to increased competition for light and heat and reduce crop lodging compared to wider row spacing such as 25 cm as plants are able to form a network of resistance between them (Kuai et al., 2021). Plants seeded in 15-cm rows yielded more per area, produced more pods per plant and lodged less than those in 30-cm rows (Morrison at al., 1990). The highest yields were achieved at a density of 45×10^4 plants ha^{-1} in combination with 15 cm row spacing (Kuai et al., 2015). Also, research on row spacing has shown that closer rows at 18 cm spacing will suppress better weed development and thus reduce the number of weeds per surface compared to wider 33 cm row spacing (Kwiatkowski, 2012). Widening of the row-spacing has led to a decrease in the number of pods per plant and the number of plants per unit area and an increase in the number of seeds per pod parameter, while 1000-seed weight was not affected, results that did not confirm a positive effect of sowing oilseed rape in rows wider than 12.5 cm (Krček et al., 2019). Practically, narrow row spacing or higher population of plants are the most helpful ways to regulate the growth of weed species (Hussain et al., 2020).

Advantages of using wider row spacing (33 cm) have been the increased branching of the plant due to excess space between the rows of plants and also an improvement of the yielding element number of siliques formed per plant (Kwiatkowski, 2012). More branching and producing more pods is primarily how oilseed rape responds to the increased space in wider rows, the same response being seen when plant density is low in areas of the stand, winter oilseed rape having a tremendous ability to compensate by adding branches and pods as space allows (Wysocki, 2020). So, branching can help surpass plant population losses due to environmental factors, it having an important contribution to the seed yield establishment.

A study on the interaction between sulphur fertilization rate and row spacing is important to finding the optimum of these elements of oilseed rape production technology, and our research aimed to identify them in the agro-climatic conditions of NE Romania over 3 years, in 2021-2023.

MATERIALS AND METHODS

Field experiments were conducted over a period of 3 years, respectively in 2020, 2021, and 2022, in the NE Romania (47.5188° N, 27.4490° E), Bivolari commune, Iasi County, in Moldavian plain conditions.

The research was performed under rainfed conditions on a very fertile soil from the class of Chernozems with the top horizon Am-molic. Soil pH is of 7.52, total nitrogen content is of 15.09 mg/kg, phosphorus content is of 21.00 mg/kg, and potassium content is of 228.54 kg/kg.

By comparing the climatic data as historical averages and the averages during 3 years of research, one can observe a consistent pattern of warming especially in the cold months between October and March with an average increase of 3ºC for this period (Table 1).

In terms of annual precipitation, during the 3 years of research, there was registered a deficit of 41.8 mm which shows deteriorating conditions for crop growing, but especially for formation of the oilseed rape yielding component in springtime (Table 2). Lack of sufficient water supply in mid to late plant growth period is a limiting factor for yield as many of the yield components such as number of seeds per silique, number of siliques per plant are all reduced in this water supply situation. During the 3 years of research, the variability of conditions ensures that the field experiments were conducted under different meteorological conditions which increase the general character of the obtained results. It can be observed the increasingly extreme meteorological phenomenon as both annual and monthly averages, dry years with concentrated rains, cooler years with optimum water levels, and long draught periods followed by torrential rains.

Table 1. Monthly temperature in the period 2020-2022 (Bivolari commune, Iasi County, Romania)

Year	Temperature - Monthly Average (°C)												Annual Mean
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	
2020	1.1	4.1	7.2	11.2	14.6	21.9	22.3	23.5	19.6	14.4	5.3	2.4	12.3
2021	0.2	-1.6	3.7	8.6	15.4	20.9	24.1	21.3	15.7	9.9	6.6	0.0	10.4
2022	0.5	3.8	3.7	10.4	16.8	22.1	23.6	23.5	16.1	12.3	5.7	1.0	11.6
Average	0.6	2.1	4.9	10.1	15.6	21.6	23.3	22.8	17.1	12.2	5.9	1.1	11.4
Historical Average	-3.8	-2.0	2.9	10.8	18.9	23.3	24.4	23.5	16.8	9.5	2.8	-1.1	10.5
Difference	4.4	4.1	2.0	-0.7	-3.3	-1.7	-1.1	-0.7	0.3	2.7	3.1	2.2	0.9

Table 2. Monthly precipitation in the period 2020-2022 (Bivolari commune, Iasi County, Romania)

Year	Rainfall - Monthly Average (mm)												Annual Sum
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	
2020	3.4	32.0	15.7	1.8	132.0	98.4	30.4	5.8	26.3	80.1	13.0	41.0	479.9
2021	19.1	28.2	45.4	40.2	67.4	109.4	40.5	132.8	6.6	3.5	10.3	61.2	564.6
2022	9.1	10.8	8.4	52.7	21.5	35.1	28.4	61.3	85.6	13.5	54.4	18.9	399.7
Average	10.5	23.7	23.2	31.6	73.6	81.0	33.1	66.6	39.5	32.4	25.9	40.4	481.4
Historical Average	27.9	25.8	28.4	43.4	55.1	80.7	69.1	55.4	52.3	23.5	30.7	30.9	523.2
Difference	-17.4	-2.1	-5.2	-11.8	18.5	0.3	-36.0	11.2	-12.8	8.9	-4.8	9.5	-41.8

Field research was organized as subdivided experimentation plots with 4 replications and with the following experimental factors:

- Factor A - Sulphur rate, with 4 treatments:
  - a1 - 0 kg SO_3/ha;
  - a2 - 24 kg SO_3/ha;
  - a3 - 48 kg SO_3/ha;
  - a4 - 72 kg SO_3/ha.

- Factor B - Row spacing, with 5 treatments:
  - b1 - 12.5 cm;
  - b2 - 25 cm;
  - b3 - 37.5 cm;
  - b4 - 45 cm;
  - b5 - 70 cm.

The variant a1b1 (0 kg/ha sulphur and 12.5 cm row spacing) was taken as control variant.

The oilseed rape hybrid selected for the field experiments was DKC Exception, a widely used hybrid due to its high yield potential, stable production in different year conditions and its potential to use the nitrogen from the soil. The entire experimental field received a basic fertilization of 60 kg N/ha, 60 kg P_2O_5/ha and 60 kg K_2O/ha by applying 400 kg/ha of complex fertilizer 15:15:15 before soil cultivator pass.

Sulphur fertilizer used in the field experiments was Sulfammo 25, which contains 25% N, 31% SO_3 and 2% MgO. The rates of Sulfammo 25 in the experimental variants with sulphur were the following: 77.5 kg/ha for the variant with 24 kg SO_3/ha, 154.8 kg/ha for the variant with 48 kg SO_3/ha, and 232.2 kg/ha for the variant with 72 kg SO_3/ha.

The total nitrogen rate assured for the entire experimental field was of 142 kg/ha, the difference of the nitrogen rate coming from the complex fertilizer 15:15:15 + Sulfammo 25 being assured by applying ammonium nitrate (33.5% N) for each experimental variant.

Sulfammo 25 fertilizer was applied in the growth stage BBCH-20 (no side shoots), and the ammonium nitrate was applied in the growth stage BBCH-31 (1 visibly extended internode), except for the control variant for which the ammonium nitrate was applied in two rates, respectively 100 kg/ha commercial product in the growth stage BBCH-20 and 145 kg/ha commercial product in the growth stage BBCH-31.

The previous crop was winter wheat, and the tillage was a minimum tillage system which entailed: one disc harrow pass at 10 cm depth for stubble cultivation followed by soil fertilization with 15:15:15 fertilizer; one cultivator pass at 20 cm depth to mobilize the soil and better distribute depth wise the applied fertilizer. For oilseed rape crops seedbed preparation is essential as the seed must be planted at 2-3 cm depth maximum and it requires optimal conditions for the small seeds to germinate. So, seedbed preparation received special attention, this being prepared with a fine cultivator.

The used planting rate was, as recommended by the seed producer, 50 germinal seeds per square meter. The planting date was for every year the beginning of the last decade of August, this being the beginning of the optimal planting interval for oilseed rape in the area of research.

Depending on row spacing two types of planting equipment was used: for 12.5 and 25 cm row spacing a classical seed drill was used, while for 37.5, 45 and 70 cm row spacing an 8 row planter was used.

Weed control was realized through the use of a graminicide, Select Super 0.8 L/ha, containing 120 g/l of cletodim, especially to eliminate volunteer wheat. For dicotiledonate weeds control it was used the herbicide Korvetto 1 L/ha containing halauxifen-metil (5 g/l) and clopyralid (120 g/l).

Oilseed rape is a very sensitive crop to pest and therefore a thorough program of insecticide application was required: in September to counter an attack by *Athalia rosae* larvae together with Aphids; one insecticide based on acetamiprid against *Meligethes aeneus* and *Epicometis hirta* in late April/early May.

Fungal pathogens are an important limitative factors for oilseed rape yield and thus the first fungicide used was Caramba Turbo containing metconazole (30 g/l) and mepiquat chloride (210 g/l), in a rate of 1 l/ha and applied in early spring in order to counter phoma (*Plenodomus lingam*) and early sclerotinia rot infections (*Sclerotinia sclerotiorum*). A second fungicide application of Pictor containing dimoxystrobin (200 g/l) and boscalid (200 g/l) used in 0.5 l/ha rate at flowering time ensures protection against sclerotinia rot infections (*Sclerotinia sclerotiorum*) and extended plant life through stay green effect from the contained strobilurins.

The experimental plots were harvested at 13% moisture content of the seeds in order to minimize silique dehiscence effects on yield.

The research was focused mainly on yield and elements that impact yield development. Therefore, the determinations made in the experimental plots involved the following elements:

- Yield (kg/ha);
- Thousand grain weight (g);
- Number of branches per plant;
- Number of pods per branch;
- Number of pods per plant;
- Number of seeds per pod;
- Number of seeds per plant.

To determine the statistical significance of the set of primary data, obtained in the field experiments, it was used the test package from the excel statistical analysis extension XLSTAT, firstly to determine correlation between the studied variables based on the values of the R^2 coefficient. Further analysis was conducted using Fisher test to strengthen the analysis of differences between variants and control (P-value < 0.05) regardless of statistical sample size. Dunett test was used to compare variant by variant with the control in order to identify which variants offer the best solution in terms of yield increases. Tukey test was used to test for significance of all pairwise comparisons, which compares each variant against each other and against control variant in order to find the most statistically significant variants which are the best options to propose as recommendations to be used in practice.

RESULTS AND DISCUSSIONS

Variant with 37.5 cm row spacing and 72 kg SO_3 per hectare generated the highest statistically significant yield of 3,689 kg per hectare with an increase of 857 kg/ha compared to the control variant yield of 2,832 kg per hectare. All tested variants have had significant increases in yield comparing to the control variant, except the variant with 24 kg of SO_3 and 70 cm spacing (Table 3).

The highest yields obtained at Sulphur rate of 72 kg SO_3 per hectare are according to the findings reported by different authors, even there are some differences in the reported results. Thus, Malhi et al. (2005) reported that applying of 15-30 kg S ha^{-1} was sufficient to prevent S deficiency in canola on most of the S-deficient soils. Grant et al. (2012) reported that 15-60 kg S ha^{-1} as sulfate usually optimize the seed yields of both open-pollinated and hybrid oilseed rape. Wielebski (2008) reported a significantly higher yield after application dose of sulphur 10-30 kg.ha^{-1}. Vaseghi et al. (2013) reported that several experiments proved an increased seed yield at 40 kg.ha^{-1} of sulphur.

Thousand seed weight is an important element in assessing the quality and quantity of yields. Statistical analysis highlights that two variants with 72 kg of SO_3 per ha with 45 or 37.5 cm row spacing have led to significant increases in thousand seed weight compared to control and the other variants (Table 4).

Table 3. Yield (kg/ha) results and their significance

Category	LS means (Average Yield 21-23)	Significance Groups						
72 kg SO_3- 37.5 cm	3689.0	A						
72 kg SO_3- 45 cm	3602.7		B					
48 kg SO_3- 37.5 cm	3403.0			C				
48 kg SO_3- 45 cm	3389.0			C				
72 kg SO_3- 25 cm	3349.5			C				
72 kg SO_3- 70 cm	3280.5				D			
24 kg SO_3- 37.5 cm	3259.0				D			
24 kg SO_3- 45 cm	3167.7					E		
48 kg SO_3- 25 cm	3061.0						F	
24 kg SO_3- 25 cm	3010.0						F	
48 kg SO_3- 70 cm	2991.7						F	
24 kg SO_3- 70 cm	2856.0							G
Control	2832.0							G

Table 4. Significant increases in thousand seed weight

Contrast	Difference	Standardized difference	Critical value	Critical difference	Pr > Diff	Significant
Control vs 72 kg SO_3 - 45 cm	-4.337	-3.541	2.905	3.558	0.010	Yes
Control vs 72 kg SO_3 - 37.5 cm	-4.240	-3.462	2.905	3.558	0.012	Yes

The total number of branches per plant positively correlates with the quantity of applied sulphur. At the same time row spacing of 45 cm between rows is favoured as it leads to the highest number of branches per plant with a significant impact for application of 72 kg SO_3/ha as well as for application of 48 kg SO_3/ha (Table 5). On average 45 cm row spacing variants and medium to high sulphur fertilization lead to an extra 3 branches of oilseed rape to develop. The obtained results are according to those obtained by Ahmad et al. (2011) by applying sulphur fertilizer in a rate of 40 kg/ha a.s. in oilseed rape crops which has led to an improvement of plant architecture as it was observed an increase in the overall number of lateral branches per plant, which positively impacted the number of siliques per plant.

Table 5. Number of branches per plant

Category	No of branches per plant
72 kg SO_3 - 45 cm	16.86
48 kg SO_3 - 45 cm	16.12
48 kg SO_3 - 70 cm	16.09
72 kg SO_3 - 37.5 cm	14.90
72 kg SO_3 - 70 cm	14.41
24 kg SO_3 - 37.5 cm	14.24
24 kg SO_3 - 70 cm	14.18
24 kg SO_3 - 45 cm	14.18
48 kg SO_3 - 37.5 cm	14.02
24 kg SO_3 - 25 cm	13.85
72 kg SO_3 - 25 cm	13.77
48 kg SO_3 - 25 cm	13.680
Control	13.430

Sulphur content positively correlates with the number of seeds per silique as it facilitates better viability of the flowers and lower stress effect in the late flowering period (Table 6). Medium row spacing of 45 cm or 37.5 cm allows for better plant canopy development and architecture facilitating surpassing stress at pollination time.

45 and 37.5 cm row spacing with high sulphur fertilization (72 kg SO_3/ha) have led to the highest significant increase compared to control regarding the number of seeds per silique for both row spacing.

The number of seeds per silique is a sensitive subject as draught, hot air temperature and more critically lack of water will greatly impact the number of pollinated ovules.

Table 6. Number of seeds per silique variation

Category	No of seed per silique
72 kg SO_3 - 45 cm	11.48
72 kg SO_3 - 37.5 cm	11.45
48 kg SO_3 - 45 cm	11.40
72 kg SO_3 - 25 cm	11.30
48 kg SO_3 - 37.5 cm	10.98
48 kg SO_3 - 25 cm	10.87
24 kg SO_3 - 45 cm	10.67
24 kg SO_3 - 37.5 cm	10.26
72 kg SO_3 - 70 cm	10.05
48 kg SO_3 - 70 cm	9.87
24 kg SO_3 - 70 cm	9.73
24 kg SO_3 - 25 cm	9.67
Control	9.03

The number of siliques per branch is also impacted by sulphur fertilization with its role in the stress management mechanism of the plant. One can observe slight increases in the number of siliques per branch in the case of medium and high sulphur fertilization variant (Table 7). The number of siliques per branch is increased when using 45 or 37.5 cm row spacing by 16.93% and 18.6%, respectively. So, in terms of row spacing, medium spacing variants offered the best compromise.

Draught, hot air temperature and more critically lack of water will greatly impact the formation of the number of flowering buds per branch and thus the number of siliques per branch.

Table 7. Number of siliques per branch variation

Category	No of siliques per branch
72 kg SO_3 - 37.5 cm	13.45
48 kg SO_3 - 45 cm	13.32
72 kg SO_3 - 45 cm	13.25
48 kg SO_3 - 37.5 cm	13.05
48 kg SO_3 - 25 cm	12.99
24 kg SO_3 - 45 cm	12.94
24 kg SO_3 - 37.5 cm	12.75
24 kg SO_3 - 25 cm	12.55
72 kg SO_3 - 25 cm	12.51
72 kg SO_3 - 70 cm	12.14
48 kg SO_3 - 70 cm	12.02
24 kg SO_3 - 70 cm	11.97
Control	11.34

The total number of siliques per plant is positively correlated with a high degree of correlation with applied sulphur rate (Table 8).

The highest number of siliques per plant was obtained in variants with 72 kg SO_3/ha (Table 9). The optimal row spacing for increasing the number of silique per plant is 37.5 cm or 45 cm. The total number of siliques per plant is impacted by the statistically significant variants with 37.5 cm and 45 cm between rows and 72 kg SO_3/ha. Practically, all variants have outperformed quantitatively and statistically the control variant.

Table 8. Regression of between factors regarding number of siliques per plant

Observations	52
Sum of weights	52
DF	39
R^2	0.993
Adjusted R^2	0.991

The number of seeds per plant is significantly higher compared to the control variant for all teste variants.
The highest number of seeds per plant was obtained in variants with high sulphur fertilization of 72 kg SO_3/ha. Also, the number of seeds per plant was higher for variants with medium to low row spacing: 37.5 cm, 45 cm, and 25 cm (Table 10).

Variants with 37.5 cm and 45 cm between rows with high sulphur fertilization (72 kg SO_3/ha) lead to the highest statistically significant increase in the number of seeds per plant by 68.36% and 67.10% respectively compared to the control variant.

Table 9. Number of siliques per plant variation

Category	Means (No of silique per plant)	Significance Groups
72 kg SO_3 - 37.5 cm	266.35	A
72 kg SO_3 - 45 cm	260.79	A
48 kg SO_3 - 37.5 cm	252.55	B
48 kg SO_3 - 45 cm	246.70	C
72 kg SO_3 - 25 cm	237.03	D
72 kg SO_3 - 70 cm	226.67	E
24 kg SO_3 - 37.5 cm	223.45	EF
24 kg SO_3 - 45 cm	219.30	FG
48 kg SO_3 - 25 cm	215.50	G
24 kg SO_3 - 25 cm	206.75	H
48 kg SO_3 - 70 cm	202.10	HI
24 kg SO_3 - 70 cm	198.40	I
Control	184.50	J

Table 10. Number of seeds per plant significance per variant

Contrast	Difference	Standardized difference	Critical value	Critical difference	Pr > Diff	Significant
Control 1 vs 72 kg SO_3 - 37.5 cm	-1342.00	-821.804	2.905	4.744	<0.0001	Yes
Control 1 vs 72 kg SO_3 - 45 cm	-1317.12	-806.572	2.905	4.744	<0.0001	Yes
Control 1 vs 72 kg SO_3 - 25 cm	-1021.76	-625.698	2.905	4.744	<0.0001	Yes
Control 1 vs 48 kg SO_3 - 37.5 cm	-885.70	-542.378	2.905	4.744	<0.0001	Yes
Control 1 vs 48 kg SO_3 - 45 cm	-847.20	-518.802	2.905	4.744	<0.0001	Yes
Control 1 vs 72 kg SO_3 - 70 cm	-794.79	-486.710	2.905	4.744	<0.0001	Yes
Control 1 vs 24 kg SO_3 - 37.5 cm	-451.20	-276.302	2.905	4.744	<0.0001	Yes
Control 1 vs 24 kg SO_3 - 45 cm	-406.00	-248.623	2.905	4.744	<0.0001	Yes
Control 1 vs 48 kg SO_3 - 25 cm	-280.00	-171.464	2.905	4.744	<0.0001	Yes
Control 1 vs 48 kg SO_3 - 70 cm	-180.00	-110.227	2.905	4.744	<0.0001	Yes
Control 1 vs 24 kg SO_3 - 25 cm	-102.90	-63.013	2.905	4.744	<0.0001	Yes
Control 1 vs 24 kg SO_3 - 70 cm	-22.00	-13.472	2.905	4.744	<0.0001	Yes

CONCLUSIONS

Following the obtained results in the specific conditions of NE Romania and for the studied hybrid, it can be concluded that the use of 37.5 cm row spacing is the optimal solution to find the best equilibrium between plant architecture development and development of yield elements. If there is no technical mean to modify planters the next best solution would be the use of 45 cm row spacing which is commonly used for soybean planting and other technical plants in order to obtain adequate yielding elements development.
In terms of sulphur fertilization it is paramount to not neglect it as low sulphur availability will

lead to significant losses of yield. Optimal rate of sulphur for the studied conditions was of 72 kg SO_3/ha.

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