Food Biotechnology & Agricultural Sciences

Received: 13 December 2025 | Revised: 15 December 2025 | Accepted: 22 December 2025
DOI: 10.70734/fbas/216131

RESEARCH ARTICLE

The Impact of Mo, Mn, Zn on Morphometric Features of Plants Marked in Autumn Before of Three Forms of Winter Rape

Anna Sikorska[1], Marek Gugała[2], Krystyna Elżbieta Zarzecka[2], Łukasz Domański[1]

1. Department of Agriculture
Vocational State School of Ignacy Mościcki
in Ciechanów, 06-400, Ciechanów, Poland

2. Faculty of Agrobioengineering,
University in Siedlce,
Siedlce, Poland

Correspondence

mgr inż. Anna Sikorska
aniasikorska6@wp.pl

Department of Agriculture
Vocational State School of Ignacy Mościcki
in Ciechanów, 06-400, Ciechanów, Poland

Abstract

Field experiment was conducted in 2019-2022 at the Experimental Station (52º03'N and 22º33'E) of the University in Siedlce, Poland. The experimental factors were: I - rapeseed lines: Gemini (traditional line), PT 275 (complex hybrid line with a traditional growth type), PX 126 (complex hybrid line with a semi-dwarf growth type). II - foliar fertilization: control object - without foliar fertilization, molybdenum, manganese, zinc. The aim of the study was to determine the effect of preparations containing molybdenum, manganese, and zinc on biometric features of plants before the inhibition of vegetation, such as: the number of rosette leaves before the inhibition of autumn vegetation, the diameter of the root neck, the height of the growth cone, the length of the taproot, the fresh and dry mass of the above-ground part of 1 rosette, the fresh and dry mass of the root system of 1 plant. The rosettes with the highest values of habit features were produced by the linear variety. Application of preparations containing molybdenum, manganese, zinc significantly affected plant parameters marked in autumn before vegetation was stopped. The greatest increase in the parameters studied in all studied varieties was demonstrated by the application of molybdenum. The leaf rosette achieved the most favourable parameters in the second and third period of summer-autumn vegetation and winter dormancy, and the weakest in the first vegetation season.

KEYWORDS
manganese, zinc, molybdenum, biometric features of plants, winter rapeseed

Introduction

Many authors [Kwiatkowski 2012; Beres et al. 2019; Jarecki et al. 2019; Sikorska et al. 2019] confirm in their studies that winter rape requires fertilization already in the autumn vegetation period. This is also confirmed by Su et al. [2015], who reported that the development of winter rape rosettes is significantly impacted by the availability of mineral components. Similarly, Jankowski et al. [2019] confirmed in their studies that foliar fertilization phases stimulated the development of rosettes in autumn, affecting the condition of plants and hardening them before winter.

Rapeseed before the autumn vegetation is stopped, in order to survive the winter period properly, should develop the proper plant habit, i.e. 8-12 leaves, the rosette should be compact enough to ensure that the apical shoot meristem does not protrude more than 2-3 cm above the soil surface. Before winter, the root system should be extensive enough to occupy the entire arable layer, and the root neck diameter should be at least 5 mm [Velicka et al. 2012]. Jankowski et al. [2019] emphasize that such plants are the most resistant to frost and temperature fluctuations and are characterized by high vigour at the beginning of the growing season, effectively compete with weeds, produce a large number of buds and are predictors of high yields.

According to Beres et al. [2019], Rios et al. [2019], foliar fertilization is a commonly used procedure in modern agriculture, but both new and well-known preparations in agricultural practice should be tested in field experiments. In rapeseed agronomy, it is beneficial to apply foliar fertilizers already in autumn and then in spring. According to Jarecki [2021], foliar feeding provides cultivated plants with essential nutrients during the vegetation period.

Rios et al. [2019] emphasize that foliar fertilization is highly efficient, minimizes pollution and is goal-oriented. However, the low mobility of several nutrients and low penetration through the leaf cuticle must be addressed.

A very important element for rapeseed is manganese (Mn). Together with copper, it takes part in the most important physiological processes of the plant, increases resistance to diseases, intensifies the photosynthesis process, but also has a beneficial effect on the absorption of phosphorus by plants. This element also takes part in the proper development of the root system.

Molybdenum (Mo) is another essential component in the microelement fertilization of rapeseed. This element reduces the amount of nitrates taken up by the plant, which helps incorporate nitrogen into protein structures. In practice, this means greater winter hardiness. It should be emphasized that excessive concentration of nitrates in the plant causes its greater sensitivity to frost.

Zinc (Zn), in turn, regulates the hormonal balance, thanks to which plants have greater resistance to diseases. According to Barrajón-Catalán et al. [2010], Sun et al. [2013], this element is involved in various biochemical pathways, such as protein biosynthesis and carbohydrate metabolism, and plays an important role in the expression of genes related to environmental stress. Zn deficiency reduces plant growth. Manconi et al. [2006], Riyajan et al. [2012] emphasize that zinc deficiency in plants of the Brasicaceae family causes strong inhibition of the photosystem II reaction centre, as well as reduced stomatal opening and growth of epicuticular waxes, which leads to increased water accumulation. According to Alloway [2009], Zn deficiency reduces the concentration of this element in edible parts of plants, which leads to an average of 31% of the world's population being exposed to Zn deficiency.

The aim of the study was to determine the effect of preparations containing molybdenum, manganese, and zinc on biometric features of plants before the inhibition of vegetation, such as: the number of rosette leaves before the inhibition of autumn vegetation, the diameter of the root neck, the height of the growth cone, the length of the taproot, the fresh and dry mass of the above-ground part of 1 rosette, the fresh and dry mass of the root system of 1 plant.

The research hypothesis assumed that the morphometric features of plants would depend on the morphotype, environmental conditions and supplementary feeding, which would allow for the recommendation of the best morphotype type in diverse climatic conditions in the study area.

Materials and Methods

Experimental design and study location

Field experiment was conducted in 2019-2022 at the Experimental Station of the University in Siedlce, Poland. The experiment was set up in a random subblock design according to the split-plot models in three repetitions.

The experimental factors were:
three rapeseed lines:
1. Gemini (population line),
2. PT 275 (complex hybrid line with a traditional growth type),
3. PX 126 (complex hybrid line with a semi-dwarf growth type).

foliar fertilization:
1. control without foliar fertilization,
2. molybdenum (33 g Mo/dm^3),
3. manganese (160 g Mn/dm^3),
4. zinc (112 g Zn/dm^3).

Foliar fertilization was applied in autumn in the 4-8 leaf stage, in doses of 0.5-1 l/ha.

Soil and agrotechnical conditions

The experiment was conducted on soil classified as Haplic Luvisol, sandy, very good rye soil complex, IVa quality class [WRBSR 2022]. The soil pH was slightly acidic and averaged from 5.68 to 5.75 in the years of the study. The soil was characterized by an average content of nitrogen, phosphorus, potassium and a low content of magnesium.

The fore-crop for winter rape in the individual years of the study was winter triticale.

Chemical protection was applied in accordance with the recommendations of good agricultural practice. Immediately after sowing, a product containing clomazone, i.e., was applied to the soil at a dose of 0.25 dm^3·ha^{-1}. In the BBCH 13-14 phase, fluazifop-P-butyl was applied at a dose of 2.0 dm^3·ha^{-1}, while in the BBCH 14-18 phase, the Horizon 250 EW fungicide was applied at a dose of 0.75 dm^3·ha^{-1}.

Statistical analysis

The results of the study were statistically developed using the analysis of variance. The significance of the sources of variation was tested using the Fischer-Snedecor "F" test, and the assessment of the significance of differences at the significance level of p=0.05 between the compared means was performed using Tukey's multiple intervals. Statistical calculations were performed based on our own algorithm written in Excel according to the mathematical model.

Climatic conditions

Climatic conditions during the summer-autumn vegetation and winter dormancy periods are presented in Table 1. In the 2019-2020 growing season, during sowing, the total rainfall was 43.9 mm and was 16.0 mm lower, while the average daily temperature was 19.9°C and was 1.4°C higher than the multi-year average. In September, rainfall was recorded more than twice as low as compared to the multi-year average, while the average air tem-

Table 1. Average air temperature (˚C), Monthly precipitation sums (mm),the value of the Sielianinov hydrothermal coefficient in during the autumn growth period and winter rest in years 2019-2022 (Agricultural Experimental Station, Poland)

MONTHS	AUTUMN GROWTH PERIOD AND WINTER REST IN YEARS 2019-2022										
	**I	II	III	Multi-year sum (1996-2010)	I	II	III	Multi-year average (1996-2010)	I	II	III
	Precipitation (mm)				Air temperature (ºC)				the value of the Sielianinov hydrothermal *		
VIII	43.9	18.2	95.4	**59.9**	19.9	20.2	17.1	18.5	2.19	0.90	5.23
IX	17.4	38.8	42.1	**42.3**	14.2	15.5	12.9	13.5	1.16	2.50	3.31
X	9.5	52.7	5.8	**24.2**	10.7	12.0	8.6	7.9	0.87	4.39	0.69
XI	17.8	34.0	0.0	**20.2**	6.1	5.6	5.4	4.0	-	-	-
XII	29.1	17.2	0.0	**18.6**	2.9	- 0.2	0.5	-0.1	-	-	-
I	12.9	22.6	6.7	**19.0**	1.9	-1.9	0.4	-3.2	-	-	-
II	26.8	10.4	2.9	**16.0**	2.9	-2.5	-2.3	-2.3	-	-	-
III	5.9	9.6	1.5	**18.3**	4.5	2.7	2.8	2.4	1.12	3.55	0.09
Sum VIII-VII/ Mean	163.3	203.5	154.4	218.5	7.9	6.4	5.7	5.1	1.33	2.83	2.33

* Coefficient value according to Skowera (2014): Extremely dry (ss) k≤0.4; Very dry (bs) 0.4-0.7; Dry (s) 0.7-1.0; Rather dry (ds) 1.0<k≤1.3; Optimal (o) 1.3<k≤1.6; Rather wet (dw) 1.6<k≤2.0; Wet (w) 2.0<k≤2.5; Very wet (bw) 2.5<k≤3.0; Extremely wet (sw) k>3.0

** I: 2019-2020; II:2020-2021; III: 2021-2022

perature was higher by an average of 0.7°C. Based on the calculated Sielianinov's coefficient (k=1.16), September was shown to be quite dry. In October and November, precipitation totals were lower than the multi-year average and warmer by 2.8°C and 2.1°C, respectively, while in December the average temperature was similar to the multi-year average, and precipitation totals were 10 mm higher. In the period from January to March, average air temperatures were significantly higher compared to the multi-year average, while in March, precipitation totals were three times lower than the multi-year average.

In the second year of the study, during sowing, the total rainfall was more than three times lower than the average for the years, while the average daily air temperature was 1.7°C higher.

In September, the total rainfall was similar to the multi-year average, and the average air temperature was higher by an average of 2.0°C. In October, the total rainfall was more than twice as high, while the average air temperature was 3.9°C higher than the annual average. In January, the total rainfall was close to the multi-year average, in February it was 5.6 mm lower, and in March it was twice as low, while the average air temperatures were close to the annual average.

In the last year of the study, August was extremely humid (k=5.23). The total rainfall was higher by an average of 35.5 mm, while the average air temperature was higher by an average of 1.4°C than in the multi-year period. In September, the average daily temperature and rainfall were close to the multi-year average, while October was very dry. In November and December, the average air temperature was higher compared to the multi-year period. In the period from January to March, the total rainfall was significantly lower, i.e. in January: almost three times, in February more than five times, and in March twelve times compared to the annual average.

The highest rainfall total in the autumn growth period and winter dormancy was recorded in the second period of the study. Based on the calculated Sielianinov's coefficient, it was a very humid season. The average air temperature in this period was 6.4°C. The 2019-2020 growing season was optimal, the total rainfall in this period was 163.3 mm, and the average air temperature was the highest and was 7.9°C.

Results and Discussion

Foliar feeding

As a result of using the preparation containing molybdenum, the greatest significant increase in the number of rosette leaves by an average of 1 piece per plant was shown. The application of zinc did not significantly increase the value of this feature. Jankowski et al. [2019] obtained an increase in the value of this feature by an average of 5% under the influence of foliar feeding, while Sikorska et al. [2019] obtained an increase in the number of rosette leaves by an average of 27.1% by foliar feeding plants with sulphur, boron in combination with amino acids. Budzyński and Jankowski [2000] as a result of the application of urea solution (10 kg N/ha) in September in the 4-5 leaf stage produced 1 leaf more in the rosette than those fertilized only before sowing at the level of 40 kg N/ha. Similar conclusions were reached by other researchers [Gaveliene et al. 2004; Miliuviene et al. 2004], who found that the use of growth regulators increases the number of leaves in the autumn period.

A statistically significant increase in the height of the growth cone compared to the control treatment was demonstrated as a result of the application of molybdenum, manganese and zinc. It should be emphasized that the differences between these treatments, where foliar feeding was used, were statistically insignificant.

The root neck diameter was larger by an average of 0.3 mm compared to the control variant as a result of the application of manganese. As a result of the application of molybdenum and zinc, a smaller but statistically significant increase in the value of this feature was also shown. Similarly, Sikorska et al. [2019] as a result of foliar feeding with sulphur, boron in combination with amino acids obtained an increase in the diameter of the root neck (on average by 11.0%) compared to the control variant. Similarly, Gaveliene et al. [2002]; Miliuviene et al. [2004] showed that the use of growth regulators increases the diameter of the root neck.

Studies have shown that the top root was 1.5 cm longer than the control object after the application of the preparation containing molybdenum. Sikorska et al. [2019] showed that foliar feeding with sulphur, boron in combination with amino acids increased the length of the tap root by an average of 9.7%. Similarly, Jankowski et al. [2019] obtained an increase in the length of the tap root as a result of foliar application of macro and microelements.

The fresh mass of the above-ground part was the highest after the application of the preparation containing molybdenum. This value was higher by an average of 2.04 g compared to the control object. It should be emphasized that after the application of zinc, the fresh mass of the above-ground part of the rosette was the same as in the object where no additional feeding was applied.

A similar trend was observed in the case of the dry mass of the above-ground part. The studies showed that the highest fresh and dry mass of the root system was found after the application of molybdenum, followed by manganese and zinc (Table 2).

Genetic factor

The genetic factor influenced the morphometric features of plants marked in autumn before the vegetation stopped. The highest number of rosette leaves, an average of 10, was shown in the Chrobry population variety. In the long-stem hybrid, this value was 9.2 pieces, while in the semi-dwarf one, 8.5 pieces per one plant. On the other hand, Sikorska et al. [2019] did not find any influence of the genetic factor in three morphotypes of winter rape on the value of this feature Wielebski and Wójtowicz et al. [2018] obtained the highest value in the population form, significantly lower in the restored hybrids. In turn, Velička et al. [2012] noted an average of 15.3% more rosette leaves in the restored hybrid compared to the linear variety.

Similarly, the height of the growth cone was the highest in the traditional variety. Statistically insignificant differences in the value of this feature were shown in the restored hybrids. In turn, Sikorska et al. [2019] showed that the population morphotype and the long-stem hybrid had the same height of the growth cone.

The largest tap root length of 20.14 cm on average was characteristic of the population variety, followed by the hybrid variety with a traditional growth type of 19.74 cm on average and the semi-dwarf variety of 17.56 cm.
The studies showed that the largest root neck diameter was in the population variety, significantly smaller in the restored hybrids.
Fresh and dry mass of the above-ground part and the root system were the highest in the population morphotype (Table 2).

Interaction of varieties and foliar feeding

The conducted studies showed that the varieties responded differently to the applied foliar feeding. The population variety and the restored hybrid with a traditional growth type increased the number of rosette leaves under the influence of the preparation containing molybdenum and manganese. The application of zinc in both varieties did not significantly increase the value of this feature. Similarly, the semi-dwarf hybrid had a greater number of leaves after the application of Mo and Mn and Zn. The same value of this feature was recorded in the objects where Mo (object 2) and Mn (object 3) were used, as well as Mn (object 3) and Zn (object 4). The fresh mass of the above-ground part was the same in the population variety after the application of Mo and Mn. A similar trend was demonstrated in the long-stem hybrid PT271. It was shown that the dry mass of the above-ground part of the population variety was the same on the control object and after the application of manganese. It should be emphasized that in this variety, the differences in the value of this feature after the application of Mo and Mn were statistically insignificant. The greatest significant increase in the fresh mass of the root system in all tested varieties occurred after the application of the preparation containing molybdenum. In the Chrobry variety, the zinc application did not significantly increase the value of this feature compared to the control variant. In the long-stem hybrid, the value of this feature was the same in the control object and in the objects where manganese and zinc were applied, while in the semi-dwarf hybrid, the same value of the fresh mass of the root system was shown in all objects where foliar feeding was applied. A similar response of the varieties to the applied preparations was noted in the case of the dry mass of the root system (Table 2).

Interaction of years and tested varieties

The studies showed interactions of years and tested varieties in relations to the number of rosette leaves. All tested varieties had the lowest value of this feature in the first year of the study, with the population variety having the highest value of this feature, on average 8.8 pcs. It should also be emphasized that this variety had the same value of this feature in the second and third year of the study, an average of 10.6 pcs. The same trend was shown in the restored hybrids. The studies showed that the height of the growth cone was the same in all tested varieties in the first growing season. The highest value of this feature was shown in the second year of the study in the population variety, an average of 2.32 cm. The PT271 variety showed the same value of this feature in the second and third year of the study. A similar trend was shown in the semi-dwarf hybrid PX113. The tap root length was the greatest in the 2020-2021 season in all tested varieties and averaged 21.33 cm. It should be emphasized that the population variety had the highest value of this feature in the first two study periods, while in the last growing season it was the long-stem hybrid PT271. In all studied morphotypes, the root neck diameter was the smallest in the first year of the study. It should be noted that the highest value of this feature was demonstrated in the second year of the study in the population variety. In this season, the restored hybrids showed the same value of this feature. The fresh mass of the above-ground part in the second and third year of the study was the highest in the Chrobry population variety. The study showed that in the first year of the study, the population variety and the restored hybrid with a traditional growth type had the same value of this feature. It should be emphasized that in the PT271 variety in all vegetation seasons the value of this feature was statistically insignificant. A similar trend was demonstrated in the case of the dry mass of the above-ground part. The fresh and dry mass of the root system in all studied varieties was the highest in the second season of the study, with the highest value of this feature being demonstrated in all years of the study in the population variety (Table 3).

Table 2. Features of winter rapeseed rosette depending on genetic factor, foliar feeding and climatic conditions

Lines	Years of research			FOLIAR FEEDING OBJECTS				Mean
				1.	2.	3.	4.	
	I	II	III	Control object	Molybdenum	Manganese	Zinc	
The number of rosette leaves (pcs.)								
Chrobry	8.8	10.7	10.5	9.6	10.6	10.2	9.6	**10.0**
PT 271	8.2	9.6	9.8	8.8	9.8	9.2	8.9	**9.2**
PX 113	7.7	8.8	8.9	8.0	8.8	8.6	8.4	**8.5**
Mean	**8.2**	**9.7**	**9.7**	**8.8**	**9.7**	**9.3**	**9.0**	
LSD 0.05 for: years - 0.2; lines - 0.2; foliar feeding - 0.2; interactions: years x lines – 0.4.; lines x foliar feeding - 0.3								
The height of the growth cone (cm)								
Chrobry	2.15	2.32	2.14	2.13	2.31	2.22	2.14	2.20
PT 271	2.10	2.08	2.12	2.03	2.14	2.11	2.11	2.10
PX 113	2.13	2.15	2.07	2.03	2.17	2.14	2.11	2.11
LSD 0.05 for: years - 0.05; lines - 0.05; foliar feeding - 0.06.; interactions: years x lines – 0.09.; lines x foliar feeding - n.s.								
The length of the taproot (cm))								
Chrobry	18.09	22.34	19.99	19.51	20.93	20.33	19.79	20.14
PT 271	17.97	21.17	20.08	19.08	20.48	19.76	19.63	19.74
PX 113	14.70	20.48	17.51	16.76	18.10	17.90	17.49	17.56
Mean	16.92	21.33	19.19	18.45	19.84	19.33	18.97	
LSD 0.05 for: years– 0.24; lines - 0.24; foliar feeding- 0.31; interactions: years x lines – 0.42.; lines x foliar feeding - n.s.								
The fresh mass of the above-ground part of 1 rosette (g)								
Chrobry	36.70	46.38	43.42	42.01	43.21	42.46	40.98	42.16
PT 271	36.86	37.57	36.46	35.91	38.00	37.07	36.87	36.96
PX 113	22.85	32.09	34.79	28.64	31.48	30.43	29.09	29.91
Mean	32.14	38.68	38.22	35.52	37.56	36.65	35.64	
LSD 0.05 for: years - 0.45. lines - 0.45. foliar feeding - 0.58; interactions: years x lines - 0.78; lines x foliar feeding - 1.00								
The dry mass of the above-ground part of 1 rosette (g)								
Chrobry	8.44	9.74	9.55	9.21	9.47	9.31	8.98	9.24
PT 271	8.48	7.89	8.02	7.90	8.36	8.15	8.11	8.13
PX 113	5.26	6.74	7.65	6.27	6.89	6.66	6.37	6.55
Mean	**7.39**	**8.12**	**8.41**	7.79	8.24	8.04	7.82	
LSD 0.05 for: years - 0.09 lines - 0.09 foliar feeding - 0.12; interactions: years x lines - 0.17; lines x foliar feeding - 0.21								
The fresh of the root system of 1 plant (g)								
Chrobry	8.22	13.13	10.17	10.08	11.14	10.52	10.27	10.50
PT 271	6.01	11.22	8.73	8.44	9.08	8.60	8.49	8.65
PX 113	5.07	8.11	6.83	6.42	6.83	6.82	6.60	6.67
Mean	6.43	10.82	8.58	8.31	9.02	8.65	8.45	
LSD 0.05 for: years - 0.14 lines - 0.14 foliar feeding - 0.13; interactions: years x lines- 0.24.; lines x foliar feeding- 0.23								
The dry mass of the root system of 1 plant (g)								
Chrobry	2.06	3.02	2.20	2.33	2.57	2.43	2.37	2.42
PT 271	1.50	2.58	1.89	1.94	2.09	1.98	1.95	1.99
PX 113	1.27	1.87	1.48	1.48	1.58	1.57	1.52	1.54
Mean	1.61	2.49	1.85	1.92	2.08	1.99	1.95	
LSD 0.05 for: years - 0.03 lines - 0.03 foliar feeding - 0.03; interactions: years x lines- 0.05; lines x foliar feeding - 0.05								
The diameter of the root neck (mm)								
Chrobry	8.13	9.13	8.43	8.42	8.52	8.80	8.50	8.56
PT 271	7.65	8.08	7.87	7.73	7.92	7.97	7.84	7.87
PX 113	7.43	8.07	7.65	7.54	7.83	7.82	7.67	7.72
Mean	7.74	8.43	7.98	7.90	8.09	8.20	8.00	
LSD 0.05 for: years - 0.07; lines - 0.07; foliar feeding - 0.07; interactions: years x lines - 0.12; lines x foliar feeding- 0.12.								

Interaction of years and foliar feeding

In the first year of the study, the number of rosette leaves increased under the influence of foliar feeding compared to the control object. It should be emphasized that the value of this feature was the same in the objects where manganese and zinc were used. In the second year of the study, the number of leaves was the same in the control object and in the object where zinc was applied, and in the third in the objects where manganese and zinc were applied. The study showed the same value of this feature on the control object and on objects where molybdenum and manganese were applied. The height of the growth cone elevation in the first and last year of the study was significantly higher in the objects where foliar feeding was applied, but the value of this feature was the same as a result of the application of Mn, Mo, Zn.

In the second season of the study, the height of the growth cone was the same on all objects as on the control object. It should be noted that the value of this feature in the individual variants with supplementary feeding was the same in all years. The tap root length was the same in the objects where Mo, Mn and Zn were used. In the second growing season, the value of this feature was the highest under the influence of the preparation containing molybdenum. In the last year of the study, the same value of this feature was shown in the fertilized objects. Fresh and dry mass of the above-ground part was the same in all years of the study on the control object and on the object where zinc was applied. On the other hand, the fresh and dry mass of the root system has the same value on the control object and on the object where zinc was applied in the first and last season of the study. The root neck diameter was the same under the influence of molybdenum and zinc application in the first and second year of the study, while in the third year of the study on the control object and where zinc was applied and on the object with molybdenum and manganese (Table 3).

Table 3. Features of winter ra peseed rosette depending on years of research and types of foliar feeding.

Years of research	FOLIAR FEEDING OBJECTS				Mean
	1. Control object	2. Molybdenum	3. Manganese	4. Zinc	
The number of rosette leaves (pcs.)					
I	7.7	8.8	8.3	8.1	**8.2**
II	9.5	10.2	9.9	9.2	**9.7**
III	9.2	10.2	9.8	9.6	**9.7**
Mean	**8.8**	**9.7**	**9.3**	**9.0**	**-**
LSD 0.05 for: years - 0.2 foliar feeding - 0.2; interactions: years x foliar feeding - 0.3					
The height of the growth cone (cm)					
I	1.98	2.20	2.20	2.12	**2.13**
II	2.17	2.22	2.17	2.18	**2.18**
III	2.06	2.20	2.11	2.07	**2.11**
Mean	**2.07**	**2.21**	**2.16**	**2.12**	**-**
LSD 0.05 for: years - 0.05; foliar feeding - 0.06; interactions: years x foliar feeding - 0.11					
The length of the taproot (cm)					
I	16.79	17.08	16.90	16.91	**16.92**
II	19.76	22.66	21.83	21.07	**21.33**
III	18.80	19.78	19.26	18.93	**19.19**
Mean	**18.45**	**19.84**	**19.33**	**18.97**	**-**
LSD 0.05 for: years - 0.24; foliar feeding - 0.31.; interactions: years x foliar feeding - 0.54					
The fresh mass of the above-ground part of 1 rosette (g)					
I	31.52	33.02	32.58	31.42	**32.14**
II	37.88	40.61	38.67	37.56	**38.68**
III	37.17	39.06	38.71	37.96	**38.22**
Mean	**35.52**	**37.56**	**36.65**	**35.64**	**-**
LSD 0.05 for: years - 0.45; foliar feeding - 0.58;; interactions: years x foliar feeding - 1.00					
The dry mass of the above-ground part of 1 rosette (g)					
I	7.25	7.60	7.49	7.23	**7.39**
II	7.95	8.53	8.12	7.89	**8.12**
III	8.18	8.59	8.52	8.35	**8.41**
Mean	**7.79**	**8.24**	**8.04**	**7.82**	**-**
LSD 0.05 for: years - 0.09; foliar feeding - 0.12; interactions: years x foliar feeding - 0.21					
The fresh of the root system of 1 plant (g)					
I	6.21	6.70	6.49	6.32	**6.43**
II	10.29	11.54	10.88	10.56	**10.82**
III	8.44	8.81	8.58	8.48	**8.58**
Mean	**8.31**	**9.02**	**8.65**	**8.45**	**-**
LSD 0.05 for: years - 0.14; foliar feeding - 0.13; interactions: years x foliar feeding - 0.23					
The dry mass of the root system of 1 plant (g)					
I	1.56	1.68	1.63	1.58	**1.61**
II	2.37	2.66	2.50	2.43	**2.49**
III	1.82	1.90	1.85	1.83	**1.85**
Mean	**1.92**	**2.08**	**1.99**	**1.95**	**-**
LSD 0.05 for: years - 0.03; foliar feeding - 0.03; interactions: years x foliar feeding - 0.05					
The diameter of the root neck (mm)					
I	7.58	7.70	7.91	7.76	**7.74**
II	8.28	8.43	8.58	8.42	**8.43**
III	7.84	8.14	8.10	7.83	**7.98**
Mean	**7.90**	**8.09**	**8.20**	**8.00**	**-**
LSD 0.05 for: years - 0.07; foliar feeding - 0.07; interactions: years x foliar feeding - 0.12					

Conclusions

The rosettes with the highest values of habit features were produced by the linear variety. Application of preparations containing molybdenum, manganese, zinc significantly affected plant parameters marked in autumn before vegetation was stopped. The greatest increase in the parameters studied in all studied varieties was demonstrated by the application of molybdenum. The leaf rosette achieved the most favourable parameters in the second and third period of summer-autumn vegetation and winter dormancy, and the weakest in the first vegetation season.

References

1. Alloway, B.J. Micronutrient Deficiencies in Global Crop Production. Springer, Dordrecht. 2008. https://doi.org/10.1007/978-1-4020-6860-7_1
2. Barrajón-Catalán, E., Menéndez-Gutiérrez, M.P., Falco, A., Carrato, A., Saceda, M., Micol, V. Selective death of human breast cancer cells by lytic immunoliposomes: Correlation with their HER2 expression level. Cancer Lett. 2010, 28; 290(2):192-203. https://doi.org/10.1016/j.canlet.2009.09.010.
3. Beres, J., Becka, D., Tomasek, J., Vasak, J. Effect of autumn nitrogen fertilization on winter oilseed rape growth and yield parameters. Plant Soil Environ. 2019, 65, 435-441. https://doi.org/10.17221/444/2019-PSE
4. Budzyński, W., Jankowski, K. Effects of autumn nitrogen fertilization on the yield and production cost of winter oilseed rape. Rośliny Oleiste - Oilseed Crops. 1997, XXI, 73-84.
5. Gaveliene, V., Novickiene, L., Brazauskiene, I., Miluviene, L., Pakalniškyte, L. Relationship of rape growth and crop production with plant growth regulators and disease. Vagos. Mokslo Darbai (Proceedings of Lithuanian University of Agriculture). 2002, 56, 9, p. 7-11.
6. IUSS Working Group WRB. World Reference Base for Soil Resources. International soil classification system for naming soils and creating legends for soil maps. 4th edition. International Union of Soil Science (IUSS), Vienna, Austria. 2022.
7. Jankowski, K.J., Sokólski, M., Szatkowski, A. The Effect of Autumn Foliar Fertilization on the Yield and Quality of Winter Oilseed Rape Seeds. Agronomy. 2019, 9, 849. https://doi.org/10.3390/agronomy9120849
8. Jarecki, W., Buczek, J., Bobrecka-Jamro, D. The response of winter oilseed rape to diverse foliar fertilization. Plant Soil Environ. 2019, 65, 125–130. https://doi.org 10.17221/5/2019-PSE
9. Kwiatkowski, C.A. Response of winter rape (Brassica napus L. ssp. oleifera Metzg., Sinsk) to foliar fertilization and different seeding rates. Acta Agrobot. 2012, 65, 161-170. https://doi.org/10.5586/aa.2012.070
10. Manconi, M., Vila, A.O., Sinico, C., Figueruelo, J., Molina, F., Fadda, A.M. Theoretical and experimental evaluation of decypolyglucoside vesicles as potential drug delivery systems, Journal of Drug Delivery Science and Technology. 2006, 16, 2, 141-146. https://doi.org/10.1016/S1773-2247(06)50021-8.
11. Nasseri, B. Effect of cholesterol and temperature on the elastic properties of niosomal membranes. Int. J. Pharm. 2005, 26; 300 (1-2): 95-101. https://doi.org 10.1016/j.ijpharm.2005.05.009
12. Rios, J.J., Garcia-Ibañez, P., Carvajal, M. The use of biovesicles to improve the efficiency of Zn foliar fertilization. Colloid. Surf. B Biointerfaces. 2019, 173, 899-905. https://doi.org /10.1016/j.colsurfb.2018.10.057
13. Riyajan, S.A., Sasithornsonti, Y., Phinyocheep, P. Green natural rubber-g-modified starch for controlling urea release. Carbohydr. Polym. 2012 Jun 5; 89(1): 251-8. https://doi.org10.1016/j.carbpol.2012.03.004. Mar 7. PMID: 24750631.
14. Sikorska, A., Gugała, M., Zarzecka, K. The Effect of Foliar Nutrition with Sulphur and Boron, Amino Acids on Morphological Characteristics of Rosette and Wintering Winter Rape (Brassica napus L.). Journal Ecology Engineering. 2019, 20(6), 190-197. https://doi.org10.12911/22998993/109453
15. Skowera, B. Changes of hydrothermal conditions in the Polish area (1971–2010). Fragmenta Agronomica. 2014, 31(2), 74–87. (in Polish)
16. Su, W., Liu, B., Liu, X., Li, X., Ren, T., Cong, R., Lu, J. Effect of depth of fertilizer banded-placement on growth, nutrient uptake and yield of oilseed rape (Brassica napus L.). Eur. J. Agron. 2015, 62, 38-45. https://doi.org10.1016/j.eja.2014.09.002
17. Sun, G., Chung, T.S., Jeyaseelan, K., Arunmozhiarasi, A. Stabilization and immobilization of aquaporin reconstituted lipid vesicles for water purification, Colloids and Surfaces B: Biointerfaces. 102, 2013, 466-471. https://doi.org/10.1016/j.colsurfb.2012.08.009.
18. Miliuviene, L., Novickiene, L., Gaveliene, V., Brazauskiene, I., Pakalniskyte, L. Possibilities to use growth regulators in winter oilseed rape growing technology. 1. The effect of retardant analogues on oilseed rape growth. Agronomy Research. 2004, 2, 207-215.
19. Velička, R., Pupalienė, R., Butkevičienė, L.M., Kriaučiūnienė, Z. Peculiarities of overwintering of hybrid and conventional cultivars of winter rapeseed depending on the sowing date. Acta Sci. Pol. Agric. 2012, 11, 53-66.
20. Wielebski, F., Wójtowicz, M. Effect of date and density of sowing and weather conditions on growth in the autumn and winter survival of winter oilseed rape morfotypes with traditional and semidraft type of growth. Fragm. Agron. 2018, 35(2), 133-145. https://doi.org10.26374/fa.2018.35.22 (in Polish)