Scientific Papers. Series A. Agronomy, Vol. LXVIII, No. 2, 2025
ISSN 2285-5785; ISSN CD-ROM 2285-5793; ISSN Online 2285-5807; ISSN-L 2285-5785

EFFECT OF PRE-SOWING ELECTROMAGNETIC TREATMENT OF TRITICALE (×*Triticosecale* Wittm.) SEEDS AND METEOROLOGICAL CONDITIONS ON GRAIN YIELDS

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Abstract

The study examined the effects of electromagnetic stimulation on seeds of two triticale varieties under different climatic conditions. A three-factor field trial was conducted in 2017-2018 and 2018–2019 at the Institute of Field Crops, Bulgaria. Before sowing, seeds were electromagnetically treated using controllable factors: voltage (U, kV), seed exposure time (τ, s), and stay period (T, days). The values for the electromagnetic options: E0-untreated seeds; E1 (U = 5.2 kV, τ = 24 s, T = 14 days); E2 (U = 5.0 kV, τ = 50 s, T = 7 days). During vegetation, organic and mineral fertilizers were incorporated. Agrometeorological conditions were assessed using Ivanov`s coefficient and De Martonne index. Grain yield was higher for the Boomerang variety in both years. The variety and fertilization had an average effect in both periods. Electromagnetic stimulation showed a greater effect during the semi-humid conditions of 2018. In 2019, based on the impact of the interaction of the electromagnetic stimulation and the variety, an increase in grain yield for the Boomerang variety for E2 was 6.0%. In 2018, for the E1 option, a higher yield of 23.7% was reported for the Boomerang variety.

Key words: *electromagnetic seed treatment, triticale, grain yields, mineral fertilization, organic fertilization.*

INTRODUCTION

The traditional cultivation of cultural plants includes the use of fertilizers and agrochemicals, which increase plant production, but at the same time lead to negative effects, resulting in disruption of relationships between biotic components in agroecosystems. In modern agriculture, ecological methods are sought to increase yields. The quality of the seeds largely determines future yield. Pre-sowing treatment of seeds has economic importance to increase sowing and productive qualities by improving their germination. For pre-sowing preparation, physical methods can be used, for example, laser irradiation, ultrasonic impact, microwave electromagnetic radiation, magnetic field influence, gamma radiation (Aladjadjiyan, 2007), and plasma (Sohan et al., 2021). It is possible for these methods to ensure increased yields from the respective culture at the expense of small, oftentimes minor costs. They are based on the fact that they increase the amount of energy through internal energy transformation, regardless of its origin, in electricity and increase the electropotential of the cell membrane (Vasilevski, 2003). Modern research found that the application of electric and magnetic fields on seeds improves germination, increases root and sprout length, fresh and dry biomass, fruit yield, leaf area, chlorophyll content, accumulation of various ions, improves stomatal conductivity, leads to an increase in the content of photosynthetic pigment, accelerates cell division, and increases the absorption of water and nutrients (Dannehl, 2018; Sarraf et al., 2020).

Triticale is a hybrid species that combines the genomes of wheat (*Triticum* ssp.) and rye (*Secale cereale* L.). Triticale has a beneficial effect on the human body, can be fractionated to yield a variety of components, including starch, dietary fiber, and protein, which can be used in both food and non-food applications (Kamanova et al., 2023). The production of the modern hexaploid varieties of triticale proves that triticale is a good alternative to traditional Polish cereals (Georgieva, 2009).

In Bulgaria and abroad, laboratory tests in the field of pre-sowing treatment with an electromagnetic field of cotton, tomato, pepper, triticale, and corn seeds showed that it is possible to increase their laboratory germination and to stimulate their development (Antonova-

Karacheva & Sirakov, 2020; Ganeva et al., 2015; Koleva & Radevska, 2021a; Koleva & Radevska, 2021b; Sirakov & Mihaylov, 2022). It was reported for a positive effect on germination indices and some parameters, characteristic of the growth and development of triticale seedlings with laser light (Możdżeń et al., 2020) and magnetic treatment (Hussain et al., 2020). It has been noted that the efficiency of seed irradiation from wheat and barley with electromagnetic waves increases with seed treatment with lower sowing qualities (Nizharadze, 2004).

Most of the experiments are limited to laboratory studies. No results have been reported from field experiments conducted with electromagnetically treated triticale seeds. The results of surveys will be valuable regarding increasing grain yields based on the inclusion of the ecological part of the cultivation technology. In our previous research, we established the limits of controllable factors of electromagnetic impact, through which it is possible to increase laboratory germination and germination energy for two varieties of triticale (Sirakov et al., 2018; Sirakov et al., 2019; Sirakov et al., 2021) and an expected increase in grain yields.

The purpose of the present study was to establish an influence and an effect of pre-sowing electromagnetic seed stimulation for triticale in two climatically different years on grain yield.

MATERIALS AND METHODS

At the experimental field of the Field Crops Institute in Chirpan at the Agricultural Academy during the period 2017-2019, a three-factor experiment was conducted. The applied factors are variety, fertilization, and electromagnetic seed treatment (EMT). The soil is Pellic vertisols. Triticale seeds were sown after the predecessor of sunflower on November 9, 2017 and November 1, 2018. The experimental plot was 18 m^2 in size, and the sowing rate was 550 seeds per m^2. The Bulgarian triticale varieties Boomerang and Colorit were tested. During the growing season, standard cultivation technology for cereals was applied.

60 kg/ha phosphoric fertilizer (P_2O_5) and organic fertilizer at a rate of 2200 kg/ha were incorporated with the main tillage in autumn. In the spring, nitrogen fertilizer (NH_4NO_3) at a rate of 120 kg/ha was spread manually on the plots. The organic fertilizer (Lumbrical) is a product from the processing of manure and other organic waste from red Californian worms and contains: organic substance 45-60%; ammonium nitrogen (NH_4-N) – 33.0 ppm; nitric nitrogen (NO_3-N) – 30.5 ppm; P_2O_5 – 1410 ppm; K_2O – 1910 ppm.

A pre-sowing stimulation device (Terziev et al., 1994) was used to treat the seeds with an electromagnetic field. The controllable factors are voltage between electrode spaces (U, kV), seed exposure time (τ, s), and stay time from treatment to sowing (T, days). The values for the options: E0-untreated seeds; E1 ($U = 5.2$ kV, $\tau = 24$ s, $T = 14$ days); E2 ($U = 5.0$ kV, $\tau = 50$ s, $T = 7$ days).

Grain yields was reported from four replicates and recalculated in kg/ha.

Climatic data were provided by the synoptic station located at the Institute's experimental field (42°12'58"N, 25°17'0"E). Agroclimatic assessment of conditions was performed. The coefficients of humidification by Ivanov (K_I) and dryness index of the De Marton index (I_{DM}) were established. The Ivanov coefficient estimates the degree of aridity for each month and was calculated based on monthly averages daily temperature and relative humidity, and sum of the precipitation (Ivanov, 1941). The De Martonne dryness index is presented for the triticale growing season and uses the average daily months temperatures and sum of the precipitation. This indicator characterizes the humidification conditions of a given territory, i.e., what type of climate it is in relation to the availability of water (De Martonne, 1926).

Results were subjected to an analysis of variance by applying the Biostat statistical program (Penchev et al., 1989-1991) to detect differences between the mean yields. Means were compared using the LSD test at probably $p = 1.0\%$, $p = 0.1\%$ and $p = 5.0\%$.

RESULTS AND DISCUSSIONS

According to the data in Table 1, the monthly temperature sum was 314.5°C and 176.4°C higher than the climatic average, respectively, during the first and second growing seasons. The amounts of precipitation during 2017-2018 were 103.0 mm more, and in the period 2018-2019, they were 54.7 mm less. According to De

Martonne index, the conditions during the period 2017-2018 refer to a semi-humid type of climate, and in 2018-2019 they are characterized as semi-dry.

During the first growing season, emergence of the crop was registered after 15 days at the sum of the active temperature of 143.9°C, the average temperature of 9.6°C, and 16.5 mm of precipitation. According to established Ivanov coefficients, conditions for crop development were favorable for most of the winter period. During the months of February and March, overwetting is observed, which corresponds to the tillering period, according to Table 2. A drought was established in April during the phase of stem elongation. This period of development is deciding on the future production because the segments of the future spikelets are different.

Table 1. Temperature and precipitation sum during the triticale vegetation periods

Period	Months									Σ
	X	XI	XII	I	II	III	IV	V	VI	
Temperature sums (°C)										
1991/21	*406.7*	*214.3*	*54.8*	*9.5*	*74.6*	*215.4*	*363.4*	*532.2*	*642.3*	*2513.2*
2017/18	388.0	244.3	125.6	65.2	97.8	200.5	471.0	584.8	646.9	2824.1
2018/19	434.0	225.3	20.7	53.8	113.1	292.6	335.2	533.4	681.5	2692.6
Precipitation (mm)										
1991/21	*46.9*	*40.7*	*70.0*	*44.4*	*38.4*	*46.3*	*43.8*	*57.3*	*50.8*	*438.6*
2017/18	80.0	48.2	38.9	23.3	109.0	83.4	8.7	62.2	87.9	541.6
±	+33.1	+7.5	-31.2	-21.1	+70.6	+37.1	-35.1	-4.9	+37.1	+103.0
2018/19	25.4	82.3	23.5	28.9	24.5	3.3	51.4	21.4	123.2	383.9
±	-21.5	+41.6	-46.5	-15.5	-13.9	-43.0	+7.6	-35.9	+72.4	-54.7
Period	Coefficient by Ivanov									De Martonne index
2017/18	1.4	1.6	1.7	1.0	6.1	2.6	0.1	0.7	0.8	26.7
2018/19	0.3	2.5	1.3	1.3	0.5	0.0	0.7	0.2	1.0	19.3

Table 2. Dates of occurrence of the main phenological phases for 2017-2019

Varieties / Phases	Colorit		Boomerang	
	2017-2018	2018-2019	2017-2018	2018-2019
Emergence	24.11.17	5.12.18	24.11.17	5.12.18
Tillering	8.03.18	28.02.19	8.03.18	28.02.19
Stem elongation	10.04.18	9.04.19	14.04.18	12.04.19
Heading	20.04.18	30.04.19	2.05.18	3.05.19
Flowering	2.05.18	13.05.19	9.05.18	17.05.19

In the second year, emergence was recorded 24 days after sowing, with a total active temperature of 211.4°C, 82.3 mm of precipitation, and an average temperature of 8.8°C. Droughts were found in the months of March and May, when the plants were going through the phases of stem elongation, heading, and flowering. The insufficient moisture in the soil during flowering reduces the possibility of fertilization and results in a poorly seeded spike.

During the period from April to June, which characterizes the conditions of moisture supply for the yield of winter crops, drought was found in both years. Therefore, the conditions were favorable for the initial development of the crop in 2017, and the drought in April negatively affected grain yield. The late emergence in 2018 retarded the development of triticale during the winter months, the flowering and fertilization occurred at an unfavorable time, which is a possible reason for the decrease in grain yield.

These statements support the data in Table 3, where it can be seen that the average yields are 2957.2 and 2392.1 kg/ha, respectively, in 2018 and 2019.

In 2018, the biggest increase in yields for both varieties of triticale was observed for the E0 + NP option, which is 26.3 and 51.3% more, respectively, for Colorit and Boomerang compared to grain yields obtained from the untreated seeds.

For options of electromagnetically stimulated seeds and fertilization, the best result was obtained for the E1+NP option and the Colorit variety: 20.3%.

Table 3. Influence of variety, EMT and fertilization on grain yields for 2018 and 2019

	Options	kg/ha	% Control		Options	kg/ha	% Control
	Colorit				Colorit		
	E0	2668.1	100.0		E0	2375.0	100.0
	E0 + L	2998.8 ^{ns}	112.4		E0 + L	2361.8 ^{ns}	99.4
	E0 + NP	3370.1 *	126.3		E0 + NP	2532.7 ^{ns}	106.6
	E1	2412.5 ^{ns}	90.4		E1	2199.3 ^{ns}	92.6
	E1 + L	2760.4 ^{ns}	103.5		E1 + L	1931.3 ^{00}	81.3
	E1 + NP	3209.7 ^{ns}	120.3		E1 + NP	2426.4 ^{ns}	102.1
	E2	2289.6 ^{ns}	85.8		E2	1843.8 ^{000}	77.6
	E2 + L	2240.3 ^{ns}	84.0		E2 + L	1986.2 ^{00}	83.6
	E2 + NP	2763.2 ^{ns}	103.6		E2 + NP	2350.0 ^{ns}	98.8
	Boomerang				Boomerang		
	E0	3052.1 ^{ns}	114.4		E0	2358.4 ^{ns}	99.3
	E0 + L	3073.0 ^{ns}	115.2		E0 + L	2493.1 ^{ns}	105.0
2018	E0 + NP	4036.8 ***	151.3	2019	E0 + NP	2934.8 ***	123.6
	E_1	3300.7 *	123.7		E1	2575.0 ^{ns}	108.4
	E1 + L	3104.9 ^{ns}	116.4		E1 + L	2290.3	96.4
	E1 + NP	3263.2 *	122.3		E1 + NP	2655.6 *	111.8
	E2	2947.9 ^{ns}	110.5		E2	2450.7 ^{ns}	103.2
	E2 + L	2760.4 ^{ns}	103.5		E2 + L	2408.3 ^{ns}	101.4
	E2 + NP	3046.6 ^{ns}	114.2		E2 + NP	2848.8 ***	121.5
	Average	2957.2			Average	2392.1	
	St. Error	214.8			St. Error	189.7	
	LSD %				LSD %		
	5.0	553.1	20.7		5.0	268.9	11.3
	1.0	736.6	27.6		1.0	358.1	15.1
	0.1	960.1	34.0		0.1	466.8	19.7

L-Lumbrical; N-nitrogen fertilizer; P-phosphorus fertilizer; L-organic fertilizer Lumbrical; N-nitrogen fertilizer; P-phosphorus fertilizer; *significance at p = 5.0%; *** significance at p = 0.1%; ^{0}significance at p < 0.05; ^{00}significance at p < 0.01; ^{000} significance at p < 0.001; ^{ns} no significance.

For the Boomerang variety for several options, the values were significantly higher compared to the control: E1 and E1 + NP, 23.7 and 22.3%, respectively. Erohin (2018) has reported increase in yield over control for barley (9.7%) and spring wheat (8.4%).

In 2019, the values for varieties for the E0 + NP option demonstrated the highest grain yield by 6.6 and 23.6% more than the control, respectively, for Colorit and Boomerang. Compared to the control, the yield values for Boomerang and for the E1 + NP and E2 + NP options are significantly higher by 11.8 and 21.5%, respectively. The yields for Boomerang variety for E1 and E2 options exceeded the control by 8.4 and 3.2%, respectively. This gives reason to note that the EMO showed a different effect depending on the conditions of the year. Bezpalko et al. (2021) have reported positive and significant results for grain yield in wheat microwave field treated seeds, and yield depends on the conditions of the year. Rye and triticale varieties showed a varied response to pre-sowing treatment with red light, and higher results were obtained in triticale (Dziwulska-Hunek et al., 2022).

The results in Table 4 show that the productivity of the Boomerang variety is significantly higher by 15.7 and 15.1% compared to Colorit in the two harvest years. In 2018, the reported grain production was 3176.2 kg/ha, higher than in 2019 (2561.2 kg/ha). A previous study found higher values of yield related traits for the Boomerang variety compared to Colorit (Muhova et al., 2021).

Table 4. Influence of variety on triticale on grain yields for 2018 and 2019

	Options	kg/ha	% Control		Options	kg/ha	% Control
2018	Colorit	2745.9	100.0	2019	Colorit	2222.9	100.0
	Boomerang	3176.2^{***}	115.7		Boomerang	2561.2^{***}	115.2
	LSD %				LSD %		
	5.0	184.4	6.7		5.0	89.6	4.03
	1.0	245.5	8.9		1.0	119.4	5.4
	0.1	320.0	11.6		0.1	155.6	7.0

***significance at $p = 0.1\%$.

The values for the electromagnetically treated variants show a progressive decrease in direction from E0 to E1 and E2 and ranged from 94.6 to 83.0% in 2018 and from 93.5 to 92.5% in 2019, according to Table 5. For option E2, a significantly lowest value was reported in 2019 compared to the control (2320.6 kg/ha). They have reported positive results regarding grain yield in wheat after seed irradiation with red light. The results showed higher values in two of the varieties tested (Szymanek et al., 2020).

Table 5. Influence of EMT on triticale on grain yields for 2018 and 2019

	Options	kg/ha	% Control		Options	kg/ha	% Control
2018	E0	3199.8	100.0	2019	E0	2509.3	100.0
	E1	3008.6^{ns}	94.6		E1	2346.3^{ns}	93.5
	E2	2674.7^{ns}	83.6		E2	2320.6^{00}	92.5
	LSD %				LSD %		
	5.0	225.8	7.1		5.0	109.8	4.4
	1.0	300.7	9.4		1.0	146.2	5.8
	0.1	392.0	12.3		0.1	190.6	7.6

^{ns} no significance; ^{00}significance at $p < 0.01$.

In contrast to EMO, fertilization increased grain yield from 3.6 to 20.8% in 2018 and by 14.4% in 2019, as can be seen in Table 6. Organic and synthetic fertilizer had a better impact on yield during the semi-humid conditions of 2018. It is known that good moisture security in the soil improves the assimilation of nitrogenous mineral fertilizers. This has been confirmed by other authors (Zhang et al., 2023; Wang et al., 2023; Boudjabi et al., 2023). Drought can affect nutrient uptake and disrupt acropetal translocation of some nutrients (Hu & Schmidhalter, 2005).

Table 6. Influence of fertilization on grain yields for 2018 and 2019

	Options	kg/ha	% Control		Options	kg/ha	% Control
2018	0	2737.3	100.0	2019	0	2300.0	100.0
	L	2841.6^{ns}	103.6		L	2245.2^{ns}	97.6
	NP	3292.7^{***}	120.8		$N_{120}P_{60}$	2630.7^{***}	114.4
	LSD %				LSD %		
	5.0	124.3	4.5		5.0	109.8	4.8
	1.0	165.5	6.0		1.0	146.2	6.4
	0.1	215.8	7.9		0.1	190.6	8.3

L-Lumbrical; N-nitrogen fertilizer; P-phosphorus fertilizer; *** significance at $p = 0.1\%$; ^{ns} no significance.

The effect of EMO on the cultivars is shown in Table 7. E2 was particularly depressing for the Colorit variety. In both years the yields were significantly under the control option - 80.7 and 85.0%. Similarly, in 2019, the grain yield obtained after electromagnetic treatment the seeds with E1 option was lower and confirmed at $p < 0.01$. It was reported an insignificantly increase in yield for the Boomerang variety, by 7.0 and 3.5% in 2018 for E1 option, as well as 6.5% for E2 option in 2019. These results correlate with those presented in Table 10, where a low effect is seen but with good reliability of the factor interaction variety and EMO (4.87%). This means that EMO affects varieties differently in different years. Despite these increases, the highest results for varieties within seasons were obtained for E0 option. Larionov et al. (2021), according to the results of other authors, indicated that the average increase in the yield of cereals (wheat, rye, barley, oats, corn) after electromagnetic treatment of seeds amount to 10-12%, but better results were also reported by 18-26%.

Table 7. Influence of variety and EMT on grain yields for 2018 and 2019

	Options	kg/ha	% Control		Options	kg/ha	% Control
	Colorit				Colorit		
	E0	3012.3	100.0		E0	2423.1	100.0
	E1	2794.2^{ns}	92.8		E1	2185.7^{00}	90.2
	E2	2431.0^{000}	80.7		E2	2060.0^{000}	85.0
2018	Boomerang			2019	Boomerang		
	E0	3387.3*	112.4		E0	2595.4*	107.1
	E1	3222.9^{ns}	107.0		E1	2507.0^{ns}	103.5
	E2	2918.3^{ns}	96.9		E2	2581.3*	106.5
	LSD %				LSD %		
	5.0	319.3	10.6		5.0	155.3	6.4
	1.0	425.3	14.1		1.0	206.8	8.5
	0.1	554.3	18.4		0.1	269.5	11.1

*significance at p = 5.0%; ^{ns} no significance; ^{00} significance at p < 0.01; ^{000}significance at p < 0.001.

According to Table 8, under the influence of organic and mineral fertilizer, the grain yield for Colorit ranged from 8.5 to 26.8%, confirmed higher to the control option in 2018. Next year, 13.9% more yield was reported. Fertilizers applied led to a greater increase in both tested seasons for Boomerang compared to Colorit. In 2018, the Boomerang variety realized a larger production from 21.3 to 40.4% compared to control, and in 2019, from 12.1 to 32.0%.

Table 8. Influence of variety and fertilization on grain yields for 2018 and 2019

	Options	kg/ha	% Control		Options	kg/ha	% Control
	Colorit				Colorit		
	0	2456.7	100.0		0	2139.4	100.0
	L	2666.5*	108.5		L	2093.1^{ns}	97.8
	NP	3114.4***	126.8		NP	2436.3***	113.9
2018	Boomerang			2019	Boomerang		
	0	3097.8***	126.1		0	2581.3***	120.7
	L	2979.4***	121.3		L	2397.2**	112.1
	NP	3448.9***	140.4		NP	2825.0***	132.0
	LSD %				LSD %		
	5.0	175.8	7.2		5.0	155.3	7.3
	1.0	234.1	9.5		1.0	206.8	9.7
	0.1	305.1	12.4		0.1	269.5	12.6

L-Lumbrical; N-nitrogen fertilizer; P-phosphorus fertilizer; *significance at p = 5.0%; ** significance at p = 1.0%; *** significance at p = 0.1%; ^{ns} no significance.

From Table 9, it can be found that the application of mineral fertilizer increased the yields for all EMO options.

The options for E0 with applied mineral fertilizer in both years showed the highest and most significant values of 29.5 and 15.5%, respectively. In 2018, the yields for E1 and E2 were 99.9 and 91.6%, respectively, to E0. Similarly, in the second harvest year for E1 and E2, yields of 100.9 and 90.7%, respectively, were reported to the control. An insignificant 2.5% increase in yield was observed after organic fertilization in 2018. Talanov (2018) have obtained the highest yield of winter rye (384 t/ha) for the pre-sowing electromagnetic treatment of seeds and application of $N_{87}P_{119}K_{75}$. Nizharadze (2010) has reported that after the treatment of wheat seeds with electromagnetic waves with a wavelength of 7.1 mm was obtained a higher grain yield of 7.4 to 13.7%. Menshova & Nizharadze (2012) have found that pre-sowing exposure to an electromagnetic field and a pulsed magnetic field of barley seeds reduced and increased the biological yield by 2.7 and 17.2 %, respectively. Field experiments have found that grain yield after electrophysical treatment of seeds from wheat is practically not lower than that of an option with applied mineral fertilizers (NPK) and exceeded the control indicators by 3.7 and 3.6% (Tibirkov et al., 2012). In maize, grain yields increase by 10 and 15% under the influence of low-frequency electromagnetic waves (Imbrea et al., 2011).

Table 9. Influence of EMT and fertilization on grain yields for 2018 and 2019

Year	Options	kg/ha	% Control	Year	Options	kg/ha	% Control
2018	E0			2019	E0		
	0	2860.1	100.0		0	2366.4	100.0
	L	3035.9^{ns}	106.1		L	2427.4^{ns}	102.6
	NP	3703.5^{***}	129.5		NP	2733.7^{***}	115.5
	E1				E1		
	0	2856.6^{ns}	99.9		0	2387.2^{ns}	100.9
	L	2932.6^{ns}	102.5		L	2110.8^{00}	89.2
	NP	3236.5^{ns}	113.2		NP	2541.0^{ns}	107.4
	E2				E2		
	0	2618.8^{ns}	91.6		0	2147.2^{0}	90.7
	L	2500.3^{ns}	87.4		L	2197.2^{ns}	92.8
	NP	2904.9^{ns}	101.6		NP	2617.4^{*}	110.6
	LSD %						
	5.0	391.1	13.7		5.0	190.0	8.0
	1.0	520.9	18.2		1.0	253.2	10.7
	0.1	678.9	23.7		0.1	330.1	13.9

L-organic fertilizer Lumbrical; N-nitrogen fertilizer; P-phosphorus fertilizer; *significance at p=5.0%; *** significance at p = 0.1%; ^{0}significance at p < 0.05; ^{00}significance at p < 0.01; ^{ns} no significance.

Table 10. Influence of factors variety (A), EMT (B), fertilization (C) on grain yields

Source of variation	df	SS	η (%)	MS	F	P value
2018						
A	1	3215104	21.48^{***}	3215104	69.71	0.0000
B	2	2569984	17.17^{***}	1284992	27.86	0.0000
C	2	4183424	27.95^{***}	2091712	45.35	0.0000
A×B	2	194368	1.30	2091712	2.11	0.12954
A×C	2	172416	1.15	97184	1.87	0.16223
B×C	4	1056512	7.06^{***}	86208	5.73	0.00091
A×B×C	4	1086336	7.26^{***}	271584	5.89	0.00077
Options	17	1.247814E+07	83.36^{***}	734008.5	15.91	0.00000
Error	54	2490688	16.64	46123.9	-	-
2019						
A	1	2060032	27.25^{***}	2060032	57.25	0.0000
B	2	502528	6.65^{**}	251264	6.98	0.00237
C	2	2086464	27.60^{***}	1043232	28.9906	0.00000
A×B	2	368064	4.87^{**}	184032	5.114105	0.00931
A×C	2	23776	0.31	11888	0.3303582	0.72487
B×C	4	33977	4.76	89944	2.499473	0.05243
A×B×C	4	217024	2.87	54256	1.507732	0.21193
Options	17	5617664	74.30	330450.8	9.182968	0.0000
Error	54	1943200	25.70	35985.18	-	-

The effect of the factors, as a result of the analysis of variance carried out, is shown in Table 10. According to the values of η, the variety and fertilization showed confirmed average effects during the two periods, which are expressed in proven differences in yields values between varieties and based on fertilization (Table 3 and Table 6). In 2018, the influence of the interaction of the three factors

A×B×C was low, but confirmed (7.26%). As shown in Table 10, a low interaction between EMO and fertilization (7.06%) was found in 2018, and according to Table 9, this refers to some of the options with organic and mineral fertilizers. In 2019, the interaction between variety and EMO was low (4.87%). The influence of EMO was higher in 2018 (17.17%) than in 2019 (6.65%). This is also confirmed by the data in Table 3, where an increase in yields can be seen for some variants of EMO compared to the control and 2019 data.

CONCLUSIONS

Based on the applied factors and statistical analysis of the data, it can be concluded that certain parameters of the electromagnetic field for seed stimulation had a positive influence on the yields of the two triticale varieties, expressed as an increase in the grain yield. The influence of the selected electromagnetic processing parameters generally showed a tendency towards lower yields. The influence of electromagnetic treatment is also determined by the conditions of the years. Variety and fertilization showed medium effects in both periods. Additional field studies with other levels of electromagnetic parameters are required to refine those that will increase grain yield. Pre-sowing electromagnetic seeds treatment can increase grain yield and contribute to the sustainability of agroecosystems.

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