https://doi.org/10.17221/364/2022-PSE

Effects of various poppy seed pre-sowing treatments on the dynamics of field emergence, structure of yield parameters, oil content and yield of seed

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Citation: Satranský M., Capouchová I., Burešová B., Procházka P. (2022): Effects of various poppy seed pre-sowing treatments on the dynamics of field emergence, structure of yield parameters, oil content and yield of seed. Plant Soil Environ., 68: 533–541.

Abstract: The effects of various pre-sowing treatments of poppy seed (chemical product Cruiser OSR, stimulation products TS Osivo and Enviseed, physical treatment by E-ventus method, biological products Polyversum and Gliorex) on dynamics of field emergence, seed yield, and structure of yield parameters were evaluated in two cultivars grown in three-year trials. Seed treatment with TS Osivo and Enviseed led to a significant increase in field emergence compared to the untreated control and was on the same level as the Cruiser OSR-treated variant. In variants treated with Polyversum, Gliorex, and E-ventus, the number of emerged plants was noticeably lower. The stand density was a key factor in achieving a satisfactory yield, given that in the structure of other yield parameters (number of capsules per plant, weight of seed per capsule, and thousand seed weight), the differences between the variants were lower and often insignificant. The average yield ranged from 0.85 t/ha (Polyversum) to 1.39 t/ha (Cruiser OSR), and the stimulant seed treatments were also proved to be effective (TS Osivo 1.23 t/ha and Enviseed 1.16 t/ha). Variants with biological and physical treatment did not differ significantly from the control (0.88 t/ha) in average yield. All parameters evaluated were strongly affected by the year (weather conditions).

Keywords: *Papaver somniferum* L; small-seeded crop; agroecological condition; precipitation; neonicotinoids restriction

Healthy seed with high vigour is the basis for the successful growth of all crops. Such seed is a primary precondition for favourable plant growth, development and, finally, for a high yield of seed (Procházka et al. 2019). This is especially true for poppy, which belongs to the small-seeded crops with an average thousand seed weight (TSW) of about 0.55 g and is characterised by a high sensitivity to unfavourable agroecological conditions, especially during germination and in the initial stages of vegetation, when a whole range of stress conditions can affect the subtle plants. Therefore, pre-sowing seed treatment leading to the reduction of the negative environmental impacts and supporting germination, growth, and vitality of healthy plants should be an integral part of poppy growing technology (Fejér and Salamon 2011).

In the Czech Republic, chemical treatment is still the most widespread treatment of poppy seed. The product Cruiser OSR, which is the predominant product used, contains an insecticidal component, thiamethoxam from the group of neonicotinoids, a fungicidal component, fludioxonil with a strong antimicrobial and antifungal effect, and another fungicidal ingredient, metalaxyl-M, which interferes with the development of the mycelium and fungal spores (Tomizawa and Casida 2005, Kilani and Fillinger 2016, Svartz et al. 2018). However, following the expected EU restriction on the use of neonicotinoids due to

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concerns about the negative impact on pollinating insects (Woodcock et al. 2018), Cruiser OSR cannot be counted on in the future, although its effect (as seed treatment) on pollinating insects was not proven (Thompson et al. 2016). Therefore, it is necessary to focus on other methods of seed treatment that could replace chemical products.

Various stimulation products can be used for the pre-sowing treatment of poppy seed, most of which are based on humic substances (Nardi et al. 2017, Procházka et al. 2019), amino acids (Teixeira et al. 2018), phytohormones (Procházka et al. 2019), microelements (Chau et al. 2019), and other compounds. Humic substances consist of humic and fulvic acids and account for approximately 65–70% of the organic matter in the soil. The mechanism of action of applied humic substances when acting on emerging plants probably consists of increasing cell membrane permeability, leading to enhanced photosynthetic activity, stimulating nutrient uptake and root cell elongation (Nardi et al. 2017). Amino acids have an important role in cell life and development. These substances may contribute to optimise the intake of some nutrients, are partially responsible for the biosynthesis of vitamins, stimulate plant growth, and help plants to withstand better environmental stress factors (drought, salinity, cold) (Sharma and Dietz 2006, Souri and Hatamian 2019). Similarly, phytohormones are biologically active compounds with a positive impact on plant growth, especially under environmental stress (McGuiness et al. 2019).

Biological products that can be used for the pre-sowing treatment of poppy seed include Polyversum and Gliorex. Polyversum is *Pythium oligandrum*-based product whose effect consists mainly in a direct antagonistic action against several pathogenic organisms (Rey et al. 2008). Gliorex, which comprises spores of *Clonostachys* sp. and *Trichoderma* sp. (Pánek et al. 2021), shows a strong ability to biologically regulate not only pathogenic fungi but also some nematodes (Sun et al. 2020).

Another possibility is using various physical methods such as E-ventus or biolaser seeds photostimulations (Tigges et al. 2002, Dłużniewska et al. 2021). Poppy seed treated with the E-ventus method is commercially offered in the Czech Republic. The E-ventus method works on the principle of low-energy accelerated electrons, which have a biocidal effect on some seed-borne pathogens (Tigges et al. 2002). The seed is not heated during the process, so its viability is not threatened (Röder et al. 2009).

Although there are several seed treatment options, including the use of stimulants, biological products, and physical methods, their effect has not been sufficiently investigated in the case of poppy seeds, and, above all, there is a complete lack of information on their efficacy at critical periods of germination and emergence of plants. Therefore, this study aimed to determine the effect of various poppy seed treatments on dynamics of plants emergence, yield component structure, seed yield, and oil content compared with Cruiser OSR treated seed and untreated control.

MATERIAL AND METHODS

Experimental conditions. The effects of various pre-sowing treatments of poppy seed on dynamics of field emergence, the structure of yield components, yield of seed, and oil content were evaluated in exact small-plot field trials carried out during the 2020–2022 growing seasons at the experimental base of the Czech University of Life Sciences Prague in Červený Újezd in the central part of Bohemia (50°4'22''N, 14°10'19''E), 398 m a.s.l., with the average annual temperature of 8.3 °C, and average sum of precipitation of 493 mm. As for the weather conditions (Table 1), 2020 exceeded the long-term standard in average monthly temperatures in April and August, while 2021 and 2022 reached higher average monthly temperatures in June and 2022 in August. Regarding precipitation, 2020 and 2021 were drier in April and 2020 in July compared to the long-term standard; the year 2021 exceeded the long-term standard in May 2022 in June, and all assessed years exceeded the long-term standard in August.

The experiment used two blue-seeded poppy cultivars of the Czech origin (Aplaus and Major). Randomised blocks in three replicates were designed with an average experimental plot area of 12 m^2. The field trials were established on March 18, 2020, March 30, 2021, and March 28, 2022, at a sowing rate of 1.75 kg seed/ha. Spring barley was used as a preceding crop in all evaluated years. Both preemergent (Callisto 480 SC – 0.2 L/ha + Command 36 CS – 0.25 L/ha) and post-emergent (Laudis WG – 0.5 kg/ha + Tomahawk – 0.5 L/ha) herbicidal treatments were used. Nitrogen fertilisation at a total dose of 100 kg N/ha was applied: part of the dose (50 kg N/ha) before sowing and the second part (50 kg N/ha) in BBCH 16–20. Fungicide treatment during vegetation was not performed. Harvesting was carried out on August 11, 2020, August 19, 2021, and August 16, 2022, using

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Table 1. The survey of average monthly temperatures and sums of precipitation (in months important for poppy vegetation) during the years 2020–2022 in comparison with long-term standard

Month	Average temperature (°C)				Σ of precipitation (mm)			
	2020	2021	2022	long-term standard	2020	2021	2022	long-term standard
February	4.50	0.19	3.78	0.3	56.9	36.2	18.4	18
March	4.51	4.60	4.57	4.0	45.4	24.2	16.3	28
April	10.24	6.26	7.52	9.2	12.6	9.3	44.6	27
May	12.14	11.25	15.63	13.6	50.4	101.9	41.9	60
June	17.45	19.86	19.91	17.0	71.8	83.1	139.1	71
July	19.10	19.75	19.60	18.9	29.2	82.1	57.5	77
August	20.51	16.98	20.42	18.7	110.9	101.9	100.6	66
Average temperature	12.70	11.27	13.06	11.68				
Σ of precipitation					377.2	438.7	418.4	347.3

a small-plot harvester (Wintersteiger, Ried im Innkreis, Austria) adapted for harvesting small-seeded crops. The field trials included six variants of pre-sowing poppy seed treatment using the chemical product Cruiser OSR, two stimulants (Enviseed and TS Osivo), two biological products (Polyversum and Gliorex), and a physical method (E-ventus). An untreated control was also included in the experiment. The overview of experimental variants is given in Table 2.

Evaluation of poppy field emergence, determination of yield, and structure of yield parameters. During the growing seasons, the dynamics of field emergence of poppy plants were evaluated for each variant using repeated counting of emerged plants from the beginning of emergence until the full emergence of the poppy stand. The evaluation was carried out at two marked sites (1 m^2) in each experimental plot. In addition to the average number of poppy plants per m^2 at the full stand emergence, the number of plants per m^2 at the end of vegetation was evaluated. The number of poppy capsules per plant and the weight of seeds per capsule were also determined. After the harvest, the seed yield and the TSW were assessed, and seed samples were taken for the oil content determination.

Oil content determination. Poppy seeds were ground using a laboratory grinder, and the obtained meal was used for analyses. Approximately 6 g of homogenised sample was weighed into the extraction thimble and extracted with petroleum ether using a Randall Hot Extraction apparatus E6 (Behr Labor-Technik GmbH, Düsseldorf, Germany). The obtained oil was weighed to the nearest ± 0.001 g. Results were calculated on a dry matter basis – seed samples were dried at 103 ± 2 °C to the constant weight (ISO 665, 2000). The analyses were performed in triplicate.

Statistical analysis. The obtained data were statistically analysed using three-factor ANOVA in the SAS program (version 9.4, SAS Institute, Cary, USA). The differences between the mean values were evaluated using Tukey's *HSD* (honestly significant difference) test at a level of significance $P \leq 0.05$.

Table 2. The overview of pre-sowing seed treatments variants

Treatment	Active substances	Dose per 1 kg of seed
Cruiser OSR	thiamethoxam 280 g/L fludioxonil 8 g/L metalaxyl-M 32.3 g/L	25 mL
TS Osivo	humic substances, amino acids, auxins, algae extract, N, P, K, B, Mo, Fe, Mg, Zn, Mn, Cu	10 mL
Enviseed	humic substances, amino acids, auxins, gibberellins, N, K, B, Cu, Fe, Mn, Zn	30 mL
Polyversum	*Pythium oligandrum*	5 g
Gliorex	*Clonostachys* spp. + *Trichoderma* spp.	4 g
E-ventus	physical method	
Control	–	

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RESULTS AND DISCUSSION

Field emergence. The results of the evaluation of the dynamics of field emergence determined by repeated plant counting are given in Figure 1. From Figure 1A, which characterises the effect of various seed treatments on the dynamics of field emergence over an average of three years (2020–2022), it is evident that the variants treated with both stimulation products Enviseed and TS Osivo reached the highest number of plants per m^2 during the first two plant counting. The same situation was also observed in individual years (Figure 1B–D). The variants treated with Enviseed and TS Osivo also belonged to the variants with the highest numbers of plants per m^2 overall; these values were at a similar level to the Cruiser OSR-treated variant. To the best of our knowledge, no information is available on the effect of pre-sowing seed treatments on germination and field emergence of poppies. However, there is some information on their effect on germination and field emergence for some other crops. Procházka et al. (2019), who evaluated the effect of soybean seed pre-sowing treatment with various stimulation products containing humic substances and phytohormones, found a positive influence of these compounds on field emergence and plant growth at the beginning of vegetation, whereas the best results were obtained with products containing auxins. Similar results were recorded in field experiments with the pre-sowing treatment of sorghum seed (Adamčík et al. 2016). In our study, variants treated with both stimulation products achieved similar field emergence, with slightly better results recorded for TS Osivo, which was enriched with algae extract. Furthermore, on average, the variant treated with TS Osivo reached a 61% higher number of plants per m^2 than the control. This increase was almost the same as reported by Carvalho et al. (2013), who studied the emergence of bean seeds treated with algae extract under laboratory conditions, and it was much higher than reported by Kurakula and Rai (2021), who found a 30% increase in field emergence in chickpea treated with algae extract. Thus, the slightly better results of TS Osivo compared to Enviseed may have been influenced by the enrichment of this product with algae.

Although the Cruiser OSR treated variant reached high values of the number of plants per m^2 at the end of plant emergence, it was one of the variants with the lowest number of plants per m^2 at the beginning of emergence (first and eventually second plant counting). According to De Viliers et al. (2005),

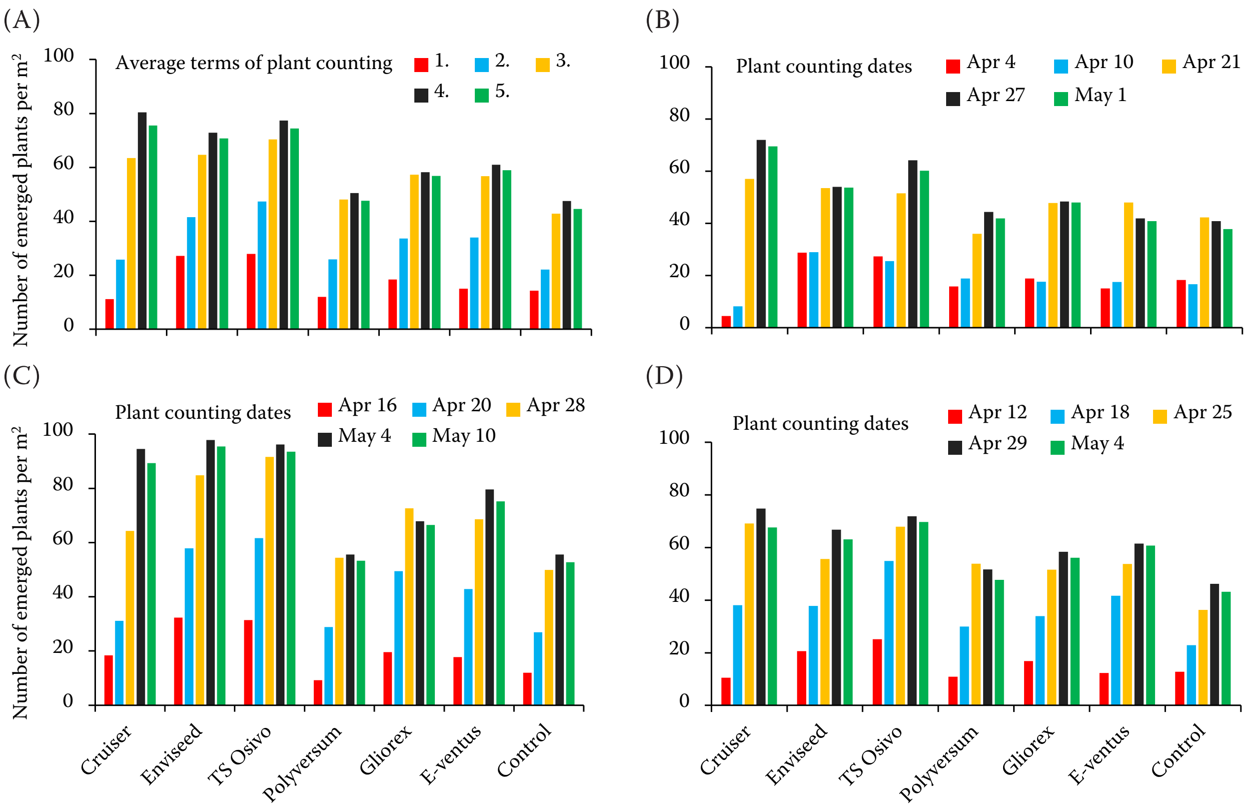

Figure 1. Dynamics of poppy field emergence in (A) average 2020–2022; (B) 2020; (C) 2021 and (D) 2022

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who investigated the effect of canola seed treatment with Cruiser OSR on germination and vigour under laboratory conditions, this trend may be explained by a phytotoxic effect of certain active substances contained in this product on the seed, which was manifested by reduced germination energy, while the final germination remained unchanged.

For the variants treated with biological products Polyversum and Gliorex, the dynamics of field emergence were slower compared to the treatment with stimulants, and, concurrently, the variants treated with biological products overall achieved a considerably lower number of plants per m^2. According to Le Floch et al. (2003), the effectiveness of biological products is strongly influenced by environmental factors. Particularly the temperature and moisture conditions in the soil during seed germination and emergence play an important role. In unfavourable conditions, especially during drought, sufficient development of biological agents cannot occur.

Yield and quality parameters. The results (Table 3) showed that the untreated control had the lowest number of plants per m^2 at the full field emergence (50.2) and differed significantly from the treated variants, except for the variant treated with Polyversum (54.3). The highest number of plants per m^2 (81.2) was found for the stimulant TS Osivo treatment, which was not statistically different from the variants treated with Cruiser OSR and Enviseed.

In order to achieve a satisfactory yield of a poppy seed, it is important not only to have a high number of plants at the beginning of the growing season but also at the end of vegetation before harvest. The results in Table 3 also showed a decrease in the density of the stand during the growing season. According to Fejér and Salamon (2011), the optimal poppy stand density at the end of vegetation varies between 50–70 plants per m^2. In our experiments, the number of plants per m^2 before the harvest ranged between 55.8 in the variant treated with Cruiser OSR (which differed significantly from all other variants) and 29.5 plants per m^2 in the untreated control that also differed from the other variants except for the variant treated with Polyversum. On average, of all

Table 3. Evaluated production and quality parameters of poppy depending on the seed treatment, cultivar, and crop year (Tukey's *HSD* (honestly significant difference) test at the level of $P < 0.05$)

	Number of plants/m^2		Number of capsules per plant	Weight of seed per capsule	TSW (g)	Yield (t/ha)	Oil content (%)
	full field emergence*	end of vegetation					
Cruiser OSR	80.1^{a}	55.8^{a}	2.2^{abc}	2.74^{a}	0.567^{a}	1.39^{a}	43.37^{a}
Enviseed	75.9^{a}	47.4^{b}	2.2^{bc}	2.57^{a}	0.554^{ab}	1.16^{b}	42.95^{a}
TS Osivo	81.2^{a}	48.9^{b}	2.4^{ab}	2.73^{a}	0.558^{ab}	1.23^{b}	43.18^{a}
Polyversum	54.3^{cd}	28.7^{d}	2.6^{a}	2.77^{a}	0.545^{b}	0.85^{d}	41.72^{ab}
Gliorex	61.3^{bc}	34.6^{c}	2.2^{abc}	2.48^{a}	0.555^{ab}	0.95^{c}	42.64^{ab}
Eventus	64.4^{b}	36.2^{c}	1.9^{c}	2.57^{a}	0.548^{b}	0.91^{cd}	41.25^{b}
Control	50.2^{d}	29.5^{d}	2.6^{a}	2.48^{a}	0.550^{ab}	0.88^{cd}	42.31^{ab}
$HSD_{0.05}$	8.8	4.27	0.3	0.34	0.019	0.09	1.65
Aplaus	64.4^{b}	39.6^{a}	2.4^{a}	0.565^{a}	2.73^{a}	1.07^{a}	43.59^{a}
Major	69.3^{a}	40.7^{a}	2.3^{a}	0.543^{b}	2.49^{b}	1.04^{a}	41.39^{b}
$HSD_{0.05}$	3.1	1.5	0.1	0.009	0.12	0.04	0.58
2020	55.9^{c}	33.1^{c}	2.4^{a}	2.23^{b}	0.521^{b}	0.84^{c}	39.46^{c}
2021	80.6^{a}	50.9^{a}	2.0^{b}	2.79^{a}	0.568^{a}	1.32^{a}	43.49^{b}
2022	64.1^{b}	36.5^{b}	2.5^{a}	2.80^{a}	0.573^{a}	0.99^{b}	44.51^{a}
$HSD_{0.05}$	4.6	2.2	0.15	0.18	0.01	0.05	0.90

TSW – thousand seeds weight. *Values in the first column show the number of plants/m^2 in the full field emergence of individual variants; these values may not be the same as the maximum values of field emergence shown in Figure 1, as these figures show the dynamics of field emergence, and not all replicates within each variant reached the maximum value of field emergence at the same term of plant counting

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variants, the reduction in the number of plants during the growing season was about 40%.

It is also evident from the results that the number of plants per m^2 at the time of harvest was a crucial factor for achieving satisfactory seed yield since the variability in the structure of other yield parameters (number of capsules per plant, weight of seed per capsule, and TSW) was relatively low. The differences between the seed treatments examined were statistically insignificant in these yield parameters in most of the cases.

The Cruiser achieved the highest average yield (1.39 t/ha) OSR treated variant, which was significantly different from all other treatments. The increase in yield was about 58% compared to the control, which was much higher than that reported by Dewar et al. (2011), who evaluated the efficacy of Cruiser OSR as a seed treatment for oilseed rape and found a yield increase of about 5–11% over the untreated control, depending on locality. However, both stimulation products (TS Osivo and Enviseed) showed a significant yield increase compared to biological and physical treatments and untreated control. On average, of all three years, the yield increase for the TS Osivo treated variant was about 40%, and for the Enviseed treated variant, about 32% compared to the control. Procházka et al. (2019) evaluated the effect of treating soybean seeds with selected stimulation products and found an increase in soybean yield of 9–18% for treated variants compared to the control. In contrast to the authors' results mentioned above, the effect of the poppy seed treatments with chemical and stimulation products used in our experiment was significantly higher. However, it should be taken into account that the small-seeded poppy copes much worse with the various stress factors that occur during germination and field emergence than seeds with higher TSW (Souza and Fagundes 2014, Janicka et al. 2021). Therefore, it can be expected that the response of poppies to supportive measures in the form of seed treatment will be higher.

In the case of the oil content in seeds, no significant differences between the individual variants were found. A trend of higher oiliness was noted for variants with higher TSW. The total oil content varied from 41.2% to 43.4%, and the differences between the evaluated variants were insignificant in most cases. The oil content recorded in the present study was higher than the 33.6% obtained by Azcan et al. (2004) and comparable with the results of Duman and Őzcan (2015) – 44.50%.

Weather conditions. In Table 4, a more detailed view of the results of individual years is provided, indicating a different structure of the yield parameters. The variation in the results observed between the years studied is in accordance with the contention of other authors that poppy seed yield is usually strongly affected by the weather conditions during the growing season (Škarpa and Richter 2011).

The year 2020 was characterised by the lowest number of plants per m^2 at the beginning of vegetation. The lack of precipitation in the first two decades of April, the decisive period of plant emergence, combined with above-average temperatures during April, was probably the main reason for this situation. As mentioned above, the decrease in the number of plants per m^2 during vegetation from the full field emergence to harvest was 40.8%. The final number of plants per m^2 at the end of vegetation was the lowest of all years evaluated and varied from 50.0 (Cruiser OSR treated variant) to 24.1 plants (control). The low number of plants per m^2 was associated with a higher average number of poppy capsules per plant. At the same time, the lowest TSW and oil content values were found in 2020, which was mainly due to insufficient precipitation during the poppy ripening period. These findings are in accordance with the conclusions of Lančaričová et al. (2016), who found a reduced oil content in poppy grown in a locality with lower rainfall during June and July. Less favourable weather conditions in 2020 also led to the lowest seed yields of the years monitored, ranging from 0.67 t/ha (Polyversum treated variant) to 1.36 t/ha (Cruiser OSR treated variant).

Even in 2021, April was below average in terms of precipitation, but the precipitation was evenly distributed, and the number of plants per m^2 at the time of full plant emergence was the highest of all years monitored. Likewise, the highest number of plants per m^2 at the end of vegetation was observed – from 66.6 plants (Cruiser OSR treated variant) to 35.0 plants (Polyversum treated variant). The higher stand density was associated with a lower average number of capsules per plant. The higher stand density, together with favourable weather conditions at the time of ripening, resulted in the highest yields of all the years evaluated, ranging from 1.14 t/ha (E-ventus) to 1.50 t/ha (Cruiser OSR and Enviseed). In 2021, higher TSW and oil content were also observed compared to 2020.

In 2022, the number of plants at the beginning and end of the vegetation period was higher compared to 2020 but lower compared to 2021, which was also

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Table 4. Evaluated production and quality parameters of poppy in individual years (Tukey's *HSD* (honestly significant difference) test at the level of $P < 0.05$)

Year	Treatment/ cultivar	Number of plants/m^2 full field emergence*	Number of plants/m^2 end of vegetation	Number of capsules per plant	Weight of seed per capsule	TSW (g)	Yield (t/ha)	Oil content (%)
2020	Cruiser OSR	72.2^{a}	50.0^{a}	2.1^{b}	2.71^{a}	0.568^{a}	1.36^{a}	39.64^{a}
	Enviseed	58.9^{ab}	38.8^{b}	2.2^{b}	1.82^{b}	0.529^{b}	0.94^{b}	39.56^{a}
	TS Osivo	66.6^{a}	36.2^{bc}	2.6^{a}	2.28^{ab}	0.512^{b}	0.96^{b}	40.48^{a}
	Polyversum	45.4^{b}	25.9^{d}	2.5^{ab}	2.54^{a}	0.530^{b}	0.67^{c}	39.76^{a}
	Gliorex	52.4^{b}	24.3^{d}	2.4^{ab}	2.21^{ab}	0.501^{bc}	0.63^{c}	38.51^{a}
	Eventus	48.7^{b}	32.5^{c}	2.3^{ab}	1.82^{b}	0.483^{c}	0.69^{c}	38.70^{a}
	Control	47.5^{b}	24.1^{d}	2.6^{a}	2.02^{b}	0.519^{b}	0.68^{c}	39.54^{a}
	$HSD_{0.05}$	13.59	5.5	0.4	0.50	0.025	0.16	2.71
	Aplaus	51.9^{b}	32.0^{b}	2.5^{a}	2.35^{a}	0.523^{a}	0.80^{b}	40.91^{a}
	Major	59.9^{a}	34.2^{a}	2.3^{b}	2.11^{b}	0.519^{a}	0.89^{a}	38.02^{b}
	$HSD_{0.05}$	4.6	1.9	1.15	0.17	0.008	0.06	0.944
2021	Cruiser OSR	94.6^{ab}	66.6^{a}	1.7^{cd}	2.92^{a}	0.568^{ab}	1.50^{a}	45.38^{a}
	Enviseed	99.7^{a}	63.9^{a}	1.8^{bcd}	2.52^{a}	0.560^{ab}	1.50^{a}	43.85^{ab}
	TS Osivo	99.9^{a}	62.9^{a}	2.2^{abc}	2.87^{a}	0.586^{a}	1.48^{a}	43.58^{ab}
	Polyversum	59.8^{d}	35.0^{c}	2.6^{a}	2.95^{a}	0.547^{b}	1.18^{b}	42.42^{ab}
	Gliorex	72.7^{cd}	46.7^{b}	1.7^{d}	2.82^{a}	0.579^{a}	1.31^{ab}	44.29^{ab}
	Eventus	79.8^{bc}	42.3^{bc}	1.7^{d}	2.64^{a}	0.568^{ab}	1.14^{b}	41.79^{b}
	Control	57.8^{d}	38.9^{bc}	2.3^{ab}	2.52^{a}	0.564^{ab}	1.15^{b}	43.11^{ab}
	$HSD_{0.05}$	18.3	9.9	0.56	0.67	0.030	0.21	3.35
	Aplaus	82.2^{a}	52.0^{a}	2.2^{a}	2.93^{a}	0.583^{a}	1.43^{a}	44.56^{a}
	Major	79.1^{a}	49.8^{a}	1.9^{b}	2.66^{b}	0.552^{b}	1.21^{b}	42.42^{b}
	$HSD_{0.05}$	6.3	3.4	0.19	0.23	0.011	0.08	1.15
2022	Cruiser OSR	75.3^{a}	50.7^{a}	2.7^{a}	2.59^{ab}	0.567^{a}	1.33^{a}	45.09^{a}
	Enviseed	69.1^{ab}	39.4^{b}	2.6^{a}	3.11^{a}	0.570^{a}	1.03^{b}	45.44^{a}
	TS Osivo	77.3^{a}	47.5^{a}	2.4^{ab}	3.06^{ab}	0.575^{a}	1.27^{a}	45.49^{a}
	Polyversum	57.6^{bc}	25.3^{d}	2.7^{a}	2.48^{bc}	0.558^{a}	0.69^{d}	42.98^{a}
	Gliorex	58.9^{bc}	32.8^{bc}	2.6^{a}	2.42^{c}	0.577^{a}	0.91^{bc}	45.13^{a}
	Eventus	64.7^{ab}	33.9^{b}	1.9^{b}	3.01^{ab}	0.593^{a}	0.91^{bc}	45.12^{a}
	Control	45.3^{c}	25.7^{cd}	2.9^{a}	2.92^{abc}	0.567^{a}	0.84^{cd}	44.28^{a}
	$HSD_{0.05}$	16.2	7.2	0.6	0.58	0.040	0.14	2.9
	Aplaus	59.3^{b}	34.8^{b}	2.6^{a}	2.92^{a}	0.587^{a}	0.96^{b}	45.30^{a}
	Major	69.1^{a}	38.2^{a}	2.4^{a}	2.68^{b}	0.558^{b}	1.04^{a}	43.74^{b}
	$HSD_{0.05}$	5.6	2.4	0.2	0.21	0.015	0.05	1.01

TSW – thousand seeds weight; *Values in the first column show the number of plants/m^2 in the full field emergence of individual variants; these values may not be the same as the maximum values of field emergence shown in Figure 1, as these figures show the dynamics of field emergence, and not all replicates within each variant reached the maximum value of field emergence at the same term of plant counting

true for the yield of seed, which ranged from 0.69 t/ha (Polyversum) to 1.33 t/ha (Cruiser OSR). Favourable weather conditions during ripening led to the highest TSW and oil content of all years evaluated.

https://doi.org/10.17221/364/2022-PSE

In conclusion, the results showed different effectiveness of the poppy seed treatment methods used on the field emergence, yield quantity and quality. The effectiveness of the biological products Gliorex and Polyversum used in our experiment and the physical treatment of poppy seed using the E-ventus method was generally lower than the stimulation products used, but even in their case, there was usually an increase in field emergence and seed yield compared to control. The use of biological and physical seed treatment methods is mainly offered in organic farming. Therefore, it would also need to continue their research and testing due to the increasing interest in organic poppy production. The variants treated with TS Osivo and Enviseed stimulation products showed similar field emergence and seed yield results as those treated with Cruiser OSR. Despite the positive effect of seed treatment with stimulation products, which was observed in our experiment, it would also need to look for new types of environmentally friendly products with a fungicidal-insecticidal effect that could be used when Cruiser OSR will be banned.

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Received: October 12, 2022
Accepted: November 8, 2022
Published online: November 28, 2022