USE OF AERIAL APPLICATION OF POD SEALANTS IN CANOLA CROPS

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Abstract
Canola is important and widely grown agricultural crop. When growing canola, a losses caused by pod shattering are a problem. These losses can be reduced by applying pod sealant. Two methods of pod sealant application, aerial and ground, were compared in 2021 growing season. A pilot experiment was set up for this purpose. The results showed that in the conditions of the Czech Republic, the use of pod sealing technology is advantageous when using both ground and aerial applications. However, the use of an aerial application is more advantageous than a ground application, because it does not cause losses due to damage to the vegetation by the crossing of agricultural machinery.

Key words: *aerial spraying; ground spraying; effectiveness of spraying; canola losses; economic evaluation.*

INTRODUCTION

Canola, or rapeseed (Brassica napus) is an important and widely grown agricultural crop. Current world production is around 70 million tons out of around 35 million hectares, with canola being grown on around 5.3 million hectares in the European Union, producing approximately 17 million tons *(USDA, 2022*). For example, in the Czech Republic, in the period between 2016 and 2020, canola was grown on an average of 368,000 hectares of arable land per year and its average annual production was 1.26 million tons (*Czech Statistical Office, 2021*).

Losses caused by pod shattering are problem in canola growing and harvesting (*Child et al., 2003; Gulden, Shirtlie & Thomas, 2003; Zhu et al., 2012*). In order to reduce these losses, canola crops are now commonly treated with pod sealants with different results (*Kosteckas et al., 2009; Nunes et al., 2015; Bauša et al., 2018; Steponavičius et al., 2019*). According to *Bauša et al. (2018)*, the application of acrylic- and trisiloxane-based pod sealant is the most promising method of pod shattering control. The essence of the function of these substances lies in the physical prevention of valve separation by gluing them together and in altering the pod moisture regime (sealant allows moisture to leave the pod but prevents getting into it).

A common way of treating canola crops by pod sealant is to apply it by spraying (*Bauša et al., 2018; Steponavičius et al., 2019*). There are various methods of spraying. Probably the most common and widely researched method of spraying is ground application using a tractor operated or self-propelled sprayer (e.g. *Anthonis, Audenaert & Ramon, 2005; Wrest Park History Contributors, 2009; Faiçal et al., 2017; Penney et al., 2021;* and many others). Another possibility is aerial application, both when using a pilot-controlled aircraft (e.g. *Viret et al., 2003; Hevitt, 2008; Jiao et al., 2021; Penney et al., 2021*; etc.) or an unmanned aerial vehicle (e.g. *Qin et al., 2016; Faiçal et al., 2017; Gibbs, Peters & Heck, 2021; Zhan et al., 2022;* and others). All spraying methods have its advantages and disadvantages. Terrestrial spraying is based on ground vehicles. Paths are needed within the crop field. Therefore, this method is usually slow and has contact with the culture, which decreases the production area and can damage healthy plants. On the other hand, small distance of spraying system and treated crop reduces the drift of chemicals to neighboring areas - terrestrial application is able to reach relatively high accuracy of spraying (*Faiçal et al., 2017)*. In contrast, according to *Nádasi and Szabó (2011)*, the aerial spraying is faster without the need for paths. However, the larger distance between the spraying system and the cultivated area increases protective substance drift to neighboring areas.

Nevertheless, the advantages and disadvantages of pod sealant aerial and ground applications have not been compared in the past. That is why the main aim of this contribution is to compare ground and aerial way of pod sealant application on the basis of a field experiment carried out on a common agricultural holding in the Czech Republic in the growing season 2021.

MATERIALS AND METHODS

A pilot experiment was set up in order to compare different technologies of canola crops treatment against spontaneous pods shattering. The experiment was established on the land block 3901 "K Bříšťanům" of the Agricultural Joint Stock Company Mžany. Track lines for application technology with a working width of 30 m were used. Five test plots 60 m wide and approximately 740 m long were created on the land block. The first plot was a control and was not treated. The second plot was treated with a tractor set with a trailed sprayer, the third with a self-propelled sprayer, the fourth by aerial application using an atomizer and the last fifth by conventional aerial spraying. Arrest Plus® protective substance was used in all cases at a rate of 1 l per hectare. The application was carried out in the interest of the greatest possible objectivity of the measurement within one day, June 29, 2021. Detailed information on application technology and application is given in Tab. 1.

Tab. 1 Used application technique and amount of applied spray mixture on individual plots.

Plot No.	Method of treatment	Machinery used	Applied dose of spray mixture
1	Control	-	-
2	Trailed tractor sprayer	Case 160 CVX +Agrio Mamut Topline (30 m)	200 l/ha
3	Self-propelled sprayer	Tecnoma (30 m)	200 l/ha
4	Aerial application using atomizer	Agricultural aircraft Čmelák Z 37 T equipped by atomizer	2 x 5 l/ha (2 x flight over the plot, there and back)
5	Conventional aerial spraying	Agricultural aircraft Čmelák Z 37 A equipped by sprayer	110 l/ha

On June 29, 2021, the day of the protective substance application, the first experiments were performed for the purpose of visual evaluation of the test plots. The pictures of the test plots were taken with the eBee X unmanned system (fixed wing) equipped with an RGB camera S.O.D.A. working in the visible part of the spectrum (senseFly SA, Cheseaux-Lausanne, Switzerland). The unmanned vehicle mission was carried out after the treatment of the canola crop with all compared application technologies.

Further measurements were focused on the effectiveness of the application of the protective substance in order to reduce pre-harvest and harvest losses of rape. Land block with pilot experiment was harvested on 30-31 July 2021 by Claas Lexion 580 combine harvester using an adapter V 900 with 9 m width. The machine was equipped with a yield mapping device. A yield map of the entire soil block with test plots was subsequently created in SW ArcGIS Pro and QGIS using the Kriging method. The individual recorded relative yield values were recalculated so that the average yield on the land block corresponded to the actually determined yield. Subsequently, individual test plots were delimited in the QGIS software. Its average yield was calculated on each of the plots. The average yields from individual plots were then compared with the average yield of the entire land block.

On July 20, 2021, 15 samples of whole plants were taken to determine the yield in the footsteps of agricultural machinery in the track lines. Three samples with an area of 3 m^2 were taken on each of the test plots. Samples were taken from an area 1 m wide across the track line and 3 m long in the direction of the track line at a distance of about 100 m from the headland. The track width of agricultural machinery was 0.5 m. During storage in the laboratory, the samples were naturally dried evenly to the same moisture of 7.2%. In order to calculate the effect of the change in yield in the track lines using different application technologies, the effect of the change in yield in the track lines on the total yield from 1 ha was compared. It was calculated with a measured average track width of 0.5 m and an area of 1 ha (100 x 100 m). To treat this area by ground application at a width of 30 m, 3.3 rides are required, i.e. 6.7 feet of agricultural machinery with a length of 100 m. In this area, there may have been a change in yield due to crossings of agricultural machinery and the total canola yield from 1 ha of area could be affected.

On August 20, 2021, the germinated canola plants from the losses were also counted. The germinated plants were counted not behind the combine's straw walkers, but only in the area behind the cutting bar. Quarter meters were used to determine the number of germinated plants. On each plot, this number was counted at 4 different locations. The average of these 4 measurements was calculated and then recalculated to the average germination from 1 m^2 area. The germinated canola plants can be considered as losses, so they were converted to 1 ha. To calculate the loss estimate, it was assumed that about 90% of rapeseed would germinate.

RESULTS AND DISCUSSION

From the visual comparison, at first glance, the damage to the canola crop in the wheel tracks in the track lines after the passage of agricultural machinery and partly also in the space between the wheels was obvious. The vegetation collapsed here, especially in the case of the passage of a trailed sprayer, due to the low ground clearance of the tractor chassis. After the passage of the self-propelled sprayer, the situation was significantly better, especially between the wheels, compared to the set with a trailed tractor sprayer. In both of these monitored variants, however, the traces of the passage of agricultural machinery were quite obvious in comparison with the control plot. On the headlands, this fact became even more significant. When visually comparing the plots treated by aerial spraying with the control plot, no change in the track lines was observed.
Already during the visual evaluation of the yield map obtained, it was observed that the lowest yield was achieved on control plot which were not treated by pod sealants. Everything is clear from Tab. 2, where the yields on the individual test plots are compared.

Tab. 2 Measured canola yield on the soil block and yields calculated from the measured yield map on the test plots.

Plot No.	Method of treatment	Yield on soil block (t/ha)	Yield on individual plots (t/ha)
1	Control		3,19
2	Trailed tractor sprayer		3,46
3	Self-propelled sprayer	3,67	3,8
4	Aerial application using atomizer		4,06
5	Conventional aerial spraying		3,8

When comparing the yield on individual test plots, Tab. 2 shows that the worst average yield from the treated plots was achieved on plot 2 treated with a trailed tractor sprayer. Plots 3 and 5 treated with a self-propelled sprayer and a conventional aerial spraying showed the same yield. The aerial application with an atomizer on plot 4 came out as the best.

Tab. 3 Table of the number of germinated plants from canola losses and canola losses derived from emerged seeds.

Plot No.	Method of treatment	Number of emerged canola seeds per ¼ m^2				Average on ¼ m^2	Number of emerged canola seeds per m^2	% of losses reduction	*Losses. (kg/ha)
		A	B	C	D				
1	Control	156	262	412	480	328	1310	100	69,5
2	Trailed tractor sprayer	344	308	203	182	259	1037	79	55,0
3	Self-propelled sprayer	208	108	252	128	174	696	53	36,9
4	Aerial application using atomizer	108	124	182	148	141	562	43	29,8
5	Conventional aerial spraying	102	96	143	98	110	439	34	23,3

*Losses were calculated on the base of the weight of a thousand canola seeds, which was 4.82 g. The calculation assumed that about 90% of all lost seeds germinated.
Tab. 3 shows the values of germinated canola seeds after harvest. Based on these values, losses on individual plots were estimated.
The largest amount of germinated plants (and therefore also losses) was found on the control plot, which was not treated. This is a clear argument in favor of treatment with pod sealants in order to reduce pre-harvest and harvest canola losses. It was also found that the effectiveness of aerial application of the preservative is quite comparable, if not better than the effectiveness of ground application. According to the results of our measurements, the conventional aerial application came out best, when the amount of losses compared to the control decreased to 34% (from 100% losses on untreated plots). Ground applications also had a positive effect on the amount of losses found, but not as significant as in the case of aerial applications. The values measured for the trailed tractor sprayer were the worst (decrease to 79% of losses only), which corresponds to the increased damage to the vegetation in the track lines, found both in the visual evaluation and in the evaluation of losses in track lines (see below).
The values of the total measured and calculated rapeseed yield and the yield measured in traces of agricultural machinery on all monitored plots are given in Tab. 4.

Tab. 4 Measured yield in track lines of agricultural machinery. Calculated reduced yield on trial plots due to lower yield in track lines.

Plot No.	Method of treatment	*Measured average yield from 3 m^2 (g)	*Measured average yield (t/ha)	Reduced yield (t/ha)	Difference in yield (kg/ha)
1	Control	1069,5	3,57	3,67	0
2	Trailed tractor sprayer	580,4	1,93	3,61	60
3	Self-propelled sprayer	769,3	2,56	3,63	40
4	Aerial application using atomizer	880,6	2,94	3,65	20
5	Conventional aerial spraying	884,4	2,95	3,65	20

*Yield measured in track lines after the crossing of agricultural machinery.

For each of the variants, the difference in yield compared to the average hectare yield of the entire land block was calculated. The average yield on this land block was 3.67 t/ha. The difference in yield was calculated on the basis of a comparison of the size of the track lines area to the area of 1 ha. Based on the data described in the methodology, the track lines area represents 3.3% of 1 ha area. Therefore, a weighted average was used to calculate the reduction in yield per hectare due to the reduction in yields in the tramlines. The average plot yield of 3.67 t/ha on the area of 9,667 m^2 was calculated and on the rest up to 1 ha (333 m^2) it was calculated with the average yield measured in the track lines given in Tab. 4.
Although the visual comparison showed exactly the same condition of the track lines in comparison with the control plot, in the case of both air-treated test plots a slightly lower yield was measured in the track lines. In our opinion, there is no objective reason for this reduction in yield. This situation could be due to the small number of yield measurements repetitions or due to different yields at yield sampling points (we could not consider the differences in yield; the yield map was not available at the time of yield sampling). Nevertheless, in the case of the control plot, the reduction in yields due to lower yields in the track lines was negligible, in the case of aerial treatment, in both cases (atomizer and conventional), the yield decreased by 20 kg/ha.
However, the reduction of yields due to the crossing of the sprayers during ground application was even more significant. In the case of a self -propelled sprayer, based on our measurements, we have determined a reduction in yields by an average of 40 kg/ha and in the case of tractor trailed sprayer, this

reduction on average was 60 kg/ha. This measured result is fully in agreement with the visual evaluation of the status of canola crop after aerial and ground application.
In 2021, in the Czech Republic, the cost of self-propelled sprayers working in services was in the range of CZK 250-270 per hectare, plus approximately 2 l/ha of consumed diesel (additional CZK 50), which in total is approximately 320 CZK/ha. The price of the aviation application was between 311 and 339 CZK/ha. The price for the treatment of one ha of canola crop was in both cases (ground x air application) approximately the same (about 320 CZK/ha). Service work (water, filling) is also approximately comparable for both applications. The price for the chemical preservative Arrest Plus® is approx. 500 CZK/ha (1 liter of the product). In the summer of 2021, the price of rapeseed was about 11,500 CZK/t. It is clear from Tab. 2 that the average yield on untreated control plots 1 was 3.19 t/ha, while the average yield on treated plots 2-5 was 3.78 t/ha. This means a difference in yield of 0.59 t/ha. Due to treatment of the canola crop by pod sealants, the revenue from one hectare was approx. CZK 6,800 more than in comparison with untreated crop. Based on the results of our measurements, it can be stated that the savings by reducing losses far exceed the price of treatment per hectare, which will be up to 1,000 CZK/ha, even with services works. The treatment of the canola crop by pod sealants it is therefore clearly advantageous and can be recommended. Similar results were obtained by the authors *Nunes et al. (2015)*, who recommended the use of pod sealant as effective in the case of later than ideal time harvesting of canola crops by various methods. *Bauša et al. (2018)* reported beneficial effect in reducing canola seed yield losses using pod sealant. Also, *Steponavičius et al. (2019)* reported 20-70% canola seeds losses reduction using pod sealant.
Based on our results, it can also be stated that the air application of pod sealant is more advantageous than the ground application. The crop undamaged by agricultural machinery showed a higher yield of another 40-60 kg/ha, which means revenue higher by another 460-690 CZK/ha. *Nádasi and Szabó (2011)* also pointed out this advantage of the aerial application. *Antuniassi (2015)* then pointed out the development of aerial applications in Brazil.

CONCLUSIONS

Based on the results of our pilot experiment, it has been shown that the use of pod sealing technology to reduce rapeseed harvest losses is recommended and it is also financially beneficial for farmers. It has also been shown that pod sealant aerial application is more advantageous than ground application because it does not cause any damage to the vegetation.

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