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ORIGINAL PAPER

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MINERAL OILS IMPACT ON YIELD OF PROGENY BULBS AND QUALITY OF CUT TULIP FLOWERS AS WELL AS SPREAD OF VIRUSES

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ABSTRACT

The experiment assess the effectiveness of two mineral oils: Sunspray 850 EC (85% mineral oil) and Sunspray Ultra-Fine (98.8% mineral oil) on tulip 'Leen van der Mark' fields. Tulip plants were sprayed once a week for three weeks. Mineral oils were applied at concentrations of 1.0, 1.5, and 2.0%. The oil preparations did not negatively affect the length of flower shoot and tepals of tulips grown in field. No phytotoxic symptoms were observed on leaves, however their color was altered. In all combinations protected using oils, the number of plants with virus symptoms on petals was lower than for control. No decrease in the commercial and the first choice bulb yields due to the mineral oils application were recorded. Mineral oils applied at concentration up to 2.0% had no negative contribution on the quality of produced tulip flowers. Despite of the selection made in the field, from 60 to 73% plants showed virus symptoms in control combination during plant forcing. Efficiency of oils in reducing the spread of viruses depended on the year of study and oil type. The best effects were achieved using Sunspray 850 EC at 1.5% concentration (26% virus-infected plants). The oil preparations, despite of high efficiency in reducing the virus spread, did not guarantee a full protection in the field in any year of study.

Key words: bulb plant, virus spread, oil substances

INTRODUCTION

Tulips are ranked nowadays at the third place in terms of cut flowers production. Market demands for healthy and high-quality material, i.e. bulbs, are very high. For many years, viruses have been the most important problem in tulip growing. Tulips are reproduced vegetatively by means of progeny bulbs, which causes considerable accumulation of viruses and favors their spread. To date, 22 different viruses able to infect tulips, are described [Mowat 1995]. The most frequent are: *Tulip breaking virus* (TBV), *Lily symptomless virus* (LSV), *Cucumber mosaic virus* (CMV), *Tabacco necrosis virus* (TNV), and *Tabacco rattle virus* (TRV). Viruses lead to worse plant growth, and lower number and weight of progeny bulbs. Tulips form lower flowers, and also produce less pollen and seeds. Five of twenty described viruses induce color breaking in petals in a form of stripes, smug and sophisticated patterns on petals, sometimes with different color [Dekker et al. 1993]. It is usually symptom of infection by TBV virus that is most common on plantations in The Netherlands and Poland [Sochacki 2007]. Viruses infecting tulip plants are persistently transferred by several aphid species: *Myzus persicae*, *Aphis gossypii*, *Aphis fabae*,

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Dysaphis tulipae, *Macrosiphum euphorbiae*, and *Aulocorthum circumflexum* [Hammond and Chastagner 1989]. Symptoms of viral infection differ depending on a variety and time from the plant infection moment. If infection occurs sooner than 11 days before flowering, symptoms on petals cannot manage to appear [Lesnaw and Ghabrial 2000 as cited in Yamaguchi and Hirai 1967]. The rate of virus spread differs at individual tulip varieties. Thomsen [1980] observed virus-like symptoms on flowers of Rose Copland on 12–15th day after infection. For Flying Dutchman cv., symptoms on flowers appeared 16 days after infection [Romanow et al. 1986 as cited in Kusaba et al. 1974]. It is possible limit virus inoculum by vector control and introduction of tulip cultivars resistant in the crop. The selection is time-consuming and is inefficient in the case of varieties with white and yellow flowers, on which symptoms are not visible, and only on leaves at early developmental stages [Sochacki 2013]. The use of chemical treatment is purposeful only in the case of valuable varieties, while it is useless at highly infected plants [Sochacki and Podwyszyńska 2012]. Studies upon the resistance of a spectrum of tulip varieties towards viruses revealed that botanical species and varieties from Kaufman's, Grieg's, and Foster's botanical groups are free from viruses [Romanow et al. 1986, Sochacki 2007]. For botanical tulip varieties, at which ELlSA test showed the TBV virus presence, no disease symptoms on plants were observed. Also at varieties from hybrid Darvin's group belonging to triploids, viruses reproduce and transfer within a plant at slow [Romanow et al. 1986]. Considering the commercial growing, breeding varieties, the sensitivity to viruses of which is often very high, prevail.

To eliminate aphids on tulip plantations, mainly insecticides are used, but they are not fully efficient, because aphids appear on plants gradually since April till end of June, and viruses infecting tulip are generally transmitted by quick acquisition and inoculation periods. Furthermore, the insecticides are also dangerous for people and bees. An alternative solution can be preparations containing mineral oils that have been introduced into the common use for orchards to compete spider mites and soft scales [Soika et al. 2008]. The oil preparations are also applied to protect potato plantations against viruses transferred by aphids in an unstable way [Wróbel 2006, 2008, 2011a, 2011b, Milošević et al. 2012].

The aim of the undertaken research was to evaluate the effectivity of two commercial oil preparations to reduce spread of viruses in a field and glasshouse cultivation of tulips. The influence of those preparations on a quality of flowers and yield of bulbs, as well as a subsequent effect on a quality of plants cultivated in a glasshouse.

MATERIAL AND METHODS

The field and greenhouse experiments with tulip bulbs of cv. Leen van der Mark were carried out in 2008–2011 in the experimental farm Felin belonging to The University of Life Sciences in Lublin (Poland, 51°23'N, 22°56'E). Forty-five bulbs with 8–10 cm diameter were planted in a square meter plots using five replicates in randomized blocks patters for each treatment. Sunspray 850 EC (85% of mineral oil, producer Sun Oil Company Belgium) and Sunspray Ultra-Fine (98.8% of mineral oil, producer HollyFrontier GB), two commercial mineral oil preparations, were used at concentrations of 1.0, 1.5, and 2.0% using 400 $L \cdot ha^{-1}$ water. The preparations were applied by means of knapsack sprayer fitted with a spray Tee-Jet. Three sprayings were applied at weekly intervals. The control was sprayed with water. Measurements of plant height from the field surface to the end of perianth and length of tepals at the full of flowering stage were noted. Plants with virus – like symptoms were counted and after they were removed and destroyed. At the end of June, the harvested progeny bulbs were dried, cleaned, counted, and weighed. The total yield and the commercial value of the bulbs were determined taking into account the bulbs with more than 11 cm circumference and weight of the first choice bulbs (>12 cm circumference).

The greenhouse experiments were conducted in order to determine the sequential impact of applied mineral oil preparations on the quality of cut tulip flowers and virus spread. Six bulbs with more than 12 cm circumference were selected from each plot and planted in plastic containers filled with the soil from the topsoil layer in the mid of October. Containers with bulbs were placed into the cold room for rooting at 9°C for 6 weeks, and then the temperature was decreased to 5°C. After 14 weeks, tulip plants were transferred from cold room to greenhouse at 16–18°C. Flowers were cut at the stage of the cumulative maturity (colored perianth leaflets). Data about the length of flower shoot, length of tepals, stem weight, and the number of plants with virus-like symptoms on petals were recorded.

Results of biometric measurements were subject to variance analysis for two-factor experiments. Differences between mean values were evaluated using Tukey test at the significance level of $\alpha = 0.05$.

The percentage data were subject to transformation according to Bliss, then variance analysis was performed. Differences between mean values were evaluated using Duncan test for two-factor experiments at the significance level of $\alpha = 0.05$.

RESULTS

Meteorological conditions in autumn 2007 did not favor well rooting of tulip plants. Sum of precipitations in October and November was low and remarkably differed from many-year average value for those months (tab. 1). In spring, tulips began their vegetation and flowering very early. Tulip plants formed the shortest stems and tepals that year. At the end of May 2008, the air temperatures were above 30 C, which made tulip vegetation earlier completed. Such distribution of rainfalls and air temperatures had unfavorable effect on progeny bulb yields, in particular the first choice bulbs. In 2008/2009 and 2009/2010 seasons, rainfall and temperature distribution favored well rooting of bulbs and did not disturb the plant growth in spring.

Table 1. Average temperature and precipitation measured in the Experimental Meteorological Station of the University of Life Science in Lublin in the years 2007–2010

Month	Mean air temperature (°C)				Total of rainfall (mm)			
	2007/ 2008	2008/ 2009	2009/ 2010	Mean for years 1951–2010	2007/ 2008	2008/ 2009	2009/ 2010	Mean for years 1995–2010
October	7.6	10.1	7.0	7.6	17.7	55.5	103.6	40.1
November	–1.1	4.8	5.5	2.6	3.9	33.1	43.1	38.2
December	–0.7	0.9	–1.7	–1.6	1.1	43.8	37.7	31.4
January	0.4	–2.7	–8.2	–3.7	36.2	20.2	35.6	23.4
February	2.2	–1.2	–2.3	–2.8	17.8	36.9	34.6	25.8
March	3.4	1.4	3.4	1.0	64.8	69.6	18.6	28.0
April	9.3 (20.6)*	11.4 (21.6)	9.4 (15.7)	7.4	55.8	2.9	24.5	39.0
May	12.8 (30.4)	13.6 (23.8)	14.5 (23.0)	13.0	101.6	71.1	156.7	60.7
June	17.7 (27.8)	16.4 (29.4)	18.0 (22.1)	16.3	25.9	125.5	65.6	65.9

* – maximum temperature

Table 2. Influence of mineral oil spraying on the length of flower shoots and tepals of 'Leen van der Mark' tulip

Treatment	Oil concentration (%)	Length of flower shoot (cm)	Length of tepals (cm)
Control	–	42.8a*	6.4a
Sunspray 850 EC	1.0	43.4a	6.3ab
	1.5	43.5a	6.3ab
	2.0	43.2a	6.3ab
Sunspray Ultra-Fine	1.0	43.6a	6.3ab
	1.5	43.8a	6.3ab
	2.0	42.9a	6.1b
Mean for years	2008	40.4c	5.3c
	2009	46.2a	7.2a
	2010	43.4b	6.3b

* Means indicated by the same letter do not differ significantly at $P \leq 0.05$

Table 3. Influence of mineral oils on the number of 'Leen van der Mark' tulips with virus-like symptoms in the field

		Symptomatic plants			
Treatment	Oil concentration (%)	2008 (%)	2009 (%)	2010 (%)	Means
Control	–	31.6e*	36.9e	22.2d	30.2C
Sunspray 850 EC	1.0	7.1ab	13.3abc	5.3a	8.5A
	1.5	11.6abc	18.2cd	9.3abc	13.0AB
	2.0	7.6ab	10.2abc	8.4ab	8.7A
Sunspray Ultra-Fine	1.0	12.9abc	12.4abc	10.7abc	12.0AB
	1.5	13.8abc	16.0bcd	11.6abc	13.7B
	2.0	12.4abc	13.3abc	8.0ab	11.2AB
Mean for years	–	13.8B	17.2C	10.7A	–

* Means indicated by the same letter do not differ significantly at $P \leq 0.05$

Table 4. Influence of mineral oil spraying on the commercial yield and total value of the 'Leen van der Mark' tulip bulbs

Treatment	Oil concentration	Commercial yield		Total yield	
	(%)	(psc·m^{-2})	(g·m^{-2})	(psc·m^{-2})	(g·m^{-2})
Control	–	38.3a*	1087.5a	151.5a	1763.7a
Sunspray 850 EC	1.0	43.0a	1162.1a	161.2a	1838.8a
	1.5	39.3a	1107.9a	153.9a	1806.7a
	2.0	40.8a	1161.7a	149.6a	1778.2a
Sunspray Ultra-Fine	1.0	39.0a	1114.9a	157.6a	1823.1a
	1.5	37.1a	1034.2a	156.4a	1682.7a
	2.0	37.3a	1028.9a	148.8a	1669.8a
Mean for years	2008	36.3a	905.8a	97.3c	1172.3c
	2009	33.2a	1026.0a	146.6b	1693.3b
	2010	48.2a	1367.0a	218.5a	2432.8a

* Means indicated by the same letter do not differ significantly at $P \leq 0.05$

Table 5. Influence of oil spraying on the yield of 'Leen van den Mark' tulip bulbs

Treatment	Oil concentration (%)	Yield of bulbs more than 12 cm circumference		Yield of bulbs 11–12 cm circumference	
		(psc·m^{-2})	(g·m^{-2})	(psc·m^{-2})	(g·m^{-2})
Control	–	22.0a*	725.8a	16.3a	361.7a
Sunspray 850 EC	1.0	25.1a	785.6a	17.8a	376.4a
	1.5	22.7a	742.1a	16.6a	362.4a
	2.0	24.8a	808.5a	15.9a	353.1a
Sunspray Ultra-Fine	1.0	23.4a	775.4a	15.6a	342.9a
	1.5	22.2a	726.0a	14.8a	308.2a
	2.0	20.6a	677.3a	16.6a	351.5a
Mean for years	2008	19.2b	570.2c	17.0a	335.5a
	2009	18.6b	661.8b	14.6b	364.2a
	2010	31.0a	1014.0a	17.1a	353.0a

* Means indicated by the same letter do not differ significantly at $P \leq 0.05$

Based on the biometric measurements of stems made at the beginning of May, no negative influence of the oil preparations on tulip flower shoot length was found. Plants sprayed with 2.0% solution of Sunspray Ultra-Fine formed shorter tepals as compared to plants of the control variant (tab. 2).

Tulips cv Leen van der Mark have bicolor flowers on which virus-infection symptoms are clearly visible in a form of irregular white smudges on petals. The number of symptomatic tulips was larger in 2008 and 2009 (31.6–36.9%), than in 2010 (tab. 3), which was associated with the weather conditions (tab. 1) and intensified aphid occurrence. Both commercial mineral oil preparations reduced viral spreading depending on the environmental conditions, but better results were obtained with Sunspray 850 EC solution at 1.0–2.0%. Tulip protection using mineral oil preparations limited the virus occurrence, yet it did not give a 100% efficiency in any of 3 years of study.

Spraying tulips using oil agents had no negative impact on the commercial and total yield of progeny bulbs. A slight decrease in the number and weight of progeny bulbs in treatment with Sunspray Ultra–Fine at 1.5–2.0% concentrations when compared to control, however that was not statistically significant (Table 4). The yielding differences were recorded in subsequent years of study, although it resulted from the atmospheric conditions during the vegetation season (tab. 1). The lowest number and weight of the total progeny bulbs was observed in 2008, and the highest yields in 2010 (tab. 4).

The 'Leen van der Mark' tulips treated with the mineral oil preparation solutions produced comparable number of the first and second quality class bulbs when compared to control. It was observed that in application of Sunspray Ultra–Fine at concentration of 2.0% the number of bulbs with more than 12 cm circumference and with 11–12 cm circumference were slightly lower than for the control, although these differences were not statistically significant (tab. 5).

No negative impact of applied mineral oils at concentrations from 1.0 to 2.0% was observed on flower shoot and tepals length and floral shoot weight of forced tulips. A mean length of tulips stems cultivated in a glasshouse was similar in all variants of the experiment. Stems of the highest fresh weight were obtained from tulips grown in a field and treated with Sunspray 850 EC oil in concentration of 1% and Sunspray Ultra-Fine in concentration of 1.5%. Tulips

Table 6. Influence of mineral oils on quality of 'Leen van den Mark' tulip cut flowers

Treatment	Oil concentration (%)	Length of flower shoot (cm)	Length of tepals (cm)	Mass of flower shoot (g)
Control	–	32.8a*	5.9ab	32.0ab
Sunspray 850 EC	1.0	31.5a	5.7b	33.6a
	1.5	32.4a	5.9ab	30.8b
	2.0	31.6a	5.8b	30.9b
Sunspray Ultra-Fine	1.0	31.8a	5.9ab	32.3ab
	1.5	32.8a	6.0a	33.9a
	2.0	32.1a	5.7b	32.2ab
Mean for years	2009	27.8b	5.8a	27.3c
	2010	30.0b	5.9a	33.8b
	2011	38.7a	5.8a	35.6a

* Means indicated by the same letter do not differ significantly at $P \leq 0.05$

Table 7. Influence of mineral oils on the numer of 'Leen van der Mark' tulips with virus-like symptoms in greenhouse

		Symptomatic plants			
Treatment	Oil concentration (%)	2009 (%)	2010 (%)	2011 (%)	Means
Control	–	73.3e*	66.6de	60.0b-e	66.6C
Sunspray 850 EC	1.0	40.0a-e	26.6ab	24.0ab	30.2A
	1.5	26.6 ab	26.6ab	20.0a	24.4A
	2.0	30.0abc	26.6ab	28.0ab	28.2A
Sunspray Ultra-Fine	1.0	73.3e	36.6abc	36.0abc	52.6BC
	1.5	63.3cde	26.6ab	36.0abc	42.0AB
	2.0	50.0 a-e	30.0abc	16.0a	32.0A
Mean for years	–	50.9B	34.2A	33.1A	–

* Means indicated by the same letter do not differ significantly at $P \leq 0.05$

treated with Sunspray 850 EC in concentrations of 1.5–2% formed stems of a lower weight, however the results were comparable to the control. Stems of the biggest length and fresh weight were obtained in the year 2011 (tab. 6).

The influence of mineral oils applied in the experiment on virus spread during tulip forcing depended on the year of study (tab. 7). The rate from 60.0 to 73.3% of plants with virus symptoms on the tepals were observed in the control. Significantly less virus-infected plants were found when Sunspray 850 EC was applied at concentration 1.5% (20.0–26.6%). Increasing the concentration to 2.0% did not improve the preparation efficiency. In the year 2009, when the viruses pression was high, the percentage of tulips with the symptoms of virus infections in combinations treated with Sunspray Ultra-Fine oil was between 73.3–50% and was comparable to the control.

DISCUSSION

Mineral oils have been tested on a wider scale in the twentieth century for ornamental plants cultivation [Asjes 1980a, 1980b, 1991, Mizell 1991, Asjes et al. 1996, Asjes and Blom-Barnhorn 2001, 2002]. They proved a high efficiency in reducing the population of many dangerous orchard plant pests [Damavandian and Moosavi 2014]. The deterrent effect of the oil substances towards aphids, along with blocking the virus transmission has been used mainly for potato cultivation [Wróbel 2006, 2008, 2011a, 2011b, Milošević et al. 2012]. The advantage of oil preparations is their efficiency in repelling aphids and lack of toxic impact on pollinating insects. Meanwhile, the influence of oil substances on a plant is controversial. Although it is subject to phytodegradation due to ultraviolet radiation, it penetrates inside tissues and can exert negative effects on photosynthesis and plant respiration [Goszczyński et al. 2003, Goszczyński and Tomczyk 2004], and in consequence the yield size. Studies upon the oil particles spread within orange leaves and stems carried out using confocal microscope showed that oil particles penetrate mainly through stomata and are transferred in intercellular spaces. More oil droplets being distributed in the outer mesophyll of the leaves than in the inner mesophyll, vascular bundle, and pith of the tissue. The oil also penetrates to the phloem and wood in stem tissues, and do not cause cellular membranes damage nor cell death. But the oil particles may be phytotoxic by blocking the translocation and distribution of metabolites and nutrients from cells [Tan et al. 2005]. Mizell [1991] using Sanspray Ultra-Fine at concentration of 2% towards 30 various tree species found that three oil sprayings, even at air temperatures about 35°C, did not cause phytotoxicity symptoms. Only some changes in leaf coloration was observed at some species, which was confirmed by own studies. Oils applied at concentrations to 2% did not cause any damage on tulip leaves, while it only affected the color; no earlier plant fading was recorded for that plant variety. In the first year of study, maximum air temperature during the day did not exceed 30 C in May, which cause earlier completing the tulip vegetation also in the control and reduced the yield of progeny bulbs as compared to other study years. However, it is the consequence of the tulip physiology, for which high temperatures induce the summer dormancy [Khodorova and Boitel-Conti 2013]. Potato plants sprayed with various oil substances revealed phytotoxicity symptoms and produces less tuber yields, depending on the type of oil and number of treatments. The Sunspray 850 EC oil at concentration up to 2% did not negatively affected the yielding. [Wróbel and Urbanowicz 2007]. Wilson [1999] reported that great number of treatments using mineral oils during the vegetation season made an inhibition of the above ground parts and dramatically reduced the progeny bulbs yield of iris. Tulips are characterized by very short vegetation period in spring. The most intensive growth of stems and leaves occurs in April and beginning of May, while progeny bulbs weight gain can be observed since the beginning of May till the mid of June [Marcinek et al. 2013]. Providing plants with optimum conditions for growth that time is detrimental for the size and quality of bulbs yield. The analysis of yields did not reveal any negative influence of Sunspray 850 EC oil on the number and weight of commercial bulbs, nor the first choice bulbs (>12 cm circumference). Tulips treated tree times with Sanspray Ultra-Fine oil at concentration of 2.0% produced lower number of commercial bulbs as compared to the control, although this difference was not statistically significant. Studies conducted upon various species of bulb plants indicated that applying oils to reduce the aphid populations can contribute to increase the fungal infections in *Botrytis cinerea* [Asjes and Blom-Barnhoorn 2001]. There was also observed higher vulnerability of hyacinth to bacteria *Xanthomonas hyacinthi* [Asjes 1980b]. In the study, no increase intensity of disease symptoms on stems and bulbs of tulip was observed.

Research conducted in The Netherlands dealing with tulips of cv. 'Halcro' indicate that the impact of mineral oil on the bulb yield depends on its concentration and number of treatments [Asjes and Blom-Barnhoorn 2001]. Spraying the plants every week beginning from the 3rd week of May up to the end of June at the concentration of 1.6% decreased the bulb yield by 10%. Mineral oil applied at 0.8% concentration reduced in 77% the spread of viruses and did not affect the yield size as compared to the control plants [Asjes and Blom-Barnhoorn 2001]. Our study revealed that the use of oil at up to 1.5% concentration is the most effective. Increasing the concentration did not improve the efficiency of preparations. Mineral oils applied independently and in combinations with insecticides reduced the viral inoculum source and spreading in lily, iris, and dahlia cultivations [Asjes 1991, Asjes et al. 1996, Asjes and Blom-Barnhoorn 2001, 2002]. Applying mineral oils at various concentrations and with various frequencies, as well as using the insecticides did not ensure a complete elimination of virus spreading [Asjes and Blom-Barnhoorn 2001, 2002], which is confirmed by the present study. Despite of significant reduction in the number of virus-infected plants in the tulip cultivation, a large percentage of infected plants was found in subsequent years.

At 'Leen van der Mark' cultivar, the virus symptoms are clearly visible on tepals, however, plants that were infected just before and after flowering cannot be eliminated. Aphids can transmit the virus onto a plant by quick acquisition and inoculation periods; from 30 seconds to 2 minutes is accepted as the optimum [Wróbel 2006]. Mineral oils act to aphids in mechanical way by blocking their spiracles and cutting off the oxygen supply [Wróbel 2006]. This makes the oxygen delivery blockage and disturbs the gaseous exchange, which leads to the aphid suffocation during 24 hours after application [Wróbel 2006]. This period is quite long, since insecticides kill aphids in 2 minutes, but it was proved that positive action of mineral oils consists mainly in disturbance of the interaction between virus particles and their ability to remain on a proboscis of aphids [Wróbel 2006]. Therefore, virus-infected plants will not by pose an infection source for others plants [Wróbel 2011a, 2011b]. Rae [2002] reported that mineral and plant-origin oils can be applied singly or in combinations with other substances in order to act different insects and mites. Studies carried out using lilies, dahlias, irises, and tulips [Asjes and Blom-Barnhoorn 2001] revealed that mixtures of oils with insecticides gave better effects in reducing the viral spread.

However, they do not guarantee the full effectiveness in the plant protection. It is not possible to accurately cover the leaves and stems with a layer of oil. Aphids appear at different times and can cause a lot of damage in early spring, even when their population is negligible [Asjes 1980a]. It should, therefore, be carried out the first oil spray preventively before the appearance of aphids. New-generation oil preparations introduced in the market are better tolerated by plants, and at the same the most effective against the pests and diseases. An effective solution is a combination of biological protection with plants more resistant to disease, which is still, time-consuming and costly procedure. For several years, trials have been carried out using cameras and other optical devices that, based on the color of the leaf, chlorophyll fluorescence, and intensity of photosynthesis, allow for the construction of automated robots to detect and remove the virus-infected plants [Polder et al. 2010].

CONCLUSIONS

1. Mineral oils applied up to three times treatments to plants at a concentration of 1.0–2.0% were not phytotoxic to the tulip and did not cause the decrease in the yield of commercial bulbs and first choice bulbs.

2. Mineral oils used at concentrations up to 2.0% in the field, do not have an adverse subsequent effect on the tulip flower quality.

3. Oil Sunspray 850 EC used at a concentration of 1,0–1.5% in the form of three sprays reduces the spread of viruses in the tulip cultivation, and subsequently it limits a number of virus infected tulip cut flowers obtained from a glasshouse cultivation.

4. Sunspray 850 EC reduced spread of viruses more effectively in comparison to Sunspray Ultra-Fine. The use of oils in concentration of 2% did not improve their effectiveness in virus spread reduction.

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