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Herbicide drift vs. crop resilience – the influence of micro-rates

Milan Brankov[1], Bruno Canella Vieira[2], Miloš Rajković[3], Milena Simić[1], Vukadinović Jelena[1], Violeta Mandić[4], Vesna Dragičević[1]*

[1]Maize Research Institute "Zemun Polje", Belgrade, Serbia
[2]University of Nebraska-Lincoln, North Platte, Nebraska, USA
[3]Institute for Field and Vegetable Crops, Novi Sad, Serbia
[4]Institute for Animal Husbandry, Zemun, Serbia
**Corresponding author: brankovmilan@gmail.com; mbrankov@mrizp.rs*

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Abstract: A greenhouse study was conducted to test the effects of low herbicide dose exposure on different crops measuring visible damages, plant height, leaf area, and dry matter. Seven crops were tested: lettuce (*Lactuca sativa* L.) cv. Novosadska majska maslena, oil pumpkin (*Cucurbita maxima* Duch) cv. Olivija, oilseed rape (*Brassica napus* L.) cv. NS Ras, pepper (*Capsicum annuum* L.) cv. Kurtovska kapija, soybean (*Glycine max* (L.) Merr) cv. ZP Laura, sunflower (*Helianthus annuus* L.) cv. NS Kruna, and tomato (*Solanum lycopersicum* L.) cv. Dunavski Rubin. Herbicide dicamba in the range of 0.14 to 1 155.6 g a.i. (active ingredient)/ha inhibited biomass, height, leaf area, and visual injury of all crops, while glyphosate doses from 0.48 to 3 840 g a.i./ha also reduced the growth of all tested species. A rate of 116 g a.i./ha mesotrione was needed to reach 80% visual injury in oilseed rape, while the same effects on lettuce only required 1.8 g a.i./ha of mesotrione. Tomato and oil pumpkin were also sensitive to low mesotrione doses, where only 1.3 g and 0.5 g a.i./ha of mesotrione was needed for 80% of biomass reduction, respectively. Lettuce was the most sensitive crop of all tested species; biomass was reduced by 80% by dicamba, glyphosate, mesotrione, and nicosulfuron at the low rates of 33 g a.i./ha, 19 g a.i./ha, 1.25 g a.i./ha, and 2.7 g a.i./ha, respectively. Among all herbicides, visible injuries were detected in dicamba at the lowest rates. Soybean was the most tolerant of glyphosate, mesotrione, and nicosulfuron. Based on the available literature and obtained results, herbicide off-target movement must be mitigated to maximise herbicide efficacy and decrease the negative influence on susceptible plants and the environment.

Keywords: weed control; contamination; environmental pollution; crop injury; pesticides

With the production of over 3 million tonnes worldwide on an annual basis, pesticides have a significant role in plant protection (Sharma et al. 2019). Pesticides have a very important role in plant protection, enabling high yields of crops. All pesticide products must be applied correctly according to specific instructions printed on the legally binding label. Since pesticides are hazardous products, their exposure to people or the environment may cause health or pollution issues (Kim et al. 2017). All applications are followed by loss when a small percentage of an application liquid does not reach the targeted area or organism. Some off-target movement is considered to be drift (Damalas 2015), but there are actually three categories of off-target pesticide exposure: particle drift, volatility, and tank contamination. All of these off-target exposures to pesticides can cause economic losses in sensitive crops (Bohnenblust et al. 2016), environmental pollution (Rashid et al. 2010), and lower weed control (Hilz and Vermeer 2013).

Particle drift is part of a pesticide application that is deflected away during or following applications.

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This is influenced mainly by wind-catching droplets that have not settled on the target yet. Spray drift can affect neighbour crops causing visual damage and potentially leading to yield losses (Felsot et al. 2010). On the other hand, weed populations exposed to sub-lethal doses of herbicide can develop metabolic resistance (Gressel 2011). For this reason, especially, it is crucial to mitigate particle drift. The likelihood of drift can be reduced by spraying with nozzles that produce larger droplets, using drift-reducing adjuvants, making drift barriers, and avoiding application in windy conditions (Ying 2018).

Volatilisation can be a source of off-target herbicide movement (Sosnoskie et al. 2015). Volatility describes how readily a substance will form a gas at a given temperature and pressure. Applications followed by high temperature and low relative humidity increase dicamba volatility (Mueller and Steckel 2019). Much research has been done to test the influence of dicamba drift following applications (Alves et al. 2017, Soltani et al. 2020). This problem was addressed when chemical companies developed formulations intending to minimise dicamba volatility (Mueller et al. 2013). Another type of off-target movement represents herbicide tank contamination (Alves et al. 2020). When applicators use the same equipment to apply different herbicides, small doses left in the sprayer can cause damage to non-target crops. Therefore, the sprayer must be properly cleaned to eliminate potential contamination risks (Browne et al. 2020).

In Serbia, maize (*Zea mays* L.) is the most widely planted crop, and herbicides are the most frequently used method for weed control. The wind is common during the spring, and it can influence applications; however, little research has been done on the effect of herbicide drift on neighbour crops. Thus, crops that commonly grow near maize were selected for evaluation. Our research tested seven crops (lettuce, oil pumpkin, oilseed rape, pepper, soybean, sunflower, and tomato) with four herbicides (dicamba, glyphosate, mesotrione, and nicosulfuron) in a dose-response bioassay under controlled conditions to present potential negative effects of herbicide applications followed by drift and crops responses to herbicide micro-rates.

MATERIAL AND METHODS

Study site and plant material. A greenhouse trial was conducted at the Maize Research Institute "Zemun Polje", Belgrade, Serbia. Seven crops were tested: lettuce (*Lactuca sativa* L.) cv. Novosadska majska maslena, oil pumpkin (*Cucurbita maxima* Duch) cv. Olivija, oilseed rape (*Brassica napus* L.) cv. NS Ras, pepper (*Capsicum annuum* L.) cv. Kurtovska kapija, soybean (*Glycine max* (L.) Merr) cv. ZP Laura, sunflower (*Helianthus annuus* L.) cv. NS Kruna, and tomato (*Solanum lycopersicum* L.) cv. Dunavski Rubin. These species were selected based on the possibility of being injured by herbicide particle drift in fields.

Herbicide material. Four herbicides were used: dicamba (Plamen SC, 577.9 g a.i. (active ingredient)/L, Galenika Fitofarmacija, Belgrade, Serbia), glyphosate (Glifol SC, 480 g a.i./L, Galenika Fitofarmacija, Belgrade, Serbia), mesotrione (Callisto® SC, 480 g a.i./L, Syngenta, Basel, Switzerland), and nicosulfuron (Motivell Extra 6 OD, 60 g a.i./L, Londerzeel, Belgium). Herbicides were applied in the following doses: 0.0005X, 0.001X, 0.005X, 0.01X, 0.1X, 0.25X, 0.5X, 1X, 2X, and 4X, where X corresponds to the full field use rate of each herbicide (dicamba at 288.9 g a.i./ha, glyphosate at 960 g a.i./ha, mesotrione at 120 g a.i./ha, and nicosulfuron at 60 g a.i./ha).

Growing conditions. Crop seeds were grown in D40H cone-trainer cells plastic cones (6.9 cm in diameter, 35.6 cm depth, the volume of 983 mL) (Stuewe and Sons, Inc., Corvallis, USA) filled with the growing substrate (Floragard, Oldenburg, Germany). Plants were watered and fertilised as needed. The greenhouse was maintained at 30/20 °C day/night and 16/8 h photoperiod (850 μmol/m^2/s photosynthetic photon flux). When plants reached 10–15 cm height, applications were made in a research spray chamber (Avico Praha, Prague, Czech Republic) calibrated to deliver 93.5 L/ha using an AI95015EVS nozzle at 414 kPa.

Plants measurements. Plants were returned to the greenhouse and evaluated 21 days after treatment for the following: biomass reduction, height reduction (except lettuce), leaf area reduction, and visual estimations of injury. Leaf area was measured using LI-COR 3100 area meter (LICOR Biosciences, Lincoln, USA). Visual assessment of injury was made on a scale of 0–100, where 0 represented no injury and 100 represented plant death. All data were converted into a percentage (%) reduction compared to the untreated control.

Statistical analyses. The experiment was conducted as a randomised complete block design with five replications in two experimental runs. One plant of each species was considered as one replication. All data, including biomass, height, leaf area reduction, and visual estimation of injury (% of control), were subjected to a non-linear regression analysis using the four-parameter log-logistic model (Ritz et al. 2015):

$$y = c + \{d - c/+\exp [b (\log x - \log e)]\} \qquad (1)$$

Where: y – reduction (%); b – relative slope at the inflection point (e); c – lower limit (%); d – upper limit; e (ED_{50}) – inflection point, and x – herbicide dose (g a.i./ha).

All statistical analyses and graphs were performed with the open-source statistical software R, version 3.2.3 (R Core Team, 2015), utilising the dose-response curves statistical add-on package.

RESULTS AND DISCUSSION

Dicamba. Dicamba applications reduced plant growth in all tested species (Figure 1). In the range of 0.14 to 1 155.6 g a.i./ha, dicamba inhibited biomass, height, leaf area, and visual injury of all tested (Table 1). The highest rates (1 155.6 g a.i./ha, 577.8 g a.i./ha, 288.9 g a.i./ha, and 72.2 g a.i./ha) of dicamba resulted in death for all tested species. At lower rates, pepper exhibited the least injury and reduction to leaf area, while oilseed rape and pepper had the slightest reduction in biomass and height. As the most tolerant species to dicamba, 80% reduction of biomass, height, leaf area, and visual injury in pepper corresponded to 180, 463, 434, and 448 g a.i./ha of dicamba, respectively. Only 22, 121, 3, and 279 g a.i./ha of dicamba were applied for 80% inhibition of biomass, leaf area, and visual injury in lettuce.

The adoption of dicamba-tolerant crops in the USA has provided a new solution for weed control; however, the literature reported problems regarding dicamba drift to sensitive crops (Egan et al. 2014). Adopting dicamba-tolerant crop technology during the last decade has increased dicamba usage

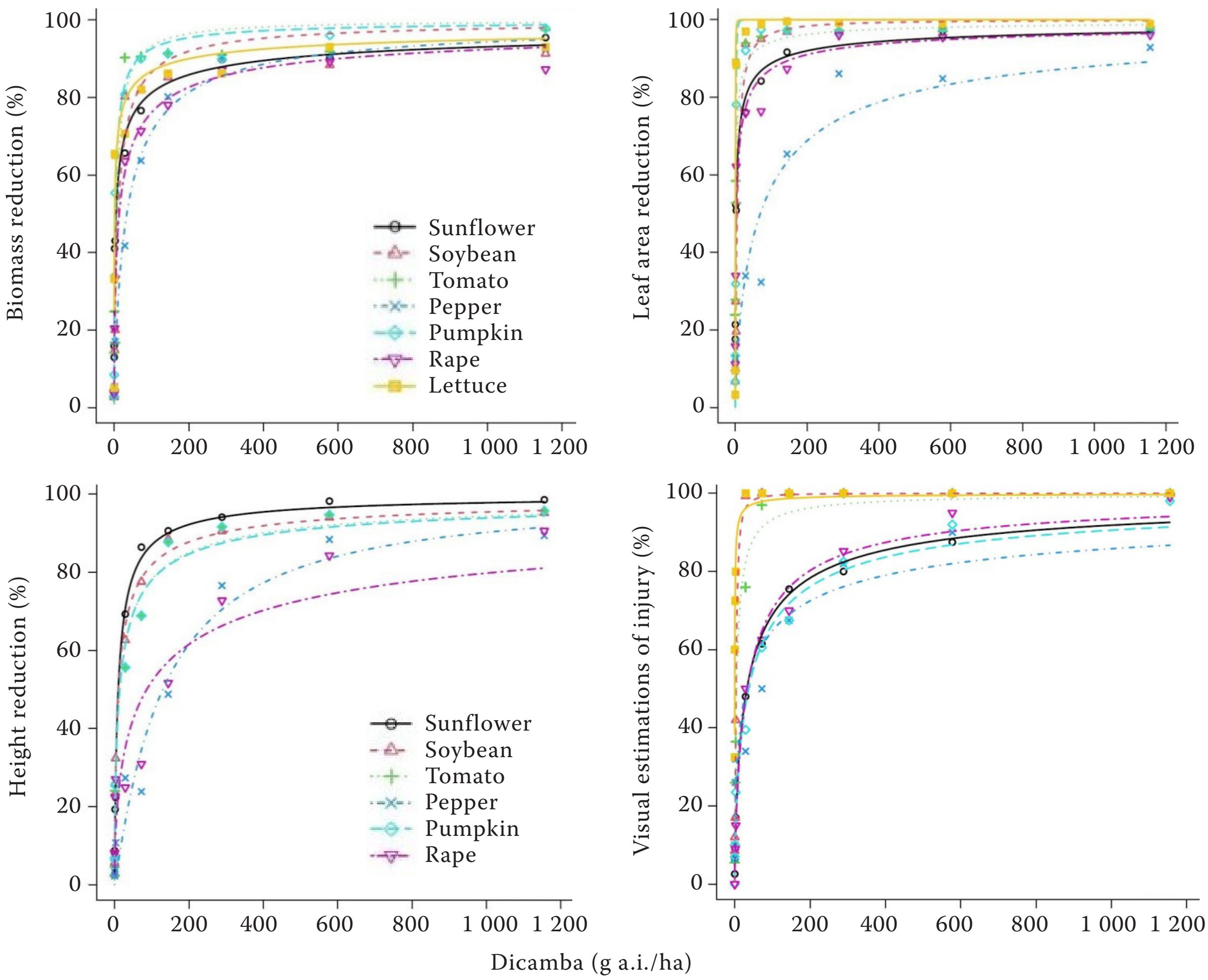

Figure 1. Biomass, height, leaf area reduction, and visual estimation of injury as affected by dicamba. a.i. – active ingredient

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Table 1. Influence of dicamba (g a.i./ha) on 50% and 80% reduction of biomass, height, leaf area and visual injury of lettuce, oil pumpkin, oilseed rape, pepper, soybean, sunflower, and tomato 21 DAT (days after treatment)

Species	Biomass reduction		Height reduction		Leaf area reduction		Visual injury	
	ED_{50}	ED_{80}	ED_{50}	ED_{80}	ED_{50}	ED_{80}	ED_{50}	ED_{80}
Lettuce	1.5 ± 0.2	33.1 ± 8.0	N/A	N/A	0.7 ± 0.05	1.22 ± 0.11	0.27 ± 0.02	2.06 ± 0.2
Oil pumpkin	3.4 ± 0.4	21.7 ± 4.6	13.8 ± 1.4	120.6 ± 14.7	1.9 ± 0.1	3.1 ± 0.24	36.9 ± 2.5	278.7 ± 22.7
Oilseed rape	13.6 ± 1.6	147.9 ± 24.8	86.4 ± 8.8	1021.5 ± 175.0	3.3 ± 0.4	38.7 ± 7.0	32.9 ± 2.1	196.0 ± 14.9
Pepper	34.1 ± 3.5	180.1 ± 22.4	129.8 ± 7.6	462.8 ± 44.5	69.8 ± 7.3	443.4 ± 63.9	30.7 ± 2.4	448.3 ± 44.6
Soybean	10.7 ± 1.1	56.7 ± 9.1	10.4 ± 1.0	83.1 ± 10.6	5.7 ± 0.5	19.1 ± 2.8	3.6 ± 0.2	8.8 ± 1.2
Sunflower	5.2 ± 0.7	85.8 ± 16.3	9.9 ± 0.91	53.3 ± 6.3	2.2 ± 0.27	28.6 ± 5.2	32.3 ± 2.1	230.7 ± 19.0
Tomato	7.0 ± 0.7	28.5 ± 4.7	14.9 ± 1.5	117.8 ± 13.9	1.2 ± 0.13	10.8 ± 1.8	5.1 ± 0.3	24.3 ± 2.3

ED_{50} – a rate that reduces 50% of the observed parameter; ED_{80} – a rate that reduces 20% of the observed parameter; N/A – not applicable; a.i. – active ingredient

(Knežević 2016), as well as the research regarding dicamba damage and drift. As an auxin herbicide, dicamba affects susceptible plants at very low rates. In our research, sunflowers, tomatoes, and pepper showed visible symptoms from low dicamba rates. Non-dicamba-resistant soybean is reported to be

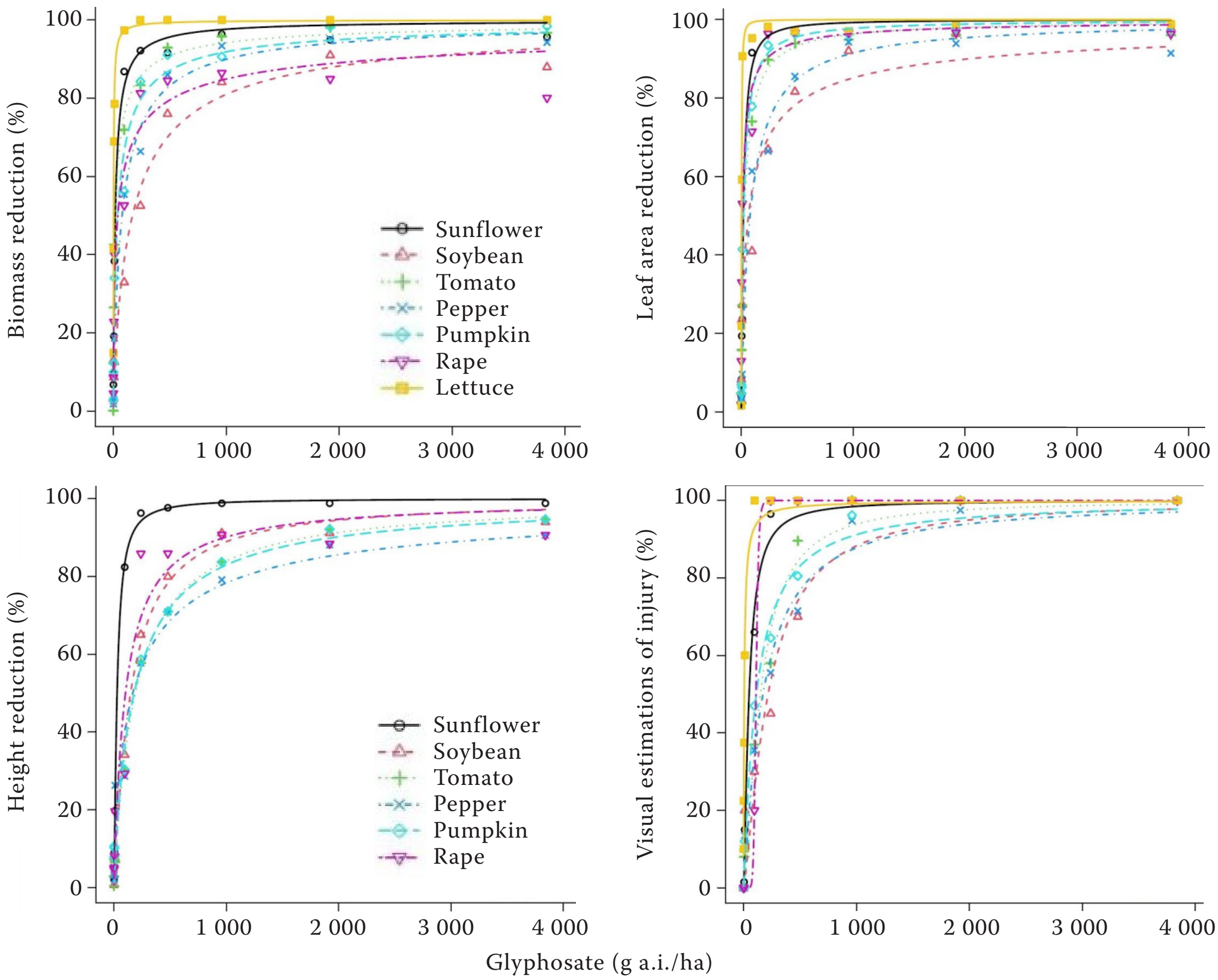

Figure 2. Biomass, height, leaf area reduction, and visual estimation of injury as affected by glyphosate. a.i. – active ingredient

very sensitive to dicamba. According to McCown et al. (2018), a rate of 1/256 of the labelled rate resulted in a 14% to 19% yield reduction. Our research indicated that a 1/27 rate of dicamba caused a 50% biomass reduction in soybean, while a rate of 1/80 caused 50% visual injury.

Dicamba off-target movements caused by tank contamination have also been investigated. Failure to clean the boom properly could result in multiple exposures to other crops during the season (Browne et al. 2020). Soltani et al. (2020) reported injury to non-tolerant soybean up to 250 m downwind. Low doses of dicamba influenced tomato and pepper plants resulting in plant injury (Hynes 2012). Also, Knezevic et al. (2018) reported that a dose of 6.54–9.13 a.i./ha caused 50% injury on grapes and tomatoes. According to Chen et al. (2020), dicamba applied at a rate of 1.4% resulted in 50% visual injury and 35% yield loss in lettuce. Results obtained by our study reported that a 1/244 rate of dicamba reduced leaf area in tomatoes by 50%. Furthermore, a rate of just 1/1 075 caused 50% visual injury. The most tolerant species was pepper, where 2/3 of the labelled rate caused 80% biomass reduction.

Glyphosate. Glyphosate doses from 0.48 to 3 840 g a.i./ha also reduced the growth of all tested species (Figure 2). As observed with dicamba, glyphosate rates from 0.25X to 4X resulted in plant death. Lettuce and sunflower were the most sensitive crops, even when exposed to the lowest glyphosate doses. Glyphosate most reduced biomass and leaf area of lettuce, while height was most reduced in sunflowers. Oilseed rape had the highest level of injury. Soybean was the most tolerant species to glyphosate; 924 g a.i./ha of glyphosate resulted in 80% of biomass reduction, while in lettuce, only 9 g a.i./ha of glyphosate achieved the same result (Table 2). Oilseed rape was the second most tolerant crop, regarding the rate needed to decrease biomass reduction to 80% (526 g a.i./ha of glyphosate). Oil pumpkin and tomato had similar 50% biomass reduction with the rate of 38.2 and 39.1 g a.i./ha. For oilseed rape, a rate of 11.8 g a.i./ha was needed to reduce leaf area by 50%. Some stimulatory effects were recorded in tomatoes from the lowest dose of glyphosate, 0.48 g a.i./ha, although none were significant.

As a result of the adoption of glyphosate-tolerant crops, glyphosate became the most used herbicide in the USA (Duke et al. 2018). However, increased glyphosate use imposed a high selection pressure on weeds, which led to weed control failures attributed to herbicide resistance (Bonny 2016). The increased use of glyphosate also created more opportunities for spray drift events. Much research has been conducted to test how low rates of glyphosate influence different crops. Reddy et al. (2010) examined the biological response of soybean and cotton to glyphosate, indicating higher sensitivity of soybean, while lower injuries were detected at further distances downwind. Mohseni-Moghadam et al. (2016) reported that bell pepper and broccoli were sensitive to low rates of glyphosate, indicating that glyphosate drift would likely be costly for farmers. Our research indicated that soybean was the most tolerant species to glyphosate. A rate of 1/6 of glyphosate resulted in 50% biomass reduction, while lettuce (1/505) and sunflower (1/56) were the most sensitive.

Mesotrione. Mesotrione rates from 0.06 to 480 g a.i./ha reduced the growth of all tested species. As all tested species were broadleaf plants, mesotrione affected plants even at low rates. The highest toler-

Table 2. Influence of glyphosate (g a.i./ha) on 50% and 80% reduction of biomass, height, leaf area and visual injury of lettuce, oil pumpkin, oilseed rape, pepper, soybean, sunflower, and tomato 21 DAT (days after treatment)

Species	Biomass reduction		Height reduction		Leaf area reduction		Visual injury	
	ED_{50}	ED_{80}	ED_{50}	ED_{80}	ED_{50}	ED_{80}	ED_{50}	ED_{80}
Lettuce	1.9 ± 0.2	9.0 ± 1.3	N/A	N/A	3.1 ± 0.21	8.11 ± 0.7	6.2 ± 0.3	26.9 ± 2.2
Oil pumpkin	38.2 ± 4.2	246.7 ± 32.9	179.5 ± 14.6	806.6 ± 88.5	21.3 ± 1.2	87.6 ± 12.6	113.2 ± 5.8	412.2 ± 23.3
Oilseed rape	39.1 ± 4.6	526.1 ± 90.3	102.8 ± 11.2	1101.0 ± 110.1	11.8 ± 1.1	75.9 ± 11.9	110.1 ± 20.6	126.4 ± 11.8
Pepper	77.2 ± 7.8	389.0 ± 45.3	167.3 ± 15.4	1148.0 ± 140.6	79.3 ± 6.8	348.0 ± 37.1	171.7 ± 7.9	590.9 ± 32.6
Soybean	169.1 ± 16.4	924.3 ± 120.1	147.9 ± 11.1	526.1 ± 53.3	64.8 ± 6.9	569.3 ± 68.6	217.0 ± 9.2	618.5 ± 30.8
Sunflower	17.0 ± 1.7	77.3 ± 13.0	28.0 ± 2.65	81.2 ± 10.1	19.6 ± 1.7	59.7 ± 8.5	49.2 ± 3.3	133.3 ± 7.5
Tomato	19.2 ± 2.1	136.8 ± 21.5	190.9 ± 13.9	761.8 ± 77.5	28.8 ± 2.7	129.8 ± 16.6	149.1 ± 6.2	391.1 ± 19.0

ED_{50} – a rate that reduces 50% of the observed parameter; ED_{80} – a rate that reduces 20% of the observed parameter; N/A – not applicable; a.i. – active ingredient

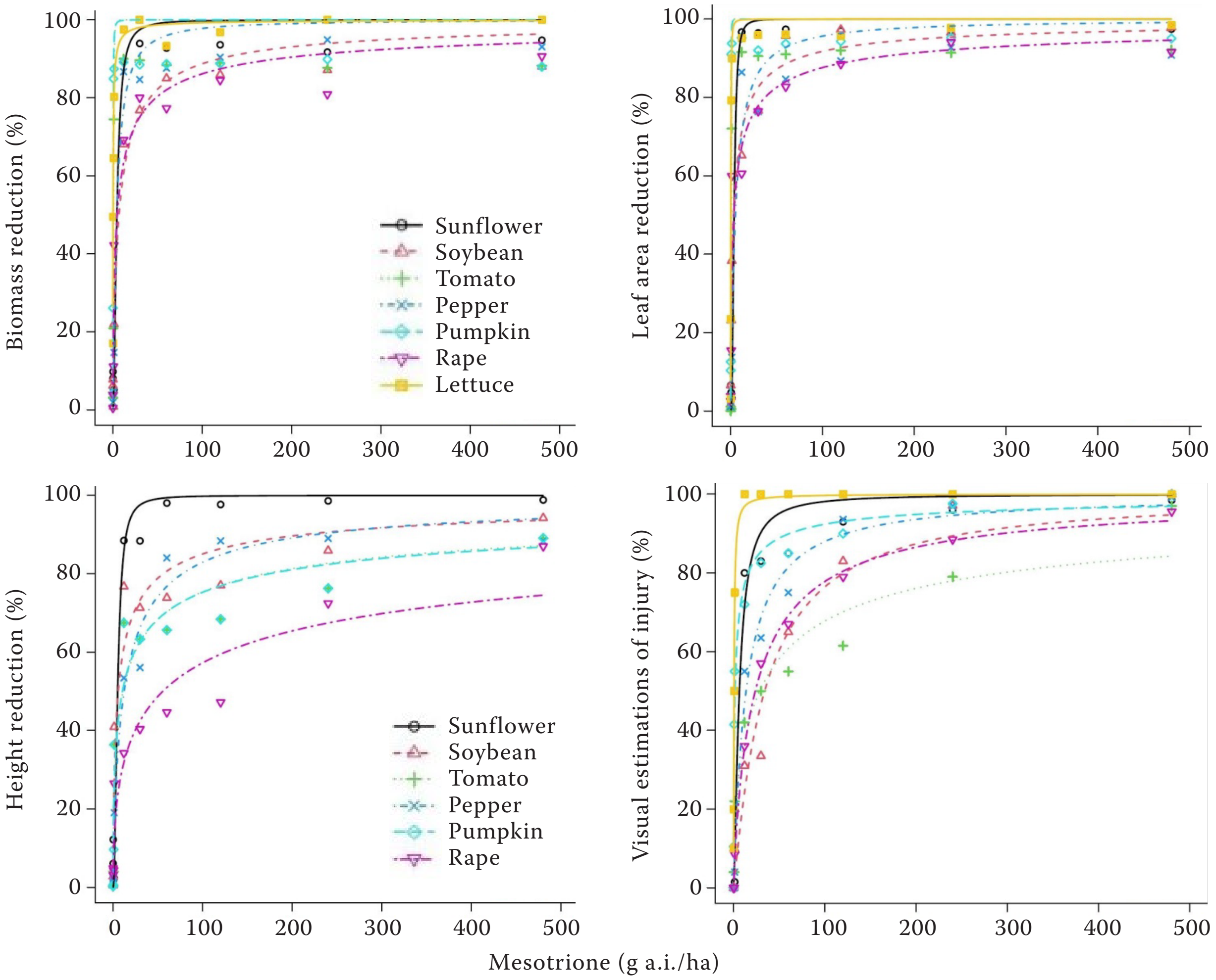

Figure 3. Biomass, height, leaf area reduction, and visual estimation of injury as affected by mesotrione. a.i. – active ingredient

ance to mesotrione was exhibited by oilseed rape, indicated by the least reduction of biomass, height, and leaf area, although the tomato had the least visual injury. As with glyphosate, lettuce was most affected by all doses of mesotrione (Figure 3). A rate of 116 g a.i./ha mesotrione was needed to reach 80% visual injury in oilseed rape, while the same effects on lettuce only required 1.8 g a.i./ha of mesotrione (Table 3). Tomato and oil pumpkin were also sensitive to low mesotrione doses, where only 1.3 g and 0.5 g a.i./ha of mesotrione was needed for 80% of biomass reduction, respectively.

ALS and HPPD-inhibiting herbicide-tolerant crops will promote increased usage of these herbicides (Kneževič 2016). Previous studies reported injury from nicosulfuron and mesotrione at a lower frequency compared to dicamba or glyphosate. Young et al. (2003) reported soybean injury and yield loss by foliar application of mesotrione. According to our findings, mesotrione can cause serious injury in the tested crops. A rate of 1/133 decreased by 50% tomato biomass. A 1/27 rate of mesotrione caused a 50% of biomass reduction in sunflower, pepper, and oilseed rape. The most tolerant crop was soybean, where a rate of 1/17 of mesotrione decreased biomass by 50%. Regarding nicosulfuron, soybean was the most tolerant. A rate of ¼ resulted in a 50% biomass reduction of soybean, while lettuce and oil pumpkin were reduced to 50% biomass at a rate of 1/625 and 1/120, respectively. Mitigating herbicide off-target movement must be a priority to minimise the potential negative effects on neighbour crops. According to our findings, low rates of dicamba provided visible injuries, even when applied at 1/1 000 of the total rate.

Nicosulfuron. Doses of nicosulfuron from 0.03 to 240 g a.i./ha reduced all evaluated characteristics (Figure 4). Of all species, lettuce was most affected, while pumpkin remained most tolerant in all metrics

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Table 3. Influence of mesotrione (g a.i./ha) on 50% and 80% reduction of biomass, height, leaf area and visual injury of lettuce, oil pumpkin, oilseed rape, pepper, soybean, sunflower, and tomato 21 DAT (days after treatment)

Species	Biomass reduction		Height reduction		Leaf area reduction		Visual injury	
	ED_{50}	ED_{80}	ED_{50}	ED_{80}	ED_{50}	ED_{80}	ED_{50}	ED_{80}
Lettuce	0.22 ± 0.02	1.25 ± 0.22	N/A	N/A	0.27 ± 0.01	0.63 ± 0.05	0.50 ± 0.02	1.81 ± 0.15
Oil pumpkin	0.2 ± 0.01	0.5 ± 0.06	10.3 ± 1.2	73.8 ± 30.1	0.25 ± 0.01	0.45 ± 0.04	1.63 ± 0.1	16.1 ± 2.0
Oilseed rape	4.8 ± 0.5	48.1 ± 8.4	55.4 ± 6.0	99.0 ± 8.9	3.4 ± 0.33	37.4 ± 5.1	23.7 ± 1.3	116.0 ± 9.0
Pepper	4.4 ± 0.4	13.7 ± 2.2	12.3 ± 1.2	77.1 ± 9.6	5.2 ± 0.4	19.5 ± 2.5	13.7 ± 0.8	54.6 ± 3.8
Soybean	6.8 ± 0.7	41.4 ± 6.2	5.7 ± 0.6	55.8 ± 9.1	3.3 ± 0.3	23.6 ± 2.8	34.0 ± 1.8	120.9 ± 8.3
Sunflower	4.4 ± 0.5	9.2 ± 1.3	5.0 ± 0.6	9.8 ± 1.4	3.7 ± 0.6	6.2 ± 1.1	6.4 ± 0.4	16.6 ± 1.4
Tomato	0.9 ± 0.03	1.31 ± 0.1	11.0 ± 1.3	68.6 ± 29.2	1.1 ± 0.1	1.2 ± 0.05	28.7 ± 2.0	293.4 ± 29.7

ED_{50} – a rate that reduces 50% of the observed parameter; ED_{80} – a rate that reduces 20% of the observed parameter; N/A – not applicable; a.i. – active ingredient

except biomass reduction. Biomass was least affected by nicosulfuron. For 50% biomass reduction of soybean, nicosulfuron had to be applied at a rate of 15 g a.i./ha, or ¼ of a field rate (Table 3). Only 0.1 g a.i./ha of nicosulfuron was needed to reduce lettuce biomass by 50%. Pepper was the second most tolerant

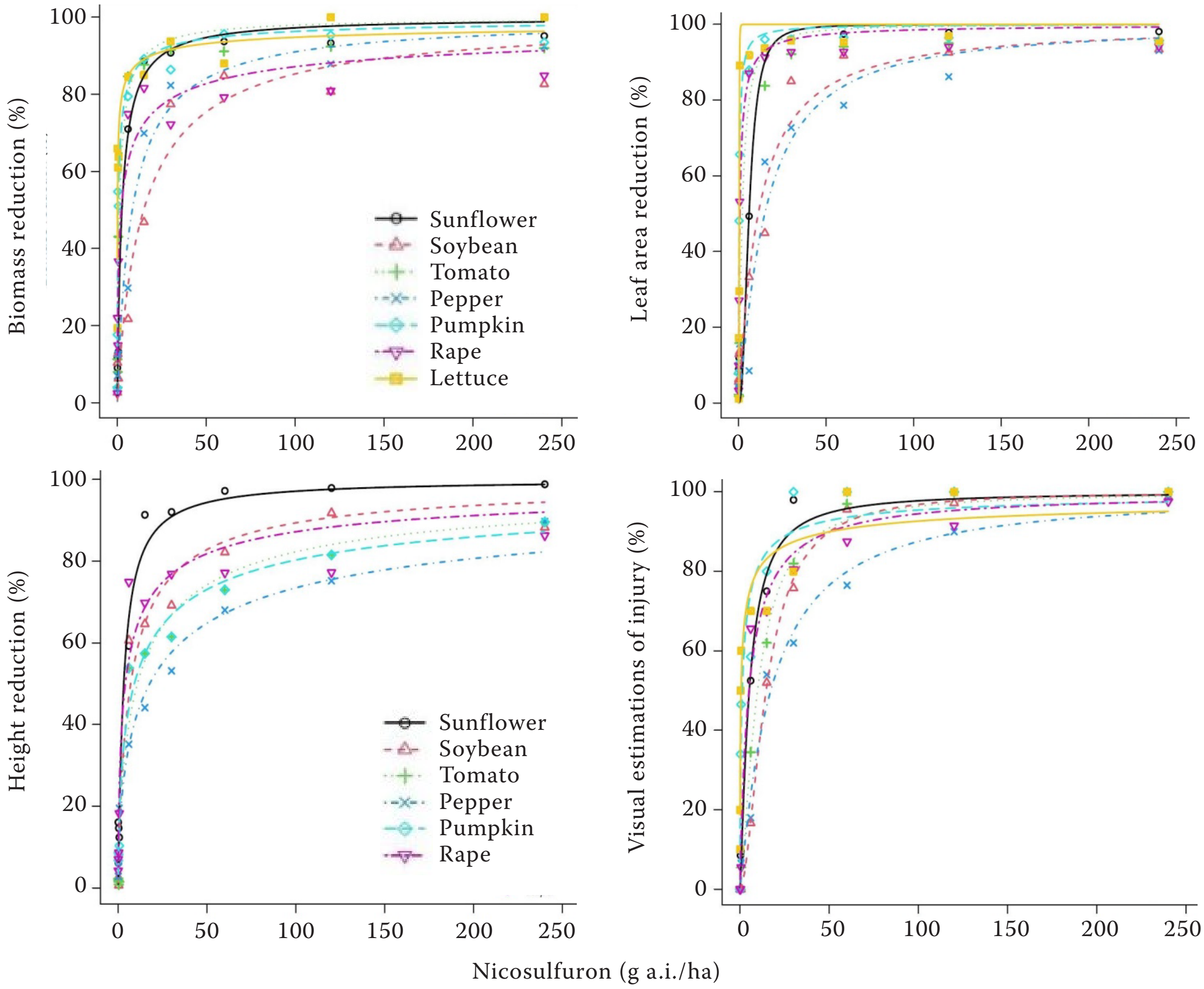

Figure 4. Biomass, height, leaf area reduction, and visual estimation of injury as affected by nicosulfuron. a.i. – active ingredient

Table 4. Influence of nicosulfuron (g a.i./ha) on 50% and 80% reduction of biomass, height, leaf area and visual injury of lettuce, oil pumpkin, oilseed rape, pepper, soybean, sunflower, and tomato 21 DAT (days after treatment)

Species	Biomass reduction		Height reduction		Leaf area reduction		Visual injury	
	ED_{50}	ED_{80}	ED_{50}	ED_{80}	ED_{50}	ED_{80}	ED_{50}	ED_{80}
Lettuce	0.1 ± 0.02	2.7 ± 0.8	N/A	N/A	0.37 ± 0.01	0.51 ± 0.03	0.59 ± 0.04	9.7 ± 1.1
Oil pumpkin	0.51 ± 0.07	4.8 ± 1.2	9.1 ± 0.8	96.7 ± 12.6	0.35 ± 0.03	1.45 ± 0.27	1.3 ± 0.1	9.3 ± 0.9
Oilseed rape	2.2 ± 0.32	34.6 ± 8.1	4.0 ± 0.4	40.9 ± 5.7	0.71 ± 0.07	3.7 ± 0.7	5.0 ± 0.3	21.5 ± 1.6
Pepper	8.4 ± 1.03	36.9 ± 5.8	17.7 ± 1.5	186.1 ± 25.7	14.9 ± 0.96	48.5 ± 6.21	17.2 ± 0.7	60.1 ± 3.8
Soybean	14.8 ± 1.5	66.6 ± 12.0	7.0 ± 0.5	39.4 ± 4.2	11.2 ± 1.03	40.7 ± 4.7	14.6 ± 0.5	31.8 ± 1.5
Sunflower	2.6 ± 0.3	10.7 ± 1.7	3.1 ± 0.3	12.1 ± 1.1	6.0 ± 0.3	10.6 ± 1.1	5.2 ± 0.3	15.4 ± 0.9
Tomato	1.3 ± 0.2	6.1 ± 1.3	10.8 ± 0.8	80.3 ± 9.2	2.1 ± 0.2	6.1 ± 0.9	9.8 ± 0.4	26.1 ± 1.4

ED_{50} – a rate that reduces 50% of the observed parameter; ED_{80} – a rate that reduces 20% of the observed parameter; N/A – not applicable; a.i. – active ingredient

to nicosulfuron, requiring 8, 18, and 15 g a.i./ha to induce a 50% reduction of biomass, height, and leaf area, respectively (Table 4). Sunflowers expressed low tolerance to nicosulfuron, where just 11 g caused 80% biomass reduction. Despite social and political pressure surrounding herbicide application, special attention should be paid to avoiding drift during herbicide applications, following all guidelines for safe application, and enabling drift mitigation.

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