

Doi: 10.46793/MAK2026.391J

## SELECTIVITY AND EFFICACY OF FLUROCHLORIDONE WITH OTHER HERBICIDES IN WEED CONTROL IN PROCESSING TOMATO (*Solanum lycopersicum* L.)

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**Abstract:** For weed control in processing tomato new herbicides need to be registered. Flurochloridone with metobromuron/dimethenamid-P was applied before and after transplanting to assess its efficacy and crop injury. All treatments provided good (75-90%) to excellent (>90%) efficacy in weed control. Also, all four treatments caused crop injury, whereby treatment with metobromuron caused higher damage. Further research must be conducted with different herbicides and rates, to keep excellent efficacy but reduce crop injury.

**Keywords:** Processing tomato, Flurochloridone, Weed control, Efficacy, Crop injury

### INTRODUCTION

Over the last fifteen years, modern agriculture has changed in many ways. Climate changes, increased world population and less arable land available, are three factors which are pushing modern agriculture forward. Due to these three factors, the global need for food has increased, so yield per growing area must be increased. On the other hand, one of the main problems in vegetable growth, including processing tomato (*Solanum lycopersicum* L.), is that at the same period of time the European Union has downdrawn many herbicides, with emphasis on some very important for vegetable production, so weed control in this crop has become troublesome (EFSA, 2025). Climate changes are also one of the key factors in combination with increased transport worldwide, which are visible due to the shift in weed population across fields. Four out of the last five years were with less precipitation or no precipitation during July and August, and with increased average temperature compared with the multi-year average (RHMZ, 2025). If compared to the period of fifteen to twenty years ago, new weeds are becoming more dominant compared to others, which implies that new practices in weed management need to be developed. Although, C<sub>4</sub> and CAM plants are becoming more dominant if compared to C<sub>3</sub> plants, due to their better adoption mechanism to drought and high temperatures (Božić, 2018). Some of the most dominant weed species in late spring grown vegetables in Serbia, which are becoming a modern threat worldwide as well, are *Abutilon theophrasti* Medik, *Amaranthus* spp., *Chenopodium* spp., *Datura stramonium* L., *Echinochloa crus-galli* L. P.Beauv, *Setaria* spp., *Solanum nigrum* L., *Sorghum halepense* (L) Pers., *Portulaca oleracea* L., *Orobanch*

spp. and *Cuscuta* spp. (Konstantinović et al., 2020; Živković et al., 2024). Their dominance compared to other weed species because of the adoption mechanism, in combination with herbicide drawdown and resistance development are serious problems with which farmers all over the world are facing. Therefore, the goal of this study was to find new solutions for weed management in processing tomato, and to evaluate its efficacy and crop safety.

## MATERIAL AND METHODS

Experimental site. The field experiment was conducted at the experimental field of the Institute of Vegetable crops Smederevska Palanka in Smederevska Palanka, during 2025 growing season. The experiment was arranged as a split-plot design with two herbicide combinations as main plots and two timing of application as subplots as well as weedy treatment - control (Table 1).

Table 1. Treatments applied in the study

Treatment	Time of application	Herbicide 1	Rate (g a.i. ha <sup>-1</sup> )	Herbicide 2	Rate (g a.i. ha <sup>-1</sup> )
Control	PRE-EM	/		/	
	POST-EM	/		/	
1	PRE-EM	metobromuron	1000	flurochloridone	500
	POST-EM	metobromuron	1000	flurochloridone	500
2	PRE-EM	dimethenamid-P	864	flurochloridone	500
	POST-EM	dimethenamid-P	864	flurochloridone	500

Both weedy subplots were transplanted at the same time with treated plots. Applied herbicide treatments included flurochloridone (Racer<sup>®</sup> - ADAMA Agricultural Solutions Ltd., Golan Street Airport City, Israel) a phytoene desaturase inhibitor (PDS - HRAC 12) applied at 500 g a.i. ha<sup>-1</sup> in tank-mix combination with metobromuron (Proman<sup>®</sup> - Certis Belchim, Londerzeel, Belgium), an inhibitor of photosynthesis at photosystem two (PSII inhibitor - HRAC 5) applied with 1000 g a.i. ha<sup>-1</sup> and dimethenamid-P (Frontier super<sup>®</sup>-BASF SE, Ludwigshafen RP, Germany) an inhibitor of very-long chain fatty acid synthesis (VLCFA - HRAC 15) applied at 864 g a.i. ha<sup>-1</sup> as main plots. Herbicides were applied before transplanting PRE-EM and after transplanting POST-EM. Main plots were 2,5 x 2 meter and contained 4 rows of tomato seedling transplanted on 0.5 x 0.25 meters distance with 10 plants in each row, so 40 plants contained in each plot. First transplanting was conducted on June 20<sup>th</sup> after which immediately herbicide application was conducted in the other subplots. Second transplanting was conducted on June 25<sup>th</sup> (5 days after PRE-EM herbicide application) whereby immediately after transplanting POST-EM herbicide application was conducted. Seedlings were transplanted when three true leaves were developed (BBCH 13). After 2 hours of each transplanting/herbicide application, the field was irrigated with an irrigation sprinkler nozzle which delivers 10 L of water per square meter per hour. The field was irrigated intensively in the first ten days after transplanting (DAT) so tomato seedlings could survive extremely high temperatures during this period of year (Table 2).

Table 2. Weather data and irrigation intervals for the period of 10 days after first transplanting

Date	June										July				
	20	21	22	23	24	25	26	27	28	29	30	1	2	3	4
Irrigation (h)	3	/	/	3.5	/	/	/	4	/	/	3.5	/	3.5	/	4
Maximum air temperature (°C)	28.3	27.6	29.8	33.9	33.4	37.4	38.8	30.6	29.1	32.0	35.4	32.9	33.3	36.9	38.2
Minimum air temperature (°C)	10.6	8.6	10.1	12.0	15.5	17.2	19.3	18.8	15.4	18.6	17.5	11.8	11.4	12.7	21.5
Precipitation (mm m <sup>-2</sup> )	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

The seedlings were grown in a 104 openings styrofoam container, whereby the seeds were sown late on May 8<sup>th</sup>. Herbicide application was conducted with a battery powered backpack sprayer “Farm® KF-16C-47” which delivers a constant pressure. A four-nozzle boom with Lechler IDK12002 nozzles was used. The pressure was 276 kPa whereby the speed was 4.56 km h<sup>-1</sup> (Table 3).

Table 3. Spraying parameters in research

Pressure (kPa)	Speed (km h <sup>-1</sup> )	Flow rate (L min <sup>-1</sup> )	Spray volume (L ha <sup>-1</sup> )	Nozzle specifications
276 ±10%	4.56	0.75	200	Lechler IDK 12002

Before herbicide application, a soil analysis was conducted (Table 4). Since the soil belongs to a heavy clay loam texture and contains 49.3% of clay, higher rates for tank-mixture of each herbicide must be applied, to achieve good soil activity but also not too high because of crop injury.

Table 4. Soil analysis results (0-30cm)

pH (H <sub>2</sub> O)	pH (KCl)	CaCO <sub>3</sub> (%)	Organic matter (%)	Total N (%)	P <sub>2</sub> O <sub>5</sub> (mg 100g <sup>-1</sup> )	K <sub>2</sub> O (mg 100g <sup>-1</sup> )	Sand	Fine sand	Silt	Clay
6.31	5.91	0.34	2.25	0.15	38.28	39.27	5.1	21.1	24.5	49.3

After 28 days of each herbicide application, crop and weed parameters were taken for selectivity and efficacy. Tomato plant number per meter, tomato height and biomass were taken, as well as weed spectrum, density and biomass. After sampling, plant material was dried in air oven at 75°C until constant weight. The data has been analyzed by ANOVA, LSD and Tukey test, with IBM SPSS Statistics, Version 26.0 and were presented as table and graphs.

## RESULTS AND DISCUSSION

Weed density and weed composition. Present weeds in the study were *Abutilon teophrasti* Medik., *Amaranthus* spp., *Datura stramonium* L., *Echinochloa crus-galli* L. P. Beauv and *Portulaca oleracea* L (Table 5). Due to the high content of clay in the soil profile (49.3%), and the increased amount of irrigated water necessary after transplanting/herbicide application, the two most dominant weed species in this study were *Echinochloa crus-galli*

a hygrophilous weed ( $F_4$ ) which prefers to grow in fields with no water deficiency, even flooded (Jovanović and Rančić, 2025). *Portulaca oleracea* was the second most dominant weed species in this study, due to its high-water requirements and possibility to change from  $C_4$  metabolism to CAM (Ren et al., 2011). A difficult to control weed in processing tomato with an optimum germination temperature range from 20-30°C such as *Datura stramonium* was also present (Jursik et al., 2004), as well as *Abutilon teophrasti* and *Amaranthus* spp., a nitrophilous weed (Radicetti et al., 2016; Vrbničanin et al., 2004), but with a less dense population. Weed composition and weed densities are given in Table 5.

Table 5. Average weed density per treatment (plants  $m^{-2}$ ) 28 DAT (Tukey,  $\alpha=0.05$ )

Treatments	Subplot	Weed species				
		<i>Abutilon teophrasti</i>	<i>Amaranthus</i> spp.	<i>Datura stramonium</i>	<i>Echinochloa crus-galli</i>	<i>Portulaca oleracea</i>
Control	PRE-EM	7.33 b	4.00 b	9.67 b	41.67 b	36.33 b
	POST-EM	7.50 b	5.00 b	9.00 b	40.33 b	34.67 b
metobromuron + flurochloridon	PRE-EM	0.00 a	0.00 a	3.67 a	5.00 a	0.83 a
	POST-EM	0.00 a	0.00 a	1.00 a	7.00 a	0.17 a
dimethenamid-P + flurochloridon	PRE-EM	1.33 a	0.00 a	0.33 a	2.67 a	0.00 a
	POST-EM	3.00 a	0.00 a	0.33 a	4.00 a	0.00 a

All four subplots showed statistically very significant differences in weed density compared to equivalent control treatments. Statistically no significant differences were observed between two treatments and between subplots in weed density of all five present weed species. Treatment 2. (dimethenamid-P + flurochloridon) provided less weed density in control of all weed species except *Abutilon teophrasti*. Compared to untreated control plots, both treatments applied either as PRE-EM or POST-EM provided 100% of control on *Amaranthus* spp. The percent of dry biomass reduction is given in Table 6.

Table 6. Average dry biomass reduction (%) 28 DAT (Tukey,  $\alpha=0.05$ )

Treatments	Subplots	Weed species				
		<i>Abutilon teophrasti</i>	<i>Amaranthus</i> spp.	<i>Datura stramonium</i>	<i>Echinochloa crus-galli</i>	<i>Portulaca oleracea</i>
Control	PRE-EM	0.00 a	0.00 a	0.00 a	0.00 a	0.00 a
	POST-EM	0.00 a	0.00 a	0.00 a	0.00 a	0.00 a
metobromuron + flurochloridon	PRE-EM	100.00 b	100.00 b	63.89 b	72.90 b	88.08 b
	POST-EM	100.00 b	100.00 b	79.37 b	51.08 b	91.61 b
dimethenamid-P + flurochloridon	PRE-EM	95.80 b	100.00 b	92.06 b	81.50 b	100.00 b
	POST-EM	88.11 b	100.00 b	86.67 b	70.76 b	100.00 b

The percentage of dry biomass reduction of *Amaranthus* spp. was 100% in all four subplots, whereby 100% of dry biomass reduction for *Abutilon teophrasti* was observed in both subplots of treatment 1. (metobromuron + flurochloridon) and for *Portulaca oleracea* 100% of dry biomass reduction was observed in treatment 2. (dimethenamid-P + flurochloridon) (Table 6). Both treatments were least efficient in *Echinochloa crus-galli* control, where the percent of dry biomass reduction varied from 51.08 but was not higher than 81.50%. The percent of dry biomass reduction of *Datura stramonium*, a difficult to control weed species in processing tomato was higher in both subplots of treatment 2. (dimethenamid-P + flurochloridon) with excellent 92.06% and satisfactory 86.67% in before and after transplanting subplots, respectively.

Another parameter followed in this study was crop injury. Crop injury was assessed by counting survived tomato plants in one meter of row length and by sampling plants and calculating the percentage of dry biomass reduction. Both treatments applied both ways caused dry biomass reduction in a serious percent (Table 7).

Table 7. Average crop injury parameters measured in the study 28 DAT (Tukey,  $\alpha=0.05$ )

Treatments	Subplots	Number of plants per meter	Dry biomass reduction (%)
<b>Control</b>	PRE-EM	4.00 b	0.00 a
	POST-EM	4.00 b	0.00 a
<b>metobromuron + flurochloridon</b>	PRE-EM	2.70 a	81.23 c
	POST-EM	2.30 a	77.41 c
<b>dimethenamid-P + flurochloridon</b>	PRE-EM	4.00 b	75.60 b
	POST-EM	4.00 b	52.43 b

Treatment 1. (metobromuron + flurochloridon) caused higher percentage of dry biomass reduction applied both ways, but more important is that this treatment caused 100% percent damage on tomato plants and reduced the average number of tomato plants per meter, which has a direct impact on the stand count and final yield (Table 7).

## CONCLUSION

According to the present one-year data, both herbicide treatments applied either before or after tomato transplanting, caused very high crop injuries. Some of those treatments caused 100% injury and must be considered as phytotoxic. The efficacy of all four subplots varied, but statistically no significant differences were observed except for *Echinochloa crus-galli* dry biomass reduction. Both treatments did not provide excellent control of *Echinochloa crus-galli* and *Datura stramonium* compared to all three other weed species. Stronger crop injuries in treatment 1. (metobromuron + flurochloridon) compared to treatment 2. (dimethenamid-P + flurochloridon) might be a result of adding metobromuron which acts synergistic with flurochloridon as well as due to the foliar activity of metobromuron as a PSII inhibitor compared to dimethenamid-P with only soil activity (Idziak and Woznica, 2020). According to the literature based on previous similar studies in processing tomato across the world, this study will be continued with other herbicide combinations, lower herbicide rates and different timing of application to provide hopefully new results with less crop injuries and with higher efficacy.

## ACKNOWLEDGMENT

The work was supported by the Ministry of Science, Technological Development and Innovation of the Republic of Serbia (Contract number: 451-03-66/2025-03/200216; 451-03-136/2025-03/200010), FAO Project (2025): "Strengthening Disaster Resilience in Agriculture".

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