

Evaluation of pre and post-emergence herbicides for weed control in potato crop

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Abstract

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The study aimed to evaluate the effectiveness of herbicides for weed control in potato crops in the Gjakova region of Kosovo. The experiment is set up using a randomized block system with four repetitions. There were a total of six treatments in the experiment: pendimethalin as a pre-emergence herbicide applied at two different doses, metribuzin applied both pre-emergence and post-emergence with fluzazifop-p-butyl, a treatment with mechanical intervention, and a control treatment. A total of 18 weed species were documented, in the control plots dominant weed species were: *Trifolium repens* L. with 18.8 plants/m², *Echinochloa crus-galli* L. 17.5 plants/m², *Plantago lanceolata* L. 15.0 plants/m², and *Lotus corniculatus* L. with 7.3 plants/m². The morphological composition of weeds was characterized by 13 dicotyledons and 5 monocotyledons. The biological composition of weeds was predominantly characterized by therophytes at 55.6%, hemicryptophytes at 30.5%, geophytes at 11.2%, and chamaephytes with a minor representation of 2.7%. The results indicate that herbicides have effectively reduced both the number of weeds, as well as the weed dry biomass, which has consequently affected potato yields. The most efficient herbicide for reducing weed species was metribuzin, a pre-emergence herbicide, with a 92.5% efficiency, while pendimethalin, a pre-emergence herbicide at a 6.0 l/ha dose, had an efficiency of 80.4%. The highest potato yield was achieved in the plots where metribuzin pre-emergence was applied, yielding 45.3 t/ha, and pendimethalin was applied at 6.0 l/ha, yielding 28.0 t/ha.

Keywords: potato crop; metribuzin; pendimethalin; weed species; herbicide efficacy

Abbreviations: Hydrometeorological Institute of Kosovo (HMIK); Food and Agriculture Organization (FAO)

Introduction

The potato (*Solanum tuberosum* L.) is one of the most important crops after rice, wheat, and maize in global production volume, ensuring food security for humans and livestock. According to Food and Agriculture Organization (FAO) statistics, in 2019, the world production of potato

crop, harvested from 19.25 million hectares, has reached 400 million tons (Ali et al., 2021), meanwhile according to FAOSTAT (2023), global potato production had decreased to 374 million tons. However, crop yield will decrease significantly due to weed interference. Potato production methods have expand significantly across regions considering various limiting factors such as climatic conditions and climate

change, water and nutrient availability, and the quality and quantity of light. These adaptations are crucial to create favorable conditions for optimal growth and development of potato (Skiba et al., 2021). Depending on their abundance and frequency, weeds have a negative impact on potato yield, particularly when competing with potato plants under various growth and developmental conditions. Based on Hidayat et al. (2013), weeds have reduced potato tuber yield by 53.4%, by 86% according to Monteiro et al. (2011), and between 10–80% according to Lal and Gupta (1984). In Kosova, 67 weed species from 120 genera and 26 families have been identified in potatoes (Mehmeti et al., 2019). It is reported that predominant weed species in potato crop in Kosovo are *Convolvulus arvensis*, *Fallopia convolvulus*, *Echinochloa crus-galli*, *Cirsium arvense*, *Datura stramonium*, *Persicaria lapathifolia*, *Chenopodium album*, *Amaranthus retroflexus*, *Equisetum arvense*, and *Lathyrus tuberosus* (Mehmeti et al., 2019). Thus, weed control is a major component of successful potato production (Abdallah et al., 2021).

Among the main herbicides used in potato cultivation and registered in Kosovo are Stomp Aqua (pendimethalin), Sencor 600 SC (metribuzin), and Fusilade Forte 15 EC (fluzifop-p-butyl) (MAFRD, 2024). Fluzifop-p-butyl-based products are used as selective trans-locative herbicides for controlling monocotyledonous annual and perennial weeds in plants such as sunflower, soybean, potato, tomato, etc. (Demaj and Mehmeti, 2016). According to Abdallah et al. (2021), metribuzin, as a pre-emergence selective herbicide, is traditionally, used mainly for annual broadleaf weed control in potatoes. If annual weeds are left uncontrolled, the tuber yield losses can reach up to 86.0%, depending on the severity of infestation (Mondani et al., 2011). Sharshar et al. (2015) concluded that the combination of herbicides metribuzin and fluzifop-p-butyl has had better efficiency for

weed control in potatoes. Additionally, pre-emergence herbicide like pendimethalin has been used for weed control in potato (Tomar et al., 2008). The main research hypothesis assumed that there are differences in potato yield, depending on the dose of pendimethalin, metribuzin, and fluzifop-p-butyl herbicides. Therefore, the conducted research aimed to evaluate the efficacy of the active substance of the herbicide pendimethalin at different dosages, metribuzin, and the combination of metribuzin with fluzifop-p-butyl for weed control and their impact on potato yield.

Material and Methods

The research was conducted in 2022 in the Gjakova Region, characterized by a continental climate (Table 1) and umbric gleysols soil type. The data on climatic conditions and average precipitation are referred to the meteorological station of the municipality of Gjakova, of the Hydrometeorological Institute of Kosovo (HMIK). During 2022, in the research conducted, temperatures and precipitation were variable. High mean temperatures were recorded in July and August, while significant precipitation occurred in April and August.

The field experiment was carried out by the method of randomized block system, with four replication, and six treatments in total (Table 2).

The potato crop was planted at a distance of 60 × 40 cm, within research plots measuring 3 × 5 m (15 m²), with pathways separated by 50 cm. Planting was carried out using a seeding machine at a depth of 12 cm, at the optimal time. The selected cultivar for planting was Agria, a late-maturing variety requiring approximately 140 days from germination to maturity under favorable climatic conditions, with tubers typically sized at 35/55 mm, amounting to roughly 41 665 plants/ha. Throughout the cultivation process, all necessary

Table 1. Mean temperature in °C and mean rainfalls in mm, in Gjakova region (HIK, 2022)

2022	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
Mean temp.	0.9	4.9	5.1	11.1	17.6	22.1	23.4	22.7	17.3	12.8	8.9	5.1
Mean rainfall	0.0	36.0	19.3	75.4	16.0	34.0	19.0	59.2	142.4	6.5	138.6	91.1

Source: Authors' own elaboration

Table 2. The used herbicides in potato crop

Treatments	Active substance	Trade name	Dose	Application
A	Pendimethalin	Stomp Aqua	4.0 l/ha	Pre-emergence
B	Pendimethalin	Stomp Aqua	6.0 l/ha	Pre-emergence
C	Metribuzin	Sencor 600 SC	0.75 l/ha	Pre-emergence
D	Metribuzin + Fluzifop-p-butyl	Sencor 600 SC + Fusilade Forte 15 EC	0.75 l/ha + 1.3 l/ha	Post-emergence
E	Mechanical intervention (hoeing)			
F	Control treatment (no herbicide or mechanical intervention)			

Source: Authors' own elaboration

agronomic practices were applied (Rusinovci et al., 2001). Fertilizer, Yara Mila NPK 7:20:28 + 2% MgO + 8% SO₂, was applied at 600 kg/ha. Additional crystal foliar fertilizer, Novalon 20-20-20+0.5 MgO + ME, was applied at 25g in 10 l/water. Herbicides were applied with a knapsack sprayer SANI 10L. Protection of potatoes against other diseases and main insects (*Leptinotarsa decemlineata* Say.) was applied according to standard recommendations.

The efficacy of herbicides was calculated by the equation (Šarić, 1991a):

$$CE \% = \frac{A \times 100}{B} \%,$$

where: CE % is the coefficient of efficacy, A is the number of destroyed weeds per m², and B is the number of weeds in the untreated 1 m² plots. The yield of potato, weed infestation, and weed dry biomass was estimated in end of experiment per 1m². The number of tubers per plant is counted by harvesting the tubers from 10/plants for each plot. Weeds were determined using botanical atlases (Mehmeti et al., 2015; Demiri, 1979), and life forms of weed vegetation according to Ellenberg et al. (1992).

Statistical analyses

Statistical analyses were performed using Anova's test, mean values were calculated and differences between mean values were evaluated based on the Tukey HSD 0.05 test.

The JMP® statistical package, Version 10.0.0, was used for statistical analysis according to Anova's test.

Results and Discussion

Weed flora vegetation

Efficacy of herbicides

The pre-emergence herbicide pendimethalin, applied at various doses, was not particularly effective in reducing weed numbers compared to metribuzin, used as a pre-emergence herbicide at 0.75 l/ha. The dominant weed species in plots treated with herbicides were: *Echinochloa crus-galli*, *Trifolium repens*, *Lotus corniculatus*, *Plantago lanceolata* and *Digitaria sanguinalis* (Table 4).

Metribuzin, the pre-emergence herbicide, showed the highest efficiency with 92.5%, followed by pendimethalin, the pre-emergence herbicide, at a dose of 6.0 l/ha with 80.4% efficacy. However, the combination of metribuzin at 0.75 l/ha + fluazifop-p-butyl at 1.3 l/ha showed lower efficacy 78.2%, followed by pendimethalin at a dose of 4.0 l/ha, resulting in 61.5% efficacy (Figure 1). The results regarding the limited effectiveness of pendimethalin herbicide after planting at lower doses align with the conclusions by Sadiku (2020). This could also be due to high precipitation after the application of pendimethalin, as a result of leaching, but, this depends on the soil type (Lee et al., 2000). However, other studies have

Table 3. Weed species recorded in potato crop

No.	Weed species	Family	Life forms	D	M	A	P
1	<i>Amaranthus retroflexus</i> L.	<i>Amaranthaceae</i>	T	*		*	
2	<i>Capsella bursa pastoris</i> L. Med.	<i>Brassicaceae</i>	T	*		*	
3	<i>Convolvulus arvensis</i> L.	<i>Convolvulariaceae</i>	G, H	*			*
4	<i>Cynodon dactylon</i> L. Pers.	<i>Poaceae</i>	G, H		*		*
5	<i>Cyperus flavescens</i> L.	<i>Cyperaceae</i>	T		*	*	
6	<i>Digitaria sanguinalis</i> L. Scop.	<i>Poaceae</i>	T		*	*	
7	<i>Echinochloa crus-galli</i> L. Beauv.	<i>Poaceae</i>	T		*	*	
8	<i>Equisetum arvense</i> L.	<i>Poaceae</i>	G		*		*
9	<i>Erodium cicutarium</i> L. L'Hér.	<i>Geraniaceae</i>	T, H	*		*	
10	<i>Lactuca serriola</i> L.	<i>Asteraceae</i>	H, T	*		*	
11	<i>Lotus corniculatus</i> L.	<i>Fabaceae</i>	H	*			*
12	<i>Matricaria chamomilla</i> L.	<i>Asteraceae</i>	T	*		*	
13	<i>Persicaria maculosa</i> Gray.	<i>Polygonaceae</i>	T	*		*	
14	<i>Plantago lanceolata</i> L.	<i>Plantaginaceae</i>	H	*			*
15	<i>Setaria pumila</i> Poir.	<i>Poaceae</i>	T	*		*	
16	<i>Solanum nigrum</i> L.	<i>Solanaceae</i>	T	*		*	
17	<i>Taraxacum officinale</i> Web.	<i>Asteraceae</i>	H	*			*
18	<i>Trifolium repense</i> L.	<i>Fabaceae</i>	C, H	*			*

D – dicotyledons, M – monocotyledons; A – annual, P – perennial.

Source: Authors' own elaboration

reported the efficacy of pre-emergence herbicide metribuzin and germination of potatoes in reducing weed numbers (Sadiku, 2020; Mirčov et al., 2006; Jaiswall, 1994; Yaduraju et al., 1993; Bellinder et al., 1996; Bellinder et al., 2000; Jovović et al., 2000, 2011, 2012). Despite targeting both broadleaf and grass weeds, the metribuzin + fluazifop-p-butyl combination had lower-than-expected efficacy. This may be due to antagonistic interactions, differences in herbicide absorption, or weed population dynamics, particularly the dominance of *Echinochloa crus-galli*, which should have been well-controlled by fluazifop-p-butyl (Minton et al., 1989). Soil characteristics, particularly organic matter content and texture, significantly affect metribuzin's behavior and effectiveness, in our case, umberic gleysols soil type (Peter and Weber, 1985). The higher precipitation amount during the time of application in April, may influenced the pendimethalin and metribuzin efficacy, however, this factor was not the focus of our research.

Efficacy of herbicides on weed dry biomass

The application of pre and post-emergence herbicides in potato crop influenced the weed dry biomass, as evidenced by the significant effects showed in Figure 2. There were statistically significant differences in the above dry biomass of weeds between plots treated with pre-emergence and post-

emergence herbicides compared to both the control plot and plots with mechanical intervention (Figure 2). Significantly, the pre-emergence herbicide, pendimethalin, applied at two different doses, showed a lower impact on reducing the weed dry biomass compared to pre-emergence metribuzin and the combination of metribuzin + fluazifop-p-butyl treatments as a post-emergence herbicide. The herbicide, metribuzin, had the highest impact on the reduction of the weed dry biomass, while other herbicides showed weaker effect in reducing the weed dry biomass. The application of pendimethalin herbicide at a rate of 4.0 l/ha showed limited effect in reducing the above dry biomass of weeds to 347.5 g/m². On the contrary, in the control plots, the weed dry biomass reached a considerably higher weight of 857.5 g/m². The variations in the above dry biomass of weeds observed between herbicide-treated plots and control plots may be attributed to climatic factors (Pestemer, 1983). In 2022, in the conducted research, temperatures and precipitation were variable, with high temperatures in April and heavy precipitation in August (Table 1). Variations in soil moisture availability and rainfall patterns, combined with higher temperatures influence the growth behaviour, survival, and distribution of both crop plants and weeds (Kumar et al., 2023). Moreover, certain studies have indicated that herbicides in potato crops have

Table 4. Weed species, herbicide efficacy on the number and weed species per m²

Weed species	A	B	C	D	E	F
<i>Amaranthus retroflexus</i> L.	0	0.2	1.5	0.2	0	1.0
<i>Capsella bursa pastoris</i> L. Med.	0.2	0	0	0	0	1.0
<i>Convolvulus arvensis</i> L.	0.7	0	0	0	0.7	1.0
<i>Cynodon dactylon</i> L. Pers.	0	0.5	0	0	0	1.5
<i>Cyperus flavescens</i> L.	1.0	0	0	0	1.5	4.5
<i>Digitaria sanguinalis</i> L. Scop.	3.5	2.7	0	0	2.2	6.0
<i>Echinochloa crus-galli</i> L. Beauv.	8.7	5.5	5.5	3.7	5.0	17.5
<i>Equisetum arvense</i> L.	0.7	0	0	1.0	1.7	1.0
<i>Erodium cicutarium</i> L. L'Hér.	0	0	0	0	1.0	1.0
<i>Lactuca serriola</i> L.	0	0	0	0	0	1.3
<i>Lotus corniculatus</i> L.	6.0	0	0	3.5	8.5	7.3
<i>Matricaria chamomilla</i> L.	0	0	0	0	0	0.8
<i>Persicaria maculosa</i> Gray.	0	0	0	0	0.2	5.8
<i>Plantago lanceolata</i> L.	2.7	0	0	6.7	5.0	15.0
<i>Setaria pumila</i> Poir.	1.5	2.5	0	0	2.0	6.0
<i>Solanum nigrum</i> L.	0	0	0	0.2	0.5	1.0
<i>Taraxacum officinale</i> Web.	0	0	0	0	2.2	2.2
<i>Trifolium repense</i> L.	10.7	6.5	0	4.7	11.2	18.8
Weed number/m ²	35.7	18.2	7.0	20.2	41.7	92.7
Number of weed species/m ²	10.0	6.0	2.0	7.0	13.0	18.0

Legend: A – pendimethalin 4.0 l/ha, pre-emergence; B – pendimethalin 6.0 l/ha, pre-emergence; C – metribuzin 0.75 l/ha, pre-emergence; D – metribuzin 0.75 l/ha + fluazifop-p-butyl 1.3 l/ha, post-emergence; E – mechinacal intervention; F – control treatment

Source: Authors' own elaboration

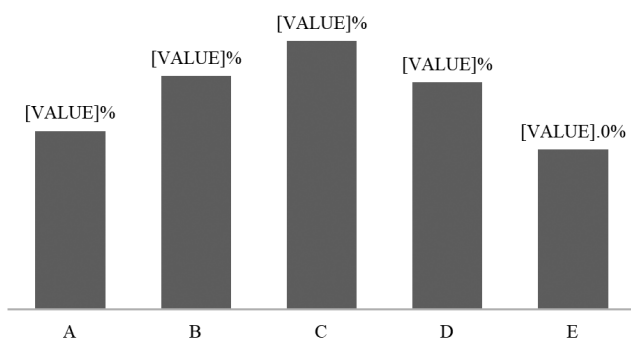


Fig. 1. Efficacy of herbicides on number of weeds
Legend: A – pendimethalin 4.0 l/ha, pre-emergence; B – pendimethalin 6.0 l/ha, pre-emergence; C – metribuzin 0.75 l/ha, pre-emergence; D – metribuzin 0.75 l/ha + fluazifop-p-butyl 1.3 l/ha, post-emergence; E – mechinacal intervention; F – control treatment

Source: Authors' own elaboration

an effect on the reduction of the weed dry biomass (Sadiku, 2020; Maholli, 2015; Neziri, 2011; Mehmeti et al., 2013; Jan et al., 2004; Jovović et al., 2011, 2012).

Potato yield and tuber quantity

The statistical data shows that herbicides have a significant impact on potato yield. All herbicides used had a higher yield compared to the control plot and had statistically significant differences compared to the control plot (Figure 3). The used herbicides differ significantly between pre-emergence herbicide metribuzin at 0.75 l/ha and all other treatments. In all the herbicide-treated, the highest yield was achieved in the plots where the pre-emergence herbicide metribuzin was used at a dose of 0.75 l/ha, with a very high yield of 45.3 t/ha, followed by pre-emergence herbicide pendimethalin at a dose of 6.0 l/ha, with 27.8 t/ha. Regarding the impact of pre-emergence herbicide metribuzin on potato yield, our results are in line with the results of other authors (Maholli, 2015; Mehmeti, 2004; Mehmeti et al., 2013; Jovović et al., 2012).

Regarding the number of tubers per potato plant, the results indicate statistically significant differences in all treatments including the application of the pre and post-emergence herbicides compared to control plots (Figure 4). Additionally, significant differences were shown between the pre-emergence herbicide metribuzin and pendimethalin at both doses, followed by the combination of post-emergence herbicides metribuzin + fluazifop-p-butyl.

The highest tuber number per plant was recorded in the plot treated with metribuzin pre-emergence, 9.0 tubers per plant, while the lowest tuber number was observed in plots

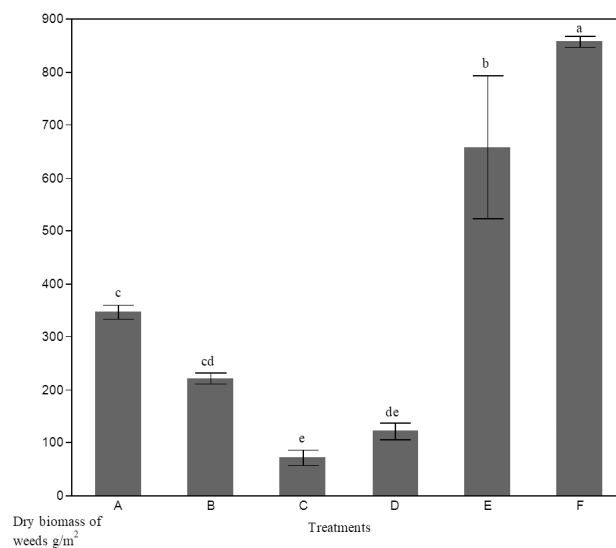


Fig. 2. Impact of herbicides in weed dry biomass (±SD, average with different letters are significant Tukey's HSD, <math>p < 0.05</math>)

Source: Authors' own elaboration

treated with the combination of metribuzin + fluazifop-p-butyl post-emergence herbicides, with 7.6 tubers per plant. Conversely, the control plot demonstrated the lowest tuber count, with 6.4 tubers per plant.

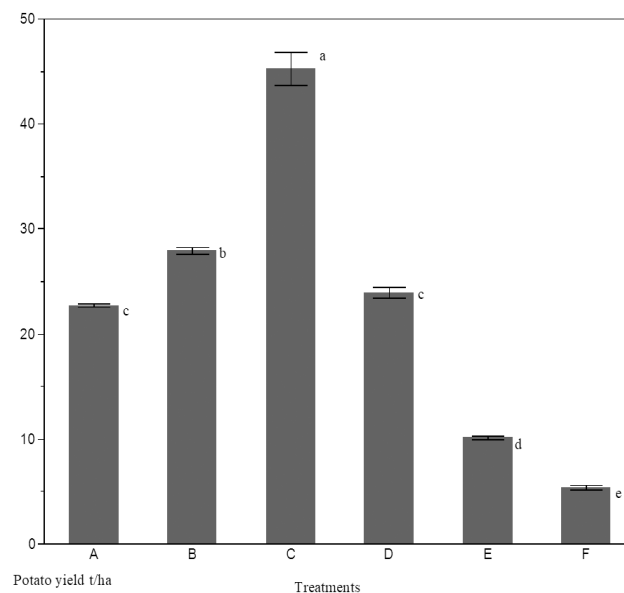


Fig. 3. Impact of herbicides in yield of potato (±SD, average with different letters are significant Tukey's HSD, <math>p < 0.05</math>)

Source: Authors' own elaboration

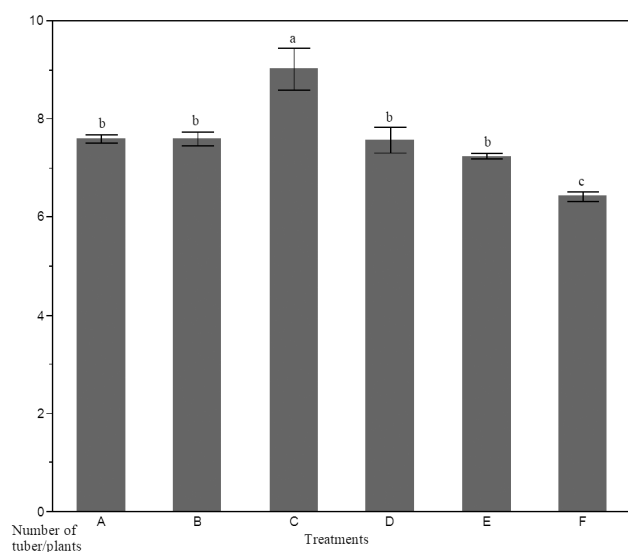


Fig. 4. Impact of herbicides in number of tubers/plant (\pm SD, average with different letters are significant Tukey's HSD, $p = 0.05$)

Source: Authors' own elaboration

Conclusions

The study results evaluated the effectiveness of pre and post-emergences of herbicides in controlling weeds in potato crop. The key findings are as follows:

In control plots 18 weed species were documented, dominated by *Trifolium repens*, *Echinochloa crus-galli*, *Plantago lanceolata*, and *Lotus corniculatus*.

Herbicide treatments significantly reduced both the number and weed dry biomass compared to plots with mechanical intervention. The pre-emergence herbicide, metribuzin was the most effective in reducing weed biomass (72.5 g/m²), while control plots had the highest weed dry biomass (857.5 g/m²).

Pre-emergence herbicide-treated plots with metribuzin and pendimethalin with different dosages had a significantly higher yield compared to the control plot.

The results of this study highlight metribuzin, as the pre-emergence herbicide, as the most effective herbicide for weed control in potato, followed by pre-emergence herbicide pendimethalin at dose of 6.0 l/ha, significantly improving yield and reducing weed vegetation. However, the combination of metribuzin + fluazifop-p-butyl did not enhance control as expected. The study emphasizes the need for long term study for proper herbicide selection, dosage, and timing for sustainable weed control and higher potato yield.

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