ISSUES REGARDING THE EFFECTIVENESS OF GLYPHOSATE ON UNCULTIVATED LANDS IN ACCORDANCE WITH THE EU REGULATIONS

Marga Grădilă*, Ciontu Valentin-Marius, Daniel Jalobă

Research – Development Institute for Plant Protection, 8 Ion Ionescu de la Brad 013813, Bucharest, Romania

Abstract

The uncultivated lands are a continuous source of weed infestation due to the fact that they help the development of a rich flora of weeds, while ensuring the accumulation in the soil of a large reserve of seeds and vegetative propagating organs that will encumber crop technologies for several years after recultivating. The most widely used herbicide for weed control on these lands is glyphosate. In November 2023, the European Commission renewed the approval of the active substance glyphosate for a period of ten years, but included a series of conditions and restrictions on use, the maximum authorised dose per year being 1440 g active substance/hectare. The aim of the study was to oversee the floristic composition of uncultivated lands and to evaluate the effectiveness of glyphosate herbicide at the maximum allowable dose (4.0 l/ha). The research was carried out in 2024, in 2 uncultivated experimental plots, one located in the RDIPP-Bucharest experimental field and other in Cocani village, Dâmbovița county. The field trials were conducted in randomized blocks of 100 m² plot area in 4 replications, with herbicides applied in postemergence when the weeds were in their earliest stages of growth and development at rates of 2.0, 4.0, and 6.0 l/ha. Effectiveness was evaluated according to the EWRS scale at 15 and 30 days after application of the treatments. Glyphosate had a good weed control efficacy with the best results obtained at 4.0 and 6.0 l/ha. At 2.0 l/ha some weed species were insufficiently controlled. At the maximum allowed rate of 1440 g a.i/ha (4.0 l/ha), the lowest effectiveness for dicots was recorded for field bindweed, perennial thistle and plantago species with an average efficacy of 50% and for monocots for perennial ryegrass with an efficacy of 56%.

Keywords: *uncultivated lands, weeds, herbicides, effectiveness, glyphosate*

1. INTRODUCTION

Uncultivated lands represent a challenging problem but also an opportunity, especially in the context of modern and sustainable agriculture, rural development and ecological transition. Land abandonment is a widespread process in many regions of the world as a consequence of social-economic conditions and changes in land use (Lana-Renault et al., 2020; Fayet et al., 2022; Quintas-Soriano et al., 2022). Land abandonment is a dynamic process, influenced by a many-sided range of social-economic, political and environmental components that vary over time and space. The impacts of land abandonment on biodiversity and the environment can be positive or negative, depending on the conservation status of the area, agro-climatic conditions and local factors (Höchtl et al., 2005; Osawa et al., 2016; Keenleyside et al., 2010; Ustaoglu and Collier, 2018; Pawlewicz and Pawlewicz, 2023).

Uncultivated lands pose a number of problems and risks related to: decreased soil fertility, loss of biodiversity, increased frequency and intensity of wildfires, soil erosion and desertification, loss of cultural and aesthetic values, reducing of landscape diversity and decrease of water supply (Benayas et al., 2007; Haddaway et al. 2014; Tarolli et al., 2014). Furthermore, abandoned lands are a source of arable lands weed infestation, which takes much time and effort to be removed (Barbotkina et al., 2020; Grădilă et al., 2022). On an uncultivated land, weeds quickly take over and trigger a process of spontaneous ecological succession, with consequences over environment, soil and the agricultural potential of the land (Vallejo et al., 2006; Tasser et al., 2007; Munroe et al., 2013; Gallemore et al., 2018, Kolecka, 2018; Pérez-Hernández and Gavilán, 2021). The abandonment of agricultural land is resulting in a shrubbery landscape with remarkable environmental, landscape and social-economical implications (Mantero et al., 2020).

Society and scientists currently have different views on how to manage abandoned lands. Some of them regard land abandonment as a way to restore natural ecosystem processes and to enhance and conserve biodiversity (Marty et al., 2003; Kleijn et al., 2006). On the contrary, other scientists and a part of the population consider that interventions for the management of abandoned agricultural land are mandatory to control the negative effects of revegetation processes (Kates et al., 2001; Morán-Ordoñéz et al., 2011; Lasanta et al., 2015). Good management of deserted agricultural lands has important consequences because of the large areas they cover and the resources and services it can provide to society as a whole.

Uncultivated agricultural lands are an endless weed infestation source as they promote the development of a rich weed flora usually perennial, while assuring in the soil the accumulation of a large ammount of seeds and vegetative breeding parts which will render crop technologies over many years after resowing (Marușcă, 2015). The management of uncultivated land flora thus becomes particularly important to avoid the spread of weeds in the agroecosystem and to protect biodiversity (Datta et al., 2018). From an economic point of view, it is much more practical to restore abandoned land on which young vegetation has been installed, requiring much less material, technological and human intervention than land on which woody vegetation has already been installed, which is what we have intended to demonstrate with this study. One of weed control method to control weeds on lands left uncultivated is chemical control while glyphosate is the most used herbicide.

In November 2023, the European Commission renewed the approval of the active substance glyphosate for another 10 years. The renewal of glyphosate is subject to certain conditions and restrictions, including a prohibition on pre-harvest use as a desiccant and measures to protect non-target organisms, the maximum authorised dose per year being 1440 g active substance/hectare (Regulation, EU 2023/2660). The aim of the study was to oversee the floristic composition of uncultivated lands and to evaluate the effectiveness of glyphosate herbicide at the maximum allowable.

2. MATERIALS AND METHODS

The research was carried out in 2024, in 2 uncultivated experimental plots, one located in the RDIPP-Bucharest experimental field and the other in Cocani village, Dâmbovița county. The field trials were conducted in randomized blocks of 100 m² plot area in 4 replications, with herbicides applied in postemergence when the annual weeds were in their earliest stages of growth and development and perennial ones before tillering at rates of 2.0, 4.0, and 6.0 l/ha.

The commercial formulation Roundup Classic Pro (360 g/L glyphosate, soluble concentrate, SL) was applied at two experimental sites: Bucharest and Cocani. At the Bucharest site, the treatment was applied on 12 April 2024 between 10:00 and 12:00. Air temperature ranged from 14 to 15°C, relative humidity from 65% to 63%, and wind speed was 0.4 m/s with a south-eastern direction. Soil temperature measured at 15 cm depth was 18°C. Precipitation was negligible prior to application (0.2 mm in both the previous week and the two weeks before application). Rainfall increased after treatment, reaching 23.5 mm one week and 26.2 mm two weeks after application. The first rainfall event occurred six days after application (14.4 mm). At the Cocani site, the treatment was applied on 18 April 2024 between 09:30 and 11:45, at an air temperature of 18°C. Wind speed ranged from 0.6 to 0.8 m/s (south-east), and soil temperature at 15 cm depth was 19.6°C. Precipitation prior to application was substantial, with 43.6 mm recorded in the two weeks before and 24.6 mm in the week preceding treatment. The first rainfall event occurred three days after application (2.7 mm), followed by 3.9 mm after one week and 12.9 mm after two weeks. At both sites, no rainfall was recorded within 6 or 24 hours after application.

The herbicide was applied using a manual pressure sprayer operating at 2 bar, equipped with TeeJet nozzles producing a fine spray, spaced 25 cm apart. The spray volume was 300 L/ha.

Experimental fields at both locations were heavily infested with annual and perennial monocotyledonous and dicotyledonous weeds, with no woody vegetation present. The sites had been unmanaged for 4-5 years, resulting in semi-natural grasslands dominated by species of low forage value. Soils at both locations were classified as brown-reddish soils with a clay loam texture. Organic matter content and pH were similar between sites (2.2% OM, pH 6.8 at Bucharest; 2.4% OM, pH 7.2 at Cocani).

Weeds density was assessed as couple of plants on square meter and as percentage of ground cover. The number of weeds per square meter was determined by weed mapping with a metric frame of 1 m^2 side in 4 repetitions on the diagonal of the plot. The percentage of weed cover was revealed visually, according to species, density and phenological aspects of each weed (sprouting, budding, flowering, fruiting, ripening, seed dispersal, height, etc.). Weed control (efficacy) was assessed one month after application of treatments in % compared to the untreated control according to the EWRS scale, at 30 days after application of the treatments.

3. RESULTS AND DISCUSSIONS

When an agricultural land is left uncultivated for the first two years, annual and biennial mono and dicotyledonous weeds develop strongly, especially invasive and difficult to control, vigurous, capable of seed-forming weeds (*Amaranthus*, *Ambrosia*, *Setaria*, *Echinochloa*, *Xanthium*, etc.). These species come to ground cover and prevail on abandoned land. At this stage, weeds can be easily controlled by appropriate measures and the land can be returned to agricultural use without great expense. This is followed by an intermediate stage of 2-5 years when some perennial deep-rooted weeds or rhizomes become established: *Cirsium arvense* (L.) Scop., *Sonchus arvensis* L., *Convolvulus arvensis* L., *Elimus repens* (L.) Gould, *Urtica dioica* L., *Carduus nutans* L., *Eryngium campestre* L., *Artemisia absinthium* L., etc. They are much more difficult to be eradicated as they persist in the soil and spread rapidly, with a high capacity to multiply and regenerate. Weed control at this stage requires the application of special, periodic control measures (repeated mowing, mulching, special agro-technical tillage, repeated chemical treatments, etc.), since perennial species pose particular problems for control, which lead to much higher expenditure. This is followed by the advanced stage of 5 - 10 years or even more during which shrubs (dog-rose, sloe), tree seedlings (locust tree, poplar, alder) start to appear. A semi-permanent vegetation is formed, actually a mixture of grass, shrubs and little trees. The land becomes practically non-agricultural, requiring seeding of competitive green crops (e.g. rye, phacelia), deep plowing, deforestation, etc., which takes several years and is very expensive (Lauringson and Talgre, 2003; Valkó et al., 2016). Based on these considerations, uncultivated land heavily afforested by annual and perennial mono and dicotyledonous weed species but without woody vegetation was selected for this study. These arable fields were uncultivated and practically transformed into semi-natural grassland, predominated by forage-free species.

In the experimental plot at ICDPP-Bucharest, dicotyledonous weeds prevailed, with approximately 70%, being present among the perennial specie: *Achillea millefolium* L., (Asteraceae) *C. arvensis* (Convolvulaceae), *Lepidium draba* L. (Brassicaceae), *Plantago* sp. (Plantaginaceae). Among the annual dicotyledonous annuals were found: *Cerastium dubium* (Bastard) Guépin (Caryophyllaceae), *Daucus carota* L. (Apiaceae*), Capsella bursa-pastoris* (L.) Medik., (Brassicaceae) and *Ambrosia artemisiifolia* L. (Asteraceae). Among the monocots, two species of the Poaceae family were noted, a perennial species valuable as forage plant *Lolium perenne* L. and *Echinochloa crus-galli* (L.) Beauv, a cosmopolitan annual species found on all soil types and in all crops (Table 1).

Under these conditions of infestation glyphosate at 6.0 l/ha (the maximum rate tested) had good weed control efficacy on the RDIPP from the uncultivated land, especially for *Lepidium*, *Cerasitium, Dauc*a and *Echinochloa* species. The rate of 4.0 l/ha ensured overall moderate efficacy, for perennial weeds (*Convolvulus*, *Plantago* and *Lolium*), the efficacy was about 50%. The lowest efficacy was recorded at the 2.0 l/ha rate with the percent control for perennials being about 35% (Table 1).

Table 1. The efficacy of Glyphosate in uncultivated lands at 30 days after treatment, RDIPP

Weed species	Efficacy (% control compared to untreated check)						
	Weeds BBCH (Majority)	Glyphosate 360 G/L			Untreated (% soil coverage)	LSD P=.05	SD
		2.0 L/HA	4.0 L/HA	6.0 L/HA			
Achillea millefolium	**49[1]-51[2]**	43.5b	64.0ab	78.7a	8.0c	25.4-34.7	13.4t
Convolvulus arvensis	**40[3]-65[4]**	30.8b	52.5a	70.4a	12.2c	26.6-31.0	11.4t
Lepidium draba	**49[1]-63[5]**	49.5b	68.8ab	80.7a	10.0c	24.0-31.9	13.6t
Plantago species	**65[4]**	43.5b	51.0b	78.7a	4.5c	15.0-22.3	9.04t
Cerasitium dubium	**65[4]**	40.5c	62.3b	81.7a	13.5d	16.4-29.2	10.7t
Daucus carota	**49[1]**	54,2	81.7a	90.0a	10.0c	6.2-20.9	16.0t
C. bursa pastoris	**69[6]**	57.8a	70.4a	72.6a	7.0b	28.2-43.6	18.2t
Ambrosia artemisiifolia	**49[1]-51[2]**	54.0b	67.2ab	71.2a	6.0c	18.3-20.0	8.5t
Lolium perenne	**47[7]-55[8]**	35.5b	56.0ab	73.5a	16.5c	32.6-39.2	35.0t
Echinochloa crus-galli	**45[9]-55[8]**	51.7b	63.6ab	81.7a	10.0c	23.3-30.4	13.7t

[1] Constant new development of young plants; [2] Inflorescence or flower buds visible;

[3]Vegetative reproductive organs begin to develop (rhizomes, stolons, tubers, runners, bulbs);

[4]Full flowering: 50% of flowers open, first petals may be fallen; [5]30% of flowers open;

[6]End of flowering: fruit set visible; [7]Flag leaf sheath opening;

[8]First individual flowers visible (still closed); [9]Flag leaf sheath swollen (late-boot);

According to the percentage of ground cover at 30 days after treatments in the untreated plot is shown in Figure 1, where Poaceae was the dominant weed family (26.5%), followed by the Brassicaceae (17%) and Asteraceae family (16%). Of the 2 species of Poaceae, *L. perenne* is an important cultivated grass species, which becomes a very competitive weed when grown in crops. Although it is a perennial species, it will still produce seeds in the first year of growth. Generally germinating at the same time as crops, it grows rapidly and competes aggressively for space, light, nutrients and water. Uncontrolled perennial ryegrass will significantly reduce yields. Although glyphosate is considered an effective herbicide for the control of this species, there are known cases of glyphosate resistance in perennial ryegrass populations (Ghanizadeh et al., 2013; Gunnarsson et al., 2017). It is a valuable component of all mixtures for both grassland and pastures and is used in deserted lands conversion programs. Of the annual dicotyledonous annuals, *C. dubium* was dominant with a 16.5% infestation and of the perennial dicotyledonous *C. arvensis* with a 12.2% infestation at 30 days after treatments in the control sample. Field bindweed is a problematic perennial weed with a deep root system and a high regeneration capacity (Timmons, 1950; Weaver and Riley, 1982). It is well-known for its resistance or tolerance to many herbicides, especially foliar and contact ones. The data in literature reports that this weed is often resistant or less sensitive to glyphosate-based herbicides due to its waxy leaves and deep roots, requiring higher rates and repeated applications (Huang et al., 2019). Other species (with a low density per square meters): *Digitaria sanguinalis* (L.) Scop., *Sorghum halepense* (L.) Pers., *E. repens, E. campestre, Polygonum convolvulus* L., *Xanthium italicum* (Moretti) Greuter, *Lamium* species and *Veronica hederifolia* L.

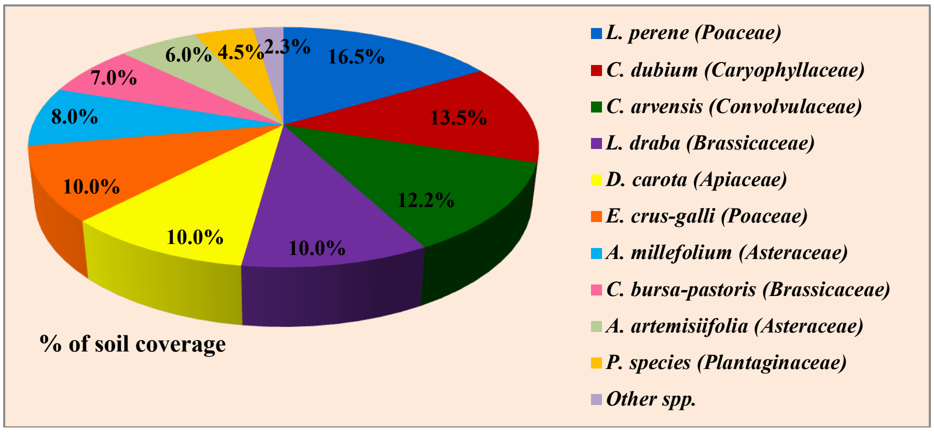

Figure 1. The distribution of weed species by botanical families at RDIPP after 30 days after treatments in the untreated plot

In the Cocani experimental plot, perennial dicotyledonous weeds were identified: *C. arvense*, (Asteraceae), *Euphorbia cyparissias* L. (Euphorbiaceae), *Rubus caesius* L. (Rosaceae), *Rumex acetosa* L. (Polygonaceae) and *Lotus corniculatus* L. (Fabaceae). Among the annual dicotyledonous annuals, 2 species were found: *Ranunculus arvensis* L. (Ranunculaceae) and *Sonchus oleraceus* L. (Asteraceae). Among the perennial monocots, *Poa pratensis* L. (Poaceaceaceae) and *Lolium pratense* (Hudson) Darbyshire (Poaceae) were present and among the annual monocots, *Setaria* species were present. Although only 3 monocotyledonous species were present, they dominated the abandoned Cocani field with a degree of weed infestation of over 55% (Table 2). Of the data analysis shown in Table 2, it can be concluded that at Cocani, at 30 days after the application of the treatments, the herbicide Glyphosate had a good efficacy in control of weeds on uncultivated lands, the best results being obtained at the highest doses. For creeping thistle the efficacy was lower being: 34.3% for the rate of 2.0 l/ha, 47.9% for for the rate of 4.0 l/ha and 64.7% for the rate of 6.0 l/ha (Table 2).

Table 2. The efficacy of Glyphosate in uncultivated lands at 30 days after treatment, Cocani

Weed species	**Efficacy (% control compared to untreated check)**						
	Weeds BBCH (Majority)	**Glyphosate 360 G/L**			**Untreated (% soil coverage)**	**LSD P=.05**	**SD**
		2.0 L/HA	**4.0 L/HA**	**6.0 L/HA**			
Cirsium arvense	**51^2-63^5**	34.3b	47.9ab	64.7a	10.7c	30.0-32.1	11.7t
Euphorbia cyparissias	**49^1-51^2**	51.5c	72.1b	90.0a	4.5d	3.2-16.4	12.0t
Ranunculus arvensis	**40^3-69^6**	55.5c	78.7b	72.1a	4.5d	3.3-15.6	6.61t
Rubus caesius	**40^3-63^5**	32.1b	59.0a	78.7a	9.5c	24.5-22.3	11.1t
Rumex acetosa	**49^1**	45.6c	59.9b	90.0a	4.5d	3.2-17.5	6.46t
Sonchus oleraceus	**51^2-63^5**	45.0c	78.7b	90.0a	5.5d	3.4-18.2	6.67t
Lotus corniculatus	**49^1-63^5**	47.9c	68.4b	80.7a	5.5d	7.4-15.4	5.7t
Poa pratensis	**43^{10}-55^8**	47.1b	62.2a	76.4a	13.5c	15.8-33.8	8.7t
Setaria species	**43^{10}-69^6**	38.9b	68.7a	80.7a	26.5c	18.1-30.4	11.1t
Lolium pratense	**45^9-55^8**	40.6b	60.6ab	73.0a	15.5c	27.9-33.8	12.6t

[10]Flag leaf sheath just visibly swollen (mid-boot)

As far as it concerns the distribution of weed species by botanical group, analysis of the data in Figure 2 shows that weeds of the Poaceae family dominated the abandoned Cocani field, followed by weeds of the Asteraceae family. Other species (with a low density per square meters): *C. nutans, E. crus-galli, Polygonum aviculare* L.*, Rumex obtusifolius* L.*, A. artemisiifolia, Chenopodium album* L. *and Taraxacum officinale* Weber.

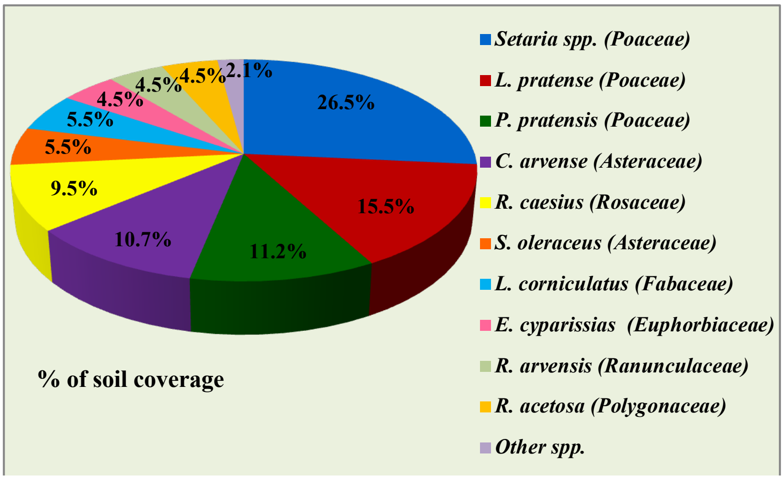

Figure 2. The distribution of weed species by botanical families at Cocani after 30 days after treatments in the untreated plot

In the experimental field, the presence of *Setaria* species with >26% ground cover in the control at 30 days after the application of the treatments was observed. *Setaria* species are among the most important monocotyledonous weeds in Romanian agriculture, especially in maize and sunflower crops. They cause damage through direct competition, yield reduction, technological difficulties and their role as hosts for pests. In the experimental plot, we identified 4 species of the foxtail: *S. viridis*, *S. glauca*, *S. verticilata* and *S. faberi*. The literature presents data on the different sensitivity of *Setaria* species to the action of herbicides. Differential selectivity has been demonstrated for 2-chloro-4-(ethylamino)-6-(isopropylamino)-s-triazines (atrazine), 2-chloro-4, 6-bis(isopropylamino)-s-triazines (propazine), and S-ethyl diisobutylthiocarbamate (butylate) in *S. faberi*, *S. glauca* and different varieties of *S. viridis*, the latter being the most tolerant to atrazine and propazine (Oliver and Schreiber, 1971; Beckie et al., 1999; Song et al., 2023). Five green foxtail *S. viridis* populations were reported in Ontario with potential resistance to the AHAS-inhibiting herbicide imazethapyr (Marles et al., 1993; Laplante et al., 2009). *L. corniculatus* was also monitored in the experimental field which, although often cultivated as a valuable forage crop, in some circumstances can become an undesirable weed in crops, especially when it spreads uncontrolled. Although it has benefits (nitrogen fixation, forage), in some crops (wheat, maize, sunflowers, etc.), birdsfoot trefoil can have negative effects as it competes with crop plants for light, water and nutrients and can easily spread in grasslands sown with other species, becoming dominant, having populations tolerant to glyphosate-based herbicides (Boerboom et al., 1990; Clua et al., 2012).

Since its market introduction in 1974, glyphosate [N-(phosphonomethyl) glycine] has become the dominant herbicide worldwide with a broad spectrum of highly effective efficacy. Glyphosate is the only herbicide that inhibits 5-enolpyruvyl-5-enolpyruvyl-3-phosphate synthase (EPSPS), there are no competing herbicide analogs or classes (Malik et al., 1989; Duke and Powles, 2008). Being a systemic herbicide, it is absorbed by the plant and then transported throughout the vascular system. It gets involved with the plant's ability to produce essential amino acids and may cause stunting and ultimately death (Hess, 2018; Freitas-Silva et al., 2022; Mendes et al., 2022). Most of the weeds found in the experimental plots showed initial symptoms of wilting and yellowing within 2 to 4 days after treatment, and complete destruction usually occurred within 1 to 2 weeks. Aspects of the experimental fields are shown in Figure 3. The larger (*Cirsium*, *Convolvulus*, *Lolium*, *Rubus*, *Platago*, etc.) and more well-rooted weeds took up to 4 weeks to be destroyed. The time taken for glyphosate to destroy weeds can vary depending on several factors including weed type, weather conditions and herbicide formulation.

We have also observed that young, actively growing weeds tend to absorb the herbicide faster than older or dormant weeds. Glyphosate is most effective when temperatures are between 15°C and 29°C and when no rainfall occurs within the first 6 hours of application because rain can wash the herbicide off before it is absorbed by the plant.

Figure 3. Aspects from experimental plots

4. CONCLUSIONS

Uncultivated lands pose a number of problems and risks related to: decreased soil fertility, loss of biodiversity, increased frequency and intensity of wildfires, soil erosion and desertification, loss of cultural and aesthetic values, reducing of landscape diversity and decrease of water supply.

The uncultivated lands are a continuous source of weed infestation due to the fact that they help the development of a rich flora of weeds, while ensuring the accumulation in the soil of a large reserve of seeds and vegetative propagating organs that will encumber crop technologies for several years after recultivating.

The uncultivated lands studied were heavily weed-infested with annual and perennial mono and dicotyledonous annual and perennial weed species but without woody vegetation.

The most widely used herbicide for weed control on these lands is glyphosate. The renewal of glyphosate is subject to certain conditions and restrictions, including a prohibition on pre-harvest use as a desiccant and measures to protect non-target organisms, the maximum authorised dose per year being 1440 g active substance/hectare.

Glyphosate had a good efficacy in weed control in the 2 experimental plots with the best results being obtained at 4.0 and 6.0 l/ha.

At 2.0 l/ha most weed species were poorly controlled. At the maximum allowed rate of 1440 g a.i/ha (4.0 l/ha), the lowest efficacy for dicots was recorded for field bindweed, perennial thistle and plantago species with an average efficacy of 50% and for monocots for perennial ryegrass with an efficacy of 56%.

The data obtained in the 2 non-cultivated fields clearly show that this dose is not enough to control all weeds and repeated applications are necessary.

ACKNOWLEDGEMENTS

The research was funded by the Ministry of Agriculture and Rural Development Romania and the Academy of Agricultural and Forestry Sciences "Gheorghe Ionescu-Șișești", Bucharest, Romania, (Project no.8388/16.12.2022).

REFERENCES

1. Barbotkina, E, Dunaieva, IE, Popovych, V, Pashtetsky, V 2020, ”Review of methods and approaches of abandoned lands identification”, In E3S Web of Conferences, Vol. 224, pp. 13.
2. Beckie, HJ, Thomas, AG, Légère, A 1999, ”Nature, occurrence, and cost of herbicide-resistant green foxtail (*Setaria viridis*) across Saskatchewan ecoregions”, Weed Technology, 13(3), pp. 626-631.
3. Boerboom, CM, Wyse, DL, Somers, DA 1990, ”Mechanism of glyphosate tolerance in birdsfoot trefoil (Lotus corniculatus)”, Weed science, 38(6), pp. 463-467.
4. Clua, A.; Conti, M.; Beltrano, J. 2012, ”The effects of glyphosate on the growth of Birdsfoot Trefoil (*Lotus corniculatus*) and its interaction with different phosphorus contents in soil. J. Agric. Sci. 4, pp. 208-218.
5. Datta, MK, Kundu, CK, Kundu, A, Hembram, J, Bera, PS, Biswas, U 2018, ”Bio-efficacy of 2, 4-D Ethyl Ester 80% EC in Non-crop area”, IJCS, 6(1), pp. 391-393.
6. Duke, SO, Powles, SB 2008, ”Glyphosate: a once-in-a-century herbicide”, Pest Management Science: formerly Pesticide Science, 64(4), pp. 319-325.
7. Fayet, CM, Reilly, KH, Van Ham, C, Verburg, PH 2022, ”What is the future of abandoned agricultural lands? A systematic review of alternative trajectories in Europe”, Land use policy, 112 (2), 105833.
8. Freitas-Silva, LD, Araújo, HH, Meireles, CS, Silva, LCD 2022, ”Plant exposure to glyphosate-based herbicides and how this might alter plant physiological and structural processes”, Botany, 100(6), pp. 473-480.
9. Gallemore, C, Munroe, D, van Berkel, D 2018, ” Rural-to-urban migration and the geography of absentee non-industrial private forest ownership: A case from southeast Ohio”, Applied Geography, 96(1), pp. 141-152.
10. Ghanizadeh H, Woolley DJ, Harrington KC, James TK 2013, ”Confirmation of glyphosate resistance in two species of ryegrass from New Zealand vineyards”, New Zealand Plant Protection, 65, pp. 89-93.
11. Grădilă, M, Jalobă, D, Ciontu, VM, Cristea, RM, Petcu, V, Marin, E, Tudora, C 2022, ”Control of annual and perennial weeds on uncultivated land”, Volume Proceedings, ISB-INMATEH, ISSN 22344-4118, pp. 14-20.
12. Gunnarsson, M, James, TK, Chynoweth, RJ, Rolston, MP 2017, ”An evaluation of the resistance of annual and perennial ryegrass to herbicides”, New Zealand Plant Protection, 70, pp. 165-170.
13. Haddaway, NR, Styles, D, Pullin, AS 2014, ”Evidence on the environmental impacts of farm land abandonment in high altitude/mountain regions: a systematic map”, Environ Evid, 3, pp. 17.
14. Hess, FD 2018, ”Herbicide absorption and translocation and their relationship to plant tolerances and susceptibility”, In Weed physiology, CRC Press, pp. 191-214.
15. Höchtl, F, Lechringer, S, Konold, W 2005, “Wilderness: What it means when it becomes a reality –a case study from the southwestern Alps”, Landscape Urban Plan., 70, pp. 85-95.
16. Huang, Z, Liu, Y, Zhang, C, Jiang, C, Huang, H, Wei, S 2019, ”Molecular basis of natural tolerance to glyphosate in *Convolvulus arvensis*”, Scientific Reports, 9(1), pp. 8133.

17. Kates, RW, Clark, WC, Corell, R, Hall, JM, Jaeger, CC, Lowe, I 2001, ”Environmental and development –sustainability science”, Science, 292, pp. 641-642.

18. Keenleyside, C, Tucker, G, McConville, A 2010, ”Farmland Abandonment in the EU: an Assessment of Trends and Prospects”, Institute for European Environmental Policy, London, pp. 1-98.

19. Kleijn, D, Barquero, RA, Clough, Y, Díaz, M, Esteban, J, Fernández, F, Gabriel, D, Herzog, F, Holzschuh, A, Jöhl, R, Knop, E, Kruess, A, Marshall, EJP, Steffan-Dewenter, I, Tscharnke, T, Verhulst, J, West, TM, Yela, JL 2006, ”Mixed biodiversity benefits of agri-environment schemes in five European countries”, Ecol. Lett., 9, pp. 243-254.

20. Kolecka, N 2018, ”Height of successional vegetation indicates moment of agricultural land abandonment”, Remote Sensing, 10(10), pp. 1568.

21. Lana-Renault, N, Nadal-Romero, E, Cammeraat, E, Llorente, JÁ 2020, ”Critical environmental issues confirm the relevance of abandoned agricultural land”, Water, 12(4), pp. 1119.

22. Laplante, J, Rajcan, I, Tardif, FJ 2009, ”Multiple allelic forms of acetohydroxyacid synthase are responsible for herbicide resistance in *Setaria viridis*”, Theoretical and Applied Genetics, 119(4), pp. 577-585.

23. Lasanta, T, Nadal-Romero, E, Arnáez, J 2015, ”Managing abandoned farmland to control the impact of re-vegetation on the environment. The state of the art in Europe”, Environmental Science & Policy, 52, pp. 99-109.

24. Lauringson, E, Talgre, L 2003, ”Problems of abandoned fields”, Agronomy Research, 1(1), pp. 63-67.

25. Malik, J, Barry, G, Kishore, G 1989, ”The herbicide glyphosate”, BioFactors (Oxford, England), 2(1), pp. 17-25.

26. Mantero, G, Morresi, D, Marzano, R, Motta, R, Mladenoff, DJ, Garbarino, M 2020, ”The influence of land abandonment on forest disturbance regimes: a global review”, Landscape Ecology, 35(12), pp. 2723-2744.

27. Marles, MAS, Devine, MD, Hall, JC 1993, ” Herbicide resistance in Setaria viridis conferred by a less sensitive form of acetyl coenzyme A carboxylase”, Pesticide biochemistry and physiology, 46(1), pp. 7-14.

28. Marty, P, Pélanquier, E, Jaudron, B, Lepart, J 2003, ”Spontaneous reforestation in a periMediterranean landscape: history of agricultural systems and dynamics of woody species”, In: The Mediterranean world environment and history (E. Fouache, Edt.), Elsevier, pp. 183-190.

29. Marușcă, T 2015, ”Recurs la tradiția satului”, Vol. 2: Însemnări și mărturii agrosilvopastorale, Editura Universității Transilvania din Brașov, pp 318.

30. Mendes, KF, Mielke, KC, D’Antonino, L, Alberto da Silva, A 2022, ”Retention, absorption, translocation, and metabolism of herbicides in plants”, In Applied weed and herbicide science, Cham: Springer International Publishing, pp. 157-186.

31. Morán-Ordoñéz, A, Suárez-Seoane, S, Calvo, L, de Luis, E 2011, ”Using predictive models as a spatially explicit support tool for managing landscapes”, Appl. Geogr., 31, pp. 839-848.

32. Munroe, DK, van Berkel, DB Verburg, PH, Olson JL 2013, ”Alternative trajectories of land abandonment: causes, consequences and research challenges”, Curr. Opin. Environ. Sustain., 5(5), pp. 471-476.

33. Oliver, LR, Schreiber, MM 1971, ”Differential selectivity of herbicides on six Setaria taxa”, Weed Science, 19(4), pp. 428-431.

34. Osawa, T, Kohyama, K, Mitsuhashi, H 2016, ”Multiple factors drive regional agricultural abandonment” Science of the Total Environment, 542, pp. 478-483.

35. Pawlewicz, A, Pawlewicz, K 2023, ”The risk of agricultural land abandonment as a socioeconomic challenge for the development of agriculture in the European Union”, Sustainability, 15(4), pp. 3233.
36. Pérez-Hernández, J, Gavilán, RG 2021, ”Impacts of land-use changes on vegetation and ecosystem functioning: Old-field secondary succession”, Plants, 10(5), pp. 990.
37. Quintas-Soriano, C, Buerkert, A, Plieninger, T 2022, ”Effects of land abandonment on nature contributions to people and good quality of life components in the Mediterranean region: A review”, Land use policy, 116, pp. 106053.
38. Regulation (EU) 2023/2660, of 28 November 2023 renewing the approval of the active substance glyphosate in accordance with Regulation (EC) No 1107/2009 of the European Parliament and of the Council and amending Commission Implementing Regulation (EU) No 540/2011.
39. Benayas, JM, Martins, A, Nicolau, JM, Schulz, JJ 2007, ”Abandonment of agricultural land: an overview of drivers and consequences”, CABI Reviews, pp. 14.
40. Song, XE, Wang, H, Dong, Q, Qiu, T, Shi, C, Li, X, ... & Yuan, X 2023, ”Comprehensive evaluation and main identification indexes of herbicide resistance of high-quality foxtail millet (*Setaria italica* L.)”, Agronomy, 13(12), pp. 3033.
41. Tarolli, P, Preti, F, Romano, N 2014, ”Terraced landscapes: From an old best practice to a potential hazard for soil degradation due to land abandonment”, Anthropocene, 6, pp. 10-25.
42. Tasser, E, Walde, J, Tappeiner, U, Teutsch, A, Noggler, W 2007, ”Land-use changes and natural reforestation in the Eastern Central Alps”, Agric. Ecosyst. Environ., 118, pp. 115-129.
43. Timmons FL 1950, ”Competitive relationships of four different lawn grasses with field bindweed and dandelion under frequent close clipping”, Ecology, 31, pp. 1-5.
44. Ustaoglu, E, Collier, MJ 2018, ”Farmland abandonment in Europe: An overview of drivers, consequences, and assessment of the sustainability implications”, Environmental reviews, 26(4), pp. 396-416.
45. Valkó, O, Deák, B, Török, P, Kelemen, A, Miglécz, T, Tóth, K, Tóthmérész, B 2016, ”Abandonment of croplands: problem or chance for grassland restoration? Case studies from Hungary”, Ecosystem Health and Sustainability, 2(2), pp. 01208.
46. Vallejo, R, Aronson, J, Pausas, JG, Cortina, J 2006, ”Restoration of Mediterranean woodlands”, In: Restoration ecology: The New Frontier (van Andel, J. & Aronson, J., Edts.), Blackwell Science, pp. 193-207.
47. Weaver, SE, Riley, WR 1982, ”The biology of Canadian weeds, *Convolvulus arvensis* L. ”, Can. J. Plant. Sci., 62, pp. 461-472.