RESEARCH

Weed composition and control in apple orchards under intensive and extensive floor management

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ABSTRACT

Weed control in apple tree (*Malus domestica* [Suckow] Borkh.) orchards continues to be a major problem. Weeds compete with fruit trees, which is manifested in production quality and quantity. The aim of this study was to determine the weed flora of apple orchards with different floor management practices and to investigate the efficacy of the diquat, oxyfluorfen, glyphosate, and fluazifop-*P*-butyl herbicides. Experiments were conducted during 2015 and 2016 in orchards under intensive (Ruski Krstur) and extensive (Sombor) floor management. Annual, perennial broad-leaf, and grass weeds were identified. Dominant weed species in both apple orchards were *Poa annua*, *Hordeum murinum*, *Conyza canadensis*, *Portulaca oleracea*, *Cynodon dactylon*, *Sorghum halepense*, *Carduus acanthoides*, *Amaranthus retroflexus*, *Cirsium arvense*, *Chenopodium album*, and *Solanum nigrum*. After the first and second assessments, the best results occurred with glyphosate in both orchards and total efficacy ranged from 88.42% to 98.32% in the orchard under intensive floor management and 90.32% to 95.55% in the orchard under extensive floor management. Diquat and oxyfluorfen have shown good results, but their efficacy was lower than for glyphosate. Fluazifop-*P*-butyl, as a selective herbicide, showed low efficacy at both sites; it had high efficacy on grass weeds, but no effects on broad-leaf weeds.

Key words: Apple orchards, herbicide efficacy, *Malus domestica*, weed composition, weed control.

INTRODUCTION

Production practices in orchard trees and vine cropping systems vary greatly by crop and growing region. Proper weed management is an integral part of a sustainable orchard production system and can have positive effects on agricultural sustainability by increasing agroecosystem productivity and improving ecological services (Tworkoski and Glenn, 2012; Fracchiolla et al., 2015). An important issue for the production of perennial crops is weed management (Carvalho et al., 2016). Weeds negatively affect orchards and small fruit plantations and compete with cultivated plants for water, nutrients, space, and sunlight; weeds stunt tree growth in young orchards and reduce yield quality and quantity in mature trees (Atay et al., 2017; Abbas et al., 2018). Weed pressure can reduce tree growth from 15% to 96%, while yield losses can reach 35% because of the adverse impact on fruit quality in which the fruit excluded ratio reaches 45% (Abouziena et al., 2016). Some weeds growing around tree trunks serve as hosts for pests and pathogens that infect the trunk and roots (Shweta et al., 2018). Weed density in fruit orchards varies with location, climate, season, soil type, crop grown, irrigation, fertilization system, and the history of orchard agricultural practices (Futch et al., 2019).

Different weeds infest apple (*Malus domestica* [Suckow] Borkh.) orchards, including annual and perennial broad-leaf and grass species; the most common broad-leaf species are *Ambrosia artemisiifolia*, *Amaranthus retroflexus*, *Chenopodium album*, *Solanum nigrum*, *Stellaria media*, *Conyza canadensis*, *Cirsium arvense*, and *Convolvulus arvensis*, while grasses are *Echinochloa crus-galli*, *Cynodon dactylon*, and *Sorghum halepense* (Derr, 2001; Lisek, 2012; 2014). These weeds are the most commonly found in Serbian orchards (Krga et al., 2013).

Many methods are used to control weeds in cultivated crops and established orchards, such as manual, mechanical, physical, biological, and chemical. Each control method has its advantages and disadvantages (Futch et al., 2019). It is difficult to accurately determine the critical periods and levels of weed control due to tree biology and the large number and variability of factors (Lisek, 2014). Weeds in fruit production are primarily managed through herbicide application (Brar et al., 2017), and the use of herbicides depends on tree age and the presence of major weed species. Herbicides were introduced in the 1970s, and they are currently the most commonly used weed control method because 92% of orchards use herbicides and only 5% are under tillage (Di Prima et al., 2018). Certain herbicides are primarily used in young trees because the risk of crop injury is lower than with other herbicides. Chemical weed control practices include the application of pre-emergence (pre.em) and post-emergence (post.em) herbicides. The pre.em herbicides are used for the residual control of annual and some perennial weeds and are usually applied in spring, while post.em herbicides are useful for controlling existing vegetation, primarily perennial and some woody weeds (Derr, 2001). The post.em herbicides cause stress in crops by negatively affecting photosynthesis, opening and closing stomata, increasing sensitivity to fungal attacks, or altering metabolic and physiological functions (Merino et al., 2020). The advantage of post.em over pre.em herbicides is that post.em herbicides can be selected based on the actual weeds, while pre.em herbicides are often applied without prior knowledge of the species that are in the soil, which results in poor weed control and loss of income (Hussain et al., 2018). These herbicides can be applied together to broaden the weed control spectrum. Fluazifop-*P*-butyl is a strong inhibitor of the enzyme acetyl-coenzyme A carboxylase (ACCase) in which it precludes the synthesis of malonyl-CoA (committed step of fatty acid in plants), thus controlling the grass weeds. It is appropriate to combine it with post.em herbicides to control broad-leaf weeds (Cieslik et al., 2017). In Serbia, pre.em herbicides (flurochloridone and napropamide) and post.em herbicides (glyphosate, glyphosate+2,4-D, oxyfluorfen, glyphosate+oxyfluorfen, glufosinate-ammonium, cycloxydim, fluazifop-*P*-butyl, and fluroxypyr) have been approved for weed control in orchards (Spasic, 2018).

Although chemical weed control is very effective, its limitations are associated with environmental protection (Brar et al., 2017) and the development of genetically-based herbicide resistance (Moretti et al., 2016). Therefore, weed management in fruit crops should favor basic values such as human and environmental safety, including soil quality; it should also consider the efficacy, cost, and impact on crop yields (Lisek, 2014).

The aim of this study was to monitor the efficacy of post.em herbicides (diquat, oxyfluorfen, glyphosate, and fluazifop-*P*-butyl) in apple orchards under intensive and extensive floor management based on weed composition.

MATERIALS AND METHODS

Field studies were conducted in orchards under intensive (Ruski Krstur 45°31'55" N; 19°24'57" E) and extensive (Sombor 45°48'07" N; 19°04'31" E) floor management in Serbia during 2015 and 2016. At the first location (intensive orchard), the assay was established in a 4-yr-old apple (*Malus domestica* [Suckow] Borkh.) orchard with 'Golden Delicious', 'Granny Smith', 'Idared', 'M9' rootstock, 'Red Chief', 'Red Delicious', and 'M26' rootstock. Tree within-row spacing was 1 m and between-row spacing was 3.5 m. Weed mowing between tree rows and manual weeding within the rows were maintained for 3 yr, and herbicides were applied for the first time in the fourth year. An anti-hail net and drip irrigation system were installed over 11 ha. The slender spindle training system was used. At the second location (extensive orchard), the experiment was established in a 14 yr-old orchard with 'Red Delicious', 'Idared', and 'M26' rootstock. Tree within-row spacing was 4 m and between-row spacing was 5 m; the open vase training system was used. Chemical weed control has never been used in the second orchard. At the first location (Ruski Krstur), the apple orchard was established on a calcic chernozem soil (first class), while the orchard at the second location (Sombor) was established on alluvial soil (Hadzic et al., 2005).

A herbicide efficiency assay was established according to the European and Mediterranean Plant Protection Organization (EPPO) standard method (EPPO/OEPP, 2020). Both experiments were conducted using a randomized complete block design with four replicates. Each plot consisted of 100 m^2. Herbicide treatment included the application of four post-emergence (post.em) herbicides: 3 L ha^{-1} diquat (7,10-diazoniatricyclo[8.4.0.02,7]tetradeca-1(14),2,4,6,10,12-hexaene; dibromide); (Reglone Forte, Syngenta, Basel, Switzerland), 5 L ha^{-1} oxyfluorfen (2-chloro-1-(3-ethoxy-4-nitrophenoxy)-4-(trifluoromethyl)benzene; Galigan 240 EC, Chemical Agrosava, Belgrade, Serbia), 5 L ha^{-1} glyphosate

(2-(phosphonomethylamino)acetic acid; Glifosav 480, Chemical Agrosava, Belgrade, Serbia), 1.2 L ha^{-1} fluazifop-*P*-butyl (butyl (2*R*)-2-[4-[5-(trifluoromethyl)pyridin-2-yl]oxyphenoxy]propanoate; Fusilade Forte, Syngenta, Basel, Switzerland), and a control without herbicide application. The efficacy of the treatment and intensity of weed density were determined by counting the number of weeds per m^2 30 and 60 d after the treatment, and phytotoxicity was also assessed. The herbicide coefficient of efficiency (Ce, %) for our data was calculated according to the formula stated by Janjic (1985), which represents a relative ratio between the number of destroyed weeds compared with the number of weeds in the control. Visual assessment of phytotoxicity was performed using the European Weed Research Council (EWRC) scale (1 to 9). Scientific names and their abbreviations according to Nikolic (2015) and EPPO (2020), respectively, are shown in Table 1. Treatment abbreviations are also listed in Table 1.

To gain an insight into weed composition in intensive and extensive orchards, the following indices were calculated: Species richness, weediness, Shannon-Weaver diversity index, Shannon-Weaver evenness index, and Simpson's dominance index (Shannon and Weaver, 1949; Magurran, 2004). The floristic similarity between treatments before and after herbicide application and between plots treated with the same herbicide before and after its application was calculated according to the Steinhaus coefficient index (S_A) based on the formula (Magurran, 2004; Nkoa et al., 2015) that includes the total number of individual plants and species abundance expressed as:

$$S_A = 2W/(a + b)$$

where a is the total number of individuals in the first plot, b is the total number of individuals in the second plot, and W is the sum of the lower of the two abundances of each species in the plot.

Table 1. Weed species and treatment abbreviations.

Nr	Plant species[1]	EPPO code	Synonym
1	*Amaranthus retroflexus* L.	AMARE	
2	*Chenopodium album* L.	CHEAL	
3	*Chenopodium hybridum* L.	CHEHY	
4	*Carduus acanthoides* L.	CRUAC	
5	*Cirsium arvense* (L.) Scop.	CIRAR	
6	*Convolvulus arvensis* L.	CONAR	
7	*Cynodon dactylon* (L.) Pers.	CYNDA	
8	*Erigeron annuus* (L.) Pers.	ERIAN	
9	*Conyza canadensis* (L.) Cronquist	ERICA	*Erigeron canadensis* L.
10	*Hordeum murinum* L.	HORMU	
11	*Lamium purpureum* L.	LAMPU	
12	*Papaver rhoeas* L.	PAPRH	
13	*Portulaca oleracea* L.	POROL	
14	*Poa annua* L.	POAAN	
15	*Solanum nigrum* L.	SOLNI	
16	*Sorghum halepense* (L.) Pers.	SORHA	
17	*Taraxacum officinale* F.H. Wigg.	TAROF	

Treatments			Abbreviations
1	Intensive orchard	Control-start	ICs
2	Intensive orchard	Control-end	ICe
3	Intensive orchard	Reglone Forte-start	IRFs
4	Intensive orchard	Reglone Forte-end	IRFe
5	Intensive orchard	Galigan-start	IGAs
6	Intensive orchard	Galigan-end	IGAe
7	Intensive orchard	Glifosav 480-start	IGLs
8	Intensive orchard	Glifosav 480-end	IGLe
9	Intensive orchard	Fusilade Forte-start	IFFs
10	Intensive orchard	Fusilade Forte-end	IFFe
11	Extensive orchard	Control-start	ECs
12	Extensive orchard	Control-end	ECe
13	Extensive orchard	Reglone Forte-start	ERFs
14	Extensive orchard	Reglone Forte-end	ERFe
15	Extensive orchard	Galigan-start	EGAs
16	Extensive orchard	Galigan-end	EGAe
17	Extensive orchard	Glifosav 480-start	EGLs
18	Extensive orchard	Glifosav 480-end	EGLe
19	Extensive orchard	Fusilade Forte-start	EFFs
20	Extensive orchard	Fusilade Forte-end	EFFe

[1]Nikolic, 2015.
EPPO: European and Mediterranean Plant Protection Organization.

The differences in weediness (number of individuals per m^2, nr ind. m^{-2}) at the start and at the end of the experiment between intensive and extensive orchards, weed species, effects of the analyzed herbicides, their interactions, and the differences between the total fresh weed mass were determined using ANOVA and the t-test ($p < 0.01$).

The relationship between the dominant/frequent weed species and the analyzed treatments was determined by correspondence analysis. Principal component analysis (PCA) identified the main components leading to weed separation according to the effects of the analyzed herbicides. All statistical analyses were performed with the Statistica 13.2 software (TIBCO Software, Palo Alto, California, USA).

There were different meteorological conditions in 2014 to 2016 (Figure 1). During the years of the experiment, conditions were moderately favorable for apple trees and weed growth. Total precipitation was higher than the perennial mean during the vegetation period. Mean monthly temperatures gradually increased, which promoted the development of weed species. When experiments were established in July 2015, the mean temperature was 24.9 °C and total precipitation 8.8 mm, whereas mean temperature was 24.5 °C and total precipitation 95.8 mm in August. This rainy weather in July and August promoted weed growth in the orchards.

RESULTS AND DISCUSSION

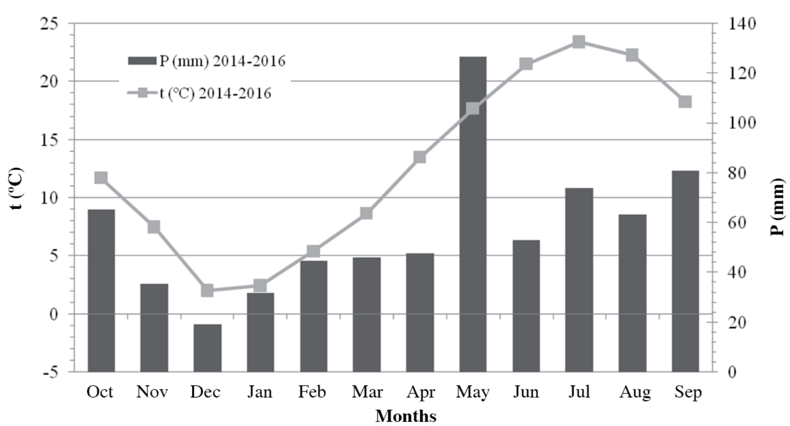
Species richness, weediness, and weed diversity were higher in the extensive than in the intensive orchard before and after herbicide application; this was expected because of limited herbicide application in the extensive orchard (Tables 2 and 3). The number of weeds per unit area after treatment in the intensive and extensive orchards was significantly lower compared with the control. Species evenness was relatively high and similar in all plots and ranged from 0.86 to 1.00. Considering that species diversity was high in all plots, dominance of the most numerous weeds was low.

The highest floristic similarity was found in control plots before and after the experiment; ICs-ICe = 98.52%; ECs-ECe = 100.00% (Table 4). In addition, relatively high S_A was determined before and after applying the herbicide fluazifop-*P*-butyl in both orchards (IFFs-IFFe = 68.70%; EFFs-EFFe = 51.23%). The lowest S_A was recorded before and after applying diquat in the intensive orchard (IRFs-IRFe = 6.00%) and glyphosate in the extensive orchard (EGLs-EGLe = 6.33%).

Significant differences were found in mean nr ind. m^{-2} for the intensive and extensive orchards between the control and treated plots before and after the herbicide treatment (Figures 2 and 3). In the intensive orchard, plots treated with diquat, oxyfluorfen, and glyphosate were significantly different from the other treatments and the control, showing their effects. Meanwhile, plots treated with fluazifop-*P*-butyl were not significantly different from the control, indicating low efficacy of this herbicide (Figure 2). Similar differences in nr ind. m^{-2} and herbicide efficacy were found in the extensive orchard (Figure 3).

Prior to treatment, correspondence analysis separated the intensive and extensive orchards with the most frequent weeds (Figures 4 and 5). Before herbicide application in the intensive orchard the most common weeds were *Amaranthus retroflexus*, *Portulaca oleracea,* and *Solanum nigrum*, which were not found in the extensive orchard (Figure 4). After

Figure 1. Mean monthly precipitation (P) and temperature (t) during the 2014 to 2016 seasons.



herbicide application, plots in both orchards in which fluazifop-*P*-butyl was applied reported the appearance of the most common species: *A. retroflexus*, *Chenopodium hybridum,* and *S. nigrum* in the intensive orchard and *Conyza canadensis*, *Carduus acanthoides*, *Cirsium arvense*, *Lamium purpureum,* and *Erigeron annuus* in the extensive orchard (Figure 5).

Significantly high differences (ANOVA; $p < 0.01$) in the nr ind. m^{-2} before and after herbicide application were found between weed species, type of orchard, and treatments and their interactions (Figures 6 and 7).

Table 2. Weed composition in an orchard under intensive floor management before and after herbicide applications.

Plant species	EPPO code	ICs	ICe	IRFs	IRFe	IGAs	IGAe	IGLs	IGLe	IFFs	IFFe
Amaranthus retroflexus	AMARE	4.00	4.00	4.50		2.00		3.25		2.75	4.00
Chenopodium album	CHEAL	3.50	3.50	3.50		3.00		2.25		2.00	3.50
Chenopodium hybridum	CHEHY	2.75	3.00	2.25	0.25	3.50		0.75		2.25	3.00
Carduus acanthoides	CRUAC										
Cirsium arvense	CIRAR										
Convolvulus arvensis	CONAR	1.25	0.75	1.00	0.25	1.00	0.25	0.75	0.75	0.50	
Cynodon dactylon	CYNDA										
Erigeron annuus	ERIAN										
Conyza canadensis	ERICA										
Hordeum murinum	HORMU										
Lamium purpureum	LAMPU										
Papaver rhoeas	PAPRH	2.75	2.75	2.50	0.25	1.25	0.25	2.50	0.25	1.50	0.25
Portulaca oleracea	POROL	5.75	5.75	5.50		4.50	0.50	4.25	0.25	3.25	0.75
Poa annua	POAAN										
Solanum nigrum	SOLNI	3.25	3.25	3.00		2.75		3.50		3.25	3.25
Sorghum halepense	SORHA	2.25	2.25	2.00		1.50	1.00	2.25		2.50	
Taraxacum officinale	TAROF										
Species richness (S)	17	8	8	8	3	8	4	8	3	8	6
Weediness (N)		25.50	25.25	24.25	0.75	19.50	2.00	19.50	1.25	18.00	14.75
Diversity index (H)		2.00	1.98	1.98	1.10	1.97	1.21	1.95	0.95	1.99	1.57
Evenness index (E)		0.96	0.95	0.95	1.00	0.95	0.88	0.94	0.86	0.96	0.88
Dominance index (D)		0.11	0.11	0.11	3.00	0.11	-0.31	0.11	-1.80	0.09	0.17

EPPO: European and Mediterranean Plant Protection Organization; I: intensive floor management; C: control; RF: Reglone Forte; GA: Galigan; GL: Glifosav 480; FF: Fusilade Forte; s: at the start of the experiment; e: at the end of the experiment.

Table 3. Weed composition in an orchard under extensive floor management before and after herbicide applications.

Plant species	EPPO code	ECs	ECe	ERFs	ERFe	EGAs	EGAe	EGLs	EGLe	EFFs	EFFe
Amaranthus retroflexus	AMARE										
Chenopodium album	CHEAL	1.25	2.25	1.25		1.25		2.25		1.50	2.25
Chenopodium hybridum	CHEHY										
Carduus acanthoides	CRUAC	5.25	5.25	5.5		4.75		4.00		2.25	5.25
Cirsium arvense	CIRAR	4.25	4.25	3.25	0.25	4.00	1.75	4.25	0.25	3.50	4.25
Convolvulus arvensis	CONAR	2.00	2.00	1.00	0.25	1.75	1.00	1.50	0.25	1.25	2.00
Cynodon dactylon	CYNDA	6.50	6.50	6.00	0.75	5.75	3.00	5.50	1.00	6.50	0.50
Erigeron annuus	ERIAN	3.25	3.25	2.50		3.00		2.75		2.25	3.25
Conyza canadensis	ERICA	7.25	7.25	7.50	0.50	7.00		6.50		6.25	7.25
Hordeum murinum	HORMU	9.25	9.25	7.75		6.50	0.25	4.25		8.75	0.25
Lamium purpureum	LAMPU	4.75	4.75	4.50	0.75	4.75	1.00	4.25	1.00	3.75	4.75
Papaver rhoeas	PAPRH										
Portulaca oleracea	POROL										
Poa annua	POAAN	10.50	10.50	8.25		9.75		10.50		9.25	
Solanum nigrum	SOLNI										
Sorghum halepense	SORHA	6.00	6.00	5.75		4.50	1.50	5.00		6.25	
Taraxacum officinale	TAROF	2.75	2.75	2.75	0.75	2.25	1.50	2.75	0.25	1.75	2.75
Species richness (S)	17	12	12	12	6	12	7	12	5	12	10
Weediness (N)		63.00	64.00	56.00	3.25	55.25	10.00	53.50	2.75	53.25	32.5
Diversity index (H)		2.35	2.37	2.34	1.70	2.35	1.79	2.37	1.39	2.29	2.07
Evenness index (E)		0.94	0.95	0.94	0.95	0.95	0.92	0.95	0.86	0.92	0.90
Dominance index (D)		0.09	0.09	0.09	-0.16	0.09	0.10	0.09	-0.12	0.10	0.11

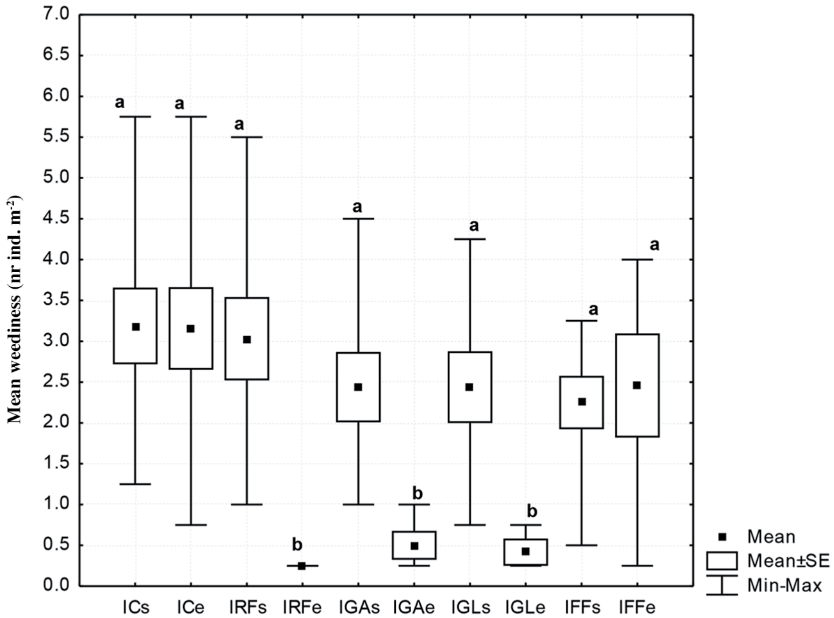
EPPO: European and Mediterranean Plant Protection Organization; E: extensive floor management; C: control; RF: Reglone Forte; GA: Galigan; GL: Glifosav 480; FF: Fusilade Forte; s: at the start of the experiment; e: at the end of the experiment.

Table 4. Floristic similarity between analyzed treatments.

Comparison of the treatments	Steinhaus coefficient index (S_A) (%)
ICs-ICe	98.52
ICs-ECs	18.08
ICe-ECe	17.00
ECs-ECe	100.00
IRFs-IRFe	6.00
IRFs-ERFs	10.59
IRFe-ERFe	12.50
ERFs-ERFe	10.97
IGAs-IGAe	18.60
IGAs-EGAs	10.03
IGAe-EGAe	20.83
EGAs-EGAe	30.65
IGLs-IGLe	12.05
IGLs-EGLs	14.38
IGLe-EGLe	33.33
EGLs-EGLe	6.33
IFFs-IFFe	68.70
IFFs-EFFs	12.63
IFFe-EFFe	9.52
EFFs-EFFe	54.23

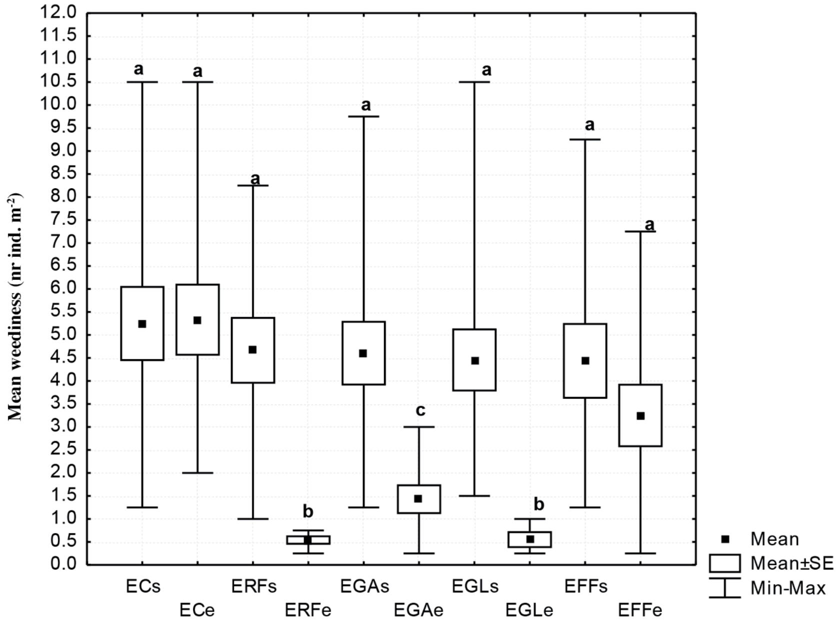
I: Intensive floor management; E: extensive floor management; C: control; RF: Reglone Forte; GA: Galigan; GL: Glifosav 480; FF: Fusilade Forte; s: at the start of the experiment; e: at the end of the experiment.

Figure 2. Significance of differences in the mean of weediness between treatments in the orchard under intensive floor management.



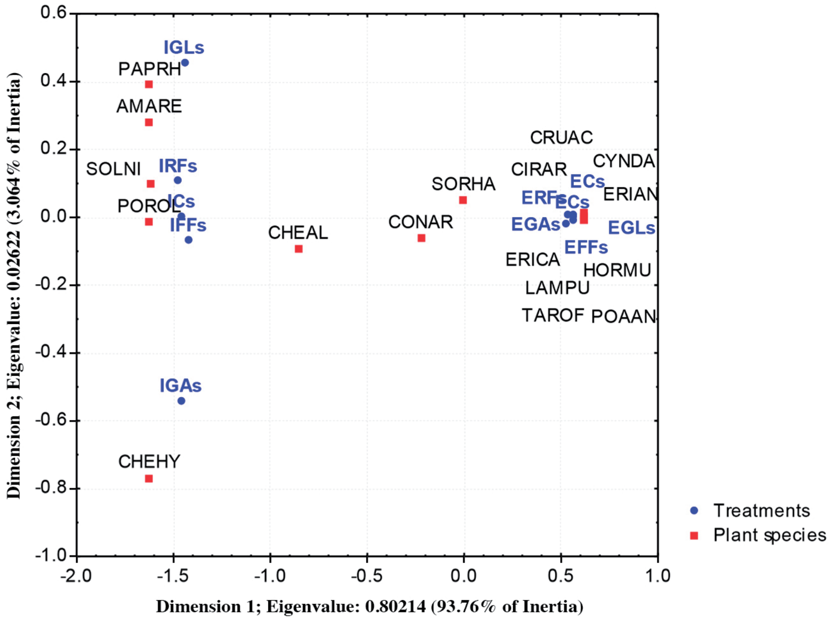
The same letters over the bars do not differ significantly according to the t-test.
I: Intensive floor management; C: control; RF: Reglone Forte; GA: Galigan; GL: Glifosav 480; FF: Fusilade Forte; s: ate the start of the experiment; e: at the end of the experiment.

Figure 3. Significance of differences in mean weediness between treatments in the orchard under extensive floor management.



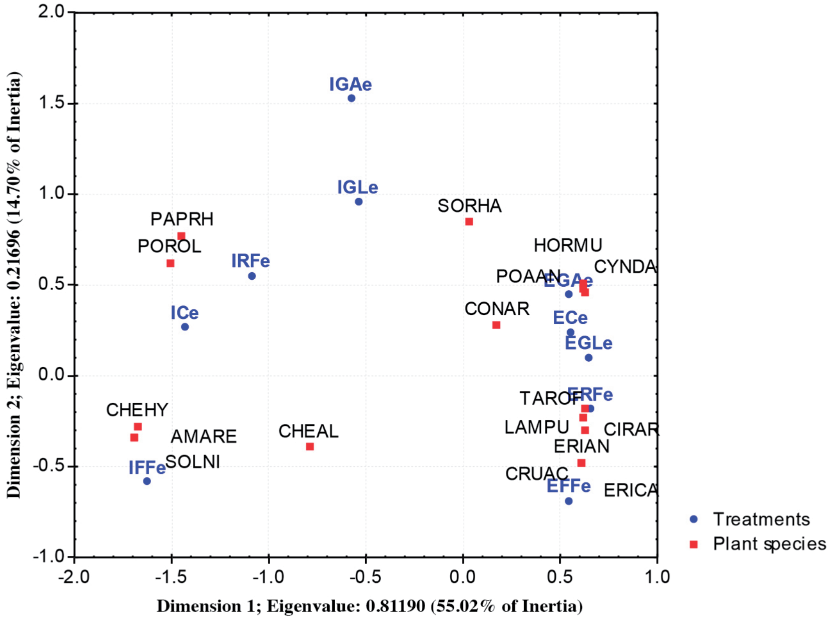
The same letters over the bars do not differ significantly according to the t-test.
E: Extensive floor management; C: control; RF: Reglone Forte; GA: Galigan; GL: Glifosav 480; FF: Fusilade Forte; s: at the start of the experiment; e: at the end of the experiment.

Figure 4. Correspondence analysis of the ratio between weed species and tested treatments before herbicide applications.



I: Intensive floor management; E: extensive floor management; C: control; RF: Reglone Forte; GA: Galigan; GL: Glifosav 480; FF: Fusilade Forte; s: at the start of the experiment; e: at the end of the experiment; AMARE: *Amaranthus retroflexus*; CHEAL: *Chenopodium album*; CHEHY: *Chenopodium hybridum*; CRUAC: *Carduus acanthoides*; CIRAR: *Cirsium arvense*; CONAR: *Convolvulus arvensis*; CYNDA: *Cynodon dactylon*; ERIAN: *Erigeron annuus*; ERICA: *Conyza canadensis*; HORMU: *Hordeum murinum*; LAMPU: *Lamium purpureum*; PAPRH: *Papaver rhoeas*; POROL: *Portulaca oleracea*; POAAN: *Poa annua*; SOLNI: *Solanum nigrum*; SORHA: *Sorghum halepense*; TAROF: *Taraxacum officinale*.

Figure 5. Correspondence analysis of the ratio between weed species and tested treatments after herbicide applications.



I: Intensive floor management; E: extensive floor management; C: control; RF: Reglone Forte; GA: Galigan; GL: Glifosav 480; FF: Fusilade Forte; s: at the start of the experiment; e: at the end of the experiment; AMARE: *Amaranthus retroflexus*; CHEAL: *Chenopodium album*; CHEHY: *Chenopodium hybridum*; CRUAC: *Carduus acanthoides*; CIRAR: *Cirsium arvense*; CONAR: *Convolvulus arvensis*; CYNDA: *Cynodon dactylon*; ERIAN: *Erigeron annuus*; ERICA: *Conyza canadensis*; HORMU: *Hordeum murinum*; LAMPU: *Lamium purpureum*; PAPRH: *Papaver rhoeas*; POROL: *Portulaca oleracea*; POAAN: *Poa annua*; SOLNI: *Solanum nigrum*; SORHA: *Sorghum halepense*; TAROF: *Taraxacum officinale*.

Figure 6. Significance of differences in weediness before herbicide applications (ANOVA – weed species × orchard type × treatments).

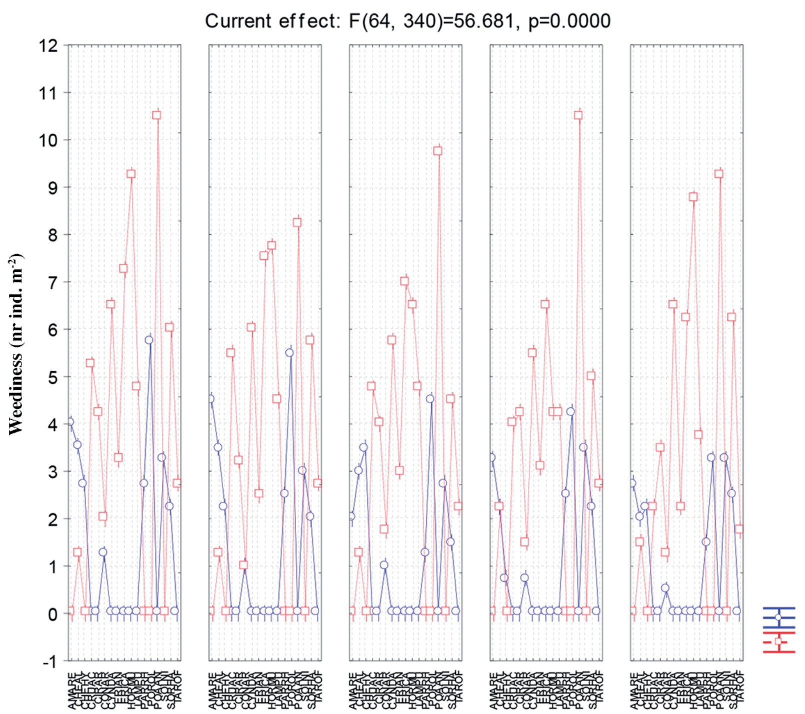
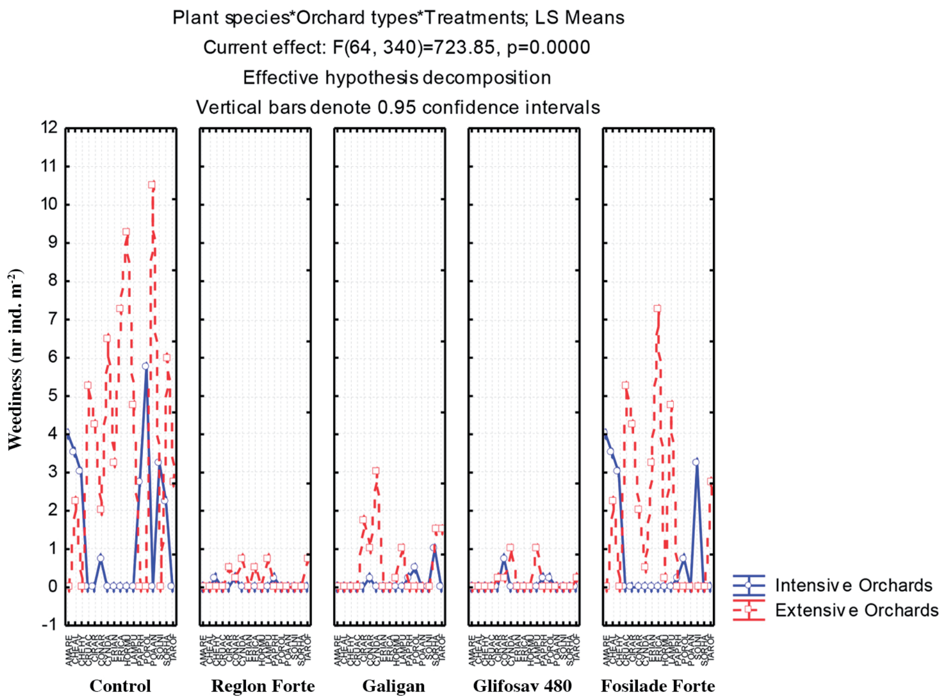
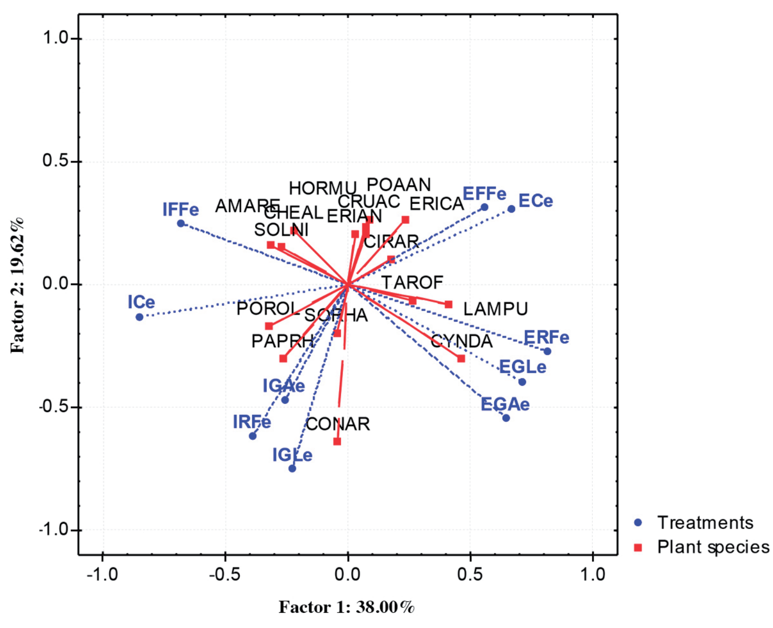


Figure 7. Significance of differences in weediness after herbicide applications (ANOVA – weed species × orchard type × treatments).



The PCA reduced the initial set of variables on two main components, which explains 57.62% of the total variability, and the effects of diquat and glyphosate on weed species were highlighted in the orchards (Figure 8, Table 5).

Figure 8. Principal component analysis between weeds and treatments after application.



I: Intensive floor management; E: extensive floor management; C: control; RF: Reglone Forte; GA: Galigan; GL: Glifosav 480; FF: Fusilade Forte; s: start of the experiment; e: end of the experiment; AMARE: *Amaranthus retroflexus*; CHEAL: *Chenopodium album*; CRUAC: *Carduus acanthoides*; CIRAR: *Cirsium arvense*; CONAR: *Convolvulus arvensis*; CYNDA: *Cynodon dactylon*; ERIAN: *Erigeron annuus*; ERICA: *Conyza canadensis*; HORMU: *Hordeum murinum*; LAMPU: *Lamium purpureum*; PAPRH: *Papaver rhoeas*; POROL: *Portulaca oleracea*; POAAN: *Poa annua*; SOLNI: *Solanum nigrum*; SORHA: *Sorghum halepense*; TAROF: *Taraxacum officinale*.

Table 5. Eigenvalues of the correlation matrix and correlation of principal components with the initial variables.

Variables	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Factor 6	Factor 7	Factor 8	Factor 9	Factor 10
ICe	**-0.85**	-0.13	0.29	0.25	0.23	0.09	-0.11	0.09	-0.12	-0.12
ECe	0.67	0.31	-0.47	0.24	-0.31	0.11	0.07	0.23	-0.11	-0.04
IRFe	-0.39	**-0.62**	-0.12	-0.51	-0.28	-0.32	-0.01	0.12	-0.04	-0.03
ERFe	**0.81**	-0.27	0.39	-0.10	0.16	-0.03	0.03	-0.03	-0.26	0.05
IGAe	-0.26	-0.47	-0.42	0.60	0.36	-0.15	0.03	0.11	0.02	0.07
EGAe	0.64	-0.55	0.25	0.39	-0.08	-0.07	0.21	-0.09	0.08	-0.09
IGLe	-0.22	**-0.75**	-0.30	-0.38	0.06	0.37	0.10	0.00	0.01	0.01
EGLe	**0.71**	-0.39	0.48	0.05	-0.04	0.09	-0.21	0.18	0.13	0.02
IFFe	-0.68	0.25	0.61	-0.01	-0.07	0.03	0.25	0.17	0.03	0.05
EFFe	0.56	0.31	-0.11	-0.50	0.54	-0.08	0.08	0.11	0.07	-0.05
AMARE	-0.32	0.16	0.37	0.07	-0.01	0.18	0.18	0.01	0.02	0.18
CHEAL	-0.22	0.22	0.24	-0.00	0.10	0.15	0.29	0.29	0.06	-0.24
CRUAC	0.09	0.27	-0.22	-0.18	0.15	-0.06	-0.00	-0.02	0.39	-0.29
CIRAR	0.18	0.10	-0.03	-0.09	0.11	-0.08	-0.01	-0.15	0.30	-0.19
CONAR	-0.04	-0.64	-0.25	-0.42	-0.04	0.38	0.39	0.07	0.13	0.15
CYNDA	0.47	-0.30	0.38	0.29	-0.30	0.06	0.05	-0.02	0.10	-0.48
ERIAN	0.03	0.21	-0.16	-0.12	0.05	-0.06	-0.16	-0.37	0.40	0.17
ERICA	0.24	0.27	-0.17	-0.27	0.36	-0.10	0.23	0.26	-0.50	-0.14
HORMU	0.07	0.20	-0.27	0.12	-0.43	0.18	-0.05	-0.03	-0.11	0.01
LAMPU	0.41	-0.08	0.29	-0.10	0.20	0.03	-0.48	0.45	0.08	0.47
PAPRH	-0.27	-0.30	-0.15	-0.20	-0.11	-0.32	-0.40	-0.11	-0.11	-0.09
POROL	-0.32	-0.17	-0.04	0.25	0.41	0.38	-0.44	-0.11	-0.25	-0.32
POAAN	0.07	0.24	-0.31	0.12	-0.48	0.24	-0.12	0.13	-0.25	0.14
SOLNI	-0.27	0.15	0.29	0.05	-0.03	0.13	0.07	-0.17	0.10	0.32
SORHA	-0.05	-0.20	-0.35	0.70	0.22	-0.36	0.26	0.18	0.14	0.22
TAROF	0.26	-0.06	0.18	-0.02	0.11	-0.18	0.21	-0.62	-0.43	0.20
Eigenvalue	3.80	1.96	1.42	1.31	0.69	0.30	0.18	0.17	0.13	0.04
% Total variance	38.00	19.62	14.16	13.12	6.87	3.02	1.84	1.70	1.28	0.38
Cumulative Eigenvalue	3.80	5.76	7.18	8.50	9.18	9.48	9.66	9.83	9.96	10.00
Cumulative, %	30.00	57.62	71.79	84.90	91.78	94.80	96.64	98.34	99.63	100.00

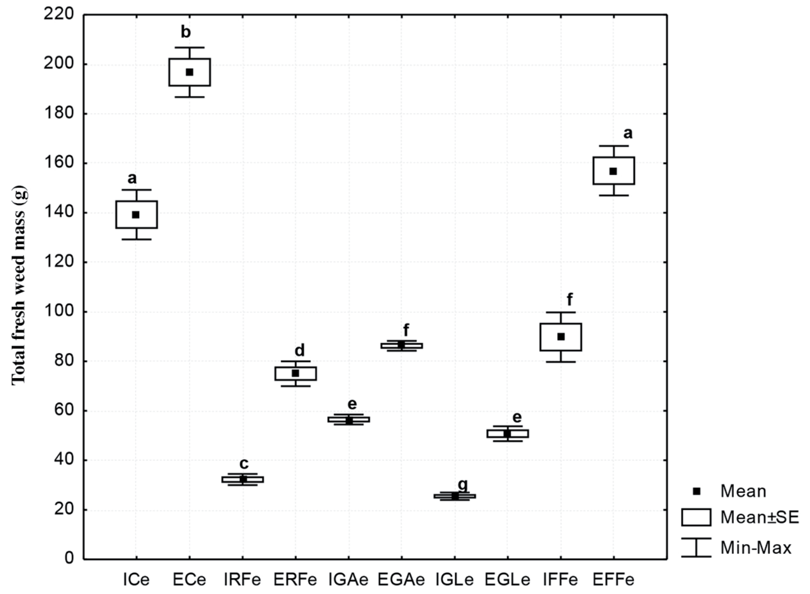
I: Intensive floor management; E: extensive floor management; C: control; RF: Reglone Forte; GA: Galigan; GL: Glifosav 480; FF: Fusilade Forte; s: at the start of the experiment; e: at the end of the experiment; AMARE: *Amaranthus retroflexus*; CHEAL: *Chenopodium album*; CRUAC: *Carduus acanthoides*; CIRAR: *Cirsium arvense*; CONAR: *Convolvulus arvensis*; CYNDA: *Cynodon dactylon*; ERIAN: *Erigeron annuus*; ERICA: *Conyza canadensis*; HORMU: *Hordeum murinum*; LAMPU: *Lamium purpureum*; PAPRH: *Papaver rhoeas*; POROL: *Portulaca oleracea*; POAAN: *Poa annua*; SOLNI: *Solanum nigrum*; SORHA: *Sorghum halepense*; TAROF: *Taraxacum officinale*.

The first principal component (Factor 1) and the second principal component (Factor 2) were dominated by the effect of these herbicides in the extensive and intensive orchards, respectively (Table 5). The first component separated weeds for herbicides diquat (ERFe = 0.81) and glyphosate (EGLe = 0.71) in the extensive orchard, such as *Cynodon dactylon* and *L. purpureum*. The second component separated weeds for the same herbicides but in the intensive orchard (IRFe = -0.62; IGLe = -0.75), such as *Convolvulus arvensis*, *Papaver rhoeas*, *Sorghum halepense,* and *P. oleracea* (Figure 8).

The t-test showed significant differences in the fresh weed mass between the intensive and extensive apple orchards after applying the tested herbicides (Figure 9).

The experimental site of the intensive orchard was infested with eight weed species belonging to different families. Data showed that therophytes (*A. retroflexus*, *P. oleracea*, *Chenopodium album*, *Ch. hybridum*, and *S. nigrum*) were the dominant plant life-form, while geophytes (*C. arvensis* and *S. halepense*) and hemicryptophytes (*P. rhoeas*) were less present. The efficacy of the applied post.em herbicides diquat, oxyfluorfen, glyphosate, and fluazifop-*P*-butyl in the intensive apple orchard is shown in Table 6.

Figure 9. Significance of differences in total fresh weed mass between treatments in orchards under intensive and extensive floor management.



The same letters above the bars do not differ significantly according to the t-test.
I: Intensive floor management; E: extensive management; C: control; RF: Reglone Forte; GA: Galigan; GL: Glifosav 480; FF: Fusilade Forte; s: at the start of the experiment; e: at the end of the experiment.

Table 6. Presence of weeds and herbicide efficacy after the first (30 d) and second (60 d) assessments in the orchard under intensive floor management.

	First assessment				
Weed species	Control	Diquat	Oxyfluorfen	Glyphosate	Fluazifop-*P*-butyl
	Nr m^{-2}	%			
Amaranthus retroflexus	4.00	87.50	87.50	93.75	56.25
Chenopodium album	3.50	92.86	92.86	100.00	28.57
Chenopodium hybridum	3.00	100.00	91.67	92.00	25.00
Convolvulus arvensis	1.25	80.00	60.00	60.00	60.00
Papaver rhoeas	2.75	90.91	90.91	81.82	45.45
Portulaca oleracea	5.75	86.96	91.30	95.65	43.48
Solanum nigrum	3.25	76.92	76.92	84.62	0.00
Sorghum halepense	2.25	100.00	33.33	100.00	100.00
Total number of weeds	25.75	-	-	-	-
Total efficacy	-	89.39	78.06	88.45	44.84
Phytotoxicity	-	1	1	1	1
	Second assessment				
Amaranthus retroflexus	4.00	100.00	100.00	100.00	0.00
Chenopodium album	3.50	100.00	100.00	100.00	0.00
Chenopodium hybridum	3.00	91.67	100.00	100.00	0.00
Convolvulus arvensis	0.75	66.67	66.67	100.00	0.00
Papaver rhoeas	2.75	90.91	90.91	90.91	9.09
Portulaca oleracea	5.75	100.00	91.30	95.65	13.04
Solanum nigrum	3.25	100.00	100.00	100.00	0.00
Sorghum halepense	2.25	100.00	55.56	100.00	100.00
Total number of weeds	25.25	-	-	-	-
Total efficacy		93.66	88.05	98.32	15.27
Phytotoxicity		1	1	1	1

Diquat efficacy was good against *Ch. album*, *Ch. hybridum*, *P. rhoeas,* and *S. halepense* after the first assessment, and it was satisfactory against *A. retroflexus*, *C. arvensis*, *P. oleracea,* and *S. nigrum*. Diquat efficacy as a contact herbicide was good after the second assessment against all the weed species, except *C. arvensis,* and total efficacy ranged from 89.39% to 93.66%. Ustuner and Diri (2018) reported that diquat dibromide efficacy at a rate of 120 and 240 g ai ha^{-1} was 90% to 100% for broad-leaf and grass weeds. The herbicide oxyfluorfen was less effective against the perennial weed *S. halepense* compared with diquat and more effective against the broad-leaf weed *P. oleracea*. The efficacy of glyphosate was good against the broad-leaf and perennial grass weed species *A. retroflexus*, *Ch. album*, *Ch. hybridum*, *P. oleracea,* and *S. halepense*, satisfactory against *P. roeas* and *S. nigrum*, but low against the perennial broad-leaf weed *C. arvensis*. After the second assessment, the efficacy of glyphosate was good against all the existing weed species. Overall efficacy ranged from 98.32% to 100%. In the intensive orchard after the treatment with the herbicides diquat, oxyfluorfen, and glyphosate, there was a highly significant reduction in the number of weeds compared with fluazifop-*P*-butyl (Figure 2). A similar trend was found in the extensive orchard in which there were significant differences in the treatment with oxyfluorfen compared with diquat and glyphosate (Figure 3). Moretti et al. (2016) reported that glyphosate and paraquat had the best results for weed control in California orchards and vineyards. In the present study, fluazifop-*P*-butyl showed low efficacy against all broad-leaf weeds, but it was good only against the grass weed *S. halepense* (100%). Phytotoxicity symptoms in apple trees were not recorded after herbicide application. According to Rankova et al. (2012), the herbicides oxyfluorfen and glyphosate achieved good efficacy against broad-leaf weed species, forming the weed association in the row strip of the plantation.

At the second location, Sombor, there was a greater difference in the type of species and number of weeds than in the first location. There was no prior chemical weed control in this extensive apple orchard, except mowing approximately three times a year. As a consequence of poor chemical weed control and agricultural techniques, the dominant weed species were biennial (*C. acanthoides* and *Conyza canadensis*) and perennial plants (*C. arvense*, *Taraxacum officinale*, *C. dactylon*, and *S. halepense*). Invasive weeds (*C. canadensis*, *E. annuus*, and *S. halepense*) were also determined because these species often colonize disturbed and ruderal areas. Weeds were at the full vegetation and intensive growth stage before the treatment; this is the stage in which the application of herbicides is normally recommended. The highest number of identified weed species belonged to the *Poaceae* family (*C. dactylon*, *Hordeum murinum*, *Poa annua*, and *S. halepense*) followed by the *Asteraceae* family (*C. acanthoides*, *C. arvense*, *E. annuus*, *C. canadensis*, and *T. officinale*). Plant families such as *Chenopodiaceae* (*Ch. album*), *Convolvulaceae* (*Convolvulus arvensis*), and *Lamiaceae* (*L. purpureum*) were represented by only one weed species. The most common grass weeds were *P. annua* and *H. murinum*, while *C. canadensis* was the most common broad-leaf weed (Table 7).

Data in Table 7 show herbicide efficacy after the first and second assessments in the extensive orchard. After the treatment, diquat showed good efficacy against *P. annua*, *C. canadensis,* and *C. acanthoides*; in addition to these weeds, there was good efficacy against *Ch. album*, *E. annuus*, *H. murinum,* and *S. halepense*. Efficacy after both assessments was satisfactory against *C. arvense*, *C. arvensis*, *C. dactylon*, and *L. purpureum*, while efficacy was low against *T. officinale*. After the first and second assessments, oxyfluorfen had good efficacy on most weed species (Table 7), while efficacy was low after the second assessment against the perennial species *C. arvense*, *C. arvensis,* and *C. dactylon*. Good efficacy of oxyfluorfen has also been found in young sour cherry plantations (Rankova and Tityanov, 2013). Glyphosate showed good efficacy in the extensive orchard against *C. acanthoides*, *C. album*, *E. annuus*, *C. canadensis*, *H. murinum*, *P. annua,* and *T. officinale* after both assessments and on *C. arvense* and *S. halepense* only after the second assessment. The efficacy of glyphosate was satisfactory on *L. purpureum*, *C. dactylon,* and *C. arvensis*. Fluazifop-*P*-butyl had high efficacy against all grass weeds (*C. dactylon*, *H. murinum*, *P. annua,* and *S. halepense*), while its efficacy was low against annual and perennial broad-leaf weeds. Glyphosate is widely used in orchards and poplar plantations (Dudic et al., 2019). Resistance to glyphosate has already occurred worldwide. Numerous authors have investigated sensitivity against glyphosate against *C. canadensis* (Krga et al., 2013; Meseldzija et al., 2015; Anagnostopoulos et al., 2020), which is an invasive weed species present in the extensive orchard at the Sombor location. Hussain et al. (2020) treated 45 trees with oxyfluorfen, atrazine, glyphosate, and pendimethalin, and glyphosate was the most effective, especially in the post.em treatment after paddy straw mulch (10-cm thickness). Based on the total efficacy of the applied herbicides, it can be concluded that diquat (82.04% to 92.84%) and glyphosate (90.18% to 95.55%) had good total efficacy, oxyfluorfen (69.87% to 80.82%) had satisfactory efficacy, and fluazifop-*P*-butyl had very low total efficacy (32.34% to 32.47%) because its spectrum of action is limited only to grass species. Phytotoxicity symptoms were not recorded in apple trees. Weed composition and selection of adequate control measures against certain weed species is important for intensive and extensive floor management in apple orchards. In addition to direct and indirect weed damage, herbicide rotation must be considered in a framework of integrated control measures as part of the anti-resistance strategy.

Table 7. Presence of weeds and herbicide efficacy of after the first (30 d) and second (60 d) assessments in the orchard under extensive floor management.

Weed species	Control	Diquat	Oxyfluorfen	Glyphosate	Fluazifop-*P*-butyl
	First assessment				
	Nr m^{-2}	%			
Carduus acanthoides	4.75	90.48	85.71	95.24	4.76
Chenopodium album	2.25	88.89	88.89	100.00	0.00
Cirsium arvense	3.75	80.24	41.18	82.35	0.00
Convolvulus arvensis	1.25	87.50	37.50	75.00	0.00
Cynodon dactylon	5.50	76.92	57.69	84.62	92.31
Erigeron annuus	2.75	84.62	92.31	92.31	7.69
Conyza canadensis	7.25	93.10	100.00	100.00	0.00
Hordeum murinum	9.25	81.08	78.38	91.89	94.59
Lamium purpureum	4.25	78.95	63.16	89.47	0.00
Poa annua	10.50	90.48	85.71	92.86	92.86
Sorghum halepense	5.25	87.50	62.50	87.50	95.83
Taraxacum officinale	2.50	72.73	45.45	90.91	0.00
Total number of weeds	59.25	-	-	-	-
Total efficacy	-	82.04	69.87	90.18	32.34
Phytotoxicity	-	1	1	1	1
	Second assessment				
Carduus acanthoides	5.25	100.00	100.00	100.00	0.00
Chenopodium album	2.25	100.00	100.00	100.00	0.00
Cirsium arvense	4.25	88.24	58.82	94.12	0.00
Convolvulus arvensis	2.00	87.50	50.00	87.50	0.00
Cynodon dactylon	6.50	88.46	53.85	84.62	92.31
Erigeron annuus	3.25	100.00	100.00	100.00	0.00
Conyza canadensis	7.25	93.10	100.00	100.00	0.00
Hordeum murinum	9.25	100.00	97.30	100.00	97.30
Lamium purpureum	4.75	84.21	89.47	89.47	0.00
Poa annua	10.50	100.00	100.00	100.00	100.00
Sorghum halepense	6.00	100.00	100.00	100.00	100.00
Taraxacum officinale	2.75	72.73	90.91	90.91	0.00
Total number of weeds	64.00	-	-	-	-
Total efficacy	-	92.85	80.82	95.55	32.47
Phytotoxicity	-	1	1	1	1

CONCLUSIONS

Based on the results, eight weed species were determined in an orchard under intensive floor management (intensive orchard) and 11 species in an orchard under extensive floor management (extensive orchard). The mean representation of weeds in the intensive orchard was lower due to the herbicides already used in this type of orchard. Annual, perennial broad-leaf, and grass weed species were identified in the experimental fields. As a consequence of poor chemical weed control and agricultural techniques, biennial and perennial weeds were dominant in the extensive orchard with the presence of invasive weeds (*Conyza canadensis, Erigeron annuus,* and *Sorghum halepense*). The herbicides diquat and oxyfluorfen can be recommended for weed control in the intensive orchard due to the dominance of annual weed species. As contact herbicides, they were not sufficient to control the weeds found in the extensive orchard. In order to control a large number of biennial and perennial weeds, it is necesarry to apply the systemic herbicide glyphosate, which had the best efficacy in both types of orchards. Fluazifop-*P*-butyl showed high efficacy on grass weeds, and its combined use with other herbicides for broad-leaf weed control should be considered. The tested herbicides did not have a phytotoxic effect on the apple trees. Statistical analysis showed a difference between the assessments before and after the application of herbicides. The measured fresh weed mass was different in intensive and extensive planting because a higher representation of weeds was found in extensive orchards.

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