Chemical control of hairy fleabane

Chemical control and herbicide resistance of hairy fleabane [*Conyza bonariensis* (L.) Cronquist] in Jordan

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Abstract

Two field experiments were conducted to evaluate the effectiveness of 12 herbicides in controlling hairy fleabane [*Conyza bonariensis* (L.) Cronquist] in a date palm orchard located in the central Jordan valley during the spring of 2017. Results showed that *C. bonariensis* resists paraquat (2.5, 5 and 7.5kg ha^{-1}), oxadiazon (5kg ha^{-1}) and oxyflourfen (3.3kg ha^{-1}) herbicides applied at normal or higher than the recommended rates. None of the three herbicides was significantly effective against the weed and treated plants continued growing normally similar to those of untreated control. Higher rates (10-fold of the recommended rates) of the same herbicides failed to control the weed. The effect of other tested herbicides on the weed was varied with bromoxynil plus MCPA (buctril[®]M), 2,4-D-iso-octyl ester, glyphosate, glyphosate trimesium and triclopyr were most effective and completely controlled the weed at recommended rates of application. Testing paraquat, oxadiazon and oxyflourfen using the normal recommended and 10-fold higher rates on two populations of *C. bonariensis* grown from seeds of the date palm and al-Twal (another site in the Jordan Valley) weed populations and grown in pots under glasshouse conditions showed that Date palm population was resistant to the three herbicides at both application rates while al-Twal site population was highly susceptible and completely controlled at normal and high rates of the three herbicides. It is concluded that certain populations of *C. bonariensis* developed resistance to paraquat, oxadiazon and oxyflourfen but control of this weed was possible using other herbicides of different mechanism of action. Herbicide rotation or other nonchemical weed control methods have been suggested to prevent or reduce the buildup and spread of resistant populations of this weed species. These results represent the first report on herbicide resistance of *C. bonariensis* in Jordan.

Keywords: *Conyza bonariensis*, chemical control, hairy fleabane, herbicide resistance, Jordan weed populations.

Introduction

Herbicides represent the advanced weed control technology that utilizes synthetic and some bio-herbicides that cause inhibition or death of treated plants. The role of herbicides on the world food

production is well known since their discovery in med. of the last century until now. However, this technology faces radical changes in effectiveness against a large number of weed species and biotypes under field conditions and lead in many cases to failure weed control due to continued development of weed tolerance/resistance and evolution and limitations in the herbicide industry and development [1]. Resistance means the survival and reproduction of herbicide treated plant after exposed to a rate of herbicide that is normally lethal to wild type [1, 2, 3, 4]. Therefore, it is a reduced response of a weed population to herbicides as a result of their selection pressure. However, when the same herbicide or herbicides of the same mechanism of action are repeatedly applied, resistant individuals increase in number and growth until dominate the site while sensitive individuals are suppressed or disappear. This however, takes a relatively long period for population shift from susceptible to totally resistant and depends on herbicide, environment and plant factors [1]. The resistance problem is becoming more severe in absence of other control methods or herbicide rotation [5]. In addition, the repeated use of low rates and/or applications beyond the label recommended growth stages and lack of tillage or other methods of control are also important contributing factors.

The genus *Conyza* includes 50–80 species spread in temperate and sub-tropical regions of America. Almost 50 of these species are spreading now as weeds in more than 40 crops in 70 countries [6, 7]. These have a high fitness and extremely efficient successful in spreading herbicide resistance within their population due to a combination of ecological properties such as a huge seed output, wide range of pollinating insects or self-fertilization, ability to outcross, short period for seeding, non-specific habitat requirements and ease and long distance seed dispersal. *C. canadensis*, *C. bonariensis*, and *C. sumatrensis* are most common while weed species include both diploids and polyploids [8] and can hybridize with each other [9].

Conyza bonariensis has been reported from different countries to resist glayphosate [10, 11, 12, 13, 14, 15, 16] and paraquat [17, 18] herbicides. The glyphosate rates required to control resistant populations were 7–10 times higher than those needed to control susceptible populations in southern Spain [19]. In addition, some biotypes have been mentioned to posses herbicide resistance in different parts of the world [3, 20, 21] and variations in resistance of the weed to both herbicides have been

reported [22]. *Conyza canadiensis* has been also reported to resist glyphosate [5, 23], ALS inhibitors [24] and paraquat [18].

In Jordan, four *Conyza* species occur in the country but *C. bonsriensis* is the most common and widely spread in different regions in irrigated vegetables and fruit trees, waste places in the Jordan valley and high lands. It is an annual of 1-2 m in height, belongs to compositae family, and produces a huge number of modified hairy seeds that disperse far from parent plants. It flowers from April to November under local conditions.

In the last few years *C. bonsriensis* became more abundant, invading new lands and appeared dominating certain cultivated fields in the Jordan valley. However, specific studies on its control or reports on its resistance to herbicides are lacking from the country. The weed has been observed occupying date palm orchards and taking over the entire fields in certain locations in the Jordan valley. Local farmers claimed that it is not readily controlled by certain commonly used contact herbicides such as paraquat. Therefore, it was thought important trying some available foliage applied herbicides against this weed species.

Materials and Methods

Two experiments were carried out under field conditions in the central Jordan valley and a single pot experiment under glasshouses conditions at the University of Jordan. These were as follows:

Field experiments

Experiment 1

The experiment was conducted on April 18, 2017 in a date palm orchard at Dahrat Al-Ramil, in the central Jordan valley. The area is located at 255 m below the sea level and characterized by its tropical climate. The soil is a sandy loam of 50% sand, 25% silt and 25% clay with 1.3% organic matter content and a pH of 7.8. Date palm trees were 15 year-old and the weed was spread almost over the entire field and growing in pure stand except in some few spot in which *Cynodon dactylon*

109 and *Prosopis farcta* were found. *Conyza bonariensis* was at a density of 30 plants m⁻² and plants were
110 at full vegetative or pre-flowering growth stages.

111 A weed-infested piece of land was chosen for the study, divided into 45 plots each of 2*2 m. Twelve
112 herbicides were used and applied in 14 treatments and another untreated three plots were included as
113 control (Table 1). All herbicides are available in various forms in local markets and included 2,4-D-
114 iso-octyl ester [62% (v/v); Esterdefore; Veterinary and Agricultural Products Mfg. Co. Ltd., Amman,
115 Jordan]; Mecoprop [60% (v/v); CMPP; Atlas Interlates Ltd.]; Glyphosate [48% (v/v); Roundup;
116 Monsanto Agriculture Company, Monsanto Europe S.A., Athens, Greece]; Glyphosate trimesium
117 [38% (w/v); Touchdown; Syngenta, Syngenta Crop Protection Pty. Ltd., Macquarie Park, NSW,
118 Australia]; Linuron + Terbutryn [Tempo 13.9% EC, Pubchem]; Triclopyr [61.6% (v/v); Garlon 4E;
119 Dow Chemical Company LLC, Indianapolis, IN, USA]; Oxyfluorfen [24% (v/v); Goal; Rohm and
120 Haas, Mozzata, Italy]; Ioxynil octanoate [25% (v/v); Hocks; Veterinary and Agricultural Products
121 Mfg. Co. Ltd. Amman, Jordan]; Paraquat [20% (v/v), Gramaxone, Sandoz, UK]; Oxadiazon [25%
122 (v/v); Ronstar, Bayer, Germany]; Bentazon [48% w/v, Basagran, BASF, Germany] and a 20% (v/v)
123 Bromoxynil plus 20% (v/v) MCPA mixture [Buctril®M; May and Baker Agrochemicals (New
124 Zealand) Ltd., Wingate, Lower Hutt, New Zealand].

125 All herbicides were applied as an aqueous spray on the foliage parts of the full vegetative to
126 pre-flowering weed and at a constant pressure in the morning in absence of air movement, using a
127 Knapsack sprayer with a single nozzle at a volume rate of 1083.3 l ha⁻¹. All herbicides were applied
128 on April 18, 2017 and visual estimation of the effects of these chemicals on weed growth was carried
129 out twice on May 3rd and 11th, 2017 using a scale ranged between zero to 10, at which 0 denotes that
130 *C. bonariensis* plants were completely controlled and not recovered after treatment., and 10 means
131 that no phytotoxicity effect of the herbicide was observed and the weed was in full growth. The
132 evaluation was carried out by three persons and the average of the three scores given was considered
133 for each plot. All plots were photographed and representative photos for severely affected or
134 completely controlled *C. bonariences* plants and least or not affected (resistant) plants by certain
135 herbicide treatments were included.

Table 1. Herbicides tested for *Conyza bonariensis* control in the Date Palm orchard in the Jordan Valley in 2017.

Common name	Trade name and a.i percentage	Chemical name	Rate of application (kg ha ⁻¹)	Method of action
Paraquat	Gramaxon 20%	1,1'-dimethyl-(4,4'-bipyridinium) dichloride	2.5, 5, 7.5	Contact
Bromoxynil/MCPA mixture	Buctril® M 20%	3,5-dibromo-4-hydroxybenzonitrile 20% (v/v) + 2-methyl-4-chlorophenoxyacetic acid (20% v/v)	3.3	Contact/translocated
Ioxynil octanoate	Hocks 25%	3,5-Diiodo-4-hydroxybenzonitrile octanoate	3.3	Contact
Bentazon	Basagran 48%	3-Isopropyl-2-1-3-benzo-thiadiazinon-(4)-2,2-dioxide	3.3	Contact
Oxyflourfen	Goal 24% E	[2-chloro-N-[[4-methoxy-6-methyl-1,3,5-triazine-2-yl)-amino]carbboennyl]sulphonamide	3.3	Contact
Oxadiazon	Ronstar 25%	2-tert-butyl-4-(2,4-dichloro-5-isopropoxyphenyl)-1,3,4-oxadiazolin-5-one	5	Contact
Linuron+Terbutryn	Tempo 13.9% EC	Linuron (13.9%) + Terbutryn 3-(3,4-dichlorophenyl)-I-methoxy-I-methyl urea plus 2-tert-butylamino-4-ethylamino-(13.9%) = (Tempo@) 6-methylthio-I,3,5-triazin	5.8	Contact
Glyphosate	Round up 48%	Isopropylamine salt of N-(phosphonomethyl)glycine	7.5	Translocated
Glyphosate trimesium	Touch down 38%	trimethylsulfonium N-[(hydroxyphosphinato)methyl]glycine	5.8	Translocated
2,4-D- iso-octyl ester	Esterdefore 62%	2,4-Dichlorophenoxyacetic acid isooctyl ester	3.3	Translocated
Mecoprop	CMPP 60%	a-(2-Methyl-4-chlor-phenoxy)-propionic acid	3.3	Translocated
Triclopyr	Garlon 4E 61.6%	2-[(3,5,6-trichloro-2-pyridinyl)oxy]acetic acid	4.16	Translocated

Experiment 2

The same procedure was followed as above in experiment 1, but only paraquat, oxyflourfen and oxadiazon herbicides were re-tested since the weed showed no response or was not affected by these chemicals at normal rates (and higher rates for paraquat) of application in the first experiment. The three herbicides were applied using 10-fold the recommended rates on 18 May 2017 and similar scale of evaluation and estimation of the herbicides effects on the weed were carried out two weeks after application. Treatments replications and the layout of experimental design were the same as for experiment 1.

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148 **Glasshouse Experiment**

149 Seeds of *C. bonariensis* were collected from mature plants of the date palm orchard weed
150 population in the central Jordan valley and al-Twal north almost 40 Km far from the first site but in
151 the same region. Seeds of both populations were sown similarly in 10 cm diameter plastic pots filled
152 with soil/peat mixture (1:1 V/V) at enough density on January 15, 2019. After emergences other
153 weeds in all pots were hand removed and only *Conyza* plants were left growing. Plants of both
154 populations were grown and irrigated as needed under unconditioned glasshouse. At full vegetative
155 growth stage weed plants in each population (total 40 pots) were divided into two groups each of 20
156 pots that split into four subgroups each of five pots. Three sub-groups of five pots each were treated
157 with paraquat, oxadiazon and oxyflourfen herbicides used at the normal recommended rates (2.5, 5
158 and 3.3kg⁻¹ for each, respectively). Similar sub-groups were treated with the same herbicides but
159 using 10-fold of the normal recommended rates of applications. Herbicides were applied using a PVC
160 shoulder-held sprayer each contains 285 ml solution calculated to cover an area of 1m² over which
161 five pots of each population was spread over and treated with a single rate of one herbicide. The effect
162 of herbicides on plants growth was visually estimated at five days after application using the same
163 evaluation scale used for evaluation of the herbicides effects in field experiments. The same
164 herbicides were re-applied on the same plants two weeks after the first application using the same
165 rates used in the first spray. The effect of herbicides was visually estimated at five days after
166 application using the same evaluation scale used before. In this experiment, each herbicide was
167 sprayed twice and exactly as done in field experiments. However, since all herbicides tested are of
168 contact action, complete coverage treatment was performed on both weed populations. Untreated pots
169 (five pots of the fourth sub-group) were included as controls and for each weed population. Visual
170 observations and herbicide effects estimates were noted and performed on all herbicides treatments
171 five days after each application.

172

173 **Statistics**

Treatments in field and glasshouse experiments were laid out in a randomized complete block design with 3 replicates for treatments in field experiments and 5 replicates for the second. Visual estimation scores on herbicides effects on weed populations and in all experiments were subjected to the analysis of variance (ANOVA) using SAS software SAS (r) version 9.1 [25]. Treatments means were separated and compared using the least significant difference test (LSD $p = 0.05$).

Results

Field experiments

Experiment 1.

The effects of tested herbicides on *C. bonariensis* were visually estimated in the field at 2 and 3 weeks after treatments. Herbicides were greatly varied in their effects on the weed (Table 2).

Table 2. Visual estimations of the effects of foliage applied herbicides on *Conyza bonariensis* control, values are average scores of two estimations at 15 and 23 days after herbicides application (DAT).

Herbicide	Score at 15 DAT	Score at 23 DAT
Untreated (Control)	10.0 ^a	10.0 ^a
Paraquat (2.5 kg ha ⁻¹)	10.0 ^a	10.0 ^a
Paraquat (5 kg ha ⁻¹)	10.0 ^a	10.0 ^a
Paraquat (7.5 kg ha ⁻¹)	9.0 ^{ab}	10.0 ^a
Bromoxynil/MCPA mixture (Buctril® M)	0.0 ^e	0.0 ^e
Ioxynil octanoate	3.0 ^{cd}	1.0 ^d
Bentazon	3.8 ^c	3.0 ^c
Oxyflourfen	9.8 ^a	10.0 ^a
Oxadiazon	7.8 ^b	9.5 ^a
Linuron+terbutryn	7.8 ^b	5.5 ^b
Gluphosate	1.8 ^{de}	0.0 ^e
Glyphosate trimesium	1.8 ^{de}	1.0 ^d
2,4-D- iso-octyl ester	0.8 ^e	0.3 ^{de}
Mecoprop	7.3 ^b	2.8 ^c
Triclopyr	1.0 ^e	0.0 ^e
LSD ≤ p (0.05)	1.8	1.0

Mean values for five replicate pots treated with each herbicide on a scale of 0-10 where 0 denotes that the weed was completely controlled and the weed had no possible recovery after treatment., and 10 means that the weed was in full growth and no herbicide phytotoxicity observed per plot. Mean values in the same column followed by the same lower-case letter are not significantly different according to Fisher's LSD at $P = 0.05$.

196 Bromoxynil/MCPA mixture (Buctril®M) was best in controlling the weed and totally controlled all
197 plants in treated plots shortly after application. This herbicide however, was followed by other highly
198 effective herbicides including 2,4-D- iso-octyl ester, triclopyr, glyphosate and glyphosate trimesium.
199 The ioxynil octanoate and bentazon showed moderate effects while paraquat, oxadiazon and
200 oxyflourfen failed to affect the weed and to a less extent were linuron + terbutryn (Tempo*) and
201 mecoprop herbicides.

202 Visual estimation of the effects of all herbicides treatments carried out at three weeks after
203 application showed bromoxynil/MCPA mixture (Buctril®M), triclopyr and glyphosate had the highest
204 effects and completely destroyed weed plants (Table 2 and Fig. 1) and these followed by 2,4-D- iso-
205 octyl ester, glyphosate trimesium and ioxynil octanoate. The effect of mecoprop was much improved
206 at this evaluation date but bentazon effect was slightly higher. However, the effect of paraquat used at
207 increasing rates of application (2.5, 5 and 7.5 kg ha⁻¹), oxadiazon (5 kg ha⁻¹) and oxyflourfen (3.3 kg ha⁻¹)
208 remained the same with no obvious phytotoxic effect on weed plants (Table 2 and Fig. 2).

209 The average effect of herbicides on *C. bonariensis* plants at the two estimation dates is shown in
210 Fig. 3. It is clearly shown that paraquat (at all application rates), oxadiazon and oxyflourfen failed to
211 control the weed. In contrast, bromoxynil/MCPA mixture (Buctril®M), glyphosate and triclopyr were
212 most effective and totally killed weed plants (Fig. 1). These chemicals however, were followed by
213 2,4-D- iso-octyl ester had almost similar effect, ioxynil octanoate and bentazon and mecoprop showed
214 moderate effects while linurone plus terbutrine formulation (Tempo*) was slightly better than the
215 least effective or failure herbicides.

216

217 **Experiment 2.**

218 Testing the highest rates (10-fold of the recommended rates) of paraquat, oxadiazon and
219 oxyflourfen herbicides failed to control the weed (Table 3). At two weeks after application, none of
220 the rates used for any of the three herbicides affected *C. bonariensis* growth but caused somehow a
221 slight change in green color of the plants with some burning on leaf tips in oxadiazon and oxyflourfen

treated plots (Fig.2). However, weed plants appeared normal and restored their green color at the second evaluation date three weeks after application (Table 3, Fig. 2).

Table 3. Visual estimations of the effects of selected foliage applied herbicides on *Conyza bonariensis* in date palm field, values are for two estimations conducted at 15 and 23 days after herbicides treatments (DAT).

Herbicides	Rate of application (kg ha ⁻¹)	Score at 15 DAT	Score at 23 DAT
Untreated (Control)	0	10.0 ^a	10.0 ^a
Paraquat	25	8.0 ^b	9 ^b
Oxyflourfen	33	9.0 ^{ab}	10 ^a
Oxadiazon	50	9.0 ^{ab}	10 ^a
LSD ≤ <i>p</i> (0.05)	-	1.3	0.7

Mean values for five replicate pots treated with each herbicide on a scale of 0-10 where 0 denotes that the weed was completely controlled and the weed had no possible recovery after treatment., and 10 means that the weed was in full growth and no herbicide phytotoxicity observed. Mean values in the same column followed by the same lower-case letter are not significantly different according to Fisher's LSD at *P* = 0.05.

Glasshouse experiment

The effects of paraquat, oxadiazon and oxyflourfen on *C. bonariensis* used at normal and high rates of application were shown in Table 4.

Table 4. The effects of low and high rates of application of three herbicides on two populations of *C. bonariences* grown from seeds collected from two sites in the Jordan valley and sown in pot experiment and sprayed twice with the herbicides at full vegetative growth stage.

Treatments	Normal rates of application (kg ha ⁻¹)	First spray 15 October 2019 Score out of 10	Second spray 30 October 2019 Score out of 10	High rates of application (kg ha ⁻¹)	First spray 15 October 2019 Score out of 10	Second spray 30 October 2019 Score out of 10
Date Palm Resistant Population of <i>C. bonariensis</i>						
Control	0	10.0 ^a	10.0 ^a	0	10.0 ^a	10.0 ^a
Paraquat	2.5	9.2 ^a	7.8 ^b	25	6.4 ^d	4.6 ^c
Oxyflourfen	3.0	9.2 ^a	8.4 ^{ab}	30	8.0 ^{bc}	7.4 ^b
Oxadiazon	5.0	9.4 ^a	8.4 ^{ab}	50	8.4 ^{ab}	7.2 ^b
Al-Twal Susceptible Population of <i>C. bonariensis</i>						
Control	0	10.0 ^a	10.0 ^a	0	10.0 ^a	10.0 ^a
Paraquat	2.5	0.8 ^c	0.0 ^d	25	1.2 ^f	1.0 ^d
Oxyflourfen	3.0	0.6 ^c	0.0 ^d	30	3.4 ^e	1.0 ^d
Oxadiazon	5.0	8.2 ^b	2.4 ^c	50	7.2 ^{cd}	2.4 ^d
LSD (<i>p</i> ≤0.05)	-	0.96	1.7			

Mean values for five replicate pots treated with each herbicide on a scale of 0-10 where 0 denotes that the weed was completely controlled and the weed had no possible recovery after treatment., and 10 means that the weed was in full growth and showed no herbicide phytotoxicity. Mean values in the same column for both weed populations followed by the same lower-case letter are not significantly different according to Fisher's LSD at *P* = 0.05.

246 *Conyza bonariensis* was not affected by any of the herbicides used and at both rates of application.
 247 Weed plants were growing normally and more or less similar to those of untreated control (Table 4).
 248 In contrast, weed plants raised from al-Twal population seeds were completely controlled with
 249 paraquat and oxyflourfen but were less so using oxadiazon and at both low and high rates. However,
 250 repeated application of the same herbicides on weed plants of date palm population resulted in some
 251 more phytotoxic effects especially with paraquat but plants almost continued growing normally
 252 thereafter (Table 4). It was noted that herbicide-resistant plants were growing higher than herbicides-
 253 susceptible, unbranched or of low number of branches, late flowering and produced less number of
 254 flowers that consequently produced lower seed number compared with herbicides-susceptible plants
 255 (Fig.4).

256

257 Discussion

258 Hairy fleabane [*Conyza bonariensis* (L.) Cronquist] populations in certain parts of the Jordan
 259 valley are rapidly expanded in the last few years. The weed invading vegetables as well as fruit tree
 260 orchards and can be observed in uncultivated lands and roadsides. It is also spread in the high lands in
 261 different field crops. Recently, some of the Date Palm farmers in the Jordan valley complained from
 262 that the weed is irresponsive to paraquat applications and is not readily controlled using this chemical.
 263 Praquat was widely used in the country for general weed control and in fruit tree orchards. Although
 264 the chemical was banded few years ago but stock of this chemical is available in stores of different
 265 agricultural companies and the herbicide is still marketed under other trade names. However, weed
 266 species resistance to this herbicide is expected since widely used by local farmers because cheap and
 267 rapidly desiccating weed plants shortly after application. Therefore, low price, low application rate
 268 and rapid effects on weeds all favored the herbicide by local farmers over other chemicals. This
 269 however, created serious ecological problems among which are paraquat-resistant weeds. Farmers
 270 however, trying other methods of weed control including tillage and weed grazing by cattle but both
 271 remain ineffective because of many weed characters among which the huge number of modified seeds
 272 produced and its ability to re-vegetate after grazed. Cattles partially graze this weed species and

273 mostly feed on shoot tops and thus enhanced the development of auxiliary buds and branches that
274 enable weed growth recovery and more seed production.

275 In the present study, beside paraquat, the widely used herbicide by farmers for general weed control
276 in orchards, other herbicides were tested for possible control of paraquat-resistant *C. bonariensis*.
277 These included contact and translocated chemicals among which was glyphosate that already reported
278 [13, 15, 16, 18, 26] as resisted by the same weed species. However, all chemicals were applied at full
279 vegetative to pre-flowering stage of the weed.

280 Our results were pronounced in which paraquat used at the three rates of application in the
281 first field experiment failed to harm the weed. Our findings agreed with results of other workers
282 reported the same weed species as resistant to paraquat [17, 18, 27]. Other contact herbicides tested
283 mainly oxadiazon and oxyflourfen are commonly used by local farmers for weed control in vegetables
284 (mainly onion and garlic) as well as in fruit trees and for general weed control in uncultivated lands in
285 different parts of the country. This may have increased the possible build up of resistance and its
286 development in certain common weed species or populations to these herbicides. However, testing the
287 three chemicals against *C. bonariensis* population in the Date palm orchard showed that all were
288 highly resisted by *C. bonariensis* although some other less used herbicides such as Linuron +
289 terbutryn formulation (Tempo*) showed slight harmful effects on the weed. Results on oxyflourfen
290 effect appeared not compatible with those of Travlos & Chachalis [28] who reported this herbicide as
291 useful for managing resistant accessions of *C. bonariensis* in a mixture with glufosinate. The effect
292 however, seems due to glufosinate.

293 In contrast, bromoxynil/MCPA mixture (Buctril®M), was most effective and completely controlled *C.*
294 *bonariensis* plants shortly after application and treated plants failed to recover. This mixture is made
295 from bromoxynil of a contact action mixed with MCPA with a systemic action and both are
296 formulated in a mixture commercialized as buctril®M. MCPA has been reported as an excellent
297 herbicide to control the same weed species at all leaf stages and all weed biotypes could be effectively
298 controlled [29]. Glufosinate is a contact herbicide with some systemic action and has been reported as
299 effective in controlling susceptible, glyphosate and paraquat-resistant populations of *C. bonariensis*

(18). In addition, diquat, glufosinate, or glufosinate + oxyfluorfen controlled glyphosate-resistant or -susceptible *C. bonariensis* [28]. These herbicides, along with various integrated management strategies, have good potential to manage or slow the spread of glyphosate resistance in this weed species.

Our results demonstrated that translocated herbicides including glyphosate and glyphosate trimesium were highly effective and almost completely controlled the weed at 2nd evaluation date. However, both showed complete weed control a week after first evaluated explaining the systemic action of these herbicides that has taken longer to translocate inside the plant and to show apparent phytotoxic effects on treated weed plants. Glyphosate has been reported as ineffective on *C. bonariensis* and the weed resists treatment with this herbicide [11, 12, 13, 15, 16, 18, 26]. The high effectiveness of the herbicide used in two forms against the same weed species in the present study may be because the chemical until the forbidden of paraquat was not widely used in the country but only against perennials that difficult to control by other herbicides or using other methods of weed control. Therefore resistance to this herbicide in the country may still not developed in this weed species. 2,4-D and triclopyr were both effective and almost completely destroyed weed plants at the normal recommended rates. However, these have taken longer than other herbicides to fully exert their harmful effects on the weed which is normally expected for translocated herbicides. These chemicals however, had their own specific mode of action observed at first evaluation time which included leaf malformation, twisting, and growth abnormality and curling. Some of these chemicals however, have been recommended by other workers [30] for use against the same weed species either alone or in mixture with glyphosate or picloram. Mixtures of glyphosate with saflufenacil and glyphosate with 2,4-D were reported as effective in controlling susceptible, glyphosate-resistant, and glyphosate-paraquat-resistant populations of *C. bonariensis* [18]. Glyphosate-resistant weed was effectively controlled using 2,4-D and dicamba [31] and the weed responded differently to both herbicides. It is worth mentioning that both MCPA and 2,4-D and triclopyr are of related groups and no kind of resistance to any of these herbicides have been developed or reported in this weed species.

Further testing of paraquat, oxadiazon and oxyflourfen showed that resistance to these chemicals by *C. bonariensis* is well developed and very high application rates of the three herbicides had no appreciable harmful effects on the weed. All treated plants maintained normal growth similar to those of untreated control. Resistance of the weed to oxyflourfen and oxadiazon herbicides represents the first report on *C. bonariensis* resistance to these chemicals. The use of other herbicides of different mode of action is necessary to mitigate the spread of resistant population and glyphosate and phenoxy herbicides have an important role at this stage either separately, in combination or when integrated with other methods of weed control. However, plant, herbicide and environmental factors have also an important role in counteracting or worsening the weed resistance problem.

Conclusions

It is concluded that adoption of integrated management of *Conyza* is essential to ensure that plants of this fast adapting genus will remain under control in arable and perennial crops. Farmers certainly are unfamiliar with *C. bonariensis* resistance to some commonly applied herbicides in different parts of the country. However, this is the first report on resistance of this weed species in Jordan and on weed resistance to herbicides in general. Since the three resisted herbicides in this study are widely used in the country and most likely included in weed control programs, therefore managements are necessary to be taken to prevent the development of resistant populations of this noxious weed species, species of the same genus and of other weed species. Agricultural practices should aim at preventing the spread of herbicide-resistant populations and reducing the buildup of resistance to the widely used herbicides. This however, can be only achieved through herbicide rotation and by using other weed control methods such as mechanical and cultural or at least minimizing the use of resisted herbicides by the weed in places where *C. bonariences* is prevailing and commonly spread. Label warnings should be also indicated on all products of the resisted chemicals by the weed and better management of the selection pressure resulted from the use of these herbicides. All possibly used chemicals against *C. bonariences* however, should be integrated with other weed control methods in order to prevent escalating populations' resistance.

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Conflicts of Interest

No conflicts of interest have been declared.

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Control

Buctril®M (3.3 kgha⁻¹)

Glyphosate (7.5 kgha⁻¹)

Glyphosate trimesium (5.8 kgha⁻¹)

2,4-D- iso-octyl ester (3.3 kgha⁻¹)

Triclopyr (4.16 kgha⁻¹)

Fig 1. Most effective herbicides used at normal recommended rates of applications against *Conyza bonariensis* at 15 DAT.

Fig. 2. Effect of oxyflourfen, paraquat and oxadiazon used at normal and 10- fold of the recommended rat of application on *Conyza bonariensis* at 15 DAT.

Fig. 3. Average two estimates of the effect of different herbicides used for control of *C. bonariensis* in Date Palm orchard in the Jordan Valley. I= LSD values at $P \leq 0.05$. (columns represent growth of treated *Conyza bonariences* plants compared with untreated control). Mean values in the same column followed by the same lower-case letter are not significantly different according to Fisher’s LSD at $P = 0.05$.

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Al-Twal susceptible pants

Date Palm resistant plants

Fig. 4. Herbicide-susceptible plant raised from seeds of al-Twal site population (left) and herbicide-resistant plant raised from seeds collected of the date palm orchard population (right) located in the Jordan valley.