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Phelipanche aegyptiaca Management with Glyphosate in Potato

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Abstract

Two years field and greenhouse studies were carried out to evaluate the efficacy of sub-lethal doses of glyphosate (Round up^{R}), ammonia gas, phosphoric acid and sulfuric acid against *Phelipanche aegyptiaca* in potato. Results showed that sequential application of sub-lethal doses of glyphosate at all tested rates significantly reduced *P. aegyptiaca* shoot number and shoot dry weight. While, the use of ammonia gas, phosphoric acid and sulfuric acid had no significant effect on the total level of *P. aegyptiaca* infection as compared to the control. The best results considering both *P. aegyptiaca* control and selectivity in potato were obtained by sequential application of sub-lethal doses of glyphosate at 60 and 80 g·ai·ha^{-1}. Sequential application of glyphosate at 60 g·ai·ha^{-1} reduced *P. aegyptiaca* infection by 100% after 100 days after potato emergence (DAPE). Except for sequential application of glyphosate at 60 and 80 g·ai·ha^{-1}, all tested rates enhanced the maturity rate of potato plants and decreased the number of marketable potato tubers.

Keywords

Ammonia Gas, Glyphosate, *Phelipanche aegyptiaca*, Phosphoric Acid, Potato, Sulfuric Acid

1. Introduction

Potato (*Solanum tuberosum*) is considered one of the most important strategic crops in the Mediterranean region. In Lebanon, the Beq'aa and Akkar provinces are the main potato producing areas in the country, with about 68% and 19% of the total production, respectively [1]. Potato is susceptible to several pests among which *P. aegyptiaca*. This parasitic weed parasitizes summer, spring and autumn planted potatoes across Lebanon and the Mediterranean region.

Phelipanche aegyptiaca Forsk (Branched broomrape) is an aggressive root holoparasite that infects roots of

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various dicotyledous plants. This parasite is an invasive insidious higher plant in Lebanon and the Mediterranean region; it causes severe yield losses in Solanaceae and Fabaceae crops [2]-[4]. Severe reduction in potato yield quantity and quality were observed due to high levels of *P. aegyptiaca* field infestations in Lebanon [4] [5]. Management of *P. aegyptiaca* remains challenging for potato producers. With variable degrees of success, several control methods have been tested against *Phelipanche* spp. infection including physical, cultural, chemical, soil solarization, trap and catch crops, resistant varieties, synthetic germination stimulants and soil amendments [3] [6]-[13].

One of the most promising methods for controlling *Phelipanche* spp. is the use of sub-lethal doses of glyphosate on crops that show tolerance to glyphosate [3] [7] [8]. The plan is to spray sub-lethal doses of glyphosate on the potato leaves (POE) early in the season, so that the glyphosate would move through the crop phloem to underground *Phelipanche* spp. attachments on the crop roots and inhibit *Phelipanche* spp. growth prior to its above ground shoot emergence. Sub-lethal doses of glyphosate were found to be effective against *Phelipanche* spp. in broad bean [14], sunflower [15], tomato [16], carrot and celery [8] and vetch [17]. Thus, the use of sub-lethal doses of glyphosate as potential and economical method to control *Phelipanche* spp. has become increasingly important. To our knowledge, the use of sub-lethal doses of glyphosate against *P. aegyptiaca* has not been confirmed in potato, most likely because of its limited selectivity, rate, and timing of application.

Inorganic compounds have also been shown to reduce *Phelipanche* spp. growth. Many researchers showed that high nitrogen fertilizers (NH_4NO_3) and sulfur powder reduced *Phelipanche* spp. growth and development [10] [18] [19]. However, our literature search revealed no published work on the effect of ammonia gas, phosphoric acid and sulfuric acid against *P. aegyptiaca*. Acidifying irrigation water may aid in creating optimum soil pH for various crop growth [20] by mitigating a small zone from where the crop roots can better obtain nutrients. A pH range of 5.5 to 6.5 is considered ideal for most crops including potato [20], but may not be for *Phelipanche* spp. because the parasite is commonly distributed in alkaline soils [3]. Most soils in the Beq'aa plain are calcareous in nature with a pH ranging between 7.5 and 8.5 and are thus amenable to *P. aegyptiaca* infestation.

The main objectives of the present work were to examine: a) *P. aegyptiaca* control using ammonia gas, phosphoric acid, sulfuric acid or sub-lethal doses of glyphosate; b) optimal rates of glyphosate application for *P. aegyptiaca* control; and c) response of potato to sub-lethal doses of glyphosate.

2. Materials and Methods

2.1. Greenhouse Experiment

A single greenhouse experiment was done at the greenhouse area of the Faculty of Agricultural Sciences at the Beirut Coastal area, during September 2009 and April 2010. *Phelipanche aegyptiaca* seeds were collected in 2008 from various potato fields in the Beq'aa plain and stored at room temperature. Potato tubers (cultivar Spunta) were spread on paper sheets and kept moist in the lab at room temperature three weeks prior to planting. Boxes were filled with a mixture of potting soil, perlite and peat moss at a rate of 1:1:1, inoculated with 100 mg of *P. aegyptiaca* seeds, and irrigated with water for a period of two weeks prior to planting potato to allow for conditioning of *P. aegyptiaca* seeds. Two tubers were planted in plastic netted boxes 30 × 40 × 30 cm.

Methyl bromide was injected in the boxes prior to planting potato tubers. Methyl bromide was selected as another 100% free *P. aegyptiaca* control (comparison with inorganic chemicals). Four moist boxes containing *P. aegyptiaca* seeds were placed in an area of 10 m^2 covered with nylon sheet and fumigated with methyl bromide at a rate of 900 g per 10 m^2. Sheets were removed 24 hrs after fumigation and boxes placed back in the greenhouse. Potato tubers were planted 20 days after fumigation.

Glyphosate (Round up^R, 48%) was sprayed on potato leaves (POE) at a rate of 125, 135, and 150 $g \cdot ai \cdot ha^{-1}$ (no surfactant was added) in a spray volume of 1000 $L \cdot ha^{-1}$. Spraying rates were selected based on preliminary studies performed in our laboratory. Each rate was tested for single and sequential applications at 20, 40, and 60 DAPE (20, 20 + 40 and 20 + 40 + 60 DAPE). Potato plants were 12 - 18 cm tall at 20 DAPE. Spraying dates were selected based on previous experience with the species as well as on various other considerations. The underground stage of development of *P. aegyptiaca* in the soil is unknown [6], and seeds of the parasite in the soil keep on germinating continuously. Additionally, the best control strategy is to eliminate the parasite before it emerges above the soil [21]. Sulfuric acid or phosphoric acid was mixed with water to have a final solution of pH 2. Diluted solutions of sulfuric or phosphoric acid were then applied at a volume of one liter per box (irrigated) every other week starting at the time of potato planting.

2.2. Field Experiments General Procedure

During the 2009 and 2010 spring seasons, field experiments were carried out at the Advancing Research Enabling Communities (AREC) of the American University of Beirut. The AREC is located in the Northern Central Beqa'a plain of Lebanon. A naturally infested field with *P. aegyptiaca* was used for both years (same field) but at different locations. The soil is a silty clay loam with a pH of 7.41, Electrical Conductivity of 0.24 ms/m and 2.4% organic matter. In both years, all plots were tilled twice with a mouldboard and disked two weeks before planting potato. The experimental area received a uniform application of 2.5 $t \cdot ha^{-1}$ of NPK (15:15:15) during planting. Nitrogen (Ammonium nitrate, 33.5%) was applied in bands 40 days after planting at a rate of 300 $kg \cdot ha^{-1}$. All plots were sprinkler-irrigated every six days to bring the soil back to field capacity (measured by using tensiometers at 0.33 bars suction). The standard certified potato cultivar "Spunta" was planted in both years at 3.0 $t \cdot ha^{-1}$. Potato rows were 0.70 m apart and within-the-row spacing was around 0.25 m. Plots were hilled 6 weeks after planting (standard practice by Lebanese farmers). To eliminate all weeds other than *P. aegyptiaca*, the entire experimental areas received a standard application of metribuzin (Sencor^R, 70%, PE) at 0.75 $kg \cdot ai \cdot ha^{-1}$ two weeks after potato sowing with a boom sprayer at a rate of 400 $L \cdot ha^{-1}$. Glyphosate was applied POE on potato plants at 20, 40, and 60 DAPE ((20, 20 + 40 and 20 + 40 + 60). Glyphosate was sprayed by a hand held CO_2-pressurized backpack sprayer that delivers 310 $L \cdot ha^{-1}$ at 138 Kpa through a Teejet 8002 flat fan spray tips. Irrigation water was withheld for two days after each spraying.

2.3. Field Experiment in Spring 2009

Ammonia gas and sub-lethal doses of glyphosate were the only treatments tested against *P. aegyptiaca*. Ammonia gas was injected in the soil (at field capacity) at 30 $kg \cdot ha^{-1}$ one week prior to planting potato to a depth of 30 - 35 cm. A tractor pulling a cylinder full with pressurized ammonia and connected to the injection system which released the ammonia gas at a pressure of 2 - 3 bars in the soil was used. The field was then lightly irrigated to avoid evaporation of the gas. During the initial potato growth and in other plots, sequential application of foliar sub-lethal doses of glyphosate at a rate of 125 $g \cdot ai \cdot ha^{-1}$ was applied on potato plants at 20, 40, and 60 DAPE (20, 20 + 40 and 20 + 40 + 60). Experimental plots (20 m long and 10 m wide) were arranged in a randomized complete block design with three replications. Each replicate or plot consists of 12 rows.

2.4. Field Experiment in 2010

Sub-lethal doses of glyphosate at 60, 80, and 100 $g \cdot ai \cdot ha^{-1}$ were the only treatments tested against *P. aegyptiaca*. These rates were selected according to the results obtained from previous field and greenhouse experiments. All rates were tested for single and sequential application at 20, 40, and 60 DAPE (20, 20 + 40 and 20 + 40 + 60). A factorial experiment was used. Experimental plots (6 m long and 2.1 m wide) were arranged in a randomized complete block design with four replications.

2.5. Experimental Measurements and Statistical Analyses

Phelipanche aegyptiaca infection in the greenhouse experiment was assessed by counting emerged shoots and underground attachments and measuring total dry weight per box. At the end of the experiment, emerged *P. aegyptiaca* shoots (above ground) were counted and pulled out. Underground shoots were counted by washing the potato roots with water and separating remaining *P. aegyptiaca* attachments from potato roots. *Phelipanche aegyptiaca* infection in the field experiments was assessed by only counting emerged shoots (above ground) and measuring their total dry weight per m^2 of the middle row in the field experiments. Potato data included number of plants per box/row (5 m), phytotoxicity visual rating according to the European Weed Research Council scoring system, height/two plants/box or ten plants/plot, total and marketable yield. Potato yield was determined by harvesting potato/box or part of the middle row in each plot (5 m). Yield quality was determined by separating harvested tubers into two classes: marketable (>6 cm diameter) and non-marketable tubers (<5 cm in diameter). Statistical analyses were performed using SAS 9.2. (SAS Institute Inc., Cary, North Carolina USA). Data were analyzed statistically using ANOVA and Protected Least Significant Difference (LSD) Test at $p = 0.05$ level of probability was used to determine significant differences between treatments means.

3. Results and Discussion

3.1. Greenhouse Experiment 2009/10

Methyl bromide and single or sequential application of sub-lethal doses of glyphosate at 125, and 150 g ai/ha applied 20, 40, and 60 DAPE significantly reduced *P. aegyptiaca* total shoot number (above and underground) and total shoot dry weight 100 DAPE compared to the control (**Table 1**) All these treatments reduced *P. aegyptiaca* infection by 100%. Sequential application of glyphosate at all tested rates significantly reduced shoot and dry weight of *P. aegyptiaca* 100 DAPE compared to the control. Sulfuric acid and phosphoric acid had no significant effect on *P. aegyptiaca* shoot number or total dry weight in comparison to the controls (**Table 1**).

Using sub-lethal doses of systemic herbicides as single or sequential applications have been found very effective against *Phelipanche* spp. in various crops. Split application with low rates of sulfunylurea herbicides inhibited *P. aegyptiaca* growth in potato [22] and tomato [12]. Sequential application of sub-lethal doses of glyphosate inhibited *Phelipanche* spp. growth in many crops [8] [14] [23].

The significance of using sequential application of systemic herbicides such as glyphosate on potato early in the season is to inhibit *P. aegyptiaca* growth prior to shoot emergence. *Phelipanche aegyptiaca* seeds are continuously induced to germinate by potato roots and develop the attachment organ, the germ tube or radicle. Sequential application of systemic herbicides may prevent the attachment of the organ or its differentiation and allow for early season control of the parasite.

Injection with methyl bromide was suggested as a control strategy for *Phelipanche* spp. by various scientists, showing effectiveness of methyl bromide in controlling and eradicating *P. ramosa* [24] [25] [26]. Although methyl bromide is very effective in eradicating and killing *Phelipanche* spp., it is not economical for broad application, and poses significant environmental impacts [27].

The observed low efficiency of phosphoric and sulfuric acid in mitigating against *P. aegyptiaca* infection could be because of low concentrations applied to the boxes or because of leaching from the boxes. However, these results contradict previous findings that report that soil pH affects seed germination and development [20]. Jain and Foy [28] found that preconditioning of *P. aegyptiaca* seeds with phosphoric acid (21 ml of 1 Molar stock solution) decreased the parasite seed germination in tomato.

Table 1. Effect of glyphosate, sulfuric acid, phosphoric acid, and methyl bromide on *Phelipanche aegyptiaca* above and underground shoot number (SN) and total shoot dry weight (TSDWT) 100 DAPE. Data represent average of four replicates (boxes). Means followed by the same letter, within each column, do not significantly differ at the 5% level according to the LSD test. DAPE: Days after potato emergence.

Treatment	Rate	Application time	SN				TSDWT	
		(DAPE)	above ground		underground		(g)	
Glyphosate (g·ai·ha^{-1})	125	20	0	b	0	b	0	b
	135	20	5	ab	4.3	ab	2	ab
	150	20	0	b	0	b	0	b
	125	20/40	0	b	0	b	0	b
	135	20/40	0	b	0	b	0	b
	150	20/40	0	b	0	b	0	b
	125	20/40/60	0	b	0	b	0	b
	135	20/40/60	0	b	0	b	0	b
	150	20/40/60	0	b	0	b	0	b
Sulfuric acid	2L/box		14.8	a	14.8	a	2.6	ab
Phosphoric acid	2L/box		10.0	a	12.3	a	2.8	ab
Methyl Bromide	900 g/10 m^2		0.0	b	0.0	b	0.0	b
Control without *Phelipanche*	0		0.0	b	0.0	b	0.0	b
Control with *Phelipanche*	0		17.8	a	12.3	a	4.6	a

Single or sequential application of glyphosate at all tested rates were toxic to the potato plants and significantly reduced potato shoot height at 30 and 60 DAPE, compared to the control (**Table 2**). Sulfuric acid, phosphoric acid, and methyl bromide had no significant effect on potato plants compared to the control. Visual potato injury appeared 10 days after the first glyphosate application and included leaf yellowing, necrosis, plant stunting, and compact potato shoots. Phytotoxicity was clearly reflected in the tuber quality of potato yield grown for fresh market with a high incidence of deformed (cracked) and small tubers (**Figures 1(A)-(D)**).

It is well known that glyphosate translocates sympoplastically and apoplastically in plants [29] [30]. During initial tuber development, tubers accumulate photosynthetic assimilates produced by the leaves and other exogenous compounds such as glyphosate. Thus, the glyphosate effect may appear as yellowing or necrosis in young leaves and malformed tubers.

3.2. Field Experiment 2009

Data on the total number of *P. aegyptiaca* shoots indicate that sequential applications of glyphosate at 125 g·ai·ha^{-1} was very effective in reducing its infection as compared to ammonia gas and/or the control (**Figure 2**). Unlike ammonia gas, glyphosate reduced *P. aegyptiaca* shoot number by 97% and 99%, after 60 and 80 DAPE respectively, compared to the control. In addition, the observed shoots were stunted and almost dead. It was shown that frequent spray of glyphosate completely controlled *Phelipanche* spp. in parsley [23] faba bean, tobacco and tomato [14].

The reasons for the low efficiency of ammonia gas in reducing *P. aegyptiaca* infection are not easily discernible. They could be because of escape of volatile ammonia from the soil upon injection or because of improper injection and distribution of the gas in the soil.

Results in **Table 3** show that glyphosate had significantly increased total potato yield compared to the ammonia treatment and the control. Moreover, the total number of potato tubers was also significantly higher by 63% in glyphosate treated plots than both the ammonia and the control plots. However, most potato tubers were small in size (non-marketable).

Table 2. Effect of glyphosate, sulfuric acid, phosphoric acid and methyl bromide on potato shoot height (PHT) and vigor (PVR). Data represent average of four replicates. Means followed by the same letter, within each column, do not significantly differ at the 5% level according to the LSD test. DAPE: Days after potato emergence; PVR: Crop phytotoxicity visual rating with 0 indicating complete death and 10 no injury.

Treatment rate	Rate	Application time	PHT (cm)				PVR (%)	
		(DAPE)	30 DAPE		60 DAPE		60 DAPE	
Glyphosate (g·ai·ha^{-1})	125	20	71.3	b	70.8	b	6.5	b
	135	20	66.3	b	78.0	b	6.8	b
	150	20	65.0	b	70.8	b	6.5	b
	125	20/40	71.5	b	76.0	b	7.0	b
	135	20/40	76.8	b	82.8	b	7.5	b
	150	20/40	76.0	b	75.8	b	6.5	b
	125	20/40/60	77.5	b	80.3	b	7.5	b
	135	20/40/60	76.5	b	83.3	b	7.8	b
	150	20/40/60	64.3	b	69.8	c	6.5	b
Sulfuric acid	2L/box		92.3	a	104.8	a	9.0	a
Phosphoric acid	2L/box		86.8	a	99.3	a	8.8	a
Methyl Bromide	900 g/10 m^2		83.0	a	92.8	a	9.0	a
Control without *Phelipanche*	0		90.8	a	102.3	a	8.8	a
Control with *Phelipanche*	0		87.0	a	90.5	ab	9.0	a

Figure 1. (A)-(C): Deformed potato tubers with cracks or fissures caused by a single or sequential application of glyphosate compared to the control or other chemicals (D).

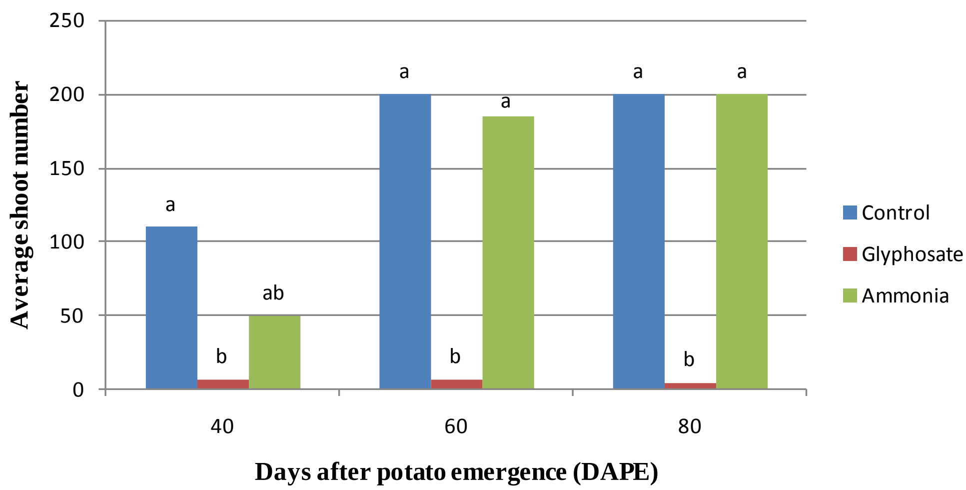

Figure 2. Effects of glyphosate and ammonia on *Phelipanche aegyptiaca* above ground total shoot number (SN). Data represent average of four replicates. Means followed by the same letter, within each column, do not significantly differ at the 5% level according to LSD test. DAPE: Days after potato emergence.

3.3. Field Experiments in 2010

Except for single application of glyphosate at 60 and 80 g·ai·ha^{-1} applied at 20 DAPE, all glyphosate treatments significantly reduced *P. aegyptiaca* infestation as compared to the control (Table 4). Single application of glyphosate at 100 g·ai·ha^{-1} at 20 DAPE resulted in significant reduction of *P. aegyptiaca* by 65% as compared to the control after 100 DAPE. Sequential application of glyphosate at 60, 80, or 100 g·ai·ha^{-1} applied at 20, 40, and 60 DAPE were the most effective treatments in reducing *P. aegyptiaca* shoot number after 100 DAPE and shoot dry weight. These treatments reduced *P. aegyptiaca* infestation by 100%, compared to the control (**Table 4**). These results demonstrate the previous observations that split application of sub lethal doses of glyphosate is recommended for the eradication of *Phelipanche* spp. Castejon-Munoz *et al.* [3] showed that glyphosate at 20 - 40 g·ha^{-1} at 12 and 14 days interval eradicated more than 80% of *Orobanche cemua* in sunflower.

Similar to the results of the green house experiment, all applications of glyphosate (60, 80, and 100 g·ai·ha^{-1}) were injurious to potato plants early in the growing season (after 60 DAPE) when compared to control (**Table 5**). Injuries appeared 10 days after first spraying and comprised of leaf yellowing, plant stunting, and compact plants. However, injury symptoms disappeared by 75 DAPE. Single or sequential application of glyphosate at all tested dosages had no significant effect on potato shoot height 60 DAPE. However, sequential application of glyphosate at 100 g·ai·ha^{-1} was toxic to potato plants and significantly reduced potato shoot height 75 DAPE.

Although single and sequential applications of glyphosate at 60 and 80 g·ai·ha^{-1} were injurious to potato plants early in the growing season, both rates had no negative effects on total potato quantity and quality (**Table 6**). While, glyphosate at 100 g·ai·ha^{-1} (Single or sequential) significantly reduced total potato yield and produced non-marketable tubers. Phytotoxicity was mostly reflected in the tuber quality of potato yield grown for fresh market with a high incidence of deformed and small tubers. These results are similar to the observations by Gilreath *et al.* [31] who observed that marketable yield of pepper declined with glyphosate dosages at 100 g·ai·ha^{-1}. Previous studies by Nadal *et al.* [32] concluded that sequential application of glyphosate at 67 g·ai·ha^{-1} completely controlled *Orobanche crenata* infestation and increased seed production of narbon bean (*Vicianar bonensis* L), compared to the control. Thus, selectivity remains the main obstacle in various crops and it could be mediated by the rate and time of application.

Table 3. Yield response of potato to single or sequential application of sub-lethal doses of glyphosate at 125 g·ai·ha^{-1} and injected ammonia gas at 30 kg·ha^{-1}. Data represent average of four replicates. Means followed by the same letter, within each column, do not significantly differ at the 5% level according to the LSD test. PTY: Potato tuber yield; TTN: Total tuber number; MTN: Marketable tuber number; NTN: Non-marketable tuber number.

Treatment	PTY		TTN		MTN		NTN	
	(Tons per ha)		(No. per ha)		(No. per ha)		(No. per ha)	
Glyphosate	16.2	a	153809.5	a	54761.90	a	99047.60	a
Ammonia	9.5	b	86666.65	b	39047.61	a	47619.04	b
Control	10.0	b	94761.89	b	38571.42	a	56190.47	b

Table 4. *Phelipanche aegyptiaca* above ground shoot number (SN) and total shoot dry weight (TSDWT) in response to sub-lethal doses of glyphosate after 100 days after potato emergence (DAPE). Data represent average of four replicates. Means followed by the same letter, within each column, do not significantly differ at the 5% level according to the LSD test.

Treatment	Rate	Application time	SN		TSDWT	
	(g·ai·ha^{-1})	(DAPE)	(per m^2)		(g per m^2)	
Glyphosate	60	20	31.3	a	20.5	a
	80	20	18.0	a	14.8	a
	100	20	9.0	b	7.8	b
	60	20/40	4.0	b	2.6	bc
	80	20/40	2.3	bc	1.4	bc
	100	20/40	1.0	c	0.7	bc
	60	20/40/60	0.0	c	0.0	c
	80	20/40/60	0.0	c	0.0	c
	100	20/40/60	0.0	c	0.0	c
Control			25.7	a	16.1	a

Table 5. Effect of glyphosate on potato shoot height (PHT) and vigor (PVR). Data represent average of four replicates. Means followed by the same letter, within each column, do not significantly differ at the 5% level according to the LSD test. DAPE: Days after potato emergence; PVR: Crop phytotoxicity visual rating with 0 indicating complete death and 10 no injury.

Treatment	Rate	Application time	PVR (%)				PHT (cm)			
	(g·ai·ha^{-1})	(DAPE)	60 DAPE		75 DAPE		60 DAPE		75 DAPE	
Glyphosate	60	20	7.6	bc	8.4	ab	58.3	a	78.4	ab
	80	20	7.1	bc	8.3	ab	59.4	a	78.2	ab
	100	20	6.6	c	7.5	bc	54.3	a	66.2	ab
	60	20/40	7.6	bc	7.6	bc	60.9	a	77.0	ab
	80	20/40	7.6	bc	7.3	bc	61.2	a	68.3	ab
	100	20/40	7.0	bc	6.1	d	56.7	a	64.0	b
	60	20/40/60	8.0	b	7.5	bc	64.5	a	80.7	ab
	80	20/40/60	7.5	bc	7.4	bc	62.3	a	66.5	ab
	100	20/40/60	7.1	bc	6.8	cd	56.1	a	64.0	b
Control			9.0	a	9.0	a	69.2	a	82.2	a

Table 6. Yield response of potato yield to glyphosate. Data represent average of four replicates. Means followed by the same letter, within each column, do not significantly differ at the 5% level according to the LSD test. DAPE: Days after potato emergence; TPY: Total potato yield; TPN: Total potato number; MPY: Marketable potato yield; NPY: Non-marketable potato yield.

Treatment	Rate	Application time	TPY		MPY		NPY	
	(g·ai·ha^{-1})	(DAPE)	(t/ha)		(t/ha)		(t/ha)	
Glyphosate	60	20	33.9	a	28.3	a	5.6	a
	80	20	29.9	a	24.0	a	5.9	a
	100	20	25.9	b	22.7	a	3.2	b
	60	20/40	36.0	a	30.9	a	5.1	a
	80	20/40	29.9	a	25.4	a	4.5	a
	100	20/40	24.9	b	19.9	b	5.0	a
	60	20/40/60	36.8	a	28.0	a	8.8	a
	80	20/40/60	30.2	a	23.5	a	6.7	a
	100	20/40/60	20.4	b	14.3	b	6.1	a
Control			26.9	a	20.6	a	6.3	a

4. Conclusion

Our results suggest that sequential foliar application (20 + 40 and 20 + 40 + 60 DAPE) of glyphosate at 60 - 80 g·ai·ha^{-1} could be used selectively to reduce *P. aegyptiaca* infection in potato. The timing of glyphosate application is crucial for successful control of *P. aegyptiaca* and could vary among potato varieties and growing seasons. Additional research is required to determine the optimum timing of glyphosate application and duration of control based on estimated *P. aegyptiaca* phenological underground growth stages in the field.

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