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Wild poinsettia biology and management – determining optimal control with herbicides and propane flaming

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ABSTRACT

Wild poinsettia (*Euphorbia heterophylla* L.) is a troublesome weed in irrigated summer crops and orchards. Data regarding the optimal herbicide rates for control of this weed, the impact of phenology on control efficacy, and non-chemical control methods for this weed are scarce. The objectives of this study were to: conduct dose-response analyses for trifloxysulfuron at 0–11.2 g a. i. ha^{-1}, glyphosate at 0–2880 g a. i. ha^{-1}, glufosinate-ammonium at 0–1600 g a. i. ha^{-1} and propane flaming at 0–83 kg ha^{-1} on wild poinsettia at 4-leaf, 8-leaf and flowering stages; evaluate the long-term control efficacy of these treatments; and link these finding to physiological models. Petri dish and pot experiments examined the germination and phenology of wild poinsettia. The calculated base temperature was 11.4 °C, and physiological time and wild poinsettia fresh weight and leaf number were strongly correlated, with R^2 values of 0.96 and 0.97, respectively. Wild poinsettia phenology had a crucial impact on herbicide efficacy. At the 4-leaf stage, all herbicide treatments were effective within the recommended rates with ED_{90} values of 3.2, 698 and 206 g a. i. ha^{-1} for trifloxysulfuron, glyphosate and glufosinate-ammonium, respectively. As the weed matured, it was less susceptible to these treatments. At the 8-leaf stage, only glyphosate and glufosinate-ammonium achieved an ED_{90} within their recommended rates. The efficacy of flaming on wild poinsettia control was high at the 4-leaf stage with a control level of 95%, compared to only 31% and 13% at the 8-leaf and flowering stages, respectively. The long-term study revealed that for the 8-leaf application, the high glyphosate rate (1440 g a. i. ha^{-1}) was the only effective treatment, with 95% fresh weight reduction and complete flowering inhibition. This study promotes optimal herbicide applications and demonstrates the potential use of propane flaming for effective wild poinsettia control. The integration of data regarding optimal control with a phenology model offers an efficient tool to improve wild poinsettia management.

1. Introduction

Wild poinsettia (*Euphorbia heterophylla* L. synonym *Euphorbia geniculata* Ortega) is a troublesome annual weed native to Central America and the southern parts of the United States. This weed is highly invasive and has spread into other regions, including Central and South Africa, the Indian Ocean islands, the Mediterranean, Argentina and Brazil (Wagner et al., 1999). Wild poinsettia reproduces exclusively via seeds which are released by an explosive dispersal mechanism (Malíková et al., 2012). A single plant can produce up to 500 seeds, with 3 seeds of about 2 mm in size in each fruit capsule (Dafni and Heller, 1980).

Wild poinsettia has become a major problem in irrigated summer crops, such as cotton (*Gossypium hirsutum*) and orchards in the central and northern parts of Israel, soybean (*Glycine max* [L.] Merr.) in Brazil and peanut (*Arachis hypogaea* L.) in the southern United States (Brecke and Tobola, 1996; Kigel et al., 1992; Nechet et al., 2006). Wild poinsettia can germinate in a wide range of temperatures, soil moistures and pH levels, enabling its almost continuous emergence throughout the growing season, from soil depths of down to 14 cm (Brecke, 1995; Brecke and Tobola, 1996). It has a short-day requirement for flowering induction that allows it to produce up to four generations per year, and vigorous vegetative growth during the crops' initial growth stages (Frigo et al., 2009). Furthermore, in early summer, individual plants can reach 2 m in height, which makes them competitive within the crop canopy (Kigel et al., 1992). Because of these biological characteristics, adequate control of this weed requires multiple herbicide applications, especially when infestation levels are high (Willard and Griffin, 1993).

Wild poinsettia can sprout adventitiously from the hypocotyl. This unique feature allows it to regenerate and produce seeds following severe injury, including massive loss of aboveground fresh weight. As a

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result, manual and mechanical control tactics are not effective when performed on later growth stages (Ishikawa et al., 1997; Latzel et al., 2009). The same regeneration ability also limits the control efficacy of the herbicides imazaquin (140 g a. i. ha^{-1}), fomesafen and acifluorfen (420 g a. i. ha^{-1}), and chlorimuron (9 g a. i. ha^{-1}). Willard and Griffin (1993) achieved adequate control on early growth stages (< 10 cm height) but poor control on large plants (> 15 cm height) with application of the same rates of herbicide. Those authors reported that plants regenerated from lower nodes, below the herbicide-treated area, and completed their growth cycle. Similar observations were made by (Langston et al., 1984), who suggested that the adventitious regrowth ability of wild poinsettia is a tolerance mechanism for contact-herbicide treatments.

In Israel, trifloxysulfuron is the main selective herbicide used in cotton, while glyphosate and glufosinate-ammonium are used for directed, non-selective weed control between the crop rows. Glyphosate and glufosinate-ammonium are also widely used in orchards and vineyards. The recommended label rates for these herbicides are not consistent: trifloxysulfuron rates range between 5.6 and 11.2 g a. i. ha^{-1}, while glyphosate and glufosinate-ammonium are registered for annual weeds at rates of 480–1440 and 500–1000 g a. i. ha^{-1}, respectively. These herbicides are effective for many annual weeds, but the negative ecological and human health aspects associated with herbicide application have resulted in great pressure on farmers to reduce herbicide rates wherever possible (Chauhan et al., 2012). On the other hand, continuous application of suboptimal rates may result in weed survival and unintended evolution of resistant populations (Norsworthy et al., 2012). To cope with the problematic aspect of herbicide-resistant weeds, but ensure sustainability, Norsworthy et al. (2012) proposed the best management practice (BMP) approach. One of its principles recommends application of optimal herbicide rates for each growth stage. However, there are no data on the optimal rates of trifloxysulfuron, glyphosate or glufosinate-ammonium for wild poinsettia control, or on the impact of weed growth stages on the optimal rate.

Another principle of the BMP approach suggests the use of non-chemical control practices where appropriate. In that respect, propane weed flaming may be a suitable alternative to herbicides (Sivesind et al., 2009; Ulloa et al., 2010a). Flaming exposes the weed tissues to high temperatures, and control is achieved by coagulation of membrane proteins, which leads to loss of membrane integrity (Ulloa et al., 2010b). Many studies have demonstrated successful application of propane flaming, broadcast and cross-row, to control weeds, and the impact of weed growth stage on control efficacy (Datta and Knezevic, 2013; Knezevic et al., 2013; Ulloa et al., 2010a, 2011, 2012). Nonetheless, there are no data on the potential usage of flaming for wild poinsettia control or the impact of its growth stage. Furthermore, herbicide and flaming efficacies are usually determined 3–14 days after treatment (DAT) and there is limited information on their long-term impact. These missing data are of great interest for perennial and long-season crops, such as cotton, where long-term control is needed.

Integration of data on weed biology and phenology can greatly improve most control means (Fand et al., 2014). Such data are employed to predict key phases within the weed's life cycle and phenology, which then support decisions regarding optimal timing of weed-control activities (Ali et al., 2013; Batlla and Luis Benech-Arnold, 2007; Chauhan et al., 2012). However, biological and phenological information on wild poinsettia is limited. Kigel et al. (1992) conducted a study on the early growth and reproduction of wild poinsettia, and found that temperatures lower than 15 °C inhibit its germination. Brecke (1995) evaluated wild poinsettia germination patterns and observed germination ability under a wide range of light, temperatures, pH, water availability, and depth conditions. These studies were fundamental in terms of understanding wild poinsettia ecology and biology, but to improve the relevant weed-control strategies, more data are needed, such as the base temperature (T_b) value. This parameter is used to develop physiology–time models that predict phenology stages and support decisions regarding the control of weeds under varied environments (Cochavi et al., 2016). The objectives of this study were to: (i) conduct dose-response analyses for trifloxysulfuron, glyphosate and glufosinate-ammonium on wild poinsettia at different growth stages, (ii) evaluate the potential use of propane flaming for wild poinsettia control and set the optimal rate and timing for application, (iii) evaluate the long-term control efficacy of these herbicides and flaming, and (iv) evaluate wild poinsettia T_b value and develop a phenology-prediction model for this weed.

2. Materials and methods

2.1. Plant material and net-house studies

Ripe wild poinsettia fruit capsules were collected in the summer of 2016 from a pear orchard in the Hula Valley in the northern part of Israel (33.04° N, 35.59° E). The fruit capsules were air-dried for 1 month in a dry-environment greenhouse (~40 °C at noontime) until the seeds separated naturally from the capsules. Seeds were cleaned of plant debris and stored at room temperature under dark and dry conditions until use. Net-house experiments were conducted at the Newe Ya'ar Research Center during the summers of 2016 and 2017 using 2-L pots filled with Newe Ya'ar silty clay soil (57% clay, 23% silt, and 20% sand, on a dry-weight basis and 2% organic matter). Pots were seeded with four wild poinsettia seeds and thinned to one plant per pot 4 days after emergence. Plants were watered by an automated mini-sprinkler irrigation system as needed. Herbicides were applied using a motorized laboratory sprayer equipped with an EvenSpray 8001E flat fan nozzle (Spraying Systems Co., Wheaton, IL, USA) delivering 200 l ha^{-1} at 245 kPa. In all experiments, trifloxysulfuron was applied with 0.1% DX alcohol polyether spreader (Adama-Agan Ltd., Ashdod, Israel). The dose response (section 2.2), flaming (section 2.3) and phenology (section 2.5) studies were performed in May 2016 (average temperature of 24.0 °C) and repeated in August of the same year (average temperature of 26.8 °C). The long-term efficacy study (section 2.4) was performed in April 2017 (average temperature of 22.0 °C) and repeated in July of the same year (average temperature of 27.5 °C).

2.2. Herbicide dose response

Dose-response studies were performed at different growth stages to determine the optimal rates for wild poinsettia control with POST applications of glyphosate (Roundup 480 g l^{-1}, SL, Monsanto), glufosinate-ammonium (Basta 200 g l^{-1}, SL. Bayer cropscience) band trifloxysulfuron (Envoke 75% WG, Syngemta). Plants were grown in the net-house and at the growth stages of 4 leaves, 8 leaves or flowering, were treated with glyphosate (0, 45, 90, 180, 360, 720, 1440 and 2880 g a. i. ha^{-1}), glufosinate-ammonium (0, 25, 50, 100, 200, 400, 800 and 1600 g a. i. ha^{-1}) or trifloxysulfuron (0, 1.8, 3.7, 5.6, 7.5, and 11.2 g a. i. ha^{-1}). Shoots were harvested 2 weeks after spraying and their fresh weight was determined. Dry weight was recorded after 72 h of drying in a 70 °C oven.

2.3. Flaming experiment

Flaming treatments were performed using a Red Dragon two-burner system equipped with two liquid-phase torches (LT 1 1/2 × 8; Flame Engineering Inc., LaCrosse, KS, USA). The burners were connected to a 12 kg propane tank mounted on a cart to simulate commercial tractor application. Burners were set in a cross-flaming design, at an angle of 45° with respect to zenith, and 20 cm from the crop line resulting in 30 cm treated band width. Burners were mounted in a staggered position to avoid intersecting flames. Three flame doses were tested at a driving speed of 3 km h^{-1} by using a gas-valve regulator connected to the gas system and adjusted to three pressures: 25, 37.5 and 50 psi.