Reduced Rates of Glufosinate in Combination with 2,4-D-Choline Impact Sweetpotato Growth and Yield

Donnie K. Miller[1], Ashley M. Barfield[1], Marcie S. Wilson[1], Jeffrey C. Gregorie[2], Taylor M. Tullos[1], and Koffi Badou-Jeremie Kouame[3]

KEYWORDS. crop injury, crop response, herbicide drift, spray tank contamination

ABSTRACT. **Potential negative impacts due to herbicide drift or sprayer contamination is a cause of major concern for sweetpotato (*Ipomoea batatas* L.) producers that was made more urgent by commercialization of crops tolerant to application of glufosinate and 2,4-D-choline. Field studies were conducted in 2020–21 to assess impacts of reduced rates of combinations of glufosinate with 2,4-D-choline on sweetpotato growth and production. Reduced rates of 1/8×, 1/10×, 1/33×, 1/66×, 1/100×, 1/128×, or 1/256× of a 1× rate of both glufosinate at 0.655 lb a.i./acre (32 oz/acre) plus 2,4-D-choline at 1.064 lb acid equivalent/acre (32 oz/acre), simulating those encountered in drift or sprayer contamination events, were applied to 'Orleans' or 'Bayou Belle' sweetpotato at 10 or 30 days after transplanting to simulate growth stage encountered when applications may occur adjacent to corn, soybean, or cotton. Glufosinate in combination with 2,4-D-choline can cause significant visual injury to sweetpotato at rates often encountered in drift or sprayer contamination events. Negative yield impacts resulting from this injury were generally greater at high rates (1/8×, 1/10×, or 1/16×) when application occurred 10 days after transplanting and with all rates when occurring at 30 days after transplanting. Negative environmental conditions not conducive to optimal sweetpotato growth, such as low moisture or extreme temperatures, can affect plant ability to recover from initial herbicide injury.**

Sweetpotato (*Ipomoea batatas* L.), a widely produced root crop of the morningglory family, is the most economically important vegetable crop in Louisiana. In 2023, 33 Louisiana sweetpotato producers planted an estimated 2146.2 ha across the state, predominantly in a six-parish area, which represented a 23.1% decrease from the previous growing season (LSU AgCenter 2024). Although statewide yield was 28,357.5 $kg \cdot ha^{-1}$, drought conditions throughout the majority of the growing season necessitated irrigation where possible, which in some cases increased production costs an estimated 30%. The farm gate value for sweetpotato in 2023 was $47.3 million, with $17 million from processing and $30.3 million from the fresh market (LSU AgCenter 2024). Production and packing fresh market costs are budgeted for 2025 at $15,157.44/ha (Guidry and Gregorie 2025). Given this high level of production costs, there is little margin for error in terms of factors such as crop injury from off-target herbicide application or sprayer contamination events that can negatively affect yield.

Maximum sweetpotato yield production requires adventitious roots to effectively produce lateral roots that directly affect the adventitious root's ability to swell and produce mature storage roots (Villordon et al. 2014). Previous research has indicated that in pot studies at ~5 to 15 d post-transplant, adventitious roots, representing 80% of the final yield, progressively grow and produce lateral roots depending on the internal auxin signaling (Villordon et al. 2014). Villordon et al. (2009) differentiated storage root development into a three-stage phenology scheme: SR1, SR2, and SR3. SR1 consists of the presence of at least one adventitious root greater than 0.5 cm in length in at least 50% of transplanted slips. SR2 consists of the presence of anomalous cambium in at least one adventitious root on 50% of the plants. SR3 consists of at least one visible storage root, an adventitious root that is swollen 0.5 cm at its widest point, in at least 50% of the plants. Storage root formation begins between 13 and 20 d in the field. Lateral root development is fundamentally dependent on auxin signaling, and anything that interferes with this process interferes with storage root formation. This is the precise window for targeting negative impacts, such as herbicide injury, to determine maximum potential to reduce yield due to reduction in storage root number (Villordon A, personal communication).

With increasing populations of weeds resistant to glyphosate herbicide, cultivar development shifted focus to developing new product formulation technologies with older herbicides and using plant genetic modification to combat such populations. One such genetically modified technology, the Enlist® weed control system (Corteva AgriScience LLC, Indianapolis, IN, USA) has been commercialized, allowing application of glufosinate and 2,4-D-choline (2,4-dichlorophenoxyacetic acid, choline salt) each alone or in combination over the top of crops that were previously intolerant to these two herbicides. Soybean [*Glycine max* (L.) Merr], cotton (*Gossypium hirsutum* L.), and corn (*Zea mays* L.) varieties with these traits are readily available for purchase and use by producers. The herbicide 2,4-D selectively controls most dicotyledonous plants including morningglory (*Ipomoea* sp.) (Siebert et al. 2004), palmer amaranth (*Amaranthus palmeri*) (Norsworthy et al. 2008) and marestail (*Conyza candensis*) (Bruce and Kells 1990) and has traditionally been used in monocotyledonous crops such as pastures, turf, and in some instances corn and small grains. Glufosinate is a nonselective herbicide that controls a large number of both grass and broadleaf weeds, making it a good tank mix partner with 2,4-D-choline (BASF Corp 2025). These new technologies

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[1]Northeast Research Station, Louisiana State University Agricultural Center, St. Joseph, LA 71366, USA

[2]Sweetpotato Research Station, Louisiana State University Agricultural Center, Chase, LA 71324, USA

[3]Agricultural Research Center, Kansas State University, Hays, KS 67601, USA

D.K.M. is the corresponding author. E-mail: dmiller@agcenter.lsu.edu.

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Table 1. Three-parameter log-logistic model and linear model parameters for sweetpotato injury, NDVI, root counts, and yield averaged across locations of Chase, Crowville, and Ville Platte, LA, in 2020–21 and St. Joseph, Ville Platte, Oak Grove, and Crowville, LA, in 2022.

Application timing[i]	Year[ii]	Response variable	Parameters[iii]			Parameters[iv]	
			d	*b*	*e*	Intercept	Slope
10 DAP	2020–21	Injury 1 WAT	100	−1.27947	0.056		
30 DAP	2020–21	Injury 1 WAT	76.28968	−1.14123	0.033998		
10 DAP	2020–21	Injury 2 WAT	100	−1.437	0.040831378		
30 DAP	2020–21	Injury 2 WAT	100	−0.8727	0.052246946		
10 DAP	2020–21	Injury 4 WAT				−1.161	720.864
30 DAP	2020–21	Injury 4 WAT				0.736	319.355
10 DAP	2020–21	NDVI				0.82349	−3.71722
30 DAP	2020–21	NDVI				0.78035	−0.4095
10 DAP	2020–21	US No. 1 count	42.71113	2.523069	0.09735		
30 DAP	2020–21	US No. 1 count	41.45298	1.080045	0.087062		
10 DAP	2020–21	US No. 1 yield	9,796.324	2.801016	0.093932		
30 DAP	2020–21	US No. 1 yield	9,024.09	1.576377	0.084981		
10 DAP	2020–21	TMY count	119.3037	2.142072	0.094473		
30 DAP	2020–21	TMY count	117.49	1.015919	0.174392		
10 DAP	2020–21	TMY yield	21,336.87	2.125485	0.098757		
30 DAP	2020–21	TMY yield	20,225.06	1.417279	0.104696		
10 DAP	2022	Injury 1 WAT				13.706	494.717
30 DAP	2022	Injury 1 WAT	100	−0.7562	0.0743		
10 DAP	2022	Injury 2 WAT				12.3	555.791
30 DAP	2022	Injury 2 WAT	96.30963	−0.96827	0.060234		
10 DAP	2022	Injury 4 WAT				−1.161	720.864
30 DAP	2022	Injury 4 WAT	47.6181	−2.14059	0.04476		
10 DAP	2022	NDVI	0.813581	0.447422	17.0633		
30 DAP	2022	NDVI	0.848031	1.377397	0.409704		
10 DAP	2022	US No. 1 count	35.9318	2.939896	0.11707		
30 DAP	2022	US No. 1 count	40.22208	0.480455	0.089024		
10 DAP	2022	US No. 1 yield	12,305.47	2.39018	0.129054		
30 DAP	2022	US No. 1 yield	12,920.84	0.620329	0.076202		
10 DAP	2022	TMY count	102.1312	3.241549	0.136105		
30 DAP	2022	TMY count	98.80086	0.846089	0.376937		
10 DAP	2022	TMY yield	14,148.83	14,148.83	0.119491		
30 DAP	2022	TMY yield	14,650.34	14,650.34	0.049919		

[i] Glufosinate plus 2,4-D-choline applied at 0, 1/10, 1/32, 1/64, and 1/100× of a 1× use rate of 0.655 lb a.i./acre 1.064 lb a.e./acre, respectively.

[ii] Chase, LA, USA (32.0968°N, 91.6988°W; 'Orleans' planted 6 Jul); Crowville, LA, USA (32.2407°N, 91.5901°W; 'Orleans' planted 2 Jun); and Ville Platte, LA, USA (30.6880°N, 92.2715°W; 'Bayou Belle' planted 3 Jun) in 2020–21. St. Joseph, LA, USA (31.9184°N, 91.2335°W; 'Bayou Belle' planted 9 Jun); Ville Platte, LA, USA (30.6880°N, 92.2715°W; 'Orleans' planted 31 May); Oak Grove, LA, USA (32.8610°N, 91.3884°W; 'Bayou Belle' planted 6 Jun); and Crowville, LA, USA (32.2407°N, 91.5901°W; 'Orleans' planted 21 May) in 2022.

[iii] The three-parameter log-logistic model: $Y = d/(1+\exp[b(\ln[x] - \ln[e])])$, where Y is the response variable of interest, b is the slope at the inflection point, d is the upper limit, e is the dose of herbicide corresponding–the midpoint of plant injury response observed between the upper limit and 0, and x is the fraction of the labeled rate of herbicide applied expressed as a decimal (i.e., 1/10× as 0.10).

[iv] The linear model: $Y = B_0 + B_1x + \varepsilon$, where Y represents the response variable of interest, x represents the fraction of the labeled herbicide applied expressed as a decimal, β_1 is the slope or the amount by which the response variable changes when the fractional herbicide rate increases by one unit, β_0 is the intercept or the value of the response variable when the fractional herbicide rate = 0, and ε is the residual.

DAP = Days after transplanting; NDVI = Normalized Difference Vegetation Index; TMY = total marketable yield; WAT = weeks after treatment.

use plants that are genetically modified to be resistant to these products so that applications may be made directly to the transformed crops.

Merchant et al. (2013) found that morningglories (*Ipomoea* sp.), when exposed to 2,4-D at 1.2, 1.75, or 2.3 L·ha^{-1}, were completely controlled. In addition, excellent control of large pitted morningglory was observed with mixtures of glufosinate and 2,4-D. Joseph et al. (2018) reported that glufosinate applied in combination with 2,4-D was one of the most effective and consistent treatments for control of pitted morningglory in research evaluating glufosinate, glyphosate, 2,4-D, and dicamba applied alone or in combination. Corbett et al. (2004) reported that glufosinate controlled 2 to 5 cm *Ipomoea* morningglory species entireleaf, ivyleaf, pitted, and tall at least 90%. Since sweetpotato is also an *Ipomoea* species, off-target movement of glufosinate and 2,4-D is a major cause for concern to producers. Drift or off-target movement was previously identified by survey respondents from two separate states as the biggest herbicide application challenge they face (Butts et al. 2021; Virk and Prostko 2022). Additionally, severe crop injury from off-target herbicide movement is possible upwards of 60-m downwind from both ground and aerial applications, which can negatively affect yield, environmental stewardship, and other beneficial species (Butts et al. 2022). As a result, it is imperative to understand

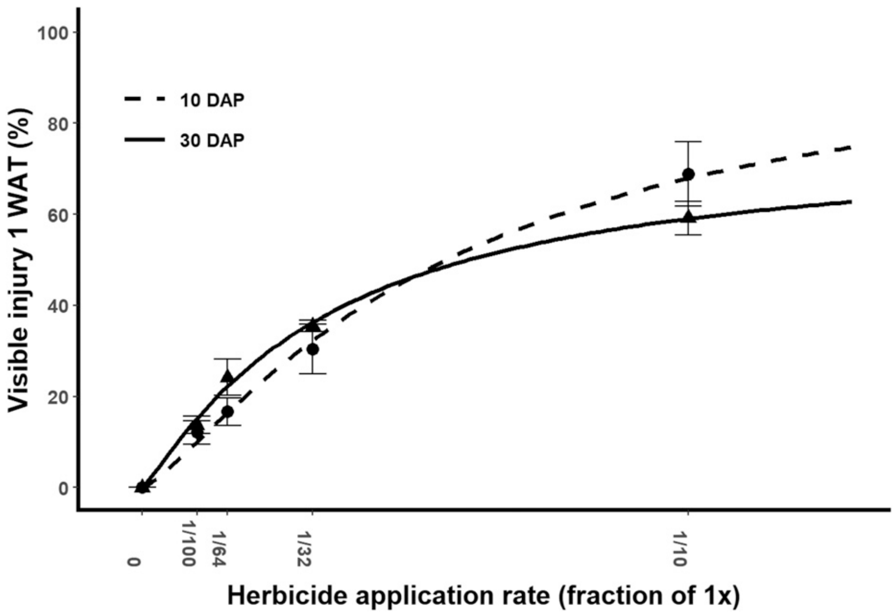

Fig. 1. Sweetpotato visible injury 1 weeks after treatment (WAT) with reduced rates of glufosinate and 2,4-D-choline applied 10 or 30 days after transplant (DAP) in 2020–21. Herbicides were applied at fractional rates of a 1× use rate of 0.655 lb a.i./acre 1.064 lb a.e./acre, respectively. A three-parameter log-logistic model parameter was averaged across locations of Chase, LA, USA (32.0968°N, 91.6988°W; 'Orleans' planted 6 Jul); Crowville, LA, USA (32.2407°N, 91.5901°W; 'Orleans' planted 2 Jun); and Ville Platte, LA, USA (30.6880°N, 92.2715°W; 'Bayou Belle' planted 3 Jun).

the implications on crop growth and development if the crop were to be exposed to an herbicide drift event.

Research has shown sweetpotato to be highly sensitive to 2,4-D with a very low concentration of only 100 ppm

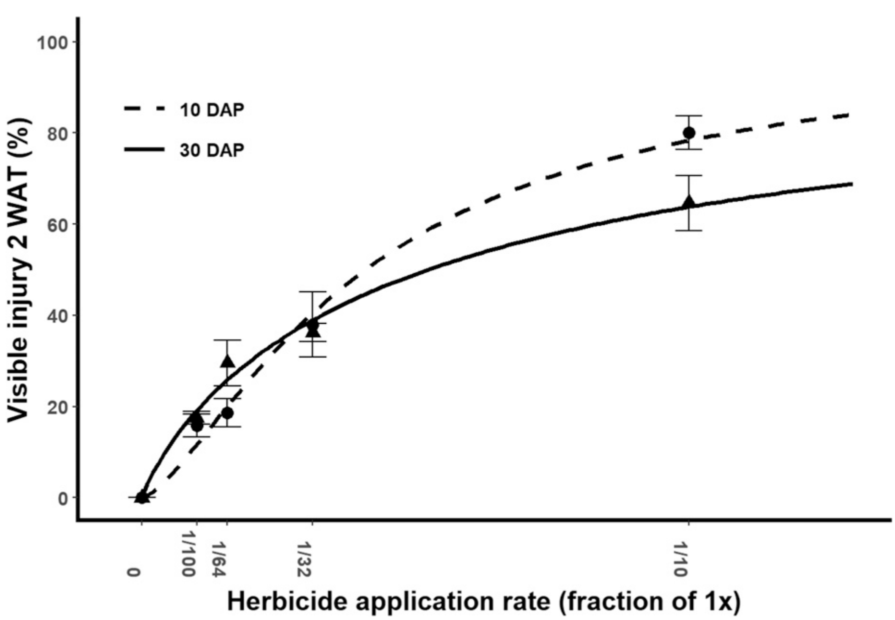

Fig. 2. Sweetpotato visible injury 2 weeks after treatment (WAT) with reduced rates of glufosinate and 2,4-D-choline applied 10 or 30 days after transplant (DAP) in 2020–21. Herbicides were applied at fractional rates of a 1× use rate of 0.655 lb a.i./acre 1.064 lb a.e./acre, respectively. A three-parameter log-logistic model parameter was averaged across locations of Chase, LA, USA (32.0968°N, 91.6988°W; 'Orleans' planted 6 Jul); Crowville, LA, USA (32.2407°N, 91.5901°W; 'Orleans' planted 2 Jun); and Ville Platte, LA, USA (30.6880°N, 92.2715°W; 'Bayou Belle' planted 3 Jun).

considered optimum to induce flowering (Mutasa et al. 2013). Miller et al. (2020) reported that application of 2,4-D-choline in combination with glyphosate at 1/10× and 1/33× of the labeled use rate in Enlist® weed control systems resulted in an 84 and 45% reduction in US No. 1 sweetpotato yield, respectively, while those same rates in addition to 1/66× resulted in 66%, 27%, and 15% reductions in total sweetpotato yield, respectively. The aforementioned Enlist® corn, cotton, and soybean crops are frequently plant in near proximity to sweetpotato production fields throughout Louisiana. Additionally, application of glufosinate plus 2,4-D-choline in these crops often coincides with critical developmental stages of sweetpotato previously discussed.

No research has been conducted on the potential impacts on sweetpotato from glufosinate applied in combination with 2,4-D-choline available for use in the Enlist® cropping system at rates that may be encountered in drift or sprayer tank contamination events. Off-target movement or sprayer contamination of this combination is a major cause for concern. With this concern in mind, research was conducted in Louisiana to (1) evaluate impact of reduced rates of this herbicide combination that may be encountered in off-target or sprayer contamination events and (2) determine the impact of application timing on growth and yield of sweetpotato.

Materials and methods

A field study was initiated in 2020 at the Louisiana State University (LSU) AgCenter Sweetpotato Research Station near Chase, LA, USA (32.0968°N, 91.6988°W; 'Orleans' planted 6 Jul) and repeated in 2021 in producer fields near Crowville, LA, USA (32.2407°N, 91.5901°W; 'Orleans' planted 2 Jun) and Ville Platte, LA, USA (30.6880°N, 92.2715°W; 'Bayou Belle' planted 3 Jun). A separate field study was conducted in 2022 at the LSU AgCenter Northeast Research Station near St. Joseph, LA, USA (31.9184°N, 91.2335°W; 'Bayou Belle' planted 9 Jun) and producer fields near Ville Platte, LA, USA (30.6880°N, 92.2715°W; 'Orleans' planted 31 May), Oak Grove, LA, USA (32.8610°N, 91.3884°W; 'Bayou Belle' planted 6 Jun), and Crowville, LA, USA (32.2407°N, 91.5901°W; 'Orleans'

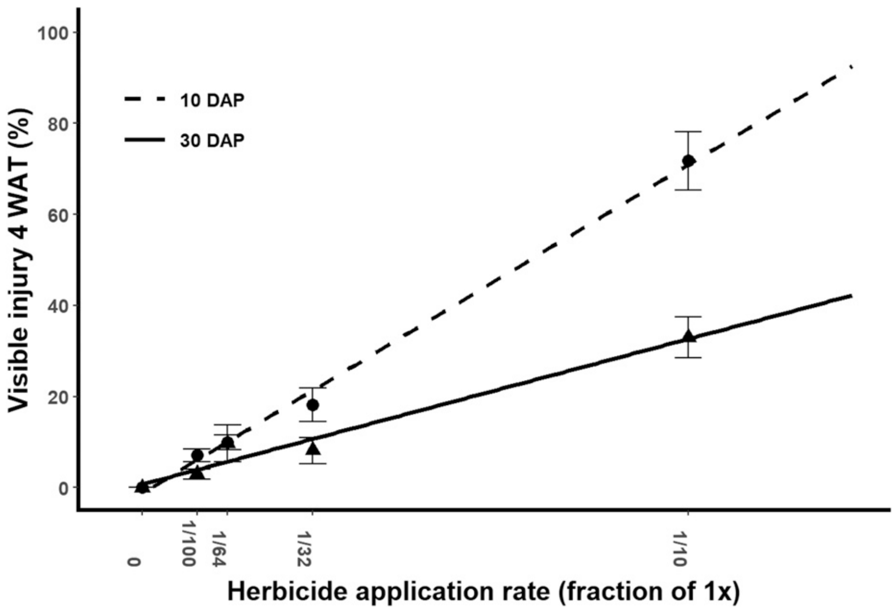

Fig. 3. Sweetpotato visible injury 4 weeks after treatment (WAT) with reduced rates of glufosinate and 2,4-D-choline applied 10 or 30 days after transplant (DAP) in 2020–21. Herbicides were applied at fractional rates of a 1× use rate of 0.655 lb a.i./acre 1.064 lb a.e./acre, respectively. Linear model parameter averaged across locations of Chase, LA, USA (32.0968°N, 91.6988°W; 'Orleans' planted 6 Jul); Crowville, LA, USA (32.2407°N, 91.5901°W; 'Orleans' planted 2 Jun); and Ville Platte, LA, USA (30.6880°N, 92.2715°W; 'Bayou Belle' planted 3 Jun).

planted 21 May). Sweetpotato slips were mechanically transplanted using standard industry practices on a 101.6-cm row with 30.54-cm in-row plant spacing, resulting in 32,391 plants/ha. To eliminate weed interference, flumioxazin (0.063 lb a.i./acre; 2 oz/acre Valor SX, Valent USA Corp, Walnut Creek, CA, USA) pretransplant followed by *S*-metolachlor (1.25 lb a.i./acre; 1.33 pt/acre Dual Magnum; Syngenta Crop Protection LLC, Greensboro, NC, USA) immediately posttransplant were applied to all plots (Gregorie C, personal communication). Subsequent applications of clethodim (0.152 lb a.i./acre; 10 oz/acre Clethodim 2E; Albaugh LLC, Ankeny, IA, USA) were applied throughout the growing season as needed for grass control (Gregorie C, personal communication). Additional hand weeding was performed as needed for broadleaf weed control. Fertilizer was applied pre-plant at 44.83 kg·ha^{-1} nitrogen (N), 123.29 kg·ha^{-1} P, and 125.54 kg·ha^{-1} K. The insecticides chlorpyrifos in 2020–21 (2.0 lb a.i./acre; 4 pt/acre Lorsban 4 E; Corteva AgriScience LLC, Indianapolis, IN, USA) and clothianidin in all years (0.2 lb a.i./acre (12 oz/acre Belay; Valent USA Corp, Walnut Creek, CA, USA) were applied in furrow before planting (Gregorie C, personal communication). The plants were monitored during the growing season, and insect control as well as overhead irrigation was scheduled as needed.

A randomized complete block experimental design with four replications was used. Treatments were placed in a factorial arrangement with factor A consisting of herbicide rate (0×, 1/10×, 1/32×, 1/64×, and 1/100× of the 1× use rate of both product in 2020 and 2021 and 0×, 1/8×, 1/16×, 1/32×, 1/64×, 1/128×, and 1/256× in 2022) and factor B consisting of application timing [10 or 30 days after transplanting (DAP)]. Wolf et al. (1993) reported drift values ranging from 1.8% to 16% from an unshielded sprayer based on wind speed. The 1× use rate of herbicides used as a basis for reduced rate applications was glufosinate at 0.655 lb a.i./acre (32 oz/acre Liberty 280 SL; BASF Corp, Research Triangle Park, NC, USA) plus 2,4-D-choline at 1.064 lb acid equivalent (a.e.)/acre (32 oz/acre, Enlist One; Corteva AgriScience LLC, Indianapolis, IN, USA). Additional spray adjuvants were not included with herbicide treatments. The plots were three rows 3.05 m wide by 7.62 m long. Two rows were treated, leaving the third as a border row.

Treatments were applied at a constant 140 L·ha^{-1} carrier volume at 193 kPa using a compressed-air

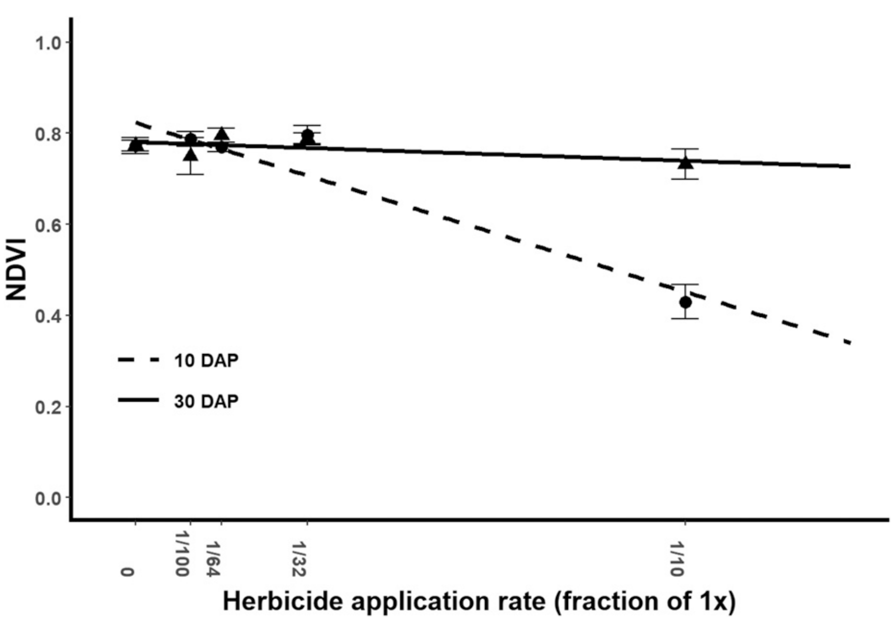

Fig. 4. Sweetpotato Normalized Difference Vegetation Index (NDVI) measurement 42 d after treatment with reduced rates of glufosinate and 2,4-D-choline applied 10 or 30 days after transplant (DAP) in 2020–21. Herbicides were applied at fractional rates of a 1× use rate of 0.655 lb a.i./acre 1.064 lb a.e./acre, respectively. Linear model parameter averaged across locations of Chase, LA, USA (32.0968°N, 91.6988°W; 'Orleans' planted 6 Jul); Crowville, LA, USA (32.2407°N, 91.5901°W; 'Orleans' planted 2 Jun); and Ville Platte, LA, USA (30.6880°N, 92.2715°W; 'Bayou Belle' planted 3 Jun).

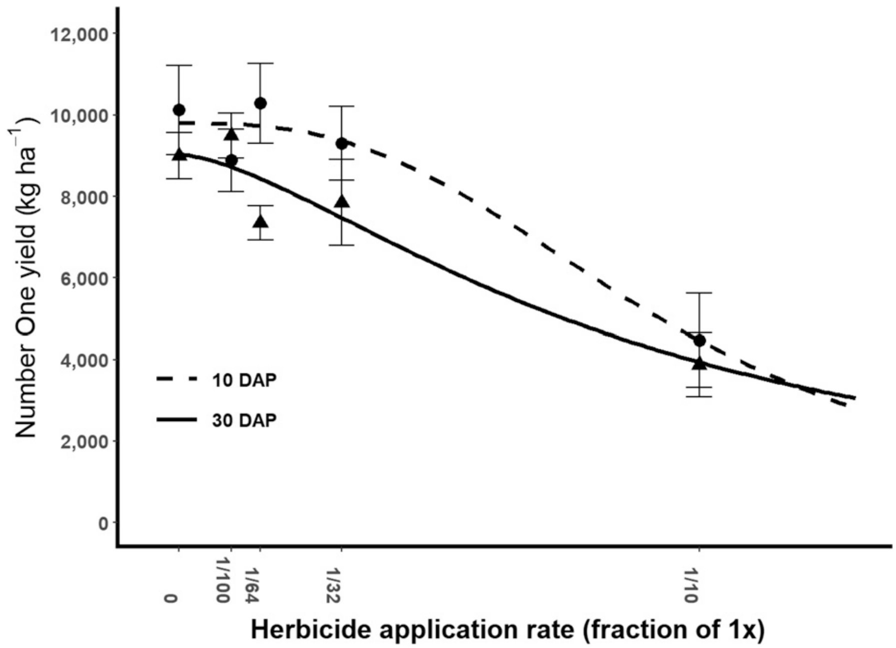

Fig. 5. US No. 1 sweetpotato yield following treatment with reduced rates of glufosinate and 2,4-D-choline applied 10 or 30 days after transplant (DAP) in 2020–21. Herbicides were applied at fractional rates of a 1× use rate of 0.655 lb a.i./acre 1.064 lb a.e./acre, respectively. A three-parameter log-logistic model parameter was averaged across locations of Chase, LA, USA (32.0968°N, 91.6988°W; 'Orleans' planted 6 Jul); Crowville, LA, USA (32.2407°N, 91.5901°W; 'Orleans' planted 2 Jun); Ville Platte, LA, USA (30.6880°N, 92.2715°W; 'Bayou Belle' planted 3 Jun). WAT = weeks after treatment.

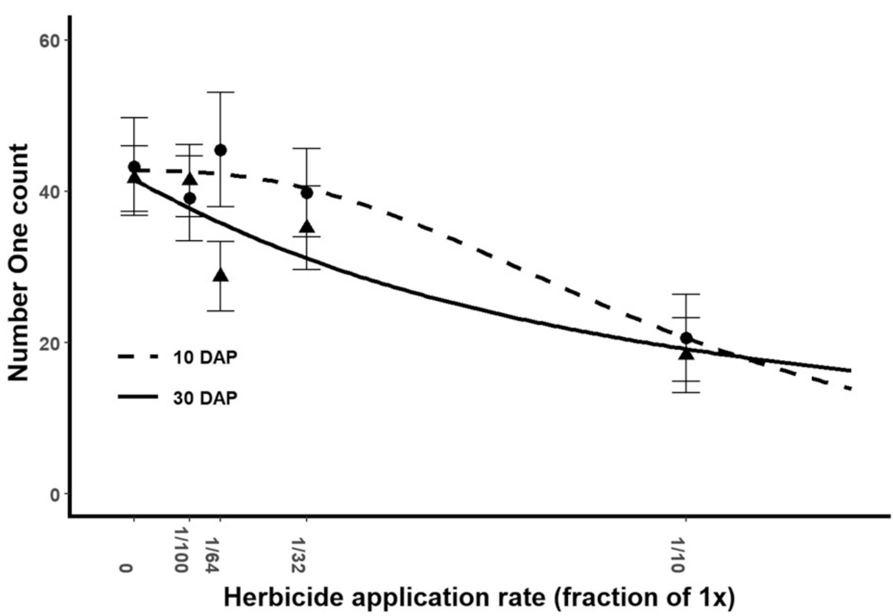

Fig. 6. US No. 1 sweetpotato root counts per harvested row following treatment with reduced rates of glufosinate and 2,4-D-choline applied 10 or 30 days after transplant (DAP) in 2020–21. Herbicides were applied at fractional rates of a 1× use rate of 0.655 lb a.i./acre 1.064 lb a.e./acre, respectively. A three-parameter log-logistic model parameter was averaged across locations of Chase, LA, USA (32.0968°N, 91.6988°W; 'Orleans' planted 6 Jul); Crowville, LA, USA (32.2407°N, 91.5901°W; 'Orleans' planted 2 Jun); and Ville Platte, LA, USA (30.6880°N, 92.2715°W; 'Bayou Belle' planted 3 Jun).

tractor-mounted sprayer equipped with air induction nozzles. Previous researchers evaluating impacts of reduced rates of herbicides on other crops have reported increased injury when carrier volumes are varied proportionally with lower herbicide rates (Ellis et al. 2008; Roider et al. 2008). Other researchers, however, have suggested that proportionally reducing carrier volume with herbicide rate may yield unrealistic results and confound results obtained (Everitt and Keeling 2009; Marple et al. 2008). Visual ratings of plant injury based on a scale of 0 = no effect to 100 = plant death was recorded at 7, 14, and 28 d after treatment (DAT). Chlorosis, necrosis, leaf strapping and cupping, and height reduction were all symptoms exhibited following treatment application. A Normalized Difference Vegetation Index (NDVI) measurement to assess plant growth and row coverage was recorded across treated rows 42 DAT in 2020 and all trials in 2022 (Trimble GreenSeeker handheld crop sensor; AGCO Corp., Duluth, GA, USA). A single row from all plots was mechanically harvested and roots separated into US No. 1, canner, or jumbo categories, counted, and weighed to determine yield. Total yield is presented as a combination of the three grade categories. US No. 1 roots are desirable for the fresh market, while all three root categories are desirable for the processing sector. US No. 1 storage roots are 5.1 to 8.9 cm in diameter, 7.6 to 22.9 cm long, straight and uniform; canner grade storage roots are 2.5 to 5.1 cm in diameter and 5.1 to 17.8 cm in length; jumbo grade storage roots are larger than US No. 1 roots. Total marketable yield (TMY) combines US No. 1, canner, and jumbo. These grades are determined based on US Department of Agriculture standards (US Department of Agriculture 2005).

The three-parameter log-logistic model (Eq. [1]) was fit to visual injury, NDVI measurement, and yield data.

$$Y = d/(1 + \exp[b(\ln[x] - \ln[e])]) \qquad [1]$$

where Y is the response variable of interest, b is the slope at the inflection point, d is the upper limit, e is the dose of herbicide corresponding to the midpoint of plant injury response observed between the upper limit and 0, and x is the fraction of the labeled rate of herbicide applied expressed as a decimal (i.e., 1/10× as 0.10) (Table 1). The nonlinear least squares function of the "stats" package was used to fit the three-parameter log-logistic model in R version 4.3.3 (R Core Team 2024).

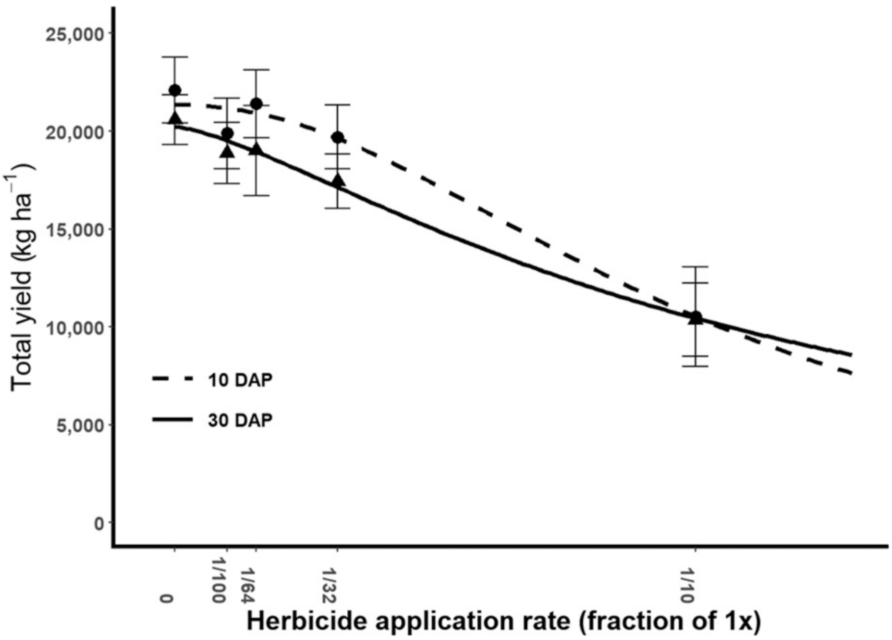

Fig. 7. Total marketable sweetpotato yield following treatment with reduced rates of glufosinate and 2,4-D-choline applied 10 or 30 days after transplant (DAP) in 2020–21. Herbicides were applied at fractional rates of a 1× use rate of 0.655 lb a.i./acre 1.064 lb a.e./acre, respectively. A three-parameter log-logistic model parameter was averaged across locations of Chase, LA, USA (32.0968°N, 91.6988°W; 'Orleans' planted 6 Jul); Crowville, LA, USA (32.2407°N, 91.5901°W; 'Orleans' planted 2 Jun); and Ville Platte, LA, USA (30.6880°N, 92.2715°W; 'Bayou Belle' planted 3 Jun).

Whenever the three-parameter log-logistic model could not be fit to data, the linear model (Eq. [2]) was fit to the data.

$$y = \beta_0 + \beta_1 + \varepsilon \qquad [2]$$

where *y* represents the response variable of interest, *x* represents the fraction of the labeled herbicide applied expressed as a decimal, β_1 is the slope or the amount by which the response variable changes when the fractional herbicide rate increases by one unit, β_0 is the intercept or the value of the response variable when the fractional herbicide rate = 0, and ε is the residual (Table 1). The lm() function of the "stats" package was used to fit the linear model in R. The appropriateness of the three-parameter log-logistic equation for describing the relation between the response variables of interest and the predictor was evaluated in each case using a lack-of-fit test. Variance homogeneity was evaluated using a Levene's test, and normality was evaluated using QQ plots and the Shapiro–Wilk test. The data were analyzed by location within the 2020 and 2021 data and within the 2022 data and model parameters compared (Ritz et al. 2015) with no statistical differences detected between parameters of locations for herbicide rates applied.

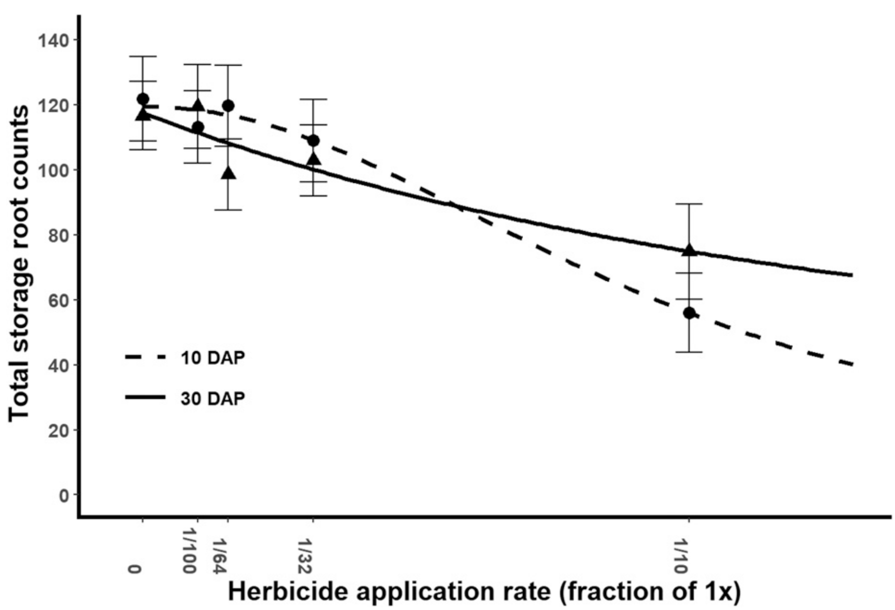

Fig. 8. Total marketable yield sweetpotato root counts per harvested row following treatment with reduced rates of glufosinate and 2,4-D-choline applied 10 or 30 days after transplant (DAP) in 2020–21. Herbicides were applied at fractional rates of a 1× use rate of 0.655 lb a.i./acre 1.064 lb a.e./acre, respectively. A three-parameter log-logistic model parameter was averaged across locations of Chase, LA, USA (32.0968°N, 91.6988°W; 'Orleans' planted 6 Jul); Crowville, LA, USA (32.2407°N, 91.5901°W; 'Orleans' planted 2 Jun); and Ville Platte, LA, USA (30.6880°N, 92.2715°W; 'Bayou Belle' planted 3 Jun).

Results and discussion

For discussion purposes, the rates will be categorized as high (1/10× in 2020–21; 1/8× and 1/16× in 2022), medium (1/32× and 1/64× in 2020–22), and low (1/100× in 2020–21; 1/128 and 1/256× in 2022). Plant injury observed was in the form of severe chlorosis/necrosis and leaf twisting within 3 to 4 d of application. When applied 10 DAP, sweetpotato was injured 68% in 2020–21 and 45 to 76% in 2022 at the high glufosinate plus 2,4-D-choline rates applied 1 week after treatment (WAT) (Figs. 1 and 9). The medium rates resulted in 16% to 32% (2020–21) and 21% to 29% (2022) injury, while injury from the low rates was 10% (2020–21) and 16% to 17% (2022). Similarly, exposure at the 30 DAP timing resulted in 59% (2020–21) and 47% to 60% (2022) visible injury for the high application rates. The medium rates resulted in 22% (2020–21) and 24% to 34% (2022) injury, while injury from the low rates was 10% (2020–21) and 10% to 15% (2022). The results were generally similar at the 2 WAT evaluation interval (Figs. 2 and 10). By 4 WAT, sweetpotato was injured 72% (2020–21) and 40% to 70% (2022) at the highest glufosinate plus 2,4-D-choline rates applied 10 DAP (Figs. 3 and 11). The medium rates resulted in 11% to 22% (2020–21) and 17% to 25% (2022) injury, while

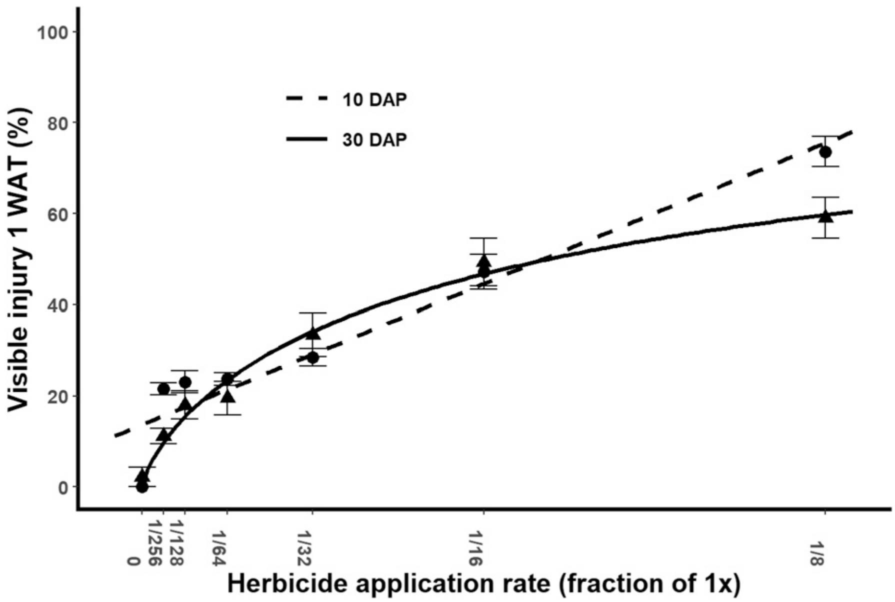

Fig. 9. Sweetpotato visible injury 1 weeks after treatment (WAT) with reduced rates of glufosinate and 2,4-D-choline applied 10 or 30 days after transplant (DAP) in 2022. Herbicides were applied at fractional rates of a 1× use rate of 0.655 lb a.i./acre 1.064 lb a.e./acre, respectively. A three-parameter log-logistic model parameter was averaged across locations of St. Joseph, LA, USA (31.9184°N, 91.2335°W; 'Bayou Belle' planted 9 Jun); Ville Platte, LA, USA (30.6880°N, 92.2715°W; 'Orleans' planted 31 May); Oak Grove, LA, USA (32.8610°N, 91.3884°W; 'Bayou Belle' planted 6 Jun); and Crowville, LA, USA (32.2407°N, 91.5901°W; 'Orleans' planted 21 May).

injury from the low rates was 7% (2020–21) and 12% to 13% (2022). Sweetpotato injury following application at the 30 DAP timing was 32% (2020–21) and 32% to 43% (2022) for the high application rates. The medium rates resulted in 5 to 10% injury (2020–21) and 5% to 15% (2022) injury, while injury from the low rates was 3% (2020–21) and 0 to 1% (2022). Miller et al. (2020) also reported, when averaging across application timings of 10 and 30 DAP, similarly high levels of sweetpotato injury following application of combinations of 2,4-D-choline with glyphosate applied at 1/10× of a 1× use rate (same as used in the current research for glufosinate and 2,4-D-choline) resulting in 58%, 74%, and 53% injury 7, 14, and 28 DAT, respectively. In addition, medium rates similar to the ones used in the current study resulted in 16% to 24%, 19% to 27%, and 9% to 11% injury at these respective timings, while the low rate of 1/100× resulted in 12%, 15%, and 7% injury. Batts et al. (2020) reported that application of 2,4-D-choline with glyphosate applied at 1/10× of a 1× use rate (same as used in the current research) 10 DAP resulted in 46% injury 14 DAT, while 2,4-D-choline alone resulted in 34% injury. In addition, at rates ranging from 1/750× to 1/10×, 2,4-D-choline alone or in combination with glyphosate at 7 and 14 DAT of the 30 DAP timing resulted in injury ranging from 14% to 75% and 18 to 93%, respectively. Joseph et al. (2018) reported glufosinate in combination with 2,4-D to be the most effective and consistent control treatments with respect to *Ipomoea* species pitted morningglory. Corbett et al. (2004) reported that glufosinate controlled 2- to 5-cm *Ipomoea* morningglory species entireleaf, ivyleaf, pitted, and tall at least 90%.

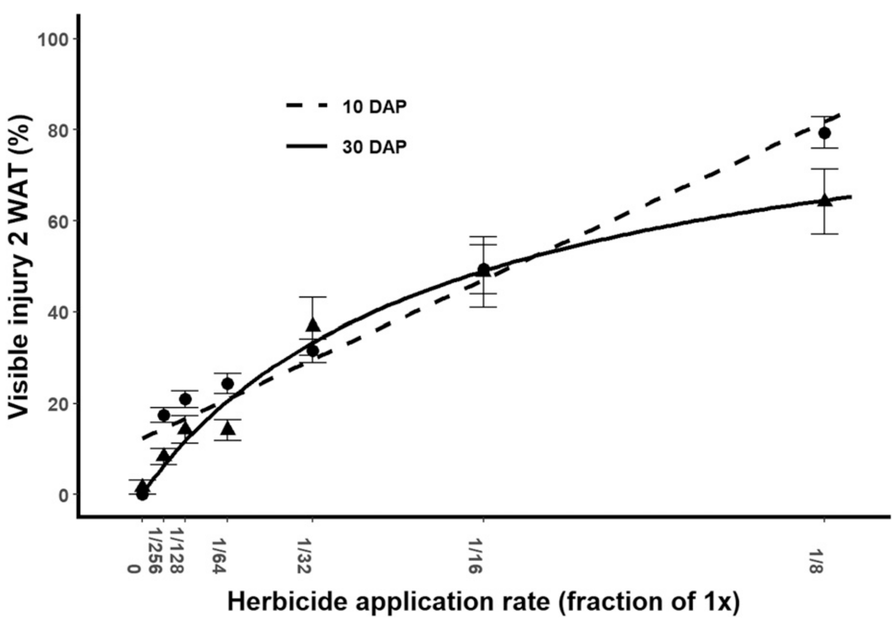

Fig. 10. Sweetpotato visible injury 2 weeks after treatment (WAT) with reduced rates of glufosinate and 2,4-D-choline applied 10 or 30 days after transplant (DAP) in 2022. Herbicides were applied at fractional rates of a 1× use rate of 0.655 lb a.i./acre 1.064 lb a.e./acre, respectively. A three-parameter log-logistic model parameter was averaged across locations of St. Joseph, LA, USA (31.9184°N, 91.2335°W; 'Bayou Belle' planted 9 Jun); Ville Platte, LA, USA (30.6880°N, 92.2715°W; 'Orleans' planted 31 May); Oak Grove, LA, USA (32.8610°N, 91.3884°W; 'Bayou Belle' planted 6 Jun); and Crowville, LA, USA (32.2407°N, 91.5901°W; 'Orleans' planted 21 May).

At 42 DAT after the 10 DAP application timing, NDVI measurement for the 0 reduced herbicide rate averaged 0.823 (2020) and 0.814 (2022) (Figs. 4 and 12). In 2020–21, NDVI measurement was 0.452, 0.707 to 0.765, and 0.786 for the high, medium, and low rates, respectively, while in 2022 those measurements were 0.711 to 0.752, 0.77 to 0.781, and 0.788 to 0.789, respectively. For the 30 DAP timing, average NDVI measurement for the 0 rate was 0.780 (2020) and 0.848. In 2020, NDVI measurement was 0.739, 0.768 to 0.774, and 0.776 for the high, medium, and low rates, respectively, while in 2022 those measurements were 0.732 to 0.788, 0.824 to 0.839,

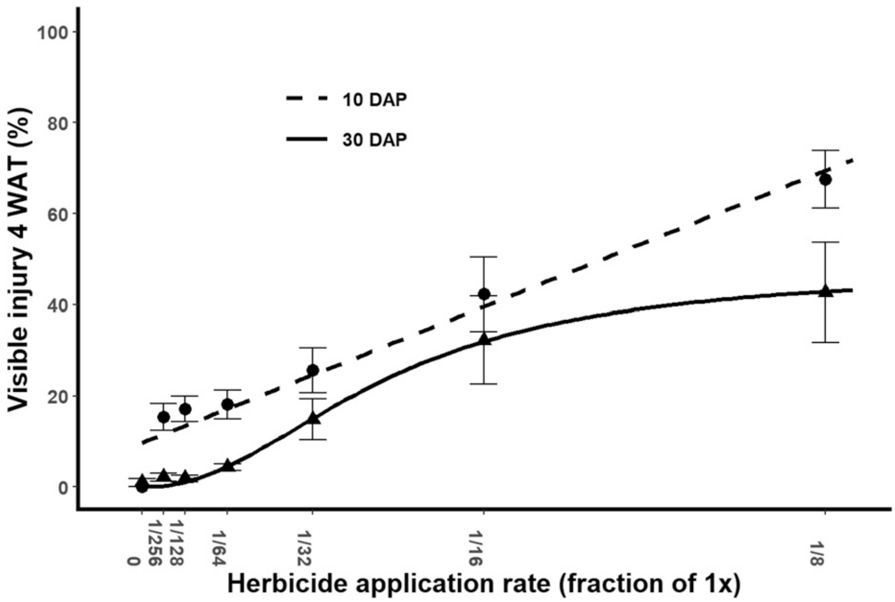

Fig. 11. Sweetpotato visible injury 4 weeks after treatment (WAT) with reduced rates of glufosinate and 2,4-D-choline applied 10 or 30 days after transplant (DAP) in 2022. Herbicides were applied at fractional rates of a 1× use rate of 0.655 lb a.i./acre 1.064 lb a.e./acre, respectively. A three-parameter log-logistic and linear model parameter was averaged across locations of St. Joseph, LA, USA (31.9184°N, 91.2335°W; 'Bayou Belle' planted 9 Jun); Ville Platte, LA, USA (30.6880°N, 92.2715°W; 'Orleans' planted 31 May); Oak Grove, LA, USA (32.8610°N, 91.3884°W; 'Bayou Belle' planted 6 Jun); and Crowville, LA, USA (32.2407°N, 91.5901°W; 'Orleans' planted 21 May).

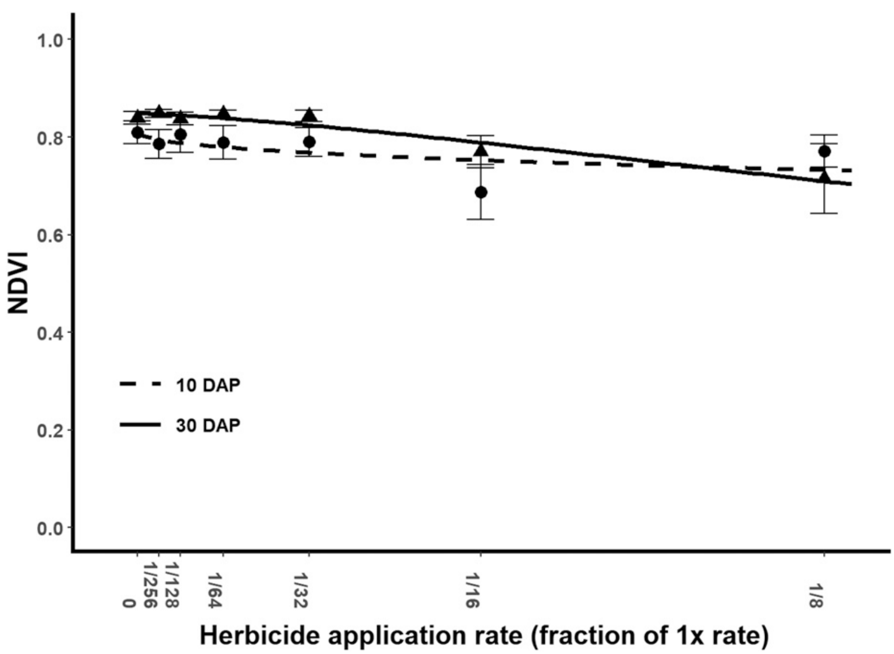

Fig. 12. Sweetpotato Normalized Difference Vegetation Index (NDVI) measurement 42 d after treatment with reduced rates of glufosinate and 2,4-D-choline applied 10 or 30 days after transplant (DAP) in 2022. Herbicides were applied at fractional rates of a 1× use rate of 0.655 lb a.i./acre 1.064 lb a.e./acre, respectively. Linear model parameter averaged across locations of St. Joseph, LA, USA (31.9184°N, 91.2335°W; 'Bayou Belle' planted 9 Jun); Ville Platte, LA, USA (30.6880°N, 92.2715°W; 'Orleans' planted 31 May); Oak Grove, LA, USA (32.8610°N, 91.3884°W; 'Bayou Belle' planted 6 Jun); and Crowville, LA, USA (32.2407°N, 91.5901°W; 'Orleans' planted 21 May).

and 0.844 to 0.847, respectively. The unusually low NDVI measurement for the high rate in 2020 for the 10 DAP timing was attributed to dry soil conditions for an extended period after application, which may have limited plant recovery potential from initial herbicide injury.

For the 10 DAP timing, US No. 1 sweetpotato yield for the 0 reduced rate averaged 9796 (2020–21) and 12,305.5 (2022) kg·ha^{-1} (Figs. 5 and 13). In 2020–21, US No. 1 yield was reduced 54.3% following application of glufosinate and 2,4-D-choline at the high rate, while the medium- and low-rate categories reduced yield less than 5%. In 2022, reductions were 15% to 48% and less than 4% in those respective rate categories. For the delayed timing, US No. 1 sweetpotato yield for the 0 reduced rate averaged 9024 (2020–21) and 12,920.8 (2022) kg·ha^{-1}. In 2020–21, US No. 1 yield was reduced 56.2%, 6.6% to 17%, and 3.2% for the high, medium, and low rates, respectively, while in 2022 those reductions were 47.1% to 57.8%, 27.5% to 36.7%, and 13.7% to 19.6%, respectively. US No. 1 root count data resulted in similar outcomes, indicating that yield reduction is primarily due to a reduction in root formation and/or development (Figs. 6 and 14).

Based on yield reductions, sweetpotato appeared most sensitive to high rates applied at the 10 DAP timing and both high and medium rates applied at the 30 DAP timing. Higher reduction percentages observed for the low rates applied 30 DAP in 2022 were attributed to extreme daytime temperatures surpassing 37.8 °C for an extended period of time during the growing season, which may have affected plant ability to recover from earlier injury. Miller et al. (2020) reported that 2,4-D-choline in combination with glyphosate applied at the 10 DAP application timing at 1/10×, 1/33×, 1/66×, or 1/100× of a 1× use rate (same as used in the current research) significantly reduced US No. 1 yield in comparison with no herbicide (0 rate) only with the highest reduced rate (33%). However, at the 30 DAP application timing, US No. 1 yield was significantly reduced 84% and 45% with the 1/10× and 1/33× rates, respectively. In addition, US No. 1 yield difference in application timing (10 or 30 DAP) was noted only with

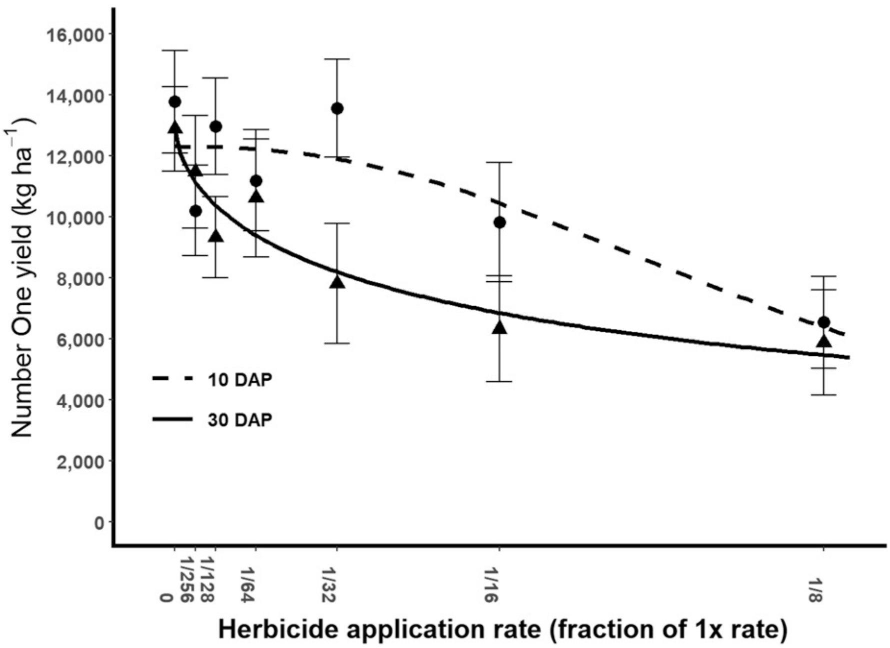

Fig. 13. US No. 1 yield following treatment with reduced rates of glufosinate and 2,4-D-choline applied 10 or 30 days after transplant (DAP) in 2022. Herbicides were applied at fractional rates of a 1× use rate of 0.655 lb a.i./acre 1.064 lb a.e./ acre, respectively. Three-parameter log-logistic model parameter averaged across locations of St. Joseph, LA, USA (31.9184°N, 91.2335°W; 'Bayou Belle' planted 9 Jun); Ville Platte, LA, USA (30.6880°N, 92.2715°W; 'Orleans' planted 31 May); Oak Grove, LA, USA (32.8610°N, 91.3884°W; 'Bayou Belle' planted 6 Jun); and Crowville, LA, USA (32.2407°N, 91.5901°W; 'Orleans' planted 21 May).

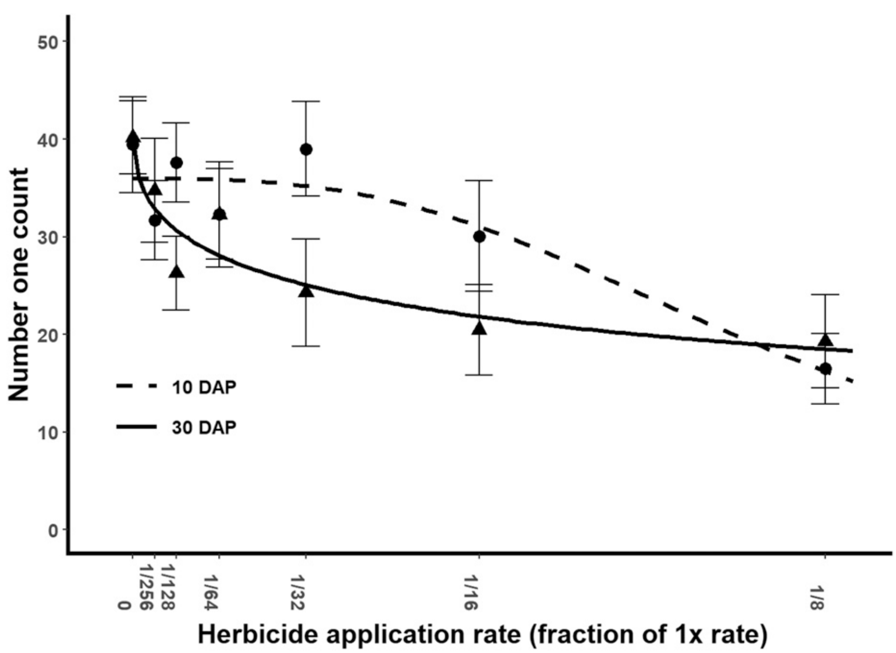

Fig. 14. US No. 1 root counts per harvested row following treatment with reduced rates of glufosinate and 2,4-D-choline applied 10 or 30 days after transplant (DAP) in 2022. Herbicides were applied at fractional rates of a 1× use rate of 0.655 lb a.i./acre 1.064 lb a.e./acre, respectively. Three-parameter log-logistic model parameter averaged across locations of St. Joseph, LA, USA (31.9184°N, 91.2335°W; 'Bayou Belle' planted 9 Jun); Ville Platte, LA, USA (30.6880°N, 92.2715°W; 'Orleans' planted 31 May); Oak Grove, LA, USA (32.8610°N, 91.3884°W; 'Bayou Belle' planted 6 Jun); and Crowville, LA, USA (32.2407°N, 91.5901°W; 'Orleans' planted 21 May).

the 1/10× and 1/33× rates when yield was lower at the later timing. Corbett et al. (2004) reported that glufosinate controlled 2- to 5-cm *Ipomoea* morningglory species entireleaf, ivyleaf, pitted, and tall at least 90%.

For the 10 DAP timing, sweetpotato TMY for the 0 reduced rate averaged 21,336.9 (2020–21) and 14,148.8 (2022) kg·ha^{-1} (Figs. 7 and 15). In 2020–21, TMY was reduced 50.6% following application of glufosinate and 2,4-D-choline at the high rate, while the medium rates reduced yield 1.8% to 7.8%. The low rate reduced yield less than 1%. In 2022, reductions were 21.9% to 52%, 2.3% to 6.7%, and less than 1% in those respective rate categories. For the delayed timing, TMY for the 0 reduced rate averaged 20,225.1 (2020–21) and 14,650.3 (2022) kg·ha^{-1}. In 2020–21, total yield was reduced 48.3%, 6.3% to 15.2%, and 3.1% for the high, medium, and low rates, respectively, while in 2022 those reductions were 54.4% to 68%, 28.2% to 40.6%, and 11.4% to 18.4%, respectively. Total root count data resulted in similar outcomes, indicating that yield reduction is primarily due to a reduction in root formation and/or development (Figs. 8 and 16).

As was the case with US No. 1 yield, sweetpotato was most sensitive to high rates applied at the10 DAP timing and all rates applied at the 30 DAP timing. This result is not surprising as canner and jumbo roots comprised a minor portion of total yield numbers (data not shown). Miller et al. (2020) reported that following application of 2,4-D-choline with glyphosate 10 DAP significantly reduced TMY in comparison with no herbicide (0 rate) only with the highest reduced rate (23%). However, at the 30 DAP application timing, yield was significantly reduced 66%, 27%, and 15%, with the 1/10×, 1/33×, and 1/66× rates, respectively. Additionally in that research, within each reduced rate, TMY difference in application timing was noted only with the 1/10× (54%) and 1/33× (26%) rates when yield was lower at the later timing.

Conclusions

Glufosinate in combination with 2,4-D-choline can cause significant visual injury to sweetpotato at rates often encountered in drift or sprayer contamination events. Negative yield

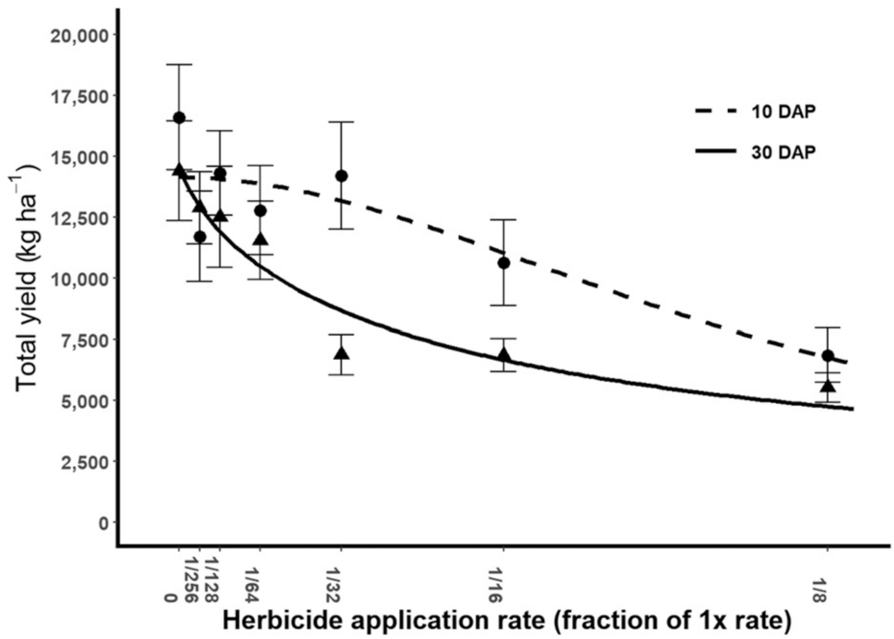

Fig. 15. Total marketable sweetpotato yield following treatment with reduced rates of glufosinate and 2,4-D-choline applied 10 or 30 days after transplant (DAP) in 2022. Herbicides were applied at fractional rates of a 1× use rate of 0.655 lb a.i./acre 1.064 lb a.e./acre, respectively. Three-parameter log-logistic model parameter averaged across locations of St. Joseph, LA, USA (31.9184°N, 91.2335°W; 'Bayou Belle' planted 9 Jun); Ville Platte, LA, USA (30.6880°N, 92.2715°W; 'Orleans' planted 31 May); Oak Grove, LA, USA (32.8610°N, 91.3884°W; 'Bayou Belle' planted 6 Jun); and Crowville, LA, USA (32.2407°N, 91.5901°W; 'Orleans' planted 21 May).

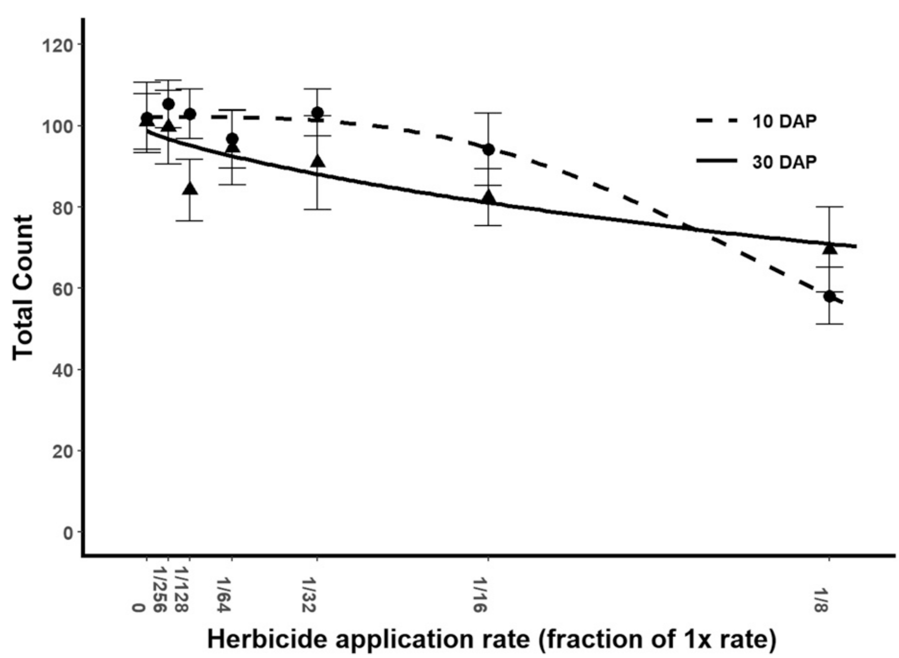

Fig. 16. Total marketable yield root counts per harvested row following treatment with reduced rates of glufosinate and 2,4-D-choline applied 10 or 30 days after transplant (DAP) in 2022. Herbicides were applied at fractional rates of a 1× use rate of 0.655 lb a.i./acre 1.064 lb a.e./acre, respectively. A three-parameter log-logistic model parameter was averaged across locations of St. Joseph, LA, USA (31.9184°N, 91.2335°W; 'Bayou Belle' planted 9 Jun); Ville Platte, LA, USA (30.6880°N, 92.2715°W; 'Orleans' planted 31 May); Oak Grove, LA, USA (32.8610°N, 91.3884°W; 'Bayou Belle' planted 6 Jun); and Crowville, LA, USA (32.2407°N, 91.5901°W; 'Orleans' planted 21 May).

impacts resulting from this injury were generally greater at high rates (1/8×, 1/10×, or 1/16×) when application occurred 10 DAP and with all rates when occurring at the 30 DAP timing. Negative environmental conditions not conducive to optimal sweetpotato growth, such as low moisture or extreme temperatures, may affect plant ability to recover from initial herbicide injury. Therefore, sweetpotato producers with multicrop farming operations are cautioned to thoroughly follow all sprayer cleanout procedures when previously spraying one of the combination herbicides evaluated or to devote different equipment to spraying Enlist® crops. In addition, proper consideration should be given to planting these crops in close proximity to sweetpotato production fields and making herbicide applications under environmental conditions that are not conducive to off-target spray movement while using drift mitigation efforts outlined on the herbicide labels.

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