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Tolerance of Azuki and White Bean to Tiafenacil Tank Mixes

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Abstract

Few studies have investigated the tolerance of azuki and white bean to preplant (PP) applications of tiafenacil herbicide mixtures in Ontario. Four field experiments were conducted in southwestern Ontario, Canada, to assess the tolerance of azuki and white bean to PP applications of tiafenacil and tiafenacil herbicide mixtures at 1X and 2X rates. In azuki bean, tiafenacil at the 1X and 2X rate cause 0.5 and 0.4% injury at 4 weeks after bean emergence (WAE), respectively, mixtures of tiafenacil with halauxifen-methyl plus bromoxynil at the 1X and 2X rates caused 1.3 and 4.6% injury, respectively; significantly greater compared to tiafenacil applied alone. Other tiafenacil herbicide mixtures evaluated caused similar azuki bean injury to tiafenacil applied alone. In white bean, the combinations of tiafenacil with metribuzin, 2,4-D ester, and bromoxynil + 2,4-D ester at the 2X rate caused 1.4-1.6% more visible injury than tiafenacil applied alone at the same rate; however, other herbicide mixtures caused similar injury levels to tiafenacil applied alone. None of the tiafenacil herbicide treatments evaluated reduced bean stand at 3 WAE. Tiafenacil + 2,4-D ester reduced bean biomass plant^{-1} and m^{-1} by 18% relative to the non-treated control at 3 WAE. At 6 WAE, none of the tiafenacil treatments evaluated affected plant height, and at harvest, none of the tiafenacil herbicide treatments influenced seed moisture content or bean yield relative to the non-treated control. These results conclude that, although certain tiafenacil mixtures may cause minor and transient injury in azuki and white bean, they do not substantially affect growth, maturity, or yield, making them suitable options for pp weed control in both azuki and white bean production.

Keywords: azuki bean, white bean, tiafenacil, herbicide mixtures, preplant applications, tank mixtures, herbicide injury, Ontario, bean tolerance, crop yield

1. Introduction

Azuki bean (*Vigna angularis* (Willd.) Ohwi & H. Ohashi) and white bean (*Phaseolus vulgaris* L.) are two major market classes of dry bean grown in Ontario, Canada with high nutritional value and versatility (Das et al., 2016; Hensall Co-op, 2020; Luzardo-Ocampo, 2020; Soltani et al., 2022). Azuki bean, commonly used in East Asian cuisine, are a rich source of protein, fiber, and essential minerals and are a vital food staple for millions of people (Agarwal & Chauhan, 2019; Shurtleff & Aoyagi, 2021; Singh et al., 2023). Azuki bean is especially valued for its versatility to be used in both sweet and savory dishes, contributing to food security in countries like Japan, China, and Korea (Havemeier, 2018; Katna et al., 2024; Shurtleff & Aoyagi, 2021; Singh et al., 2023). White bean, also known as navy bean, is important in human diets, commonly used in soups, stews, and baked dishes, and has high protein content, low fat, and considerable amounts of iron and folate (Amin & Borchgrevink, 2022; Howard et al., 2018; Morris, 2020; Siddiq et al., 2011). Both azuki and white bean, play a key role in crop production systems, improving soil fertility by fixing nitrogen which benefits subsequent crops in the rotation (Katna et al., 2024; Kumar et al., 2023; Pandiyan et al., 2021). Dry bean, as sustainable and nutrient-rich foods, are crucial in addressing global food insecurity and promoting environmentally friendly farming practices, making them essential for both human diets and sustainable agricultural systems around the globe (Havemeier, 2018; Islam et al., 2024; Kumar et al., 2022; Sharma et al., 2024).

Controlling weeds, especially multiple herbicide-resistant (MHR) weeds such as Canada fleabane (*Conyza canadensis* (L.) Cronq.) before planting is crucial for effective weed management and to ensure the success of dry bean production in Ontario (Brown et al., 2016; Budd, 2016; Budd et al., 2016a, 2016b; Byker et al., 2013; Ford et al., 2014; Soltani et al., 2018, 2022, 2024; Vanhie, 2020). Canada fleabane is a highly competitive weed that can reduce crop yields by shading plants, competing for water and nutrients, and interfering with planting and harvest operations (Budd, 2016; Vanhie, 2020). Early intervention is key to preventing dry bean yield losses from MHR

Canada fleabane interference and minimizing the need for more aggressive (and potentially harmful) weed control measures later in the season. Preplant (PP) weed control strategies, such as applying multiple herbicide modes of action, using non-chemical methods such as tillage can help reduce weed presence before planting and prevent seedbank replenishment (Brown et al., 2016; Byker et al., 2013; Ford et al., 2014; Soltani et al., 2024). There are currently few preplant herbicide options available for MHR Canada fleabane weed control in dry bean. Additional research is needed to identify herbicides and herbicide mixtures with both preplant burndown and residual activity in dry bean production (OMAFRA, 2024).

Tiafenacil is a relatively new herbicide from the N-phenyl-imide family, classified under WSSA Herbicide Group 14 (Park et al., 2018). It effectively controls a wide range of monocot and dicot weeds and can be applied either before planting or after planting but prior to crop emergence (preemergence, PRE) in corn, soybean, and wheat (Anonymous, 2020; Park et al., 2018). Tiafenacil works by inhibiting the protoporphyrinogen IX oxidase (PPO) enzyme, leading to the breakdown of cell membranes in susceptible weed species such as barnyardgrass, wild buckwheat, volunteer canola, kochia, common lambsquarters, wild oat, redroot pigweed, prickly lettuce, common purslane, Russian thistle, velvetleaf, and waterhemp (Park et al., 2018; Haring & Hanson, 2020; Health Canada, 2022). Tiafenacil applied alone or in herbicide mixtures has also been shown to control herbicide-resistant weed biotypes, including glyphosate-resistant (GR) and multiple herbicide-resistant (MHR) Canada fleabane, waterhemp, and Palmer amaranth (EPA, 2020; Haring & Hanson, 2020; Soltani et al., 2021a, 2021b, 2023; Westerveld, 2021; Westerveld et al., 2021). Tiafenacil is effective at low doses, rapidly decomposes in soil, and has minimal ecological toxicity with limited impact on non-target organisms (EPA, 2020; Park et al., 2018). The co-application of tiafenacil with bromoxynil, metribuzin, halauxifen-methyl, 2,4-D ester, tribenuron, and combinations of these herbicides with multiple modes of action can further improve weed control prior to dry bean emergence (Soltani et al., 2021b; Westerveld, 2021; Westerveld et al., 2021).

There is limited information regarding the sensitivity of azuki and white bean to tiafenacil applied alone and in herbicide mixtures with bromoxynil, metribuzin, halauxifen-methyl, 2,4-D ester, tribenuron and combinations of these herbicides when applied preplant (PP) in Ontario. The objective of this study was to assess the tolerance of azuki and white bean to tiafenacil, tiafenacil + bromoxynil, tiafenacil + metribuzin, tiafenacil + halauxifen-methyl, tiafenacil + 2,4-D ester, tiafenacil + bromoxynil + metribuzin, tiafenacil + bromoxynil + halauxifen-methyl, tiafenacil + bromoxynil + 2,4-D ester, and tiafenacil + tribenuron applied PP at the recommended rate (1X) and twice the recommended rate (2X) to simulate spray overlap, under Ontario environmental conditions.

2. Materials and Methods

A total of four field experiments were conducted at the Huron Research Station in Exeter, ON (one site in 2021), and at the University of Guelph Ridgetown Campus in Ridgetown, ON (two sites in 2022 and one site in 2023). Seedbed preparation at all sites consisted of fall moldboard plowing, followed by two passes with a field cultivator and rolling basket harrows in the spring.

The design of this experiment was a factorial with two factors. Trials were established in the field as a split plot with three to four replicates. Herbicide treatment was the whole plot factor, laid out as a Randomized Complete Block Design (RCBD), and dry bean market class was the split plot factor. Treatments included non-treated control and tiafenacil, tiafenacil + bromoxynil, tiafenacil + metribuzin, tiafenacil + halauxifen-methyl, tiafenacil + 2,4-D ester, tiafenacil + bromoxynil + metribuzin, tiafenacil + bromoxynil + halauxifen-methyl, tiafenacil + bromoxynil + 2,4-D ester, and tiafenacil + tribenuron applied preplant at 1X and 2X rates as listed in Tables 1-3. The entire experimental area was maintained weed-free with glyphosate (900 g ha^{-1}) plus pendimethalin (1000 g ha^{-1}) plus halosulfuron (35 g ha^{-1}) applied preplant followed by quizalofop-p-ethyl (72 g ha^{-1}) plus fomesafen (240 g ha^{-1}) applied postemergence. Hand hoeing were used as required for the duration of the growing season. All tiafenacil herbicide treatments included MSO concentrate (0.5% v/v)

Experimental plots measured 3.0 m in width and were either 8 m or 10 m in length. Each plot contained two rows of 'Erimo' azuki bean and two rows of 'T9905' white bean seeded approximately 4 cm deep at the rate of approximately 230,000 seeds ha^{-1}, in rows spaced 75 cm apart in late May to early June each year.

Herbicides were applied up to 10 days before planting using a CO_2-pressurized backpack sprayer. The sprayer was equipped with a 1.0 m wide spray boom and three ULD-120-02 nozzles spaced 0.5 m apart, providing a spray width of 1.5 m. The sprayer was calibrated to deliver a water volume of 200 L ha^{-1} at a pressure of 240 kPa.

Visible azuki and white bean injury was assessed at 1, 2, 4, and 8 weeks after bean emergence (WAE) using a scale from 0 (no injury) to 100 (complete plant death). Bean plant stand (measured as the number of plants per meter of row at 3 WAE), aboveground dry biomass (measured as dry weight per plant and per meter of row from a 1 m section of each market class harvested at 3 WAE, dried at 60 °C for 48 hours before weighing), and plant height (average height of 10 plants per plot in cm at 6 WAE) were recorded.

At harvest maturity, when approximately 90% of the pods had turned from green to golden, azuki and white bean were harvested using a small plot combine. Seed moisture content and weight were recorded, and yields were adjusted to 13% moisture content for azuki bean and 18% moisture content for white bean.

Data analysis was conducted using Proc GLIMMIX in SAS (Ver. 9.4, SAS Institute Inc., Cary, NC), at a significance level of 0.05. The fixed effects in the model were herbicide treatment, dry bean market class, and their interaction. Random model effects were environment (year-location combinations), replicate within environment and its interaction with herbicide treatment, and the environment by herbicide treatment by dry bean market class interaction. Parameters other than visible dry bean injury were expressed as a percentage of the non-treated control and all variables were analyzed using a Gaussian distribution. Percent visible dry bean injury had an arcsine square root transformation applied prior to analysis. Pairwise comparisons among least square means were subjected to the Tukey-Kramer adjustment. The non-treated control was excluded from the analysis for dry bean injury because it was assigned a value of zero. However, the p-values in the LSMEANS output table could still be used to determine whether treatment means differed from zero. Means transformed for analysis were back-transformed for presentation.

3. Results and Discussion

3.1 Visible Injury

The analysis of the main effects for market classes showed that there was < 1% difference in azuki compared to white bean injury at 1, 2, and 8 weeks after emergence (WAE) (Table 1). Overall, tiafenacil alone and its mixture with herbicides evaluated caused 0.3-3.2%, 0.3-3.3%, and 0-0.4% visible injury (averaged for azuki and white bean) at 1, 2, and 8 WAE in dry bean, respectively (Table 1). There was no statistically significant increase in dry bean injury when bromoxynil, metribuzin, halauxifen-methyl, 2,4-D ester, bromoxynil + metribuzin, bromoxynil + halauxifen-methyl, bromoxynil + 2,4-D ester, or tribenuron were added to tiafenacil at 1 and 8 WAE. At 4 WAE, tiafenacil + bromoxynil + halauxifen-methyl at the 2X rate increased dry bean injury 3.7% compared to tiafenacil applied alone..

Table 1. Azuki and white bean visible injury response to preplant applications of tiafenacil alone or in herbicide mixtures from four trials conducted near Exeter, ON (2021) or Ridgetown, ON (2022, 2023). Means for a main effect were separated only if the interaction involving the main effect was negligible[a,b]

Main effects	Rate (g ai ha^{-1})	Visible Crop Injury[c]			
		1 WAE	2 WAE	4 WAE	8 WAE
		---------------------------- % ----------------------------			
Dry Bean Market Class					
Azuki		1.1	1.5 b	0.8	0.0 a
White		1.0	0.9 a	0.6	0.1 b
BEAN P-value		0.6840	0.0241	0.2642	0.0270
Herbicide Treatment[d]					
Non-treated control		0.0 a	0.0 a	0.0	0.0 a
Tiafenacil	25	0.3 ab	0.4 abc	0.4	0.0 a
Tiafenacil + bromoxynil	25 + 280	0.4 ab	0.3 ab	0.3	0.0 a
Tiafenacil + metribuzin	25 + 200	0.6 ab	0.6 abcd	0.4	0.0 a
Tiafenacil + halauxifen-methyl	25 + 5	0.9 ab	1.2 bcd	1.0	0.0 a
Tiafenacil + 2,4-D ester	25 + 528	0.6 ab	0.8 abcd	0.4	0.0 a
Tiafenacil + bromoxynil + metribuzin	25 + 280 + 200	0.4 ab	0.5 abcd	0.5	0.0 a
Tiafenacil + bromoxynil + halauxifen-methyl	25 + 280 + 5	1.3 ab	1.0 abcd	0.8	0.1 ab
Tiafenacil + bromoxynil + 2,4-D ester	25 + 280 + 528	0.7 ab	0.7 abcd	0.5	0.1 ab
Tiafenacil + tribenuron-methyl	25 + 7.5	0.6 ab	0.6 abcd	0.4	0.1 ab
Tiafenacil	50	0.8 ab	0.7 abcd	0.5	0.2 b
Tiafenacil + bromoxynil	50 + 560	0.7 ab	0.7 abcd	0.5	0.1 ab
Tiafenacil + metribuzin	50 + 400	1.4 b	1.4 bcd	1.1	0.4 b
Tiafenacil + halauxifen-methyl	50 + 10	3.0 b	3.7 cd	2.2	0.4 b
Tiafenacil + 2,4-D ester	50 + 1056	1.6 b	3.2 bcd	1.2	0.0 a
Tiafenacil + bromoxynil + metribuzin	50 + 560 + 400	0.9 ab	0.9 abcd	0.6	0.1 ab
Tiafenacil + bromoxynil + halauxifen-methyl	50 + 560 + 10	3.1 b	4.1 d	2.3	0.4 b
Tiafenacil + bromoxynil + 2,4-D ester	50 + 560 + 1056	3.2 b	3.3 bcd	1.4	0.1 ab
Tiafenacil + tribenuron-methyl	50 + 15	0.8 ab	0.8 abcd	0.4	0.0 a
Interaction					
HERB × RATE P-value		0.0867	0.0894	0.0291	0.4500

Note. [a] Abbreviations: BEAN, dry bean market class; HERB, herbicide treatment; WAE, weeks after crop emergence.

[b] Means followed by the same letter within a column are not significantly different according to a Tukey-Kramer multiple range test at $P < 0.05$.

[c] Non-treated control excluded from analysis due to zero variance; comparison of herbicide treatments with the value zero obtained using LSMEANS table from the GLIMMIX procedure.

[d] All treatments included methylated seed oil (0.5% v/v).

There was a significant dry bean market class by herbicide treatment interaction for visible crop injury at 4 WAE (Table 2). In azuki bean, tiafenacil + halauxifen-methyl and tiafenacil + bromoxynil + halauxifen-methyl applied PP at the 1X rate caused 2.1 and 1.3% azuki bean injury, respectively which were greater than the non-treated control. In azuki bean, tiafenacil + halauxifen-methyl and tiafenacil + bromoxynil + halauxifen-methyl applied PP at the 2X rate caused 4.0 and 4.6% azuki bean injury, respectively which were greater than the non-treated control. In white bean, tiafenacil + metribuzin, tiafenacil + 2,4-D ester, and tiafenacil + bromoxynil + 2,4-D ester applied PP at the 2X rate caused 2.1, 2.3, and 2.3% white bean injury, respectively which were greater than the non-treated control.

Azuki bean was more sensitive to halauxifen herbicide mixtures than white bean. At 4 WAE, tiafenacil + halauxifen-methyl (1X rate), tiafenacil + halauxifen-methyl (2X rate), and tiafenacil + bromoxynil + halauxifen-methyl applied PP (2X rate) rates caused 1.8, 3.0, 3.8% greater injury in azuki bean than white bean, respectively (Table 2). In contrast, tiafenacil + metribuzin and tiafenacil + 2,4-D ester applied PP at the 2X rates caused 1.7 and 1.8% greater injury in white bean compared to the azuki bean, respectively (Table 2). However, all other evaluated tiafenacil herbicide mixtures caused comparable visible injury in both azuki and white bean (Table 2).

Table 2. Visible crop injury 4 WAE following preplant application of tiafenacil alone or in herbicide mixtures from four trials conducted near Exeter, ON (2021) or Ridgetown, ON (2022, 2023)[a,b]

Herbicide Treatment[d]	Rate (g ai ha^{-1})	Visible crop injury[c]	
		Adzuki	White
		%	
Non-treated control		0.0 a	0.0 a
Tiafenacil	25	0.5 abc	0.3 ab
Tiafenacil + bromoxynil	25 + 280	0.4 ab	0.3 ab
Tiafenacil + metribuzin	25 + 200	0.3 ab	0.4 ab
Tiafenacil + halauxifen-methyl	25 + 5	2.1 bc Y	0.3 ab Z
Tiafenacil + 2,4-D ester	25 + 528	0.5 abc	0.2 ab
Tiafenacil + bromoxynil + metribuzin	25 + 280 + 200	0.6 abc	0.4 ab
Tiafenacil + bromoxynil + halauxifen-methyl	25 + 280 + 5	1.3 bc	0.5 ab
Tiafenacil + bromoxynil + 2,4-D ester	25 + 280 + 528	0.6 abc	0.5 ab
Tiafenacil + tribenuron-methyl	25 + 7.5	0.4 ab	0.3 ab
Tiafenacil	50	0.4 ab	0.7 ab
Tiafenacil + bromoxynil	50 + 560	0.5 abc	0.4 ab
Tiafenacil + metribuzin	50 + 400	0.4 ab Z	2.1 b Y
Tiafenacil + halauxifen-methyl	50 + 10	4.0 bc Y	1.0 ab Z
Tiafenacil + 2,4-D ester	50 + 1056	0.5 abc Z	2.3 b Y
Tiafenacil + bromoxynil + metribuzin	50 + 560 + 400	0.5 abc	0.7 ab
Tiafenacil + bromoxynil + halauxifen-methyl	50 + 560 + 10	4.6 c Y	0.8 ab Z
Tiafenacil + bromoxynil + 2,4-D ester	50 + 560 + 1056	0.7 abc	2.3 b
Tiafenacil + tribenuron-methyl	50 + 15	0.5 abc	0.3 ab

Note. [a] Abbreviations: WAE, weeks after crop emergence.

[b] Means followed by the same letter within a column (a-d) or row (X-Z) are not significantly different according to a Tukey-Kramer multiple range test at $P < 0.05$. Rows without an uppercase letter have no differences among market classes.

[c] Non-treated control excluded from analysis due to zero variance; comparison of herbicide treatments with the value zero obtained using LSMEANS table from the GLIMMIX procedure.

[d] All treatments included methylated seed oil (0.5% v/v).

The results are consistent with other studies, where preplant applications of glyphosate + tiafenacil mixed with 2,4-D ester or bromoxynil + 2,4-D ester caused up to 8% injury in white bean. In contrast, tiafenacil mixtures with bromoxynil, metribuzin, and halauxifen-methyl resulted in minimal and transient injury in white bean (Soltani et al., 2023). Other studies also found that the PRE application of tiafenacil at 25 g ai ha^{-1} caused 0-4% injury in azuki, kidney, small red, and white bean (Soltani et al., 2021b). Similarly, Sprague et al. (2020) observed no visible injury, when tiafenacil was applied PP at 24 g ai ha^{-1} in black bean. Westerveld (2021) reported no visible soybean injury at 1, 2, and 4 WAE with tiafenacil or tiafenacil + metribuzin applied PP.

3.2 Bean Stand, Biomass, Height, Seed Moisture Content, and Yield

The main effect of dry bean market class found that azuki bean had a higher plant stand, greater biomass plant^{-1}, greater biomass 1 m row^{-1}, greater height, and lower yield compared to white bean. There was no difference in moisture content at harvest.

The analysis of the main effects of herbicide treatments across dry bean market class indicated that there was no effect of tiafenacil herbicide treatments (1X rate) evaluated on dry bean stand (3 WAE), biomass plant^{-1} (3 WAE), biomass 1 m row^{-1} (3 WAE), height (6 WAE), maturity (as indicated by moisture content at harvest), and yield relative to the non-treated control (Table 3). There was no effect of tiafenacil herbicide treatments (2X rate) evaluated on dry bean stand (3 WAE), biomass plant^{-1} (3 WAE), biomass 1 m row^{-1} (3 WAE), height (6 WAE), maturity (as indicated by moisture content at harvest), and yield relative to the non-treated control; except tiafenacil + 2,4-D ester which reduced dry bean biomass plant^{-1} and biomass 1 m row^{-1} 19% relative to the non-treated control (Table 3).

Table 3. Azuki and white bean responses to preplant applications of tiafenacil alone or in herbicide mixtures from four trials conducted near Exeter, ON (2021) or Ridgetown, ON (2022, 2023). Parameters evaluated were relative measures of stand count and dry biomass 3 WAE, plant height 6 WAE, and moisture and yield at harvest. Means for a main effect were separated only if the interaction involving the main effect was negligible[a,b]

Main effects	Rate (g ai ha^{-1})	Stand	Biomass		Height	Moisture	Yield
			Plant^{-1}	m^{-1}			
		%					
Dry Bean Market Class							
Azuki		101 b	99 a	96 a	102 a	100	99 b
White		93 a	88 b	90 b	100 b	100	101 a
BEAN P-value		<0.0001	<0.0001	<0.0001	0.0201	0.9278	0.0092
Herbicide Treatment[c]							
Non-treated control		100	99 ab	100 a	100 ab	100 ab	100 ab
Tiafenacil	25	100	100 ab	96 ab	102 ab	100 ab	98 ab
Tiafenacil + bromoxynil	25 + 280	99	106 a	104 a	105 a	100 ab	101 ab
Tiafenacil + metribuzin	25 + 200	96	94 abc	96 ab	104 ab	100 ab	103 a
Tiafenacil + halauxifen-methyl	25 + 5	103	101 ab	96 ab	100 ab	100 ab	100 ab
Tiafenacil + 2,4-D ester	25 + 528	102	93 abc	89 ab	102 ab	100 ab	103 a
Tiafenacil + bromoxynil + metribuzin	25 + 280 + 200	97	95 abc	95 ab	102 ab	99 ab	100 ab
Tiafenacil + bromoxynil + halauxifen-methyl	25 + 280 + 5	97	96 abc	95 ab	103 ab	100 ab	103 a
Tiafenacil + bromoxynil + 2,4-D ester	25 + 280 + 528	101	96 abc	91 ab	104 ab	100 ab	99 ab
Tiafenacil + tribenuron-methyl	25 + 7.5	95	98 abc	97 ab	102 ab	100 ab	98 ab
Tiafenacil	50	97	93 abc	94 ab	101 ab	99 ab	98 ab
Tiafenacil + bromoxynil	50 + 560	98	93 abc	92 ab	101 ab	99 ab	99 ab
Tiafenacil + metribuzin	50 + 400	93	87 abc	89 ab	98 ab	98 a	98 ab
Tiafenacil + halauxifen-methyl	50 + 10	89	84 bc	89 ab	97 b	101 b	99 ab
Tiafenacil + 2,4-D ester	50 + 1056	95	81 c	81 b	101 ab	101 b	100 ab
Tiafenacil + bromoxynil + metribuzin	50 + 560 + 400	94	92 abc	95 ab	100 ab	99 ab	101 ab
Tiafenacil + bromoxynil + halauxifen-methyl	50 + 560 + 10	92	85 bc	89 ab	97 b	99 ab	94 b
Tiafenacil + bromoxynil + 2,4-D ester	50 + 560 + 1056	96	92 abc	88 ab	100 ab	101 b	101 ab
Tiafenacil + tribenuron-methyl	50 + 15	100	97 abc	92 ab	103 ab	98 a	101 ab
HERB P-value		0.0565	0.0006	0.0027	0.0025	0.0038	0.0306
Interaction							
HERB × RATE P-value		0.5260	0.3269	0.1960	0.5795	0.5675	0.1898

Note. [a] Abbreviations: BEAN, dry bean market class; HERB, herbicide treatment; WAE, weeks after crop emergence.

[b] Means followed by the same letter within a column are not significantly different according to a Tukey-Kramer multiple range test at $P < 0.05$.

[c] All treatments included methylated seed oil (0.5% v/v).

The results are consistent with previous studies, where preplant applications of glyphosate + tiafenacil mixed with bromoxynil, metribuzin, halauxifen-methyl, 2,4-D ester, bromoxynil + metribuzin, bromoxynil +

halauxifen-methyl, or bromoxynil + 2,4-D ester did not negatively affect white bean stand, dry biomass, height, maturity, or yield (Soltani et al., 2023). Other studies have also observed that PRE application of tiafenacil at 25 g ai ha^{-1} had no negative impact on plant stand, dry biomass, height, seed moisture content, or yield in azuki, kidney, small red, and white bean (Soltani et al., 2021b). Sprague et al. (2020) also reported no plant stand reduction, or yield loss when tiafenacil was applied PP at 24 g ai ha^{-1} in black bean. In addition, Westerveld (2021) observed no adverse effect on soybean yield with tiafenacil or tiafenacil + metribuzin applied PP to control MHR Canada fleabane in soybean.

4. Conclusions

The results of this study demonstrate that preplant applications of tiafenacil, either alone or in combination with bromoxynil, metribuzin, halauxifen-methyl, 2,4-D ester, bromoxynil + metribuzin, bromoxynil + halauxifen-methyl, bromoxynil + 2,4-D ester, and tribenuron-methyl applied at 1X and 2X rates, generally caused minimal and transient injury to azuki and white bean. While some tiafenacil tank mixtures, particularly tiafenacil + halauxifen-methyl and tiafenacil + bromoxynil + halauxifen-methyl, resulted in slightly higher injury in azuki bean compared to white bean, the overall impact on plant growth, biomass, height, maturity, and yield was negligible. None of the tiafenacil treatments significantly reduced bean stand or affected yield at harvest, suggesting that tiafenacil in combination with herbicides evaluated can be safely used for weed control especially for control of MHR Canada fleabane biotypes in both azuki and white bean production without negatively affecting crop performance.

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Drs. Peter Sikkema and Nader Soltani were responsible for this manuscript’s study design and writing. Christy Shropshire conducted the statistical analysis of the data collected.

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