Snap Bean (*Phaseolus vulgaris* L.) Response to Postemergence Herbicides at Different Growth Stages

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ABSTRACT. **Weeds competing with snap beans can reduce harvest efficiency and lower yields. Postemergence herbicides are most effective when applied to small weed seedlings, but their application timing must also account for crop development to avoid injury. Achieving a balance between effective weed control and crop safety can be challenging, especially if crop emergence is uneven. In 2021, field experiments were conducted in Delaware, Pennsylvania, and New York, USA, to evaluate crop response to bentazon (0.84 kg a.i./ha), fomesafen (0.21 kg a.i./ha), and bentazon plus fomesafen or imazamox (0.04 kg a.i./ha) when applied postemergence at the cotyledon, unifoliate, and first trifoliate snap bean growth stages. Snap bean injury was greatest in herbicide treatments containing bentazon plus fomesafen (10%–34%). Averaged across herbicides, applications at the trifoliate stage were the least injurious to snap beans. Crop yield was most affected by the bentazon plus fomesafen and imazamox treatments (77% and 76% of untreated control, respectively), and by applications at the cotyledon stage (78% of untreated control). Results highlight that applications of postemergence herbicides should adhere to label guidelines (i.e., treatment after the first trifoliate leaf is fully expanded) to ensure crop safety and maximize yields.**

Approximately 65,000 ha of snap beans (*Phaseolus vulgaris* L.), valued at $360 million, are harvested annually in the United States, with two thirds of production supplying the processing industry (US Department of Agriculture–National Agriculture Statistics Service 2024). Weeds pose a significant threat to snap beans and other specialty legume production through competitive interactions that reduce crop yields (Bailey et al. 2003; Kee et al. 1997; Odero and Wright 2018). In addition, weed berries (e.g., *Solanum* spp.) and stems (e.g., *Amaranthus* spp.) can contaminate harvested product, which may increase processing costs, reduce grower payments, or result in the crop being deemed unacceptable for processing (Bailey et al. 2003; Kee et al. 1997; Pavlovic et al. 2025b).

Mid-Atlantic snap bean growers rely heavily on synthetic herbicides for weed control (Pavlovic et al. 2025a). Postemergence treatments are most effective against weed seedlings less than 5 to 7 cm tall, although application timing must also consider crop developmental stage to minimize crop injury and avoid impacts on yield (Bailey et al. 2003). Label guidelines specify that bentazon, fomesafen, and imazamox, which are some of the most used postemergence herbicides in snap beans, should only be applied after the first trifoliate leaf is fully expanded (Wyenandt et al. 2024). Uneven crop emergence, which may be caused by unfavorable weather conditions such as drought, can lead to variable plant size across a field, presenting a significant management challenge for growers. We examined how herbicide selection and application timing affect snap bean injury and yield, providing valuable insights to help growers, extension personnel, and crop consultants make informed weed management decisions that minimize crop injury and support optimal yields.

Materials and methods

This study was conducted in 2021 at Cornell AgriTech in Geneva, NY, USA (lat. 42.88°N, long. 77.01°W); the Penn State Horticultural Research Farm in Rock Springs, PA, USA (lat. 40.71°N, long. 77.94°W); and the University of Delaware's Carvel Research and Education Center in Georgetown, DE, USA (lat. 38.64°N, long. 75.46°W). 'Caprice' (Delaware, USA), 'Outlaw' (Pennsylvania, USA), and 'Huntington' (New York, USA) snap beans were planted on 16, 18, and 25 Jun, respectively. Seeding rates followed commercial guidelines (160,000–272,000 seeds/ha in rows spaced 0.76 m apart). Individual plots were 6 to 9 m long and 1.5 to 3 m wide. Field sites received applications of 2.14 kg a.i./ha of *S*-metolachlor (Dual Magnum®; Syngenta Crop Protection, Greensboro, NC, USA) immediately after seeding to suppress weed emergence.

The study was conducted as a two-factor factorial, with herbicide treatments and snap bean stage at the time of application as the main factors. Herbicide treatments included bentazon at 0.84 kg a.i./ha (Basagran®; BASF Agricultural Solutions, Research Triangle Park, NC, USA), fomesafen at 0.21 kg a.i./ha (Reflex®; Syngenta Crop Protection), bentazon plus fomesafen, and bentazon plus imazamox at 0.04 kg a.i./ha (Raptor®; BASF Agricultural Solutions). All herbicide solutions included non-ionic surfactant at 0.25% v/v. Timing of application included treatments to snap beans at the cotyledon stage [which occurred 6–7 d after planting (DAP) across all sites], the unifoliate leaf stage (9–13 DAP), and the first trifoliate leaf expanded stage (15–20 DAP) of development. Applications were made with CO_2-pressurized backpack sprayers calibrated to deliver 187 $L \cdot ha^{-1}$.

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Table 1. Snap bean injury and yield responses to bentazon, fomesafen, and imazamox applied at three different crop developmental stages in Mid-Atlantic field trials (2021).

	Injury (%)				
		At harvest			
Factor	1 WAT	Cotyledon	Unifoliate	Trifoliate	Relative yield (%)[i]
Herbicide (kg a.i./ha)[ii]					
Bentazon 0.84	12 b[iii]	0 d	6 a–d	1 cd	95 a
Fomesafen 0.21	20 b	12 ab	11 ab	3 b–d	91 ab
Bentazon 0.84 + fomesafen 0.21	34 a	16 a	18 a	10 a–c	77 bc
Bentazon 0.84 + imazamox 0.04	17 b	12 ab	13 ab	6 cd	76 c
P value	<0.0001	0.0013			0.0010
Crop stage					
Cotyledon	23 a	—	—	—	78 b
Unifoliate	24 a	—	—	—	86 ab
Trifoliate	14 b	—	—	—	89 a
P value	0.0074	—			0.0283

[i] Yield is expressed as a percentage of the untreated control, which averaged 0.66 $kg \cdot m^{-1}$ of the row across locations.
[ii] 1 $kg \cdot ha^{-1}$ = 0.8921 lb/acre; 1 $kg \cdot m^{-1}$ = 0.67 lb/ft.
[iii] Means followed by the same letter in a column are not significantly different based on Tukey's honestly significant difference test (α = 0.05).
WAT = weeks after treatment.

Untreated snap bean control plots (no postemergence herbicides applied) were included as a reference for injury ratings. All treatments were replicated three times at each site. Fertilization and other pest management treatments followed regional guidelines (Wyenandt et al. 2024).

Injury, primarily expressed as stunting, was rated on a scale of 0% (no injury) to 100% (complete plant death) throughout the season at each location. Although injury was assessed at multiple time points, only data from 1 week after treatment (WAT) and at harvest are presented. Yield data were collected by harvesting and weighing marketable beans (US Department of Agriculture 1997) from 3 m of crop rows in Pennsylvania and New York, USA, and are expressed as a percentage of the untreated controls to allow for comparison across sites. Statistical analyses were conducted using the GLIMMIX procedure in SAS v. 9.4 (SAS Institute, Cary, NC, USA). Herbicide rate, application timing, and their interaction were fixed effects; location and replication nested in location were random effects. When no significant ($P > 0.05$) interactions occurred, data were combined across fixed effects. Significant ($P \leq 0.05$) effects were compared using Tukey's honestly significant difference multiple comparisons adjustment.

Results and discussion

All results are presented in Table 1. Herbicide selection and application timing affected snap bean injury significantly ($P \leq 0.05$) at 1 WAT. Bentazon plus fomesafen caused the greatest observed injury (34%). Fomesafen alone, bentazon plus imazamox, and bentazon alone injured snap beans 12% to 20%. Herbicide applications at early growth stages (cotyledon and unifoliate) resulted in similar levels of injury (23% and 24%, respectively), with both causing more damage to snap beans than applications made at the first trifoliate leaf stage (14%).

Injury at harvest was affected by the interaction between herbicide selection and application timing ($P \leq 0.05$). Bentazon caused minimal crop injury ($\leq$ 6%) at harvest, regardless of application timing. The combination of bentazon plus fomesafen resulted in the greatest stunting across all timings. Across all herbicides, injury was generally less when herbicide applications were made at the recommended timing (first trifoliate stage).

Averaged across application timings, bentazon maintained the greatest yield (95% of untreated control), followed by fomesafen (91%), whereas bentazon plus fomesafen (77%) and imazamox (76%) reduced yields severely relative to the untreated check. Applications at the trifoliate stage preserved yield potential (89% of the untreated check) compared with the unifoliate (86%) and cotyledon (78%) stages.

Our findings were consistent with current label guidelines, showing little to no injury when herbicides were applied at expansion of the first trifoliate leaf. Adverse conditions, including cool, wet soils or drought, can delay germination and lead to uneven emergence, complicating weed control. Although smaller weeds are easier to manage, younger snap beans are more vulnerable to herbicide injury. The same factors that delay crop emergence and development may also enhance sensitivity to postemergence herbicide treatments. Growers must weigh the benefits of early weed control against the potential damage to less developed plants. These results underscore the value of agronomic practices that promote uniform emergence, such as precise seed placement and good seedbed preparation. When emergence is uneven, careful herbicide selection becomes crucial to minimize injury and protect yield. However, weed community composition must be considered, as herbicides vary in their spectrum of control and may not be equally effective against all weed species.

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