Title: Postemergence Herbicide Timing Effects on Snap Bean Development and Yield

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Introduction: Pennsylvania, Delaware, Maryland, New Jersey, and New York grow over 46,000 acres of snap beans, combined (NASS, 2017). Because of the crop's short stature and the comparatively short window between planting and harvest, season-long weed control is necessary to maximize snap bean production. Weeds that compete with the crop can also reduce harvest efficiency, harbor pests and pathogens, and interfere with the deposition of other pesticides. Many weeds of concern (e.g. lambsquarters, smooth pigweed, common ragweed, nightshade, and velvetleaf) can emerge with the crop and must be rigorously managed to prevent direct and indirect impacts on crop yield. Postemergence (POST) applied herbicides are most effective when applied to small (typically < 2-3" in height) seedlings. However, application timings must also factor in crop development to minimize injury potential and subsequent impacts on crop maturity. For example, Basagran, Raptor, and Reflex applications must be made after the first trifoliate leaf is fully expanded. Growers may face decision challenges if uneven stand emergence impacts plant size throughout a field. *The objective of this study is to describe the impacts of 1) herbicide and 2) application timing on crop injury and yield to provide producers who may treat plants at less developed growth stages guidance about expected crop responses.*

Materials and Methods: In 2021, this multi-state trial was conducted at the Cornell AgriTech Experiment Station in Geneva (NY), the Penn State Horticultural Research Farm in Rock Springs (PA), and University of Delaware's Carvel Research and Education Center in Georgetown (DE). Snap beans were planted at commercial seeing rates (65,000 to 110,000 seed per acre) on 16 June in DE, 18 June in PA, and 25 June in NY. Field sites received applications of Dual Magnum at labeled rates to suppress weeds and permit observations of postemergence herbicide damage without confounding factors.

Herbicide treatments included: Basagran (1.5 pt/A), Reflex (0.75 pt/A), Basagran (1.5 pt/A) plus Reflex (0.75 pt/A) and Basagran (1.5 pt/A) plus Raptor (4 oz/A). All herbicide solutions included NIS at 0.25% v/v.

Timing treatments included: cotyledon (23 June-DE and 1 July-NY), unifoliate (29 June-DE, 28 June-PA, and 4 July-NY), first trifoliate (6 July-DE, 6 July-PA, and 10 July-NY), and first flower (21 July-PA and 27 July-NY) stages of development.

Applications were made with CO2-pressurized backpack sprayers calibrated to deliver 20 GPA to plots that were two rows wide and 20 to 30 feet in length. Untreated bean plots (no postemergence herbicides applied) were included as a reference for injury ratings. All treatments were replicated three to four times at each site. Injury ratings (stunting and necrosis) on a scale of 0% (no injury) to 100% (complete plant death) were made throughout the season at each location. Yield data was collected in PA and NY.

Results: Injury (%) in snap beans at 10 to 14 days after treatment (DAT) and maximum observed injury (%) during the season were affected by herbicide, application timing, and state (Tables 1 to 4). In general, the greatest amount of crop injury was observed with Basagran plus Reflex, particularly when the mixture was applied at the cotyledon and unifoliate stages of bean development. Reflex applied alone and Basagran plus Raptor were the next most injurious treatments. Averaged over application timings and states, mean percent (%) injury at 10 to 14 DAT was 11% for Basagran, 15% for Reflex, 26% for Basagran plus Reflex, and 16% for Basagran plus Raptor; mean maximum percent (%) injury observed during the season was 13%, 19%, 30% and 22% for Basagran, Reflex, Basagran plus Reflex, and Basagran plus Raptor, respectively.

Younger, less developed plants were more severely injured by herbicide applications than older/larger ones. Averaged across herbicides and states, mean percent (%) injury at 10 to 14 DAT was 24%, 29%, 12% and 1% for applications made at the cotyledon, unifoliate, trifoliate, first flower stages of development, respectively. Mean maximum percent (%) injury observed during the season was 31% (cotyledon), 31% (unifoliate), 17% (trifoliate), and 2% (first flower). Although first flower is not a recommended application timing, it was included in this study to demonstrate how much crop maturity can influence herbicide injury potential.

Differences were also observed among states. Averaged over herbicides and timings, the least amount of crop damage was reported in PA, followed by DE. NY saw the most injury with maximum injury ratings up to 85% (Basagran plus Reflex at unifoliate leaf stage). The significant weather that the NY site experienced in 2021 likely accounted for the disparity. Geneva received 6 inches of rainfall in July, which resulted in waterlogged soils. Snap beans at Cornell AgriTech were unable to recover from the combined stress effects (e.g. herbicides and standing water). This also influenced bean yields. While no differences were observed in bean weights across all treatments in PA (1324 g/10 ft^2), NY's were substantially impacted by herbicide injury. For example, Basagran plus Reflex or Raptor applied at the unifoliate stage reduced yields 22 to 36% relative to the control plots (984 g/10 ft^2).

S**ummary and Outreach:** Postemergence herbicides applied in snap beans can cause significant damage to the crop depending on the active ingredient and the time of application. While there was some variability across states, Basagran applied alone was typically the least injurious herbicide evaluated while tank mixes resulted in more visual damage. Results from this study also indicate that early (cotyledon, unifoliate) applications of registered postemergence herbicides can result in significant crop injury and yield reductions, compared to applications made according to label recommendations (e.g. first fully expanded trifoliate leaf for the herbicides included in the trial). Injury symptoms can persist across time (Tables 2, 3, 4), particularly if additional/external stressors (e.g. weather extremes) occur during the growing season. Crop plants that "get behind" early may not be able to "catch up". Results from these trials were presented at the Mid-Atlantic Fruit and Vegetable convention on February 1st ("*Impact of Herbicide Timing for Postemergence Weed Control in Snap Beans – Snap Beans" Mid-Atlantic-Convention-Program-22-website.pdf* (pvga.org)) and at the 2022 Empire State Producers Expo in the session "Snap Beans: Stress Mitigation" on March 1st (*Virtual-Session-Schedule-JANUARY-19.pdf* (nysvga.org)).

Table 1. Mean Injury (%) at 10 to 14 Days After Treatment and Maximum Observed Injury (%) for Each Herbicide by Timing Combination in Each State in 2021. Basagran (1.5 pt/A), Reflex (0.75 pt/A), Basagran (1.5 pt/A) plus Reflex (0.75 pt/A) and Basagran (1.5 pt/A) plus Raptor (4 oz/A).

		Injury (%) 10 to 14 DAT			Maximum Observed Injury (%) In Season		
Herbicide	Timing	DE	PA	NY	DE	PA	NY
Untreated	.	0	0	0	0	0	0
Basagran	Cotyledon	10	.	8	21	.	13
Reflex	Cotyledon	28	.	27	31	.	27
Basagran + Reflex	Cotyledon	46	.	37	55	.	37
Basagran + Raptor	Cotyledon	12	.	20	27	.	40
Basagran	Unifoliate	12	20	38	12	20	38
Reflex	Unifoliate	10	5	52	12	5	62
Basagran + Reflex	Unifoliate	22	20	78	22	20	85
Basagran + Raptor	Unifoliate	14	25	47	14	25	55
Basagran	Trifoliate	0	5	12	5	8	12
Reflex	Trifoliate	5	6	20	13	11	27
Basagran + Reflex	Trifoliate	12	11	30	27	13	32
Basagran + Raptor	Trifoliate	5	9	30	15	11	32
Basagran	First Flower	.	1	0	.	1	3
Reflex	First Flower	.	1	0	.	1	3
Basagran + Reflex	First Flower	.	2	0	.	2	3
Basagran + Raptor	First Flower	.	2	0	.	2	3

Table 2. Mean Injury (%) and Maximum Observed Injury (%) for Each Herbicide by Timing Combination in Pennsylvania in 2021. UNI = Unifoliate, TRI = Trifoliate, R1 = First Flower. Basagran (1.5 pt/A), Reflex (0.75 pt/A), Basagran (1.5 pt/A) plus Reflex (0.75 pt/A) and Basagran (1.5 pt/A) plus Raptor (4 oz/A).

		Percent (%) Crop Injury (0 = No injury, 100 = Plant death)			
Herbicide	Timing	7/7/2021	7/16/2021	7/26/2021	Max. Percent (%) Injury
Basagran	UNI	18.3	20.0	13.3	20.0
Reflex	UNI	5.0	5.0	4.3	5.0
Basagran + Reflex	UNI	20.0	20.0	13.3	20.0
Basagran + Raptor	UNI	18.3	25.0	21.7	25.0
Basagran	TRI	7.0	8.0	5.7	8.0
Reflex	TRI	11.3	10.7	6.3	11.3
Basagran + Reflex	TRI	12.3	13.0	11.3	13.0
Basagran + Raptor	TRI	9.7	11.3	9.0	11.3
Basagran	R1	0.0	0.0	1.0	1.0
Reflex	R1	0.0	0.0	1.0	1.0
Basagran + Reflex	R1	0.0	0.0	2.0	2.0
Basagran + Raptor	R1	0.0	0.0	2.0	2.0

Table 3. Mean Injury (%) and Maximum Observed Injury (%) for Each Herbicide by Timing Combination in Delaware in 2021. COT = Cotyledon, UNI = Unifoliate, TRI = Trifoliate. Basagran (1.5 pt/A), Reflex (0.75 pt/A), Basagran (1.5 pt/A) plus Reflex (0.75 pt/A) and Basagran (1.5 pt/A) plus Raptor (4 oz/A).

		Percent (%) Crop Injury (0 = No injury, 100 = Plant death)				
Herbicide	Timing	6/28/2021	7/6/2021	7/15/2021	7/22/2021	Max. Percent (%) Injury
Basagran	COT	21.0	10.0	7.3	0.0	21.0
Reflex	COT	31.0	28.3	28.3	14.3	31.0
Basagran + Reflex	COT	55.0	46.0	45.0	17.3	55.0
Basagran + Raptor	COT	26.7	11.7	19.3	8.0	26.7
Basagran	UNI	0.0	7.3	12.3	8.7	12.3
Reflex	UNI	0.0	11.7	10.0	0.0	11.7
Basagran + Reflex	UNI	0.0	14.7	21.7	10.0	21.7
Basagran + Raptor	UNI	0.0	6.7	14.3	5.0	14.3
Basagran	TRI	0.0	0.0	5.0	0.0	5.0
Reflex	TRI	0.0	0.0	12.7	5.0	12.7
Basagran + Reflex	TRI	0.0	0.0	26.7	12.3	26.7
Basagran + Raptor	TRI	0.0	0.0	15.3	5.0	15.3

Table 4. Mean Injury (%) and Maximum Observed Injury (%) for Each Herbicide by Timing Combination in New York in 2021. COT = Cotyledon, UNI = Unifoliate, TRI = Trifoliate, R1 = First Flower. Basagran (1.5 pt/A), Reflex (0.75 pt/A), Basagran (1.5 pt/A) plus Reflex (0.75 pt/A) and Basagran (1.5 pt/A) plus Raptor (4 oz/A).

		Percent (%) Crop Injury (0 = No injury, 100 = Plant death)						
Herbicide	Timing	7/4/2021	7/10/2021	7/17/2021	7/24/2021	8/1/2021	8/16/2021	Max Percent (%) Injury
UTC	.	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Basagran	COT	13.3	8.3	1.7	0.0	0.0	0.0	13.3
Reflex	COT	23.3	26.7	20.0	23.3	21.7	10.0	26.7
Basagran + Reflex	COT	33.3	36.7	25.0	25.0	26.7	15.0	36.7
Basagran + Raptor	COT	13.3	20.0	28.3	40.0	36.7	16.7	40.0
Basagran	UNI	0.0	38.3	38.3	33.3	36.7	10.0	38.3
Reflex	UNI	0.0	61.7	51.7	46.7	33.3	20.0	61.7
Basagran + Reflex	UNI	0.0	85.0	78.3	73.3	73.3	30.0	85.0
Basagran + Raptor	UNI	0.0	41.7	46.7	55.0	46.7	23.3	55.0
Basagran	TRI	0.0	0.0	10.0	11.7	11.7	3.3	11.7
Reflex	TRI	0.0	0.0	26.7	20.0	15.0	3.3	26.7
Basagran + Reflex	TRI	0.0	0.0	30.0	30.0	31.7	10.0	31.7
Basagran + Raptor	TRI	0.0	0.0	23.3	30.0	31.7	11.7	31.7
Basagran	R1	0.0	0.0	0.0	0.0	3.3	0.0	3.3
Reflex	R1	0.0	0.0	0.0	0.0	3.3	0.0	3.3
Basagran + Reflex	R1	0.0	0.0	0.0	0.0	3.3	0.0	3.3
Basagran + Raptor	R1	0.0	0.0	0.0	0.0	3.3	0.0	3.3

Take Home Points:

- *Registered herbicides can cause injury to snap beans; the degree of injury varies among active ingredients/combinations of active ingredients*
- *Applications made to beans at the cotyledon and unifoliate growth stages resulted in increased injury, as compared to the recommended 1st trifoliate leaf, although this was affected by location and additional stresses*
- *Local environmental conditions can enhance injury symptoms across time (and reduce yields)*
- *Balancing weed control with crop safety can be difficult, but growers should be aware that early applications are not advised*