Title: In-row cultivation using camera guidance technology in snap bean

Personnel:
Tosh Mazzone, Research Technologist III, Dept. Of Plant Science, The Pennsylvania State University,
University Park, PA 16802; (814) 863-1303; tar5262@psu.edu.
John Wallace, Assistant Professor of Weed Science / Extension Specialist for Field and Forage Crops,
Dept. Of Plant Science, The Pennsylvania State University, University Park, PA 16802; (814) 863-1014;
jmw309@psu.edu.

Introduction:

Weed management in snap bean continues to be a challenge for growers in Pennsylvania and other Mid-Atlantic states. Snap bean production is challenged by the lack of available weed control tools, particularly the lack of effective labeled herbicides (Odero et. al., 2018). Poor weed control can reduce snap bean yields by over 50% (Aguyoh and Masiunas, 2003; William and Warren, 1975). Mechanical cultivation is an alternative to postemergence herbicides in snap bean. Improving weed control efficacy with mechanical cultivation requires understanding of optimal timing relative to weed emergence. In general, cultivation is more effective when targeting newly emerged weeds. However, snap beans may be more sensitive to mechanical injury at this stage, which occurs at early crop growth stages. Additionally, cultivation requires precise adjustment of between row tools to avoid crop injury. In-row weeds typically escape cultivation when they germinate in the crop row, which limits weed control efficacy.

New cultivation technologies that are now commercially available have the potential to improve snap bean production. Recent advances in cultivator technology have increased the potential for use of in-row cultivation tools, such as finger-weeders, to control weeds. Finger weeders disturb soil in and around the base of crop plants with enough force to kill newly germinating weeds. Camera guidance systems facilitate cultivation within snap bean rows and allow for use of flatter cultivation sweeps between rows, which minimizes soil disturbance. Camera guidance systems can improve the speed, productivity, and efficacy of cultivation.

We are requesting funding to conduct field trials that will evaluate in-row cultivation timing and working depth to identify tradeoffs between weed control efficacy and crop injury. Through this research, we aim to develop recommendations for using in-row cultivation with finger weeders to reduce crop injury while maintaining effective weed control. Organic and conventional snap bean growers have limited herbicide options, so both can benefit from improved cultivation-based weed control methods. The results of this research will be shared with growers through Penn State Extension.

Objective:

Understanding the tradeoff between weed control and crop tolerance is a significant knowledge gap that prevents use of in-row crop cultivation in horticultural crops. We propose to establish a field research trial that will evaluate cultivation timing of in-row cultivation with finger-weeders and camera-based guidance to optimize weed control and minimize crop injury (**Table 1**).

Table 1. Key field operations during snap bean field trial.

Treatment	Beans planted	PRE	POST	Cultivation	Harvest
1. PRE + POST Herbicide	June 15	June 15	July 13		August 11
2. PRE + V2 Culti.		June 15	-	July 6 (21 DAP)	
3. PRE + V4 Culti.		June 15	-	July 20 (35 DAP)	
4. PRE + V6 Culti.		June 15	-	July 28 (43 DAP)	
5. Cultivate 1X		-	-	July 6	
6. Cultivate 2X		-	-	July 6 + 20	
7. Cultivate 3X		-	-	July 6 + 20 + 28	

Materials and Methods:

Field trials were conducted in 2021 growing season at PSU Research Farm, Rock Springs, PA. Herbicide and cultivation treatments were imposed in a randomized complete block design with four replications. The experimental site was chisel plowed and followed by a heavy disc to prepare the seedbed. Plot size was 50 feet by four crop rows (10 feet) wide. Snap beans were planted at 75 lb/acre (Target 120,000 plant population/acre) and a 1’’ depth using cultivar ‘Caprice’ (Seedway, LLC., Hall, NY). In herbicide control plots, herbicide Dual Magnum (12 fl oz/ac) was applied at crop planting followed by a POST application at V2 growth stage of Basagran (1.5 pt/ac) + Raptor (4 fl oz/ac) + NIS (0.25% v/v).

Cultivation was accomplished with finger weeders (Einboeck, Austria) toolbar-mounted to a Vibro Crop Interrow Cultivator (Kongskilde, Denmark) and using a Row-Guard 500 side-shifting three-point hitch (Einboeck, Austria) guided by cultivator-mounted camera Row-Guard 500 (Einboeck, Austria) (**Figure 1**). Cultivation treatment timings are summarized in **Table 1**.

Crop stand was estimated after cultivation was concluded by counting plants in a 28’’ length of two crop rows and averaging four counts per plot. Weed biomass was quantified just prior to bean harvest, by cutting aboveground weed biomass in two 0.5 m^2 quadrats encompassing two crop rows per plot, drying until constant weight and weighing. Crop yield was quantified by harvesting beans in four 28’’ lengths of crop row and obtaining an average per plot prior to scaling up to fresh weight ton/acre.

Statistical analysis was conducted by fitting linear mixed effect models to yield and stand count data. Additionally, a general linear model using a Poisson distribution was fit to weed biomass. If responses were found to be significant, post-hoc means were separated using paired contrasts of estimated treatment means using Tukey’s LSD test at alpha level p=0.05.

Figure 1. Cultivator setup using camera guidance to direct finger-weeder cultivators at V1-2 crop growth stage.

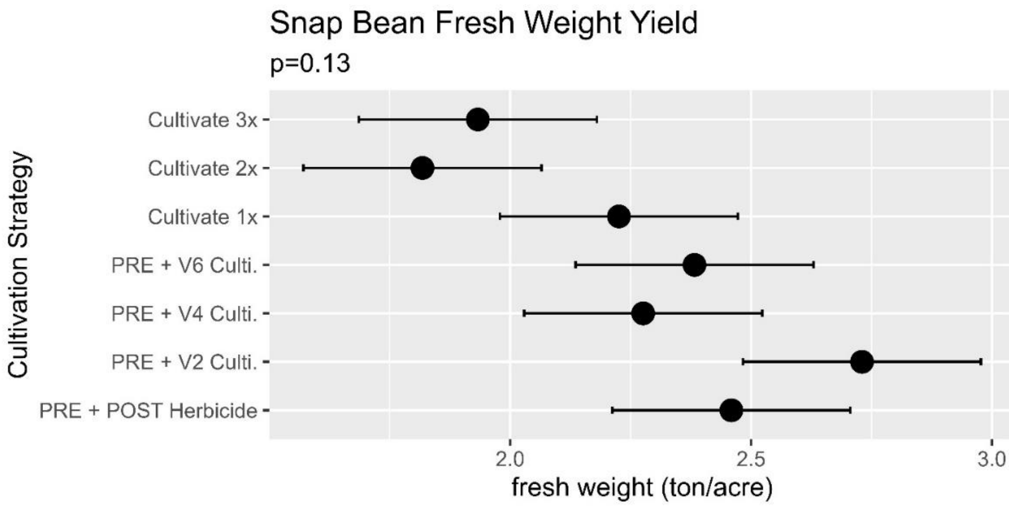
Results and Discussion:

Crop yield was estimated at crop maturity (**Table 2, Figure 2**). Based on findings, increasing cultivation frequency from 1 to 3 events, and varying cultivation timing did not impact yield.

Table 2. Crop Stand, Yield and Weed Biomass

Treatment	Crop Stand Plants/Acre		Crop Yield Ton/Acre	Weeds Control*	Weeds Lb/Acre	
PRE + POST Herbicide	163000	c	2.5		1	a
PRE + V2 Cultivation	139000	bc	2.7		17	c
PRE + V4 Cultivation	142000	c	2.3		85	e
PRE + V6 Cultivation	152000	c	2.4	>95%	17	c
Cultivate 1X	130300	ac	2.2		55	d
Cultivate 2X	88100	a	1.8		3	b
Cultivate 3X	98000	ab	1.9		23	c
p-value	<0.01		0.128		<0.0001	

Figure 2. Fresh weight (ton/acre) snap bean yield for cultivation and herbicide treatments. Fresh weight was estimated by harvesting and weighing fresh beans 57 days after planting.



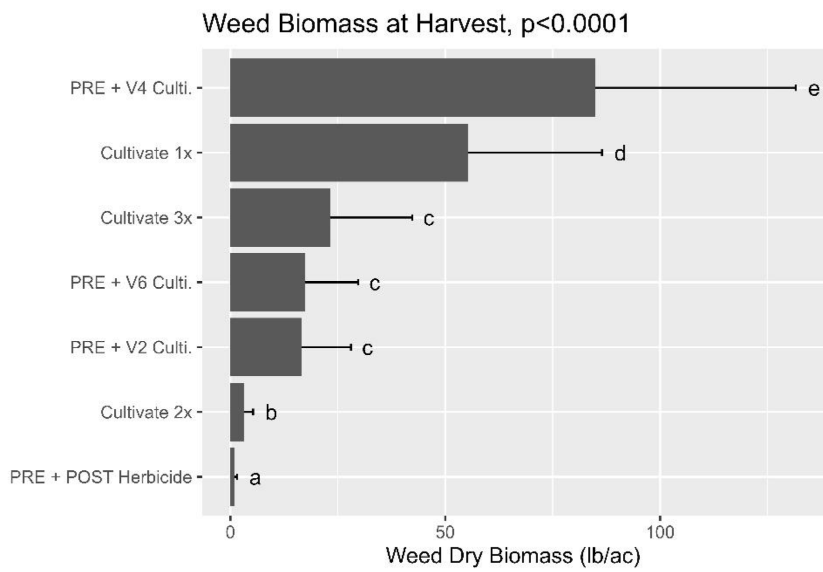
Cultivation treatment effect on yield was not observed (Table 2, Figure 2, *p*=0.13). Although not significant, the PRE + V2 Cultivation treatment resulted in the highest numerical yield of all treatments (2.7 ton/ac) which was 50% greater than Cultivating 2x (1.8 ton/ac) and 41% greater than Cultivating 3x (1.93 ton/ac). The second highest yield was observed in the PRE + POST Herbicide treatment (2.5 ton/ac), which was 35% greater than the Cultivating 2x treatment. These results suggest that there may be potential for increased crop injury when cultivating multiple passes throughout the growing season. In addition, a PRE-emergent herbicide program followed by a single cultivation event may be used without impacting yields.

The results of this field trial suggest that a single cultivation event from V2-V6 crop growth stage will not impact crop yields. Precision between- and in-row cultivation could be used as a follow-up to a residual herbicide pass. However, cultivation may become riskier at later crop growth stages. Although not significantly different, a cultivation event at V2 resulted in numerically higher yield than both later cultivation timings, which suggests that either young crop plants can recover quickly from cultivation or that cultivation at later crop growth stages may be more injurious. For a grower using finger-weeder cultivation as a primary in-season weed control, these results suggest that up to three cultivator passes may be conducted from V2-V6 crop growth stage without impacting yield.

The target snap bean population was 120,000 plants/acre. However, planting issues caused irregular seed drop and, as a result, some plant populations are higher than the target population (**Table 2**). Results demonstrated that increasing cultivation reduced snap bean populations, which were reduced by the greatest amount in the Cultivation 2x treatment (-46% compared to herbicide control) and the Cultivation 3x treatment (-40% compared to herbicide control). Populations were least impacted in the PRE + V6 Cultivation (-15% compared to herbicide control). The most common cultivation injury to crop plants was by disturbance of roots causing desiccation of plants and death (**Figure 3**).

Figure 3. Typical injury of snap bean caused by finger weeder operation too close to plant roots.

Figure 4. Dry matter weed biomass observed at plant harvest for cultivation treatments.



Weed control was generally high (>95%) across all treatments due to low weed populations in the field, as well as secondary tillage to prep the seedbed. The primary weed species in the field were annual broadleaf species, including common ragweed (*Ambrosia artemisiifolia*) and lambsquarters (*Chenopodium album*). However, weed biomass results indicate that all cultivation treatments resulted in a higher weed biomass than the PRE + POST herbicide control (**Figure 4**). Notably, results demonstrate that there were fewer weeds following 2X and 3X cultivation events than 1X. So, for an organic grower, additional cultivation passes are likely to improve weed management. These results suggest that a single cultivation event following a PRE does not replace the benefits of a POST herbicide application. Additionally, waiting to cultivate until V4 may result in additional weed pressure.

Additional field trials should be considered to evaluate the effectiveness of finger weeders on annual grass species or higher weed pressure scenarios.