NORTHWEST CROPS & SOILS PROGRAM

2023 Organic Black Bean Seeding Rate Trial

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THE UNIVERSITY OF VERMONT EXTENSION

2023 ORGANIC BLACK BEAN SEEDING RATE TRIAL

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Dry beans (*Phaseolus vulgaris*), a high-protein pulse crop, have been grown in the Northeast since the 1800's. As the local food movement continues to diversify and expand, consumers are asking stores to carry more locally-produced foods, and dry beans are no exception. But the yield and quality of organic dry beans has been affected by the lack of information on variety selection, inadequate management of diseases and weeds, and suboptimal recommendations for no-till production. Due to these production challenges, the exponential increase in consumer demand for organic dry beans has not been realized. Current management practices for organic dry beans can deplete the soil because of the reliance on tillage and cultivation for weed management and harvesting. Direct-harvested dry beans, specifically black beans, have shown promise for incorporation into rolled-crimped cereal rye mulch cropping systems and could reduce the negative impacts on soil health while still suppressing weeds. Dry bean performance may be enhanced in the rolled-crimped cereal rye mulch system by increasing dry bean seeding rate. In the 2022-2023 growing season, the University of Vermont Extension Northwest Crops and Soils Program (NWCS) conducted a trial to evaluate five black bean seeding rates in a conventional tillage system compared to a no-till system.

MATERIALS AND METHODS

The trial was conducted at Borderview Research Farm in Alburgh, VT in the 2022-2023 growing season to evaluate the impact of black bean seeding rate on crop productivity and weed biomass in an organic no-till production system compared to a tilled system. The experimental design was a randomized complete block with split plots and four replicates. Main plots were the two tillage systems and sub-plots were five black bean seeding rates. Trial management details are provided in Table 1 below.

Table 1. Management details for the black bean seeding rate trial, Alburgh, VT, 2022-2023.

Location	Borderview Research Farm, Alburgh, VT	
Soil type	Benson rocky silt loam, over shaly limestone, 8 to 15 % slopes	
Previous crop	Spring grains	
Plot size (feet)	10 x 20	
Row spacing (inches)	30	
Replicates	4	
Black bean variety	*Zorro*	
Black bean seeding rates (pure live seeds ac^{-1})	60,000, 120,000, 180,000 240,000, and 300,000	
Tillage operations	Tillage	No-till
	Pottinger TerraDisc	Cereal rye (var *ND Gardner*)
		Planting date: 17-Sep 2022
		Seed rate: 3 million pure live seeds ac^{-1}
		Roll/crimp 1-Jun 2023
Black bean planting date	31-May-23	1-Jun-23
Black bean harvest date	3-Oct-23	4-Oct-23

For the no-till treatment, winter rye (var *ND Gardner*) was obtained from Albert Lea Seed (Albert Lea, MN) and was planted on 17-Sep 2022 at a rate of 3 million pure live seeds ac^{-1} using a Sunflower no-till grain drill. In the spring prior to termination, rye biomass was measured by collecting four representative samples using a $0.5m^2$ quadrat. All above ground plant material was collected using hand clippers, weighed, dried, and reweighed to calculate dry matter and yield. The rye was rolled down using a 10 foot I&J Crop Roller Crimper (Camp Douglas, WI) on 1-Jun 2023. The variety *Zorro* black bean was obtained from Central Bean Co. (Quincy, WA) for this trial. Black beans were planted into rolled down rye on 1-Jun 2023 using a John Deere no-till planter. For the tilled treatment, the seedbed was prepared using a Pottinger TerraDisc. Black beans were planted into tilled soil on 31-May 2023 using a 4-row cone planter with John Deere row units fitted with Almaco seed distribution units (Nevada, IA). Prior to planting, all seeds were treated with dry bean inoculant (*Rhizobium leguminosarum biovar phaseoli*). Plot sizes were 10ft x 20ft, with 4 rows at 30-inch spacing.

Dry bean emergence was measured 3 weeks after planting on 21-Jun 2023. The number of plants in two 1-meter sections was recorded. To assess peak dry bean and weed biomass during the growing season, all above ground plant material was removed from within one $0.5\text{-}m^2$ quadrat per plot using hand clippers when dry bean plants reached R6/R7 growth stage: 11-Aug for tilled plots and 23-Aug for no-till plots. This stage is characterized by the oldest pods having developed seeds. Other parts of the plant have full-length pods with seeds almost as large as the first pods and pods will be developed over whole plant. Samples were then weighed, dried, and reweighed to determine dry matter and yield. All plots were scouted for incidence of white mold (*Sclerotinia sclerotium*), on 7-Sep 2023. Twenty plants per plot were assessed for the presence or absence of white mold symptoms. For each plot, the number of plants with an incidence of white mold (i.e. any part of the plant displayed symptoms of white mold infection) was recorded. Prior to harvest, each plot was given a lodging score from 1 to 5, where 1 means almost all plants were erect and 5 means all plants were down. Plants were ready to harvest approximately 5 days after 95% of plants were brown/yellow. Although black beans in the no-till plots reached peak biomass (R6/R7) almost two weeks later than black beans in the tilled plots, all beans reached harvest maturity around the same time. Black beans were harvested on 3-Oct 2023 in the tilled plots and 4-Oct 2023 in the no-till plots. All plants were counted, then hand-pulled from two 1-m row lengths in the center two rows of each plot. Plants were then hung to dry in a well-ventilated space. Once dry, the beans were threshed using a portable Almaco thresher with a rasp bar rotor. The beans were then weighed for plot yield and tested for harvest moisture and test weight using a DICKEY-John Mini-GAC Plus moisture and test weight meter. To assess differences in seed size, a 100-seed weight assessment was done by counting out 100 seeds and recording the total seed weight for three samples per plot.

Data were analyzed using a general linear model procedure of SAS (SAS Institute, 1999). Replications were treated as random effects, and treatments were treated as fixed. Mean comparisons were made using the Least Significant Difference (LSD) procedure where the F-test was considered significant, at $p<0.10$. Variations in yield and quality can occur because of variations in genetics, soil, weather, and other growing conditions. Statistical analysis makes it possible to determine whether a difference among treatments is real or whether it might have occurred due to other variations in the field. At the bottom of each table an LSD value is presented for each variable (i.e. yield). Least Significant Differences (LSDs) at the 0.10 level of significance are shown. Where the difference between two treatments within a column is equal to or greater than the LSD value at the bottom of the column, you can be sure that for 9 out of 10 times, there is a real difference between the two treatments. In this example, treatment C is significantly different from treatment A but not from treatment B. The difference between C and B is equal to 1.5, which is less than the LSD value of 2.0. This means that these treatments did not differ in yield. The difference between C and A is equal to 3.0, which is greater than the LSD value of 2.0. This means that the yields of these treatments were significantly different from one another.

Treatment	Yield
A	6.0^{b}
B	7.5^{ab}
C	**9.0^{a}**
LSD	2.0

RESULTS

Weather data were recorded throughout the season with a Davis Instrument Vantage Pro2 weather station, equipped with a WeatherLink data logger at Borderview Research Farm in Alburgh, VT (Table 2). Below average temperatures and increased precipitation persisted for most of the dry bean growing season. There was a total of 23.8 inches of rain from June to September. There was a total of 2184 accumulated Growing Degree Days (GDDs), which is slightly below the 30-year average.

Table 2. Weather data for Alburgh, VT, 2022.

	2022			
Alburgh, VT	June	July	August	Sept
Average temperature (°F)	65.7	72.2	67.0	63.7
Departure from normal	-1.76	-0.24	-3.73	1.03
Precipitation (inches)	4.40	10.8	6.24	2.40
Departure from normal	0.14	6.69	2.73	-1.27
Growing Degree Days (50-86°F)	483	712	540	449
Departure from normal	-41	17	-101	62

Based on weather data from a Davis Instruments Vantage Pro2 with WeatherLink data logger.
Historical averages are for 30 years of NOAA data (1991-2020) from Burlington, VT.

There were no significant interactions between the main effects of tillage and seeding rate on black bean yield and quality or on weed biomass production (Table 3). Tillage treatment had a statistically significant effect on emergence populations and percent emergence, as well as whole plant biomass production, lodging, and 100-seed weight. Black bean seeding rate also significantly impacted emergence populations and percent emergence, in addition to dry bean and weed biomass, harvest populations, and seed yield. Rye biomass was uniform across the field and statistical analysis was not done because there were no treatment differences just prior to termination when biomass was collected. Biomass production was very high in this year's trial. The average rye dry matter yield at termination was 11,722 lbs.

Table 3. Statistical significance of tillage, seeding rate, and interactions on black bean productivity, Alburgh, VT, 2023.

	Tillage treatment	Dry bean seeding rate	Treatment x seeding rate
Emergence population	**†	***	NS
Percent emergence	**	**	NS
Whole plant biomass	*	*	NS
Weed biomass	NS‡	**	NS
White mold incidence	NS	NS	NS
Lodging	*	NS	NS
Harvest population	NS	***	NS
Harvest moisture	NS	NS	NS
Test weight	NS	NS	NS
Seed yield	NS	*	NS
100-seed weight	*	NS	NS

† ***p<.0001; **.0001<p<.01; *.01<p<0.1

‡NS; no significant difference between treatments.

Trial results by tillage treatment are summarized in Tables 4 and 5. Black bean emergence populations were significantly greater overall in the tilled treatment than in the no-till treatment. There was 80.1% emergence in the tilled treatment statistically greater than the 69.1% emergence in the no-till treatment. At the time of peak dry bean biomass, whole plant biomass was statistically greater in the tilled treatment than the no-till treatment by 1159 lbs ac^{-1}. There was no statistical difference however, in weed biomass between treatments. The average amount of weed biomass was 130 lbs ac^{-1}. White mold incidence was very low with a trial average of less than one plant out of twenty displaying symptoms of infection. Plant lodging was statistically greater in the no-till treatment, with a rating of 3.35. There were also no statistical differences in harvest population, moisture, test weight, or seed yield between the tilled and no-till treatments. The average plant population at harvest was 112,186 plants ac^{-1}. The average harvest moisture was 15.8%, which means that additional drying was required to reach a safe storage moisture. The average test weight of black beans in this trial was 57.0 lbs bu^{-1}. In 2023, the average seed yield (adjusted to 0% moisture) was 2795 lbs ac^{-1}. Black beans in the no-till treatment had a 100-seed weight of 24.1 grams which was significantly higher than black beans in the tilled treatment, which had a 100-seed weight of 23.6 grams.

Table 4. Emergence, whole plant bean and weed biomass, and white mold incidence by treatment, Alburgh, VT, 2023.

Treatment	Emergence		Dry matter yield: Dry beans	Dry matter yield: Weeds	White mold incidence
	plants ac^{-1}	%	lbs ac^{-1}		# out of 20 plants
Tillage	**140,664[a]**†	**80.1[a]**	**5406[a]**	176	0.01
No-till	116,833[b]	69.1[b]	4247[b]	85	0.00
LSD (p=0.10)‡	13,906	6.36	617	NS§	NS
Trial Mean	128,749	74.6	4827	130	0.01

†Within a column, treatments marked with the same letter are statistically similar (p=0.10); top performer is in **bold.**
‡LSD; least significant difference at the p=0.10.
§NS; no significant difference between treatments.

Table 5. Black bean harvest characteristics by treatment, Alburgh, VT, 2023.

Treatment	Lodging	Harvest population	Harvest moisture	Test weight	Dry matter seed yield	100-seed weight
	1-5 scale†	plants ac^{-1}	%	lbs bu^{-1}	lbs ac^{-1}	grams
Tillage	2.85[b]	121,347	15.4	57.0	2909	23.6[b]
No-till	**3.35[a]**‡	103,025	16.2	57.0	2681	**24.1[a]**
LSD (p=0.10) ¥	0.46	NS§	NS	NS	NS	0.37
Trial Mean	3.10	112,186	15.8	57.0	2795	23.8

†Lodging scale: 1=all plants erect; 5=all plants horizontal
‡Within a column, treatments marked with the same letter are statistically similar (p=0.10); top performer is in **bold.**
§NS; no significant difference between treatments.
¥LSD; least significant difference at the p=0.10.

Trial results by black bean seeding rate are summarized in Tables 6 and 7 below. As expected, the highest seeding rate (300,000 plants ac^{-1}) had the highest population compared to other seeding rates. Interestingly, the lowest seeding rate (60,000 plants ac^{-1}) had the best emergence compared to the other seeding rates. Percent emergence was 91.0% in the 60,000 plants ac^{-1} treatment. There was no significant difference in percent emergence between the other four seeding rates. The 300,000 plants ac^{-1} treatment had 5937 lbs ac^{-1} of whole plant biomass and that was significantly greater than the other treatments. The other seeding rates were not significantly different in terms of bean biomass. Weed biomass was significantly higher in the 60,000 plants ac^{-1} treatment, 403 lbs ac^{-1}. Weed biomass was statistically similar in the other four seeding rates. Lodging ranged from 2.75 to 3.50 and was not significantly different between the seeding rates. Harvest populations were significantly higher in the 300,000 plants ac^{-1} treatment, and this was not statistically different from the 240,000 plants ac^{-1} treatment. Statistically, the 60,000 plants ac^{-1} treatment had a lower harvest population than all other seeding rates. Harvest moisture and test weight were not statistically different between seeding rates. Dry matter seed yield was highest in the 300,000 plants ac^{-1} treatment, but was not statistically different from all other seeding rates except the 60,000 plants ac^{-1} treatment. The 100-seed weight was not significantly different between the seeding rates.

Table 6. Emergence, whole plant bean and weed biomass, and white mold incidence by seeding rate, Alburgh, VT, 2023.

Treatment	Emergence		Dry matter yield: Dry beans	Dry matter yield: Weeds	White mold incidence
	plants ac^{-1}	%	lbs ac^{-1}		# out of 20 plants
60,000	54,778[e]	**91.0[a]**	4257[b]	**403[a]**	0.00
120,000	83,000[d]	68.9[b]	4716[b]	70[b]	0.01
180,000	130,142[c]	72.6[b]	4744[b]	87[b]	0.00
240,000	157,699[b]	65.7[b]	4479[b]	6[b]	0.01
300,000	**218,124[a]**†	75.0[b]	**5937[a]**	86[b]	0.02
LSD (p=0.10)‡	21,987	10.1	976	148	NS§
Trial Mean	128,749	74.6	4827	130	0.01

†Within a column, treatments marked with the same letter are statistically similar (p=0.10); top performer is in **bold.**
‡LSD; least significant difference at the p=0.10.
§NS; no significant difference between treatments.

Table 7. Black bean harvest characteristics by seeding rate, Alburgh, VT, 2023.

Treatment	Lodging	Harvest population	Harvest moisture	Test weight	Dry matter seed yield	100-seed weight
	1-5 scale†	plants ac^{-1}	%	lbs bu^{-1}	lbs ac^{-1}	grams
60,000	2.75	43,812[d]‡	17.3	55.8	2318[b]	23.4
120,000	3.00	77,667[c]	14.8	58.1	2864[a]	23.9
180,000	3.00	114,177[b]	15.2	58.2	2931[a]	23.9
240,000	3.25	148,696[a]	15.7	57.0	2811[a]	23.7
300,000	3.50	**176,577[a]**	16.0	55.9	**3052[a]**	24.2
LSD (p=0.10) ¥	NS§	29070	NS	NS	382	NS
Trial Mean	3.10	112,186	15.8	57.0	2795	23.8

†Lodging scale: 1=all plants erect; 5=all plants horizontal
‡Within a column, treatments marked with the same letter are statistically similar (p=0.10); top performer is in **bold.**
§NS; no significant difference between treatments.
¥LSD; least significant difference at the p=0.10.

DISCUSSION

In the 2022-2023 growing season, the UVM Extension Northwest Crops and Soils Program initiated the second year of an organic black bean seeding rate trial to evaluate the impact of black bean seeding rate in traditional tillage and no-till systems. Winter rye planted in the fall of 2022 produced 11,722 lbs ac^{-1} dry matter biomass. Black bean yields were very good in both till and no-till systems with a trial average of 2795 lbs ac^{-1} at 0% seed moisture. Tillage treatment had more of an impact on black bean establishment and biomass production and minimal impact on black bean yield. The thick layer of biomass left after the rye was rolled and crimped reduced black bean emergence in the no-till treatment, which led to lower emergence populations. This likely contributed to the significantly higher whole plant bean biomass in the tilled treatment. Another factor that may have resulted in reduced whole plant biomass was that plants in the no-till treatment had longer, thinner stems. Stem length and diameter were not measured in this trial and so these cannot be compared statistically. Lodging was also statistically higher in the no-till treatment, which makes sense if plants that had to grow through thick rye biomass were taller and had thinner stems, that those plants would then be more prone to lodging. Despite the difference in plant populations and biomass production during the season, harvest populations and seed yield were not significantly different between the tilled and no-till treatments this year. Black bean yields were higher this year than in 2022. Figure 1 below compares black bean yields between tillage treatments in 2022 and 2023. In 2022, black bean yields were significantly reduced in the no-till treatment. Improvements were made in 2023 to the planter, adding more weight to cut through the rye better and establish good seed to soil contact. Minimal disturbance to the rye also resulted in improved weed suppression in the no-till system in 2023.

Weed management is crucial and can be challenging especially in a year with excessive precipitation like 2023. Despite the heavy rainfall and wet soil conditions, successful weed management in both tillage systems resulted in relatively low weed pressure this year, with a trial average of 130 lbs ac^{-1} of dry matter. Weed biomass was only statistically greater in the 60,000 plants ac^{-1} treatment and there were no statistically significant differences between the other seeding rates. This suggests that there is no significant benefit in terms of weed suppression by increasing seeding rates from 120,000 to 300,000 plants ac^{-1}. This is similar to the 2022 results, where there were no significant differences in weed biomass between any of the seeding rates. In 2022, there was statistically higher weed biomass in the no-till system than the tilled system, but that is likely the result of the challenges at planting and was addressed in 2023 with the improvements made to the planter.

Increasing the seeding rate did significantly increase black bean emergence populations in this year's trial. This was also observed in 2022. Interestingly, percent emergence was statistically greater in the 60,000 plants ac^{-1} treatment. The other four seeding rates had about 65-75% emergence and were not statistically different from one another. Beans planted at a very low seeding rate like 60,000 plants ac^{-1} would have less competition, and that may explain why there was statistically higher emergence. Black bean seed yield was highest in the 300,000 plants ac^{-1} treatment, but not statistically different from the 120, 180, or 240,000 plants ac^{-1} treatments. A challenge with increasing seeding rate is achieving that high of a target plant population. For example, plots where the target seeding rate was 300,000 plants ac^{-1}, the emergence population was 218,214 plants ac^{-1} and the final harvest population was only 176,577 plants ac^{-1}. Figure 2 below shows the emergence population by seeding rate treatment for both tilled and no-till systems in 2022 and 2023. Emergence populations in the tilled system were similar between 2022 and 2023, but were all below the target seeding rate by 25,000 to 60,000 plants ac^{-1} except for at the lowest seeding rate. It is possible to achieve the target plant population at a very low seeding rate, but that is not going to produce high crop yields. Improvements were made in the no-till system from 2022 to 2023, with an overall increase in emergence populations for all the seeding rates in 2023. There was a greater difference in emergence populations between the tilled and no-till systems in 2022 than in 2023. Getting good establishment and high stand counts are both very important to maintaining high seed yields, especially in a no-till system. And while increasing seeding rate may increase plant populations, there may only be a significant increase in seed yield when the seeding rate is doubled from 60,000 to 120,000 plants ac^{-1}. Continuing to increase seeding rate up to 300,000 plants ac^{-1} does not statistically improve seed yield. This is different from 2022, where there were significant interactions between seeding rate and tillage treatment. In the tilled system, the average seed yield was 3079 lbs ac^{-1} and there was no significant increase in seed yield with seeding rates from 60, 000 to 240,000 plants ac^{-1}. Only at a seeding rate of 300,000 plants ac^{-1} did seed yield increase significantly. In the no-till system the average seed yield was 1392 lbs ac^{-1}, and the seed yield was significantly reduced when planted at the lowest seeding rate. With poor emergence and low plant populations, a higher seeding rate was necessary to achieve good seed yields in a no-till system. But if this management system can be fine tuned and improved upon, then high black bean yields can be achieved in a no-till system without having to plant at higher seeding rates, as was observed in 2023.

It is important to remember that these data represent only one year of research at one location. Additional research must be done to better understand incorporating black beans into a no-till production system and the impact that increased seeding rate has on dry bean productivity, disease suppression, and weed management.

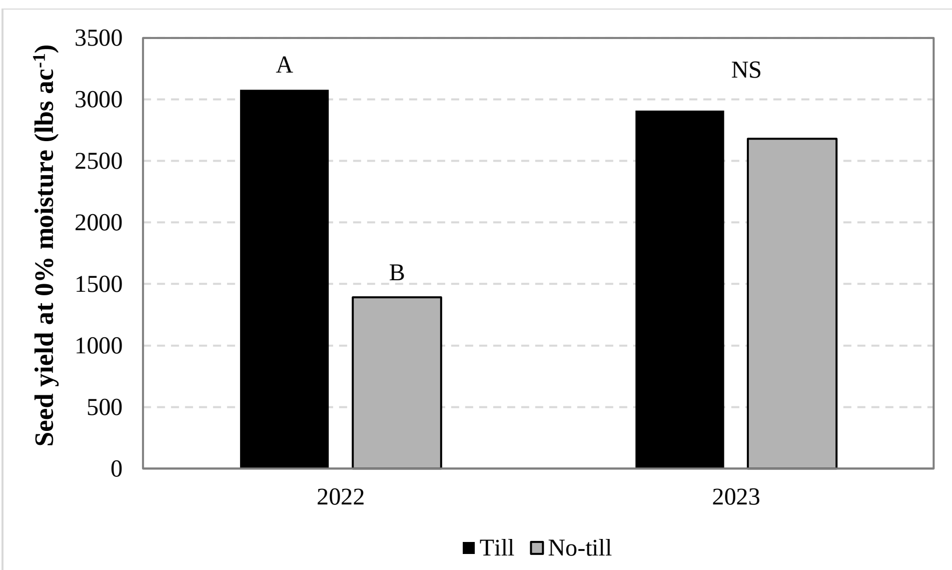

Figure 1. Black bean seed yield by tillage treatment in 2022 and 2023, Alburgh, VT, 2023. For each year, columns marked with different letters are statistically different (p=0.10). NS indicates that there was no statistical difference between treatments.

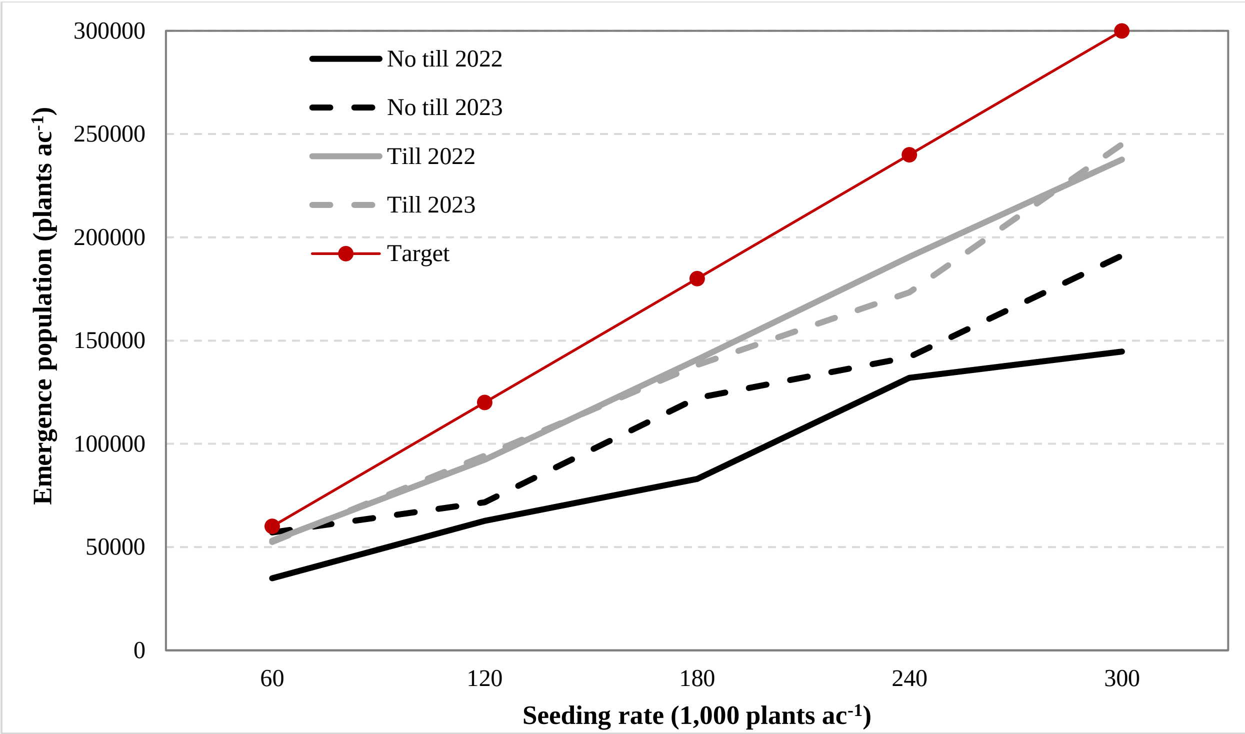

Figure 2. Black bean emergence population in tilled and no-till systems compared to target seeding rates in 2022 and 2023, Alburgh, VT, 2023.

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