2022 Organic Black Bean Seeding Rate Trial

Dr. Heather Darby, UVM Extension Agronomist
Ivy Krezinski
UVM Extension Crops and Soils Technicians
(802) 524-6501

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THE UNIVERSITY OF VERMONT EXTENSION

2022 ORGANIC BLACK BEAN SEEDING RATE TRIAL

Dr. Heather Darby, University of Vermont Extension
heather.darby[at]uvm.edu

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 2021-2022 growing season, the University of Vermont Extension Northwest Crops and Soils Program (NWCS) initiated a trial to evaluate various black bean seeding rates in a conventional tillage system compared to a no-till system on crop productivity and weed biomass.

MATERIALS AND METHODS

The trial was conducted at Borderview Research Farm in Alburgh, VT in the 2021-2022 growing season to evaluate the impact of dry 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, 2021-2022.

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: 20-Sep 2021 Seed rate: 3 million live seeds ac^{-1} Roll/crimp 31-May 2022
Black bean planting date	31-May 2022	6-Jun 2022
Black bean harvest date	22-Sep 2022	29-Sep 2022

For the no-till treatment, winter rye was planted on 20-Sep 2021 at a rate of 3 million pure live seeds ac^{-1} using a Sunflower no-till grain drill. In the spring, the rye was rolled down using a 10 foot I&J Crop Roller Crimper (Camp Douglas, WI) on 31-May 2022. Prior to termination, rye biomass was measured by collecting five 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. Black beans (VNS) were planted into rolled down rye on 6-Jun 2022 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 2022 using a 4-row cone planter with John Deere row units fitted with Almaco seed distribution units (Nevada, IA). Prior to planting, all seed was 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 2-3 weeks after planting on 22-Jun 2022. The number of plants in two 1-meter sections were recorded. To assess peak dry bean and weed biomass during the growing season, all above ground plant material was removed from within one $0.5m^2$ quadrat per plot using hand clippers when dry bean plants reached R6/R7 growth stage. This stage is characterized by oldest pods having developed seeds (other parts of the plant have full-length pods with seeds almost as large as first pods; 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 2022. Twenty plants per plot were assessed for the presence or absence of white mold symptoms. Incidence was low, so no further assessment on the severity of white mold damage was done. 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. Black beans were harvested on 22-Sep 2022 in the tilled plots and 29-Sep 2022 in the no-till plots due to delayed planting. 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 Swanson B-1 thresher with a rasp bar rotor. Beans were then weighed to calculate yields and a DICKEY-John MINI GAC meter used to determine bean moisture content.

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). Cool and wet conditions persisted throughout the growing season in 2022. Temperatures were cooler than average from June through September and precipitation was above average for every month except July. There was a total of 20.5 inches of precipitation, which is 5 inches above the 30-year normal for June through September. The cool temperatures resulted in a total of 2106 accumulated Growing Degree Days (GDDs), that was 139 below the 30-year average.

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

	2022			
Alburgh, VT	June	July	August	Sept
Average temperature (°F)	65.3	71.9	70.5	60.7
Departure from normal	-2.18	-0.54	-0.20	-1.99
Precipitation (inches)	8.19	3.00	4.94	4.40
Departure from normal	3.93	-1.06	1.40	0.73
Growing Degree Days (50-86°F)	459	674	630	343
Departure from normal	-64	-20	-11	-44

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.

The main effects of tillage and seeding rate had significant impacts on bean production. Table 3 below summarizes the significance of main effects and main effect interactions. There was a tillage treatment by seeding rate interaction for black bean emergence population and for whole bean plant biomass, illustrated in Figures 1 and 2 below. The tillage treatment by seeding rate interaction for emergence suggests that the seeding rate treatments responded differently under different tillage methods. While emergence increases with seeding rate for both treatments, dry bean emergence was higher overall when planted into tilled soil than into rolled down cereal rye. Emergence was likely suppressed by the thick layer of rye biomass. The winter rye produced approximately 6590 lbs or 3.3 tons ac^{-1} of dry matter. The 60,000 seeds ac^{-1} treatment had emergence closest to the target population for both tillage treatments and the difference between emergence and target seeding plant populations increased with seeding rate. Whole bean plant biomass, assessed at R6/R7 growth stage, was consistently lower in the no-till plots across all seeding rates. Unlike emergence population, the lowest seeding rate had the greatest whole plant biomass in the tilled plots. Biomass did increase with seeding rate in the 120,000 to 300,000 seeds ac^{-1} treatments, but were all lower than the 60,000 seeds ac^{-1} treatment. In the no-till plots, the lowest seeding rate had the least biomass, and plant biomass increased with seeding rate, although there was little difference between the 240,000 and 300,000 seeds ac^{-1} treatments. When planted at 60,000 seeds ac^{-1}, dry beans were able to make up for the low populations with increased biomass under a traditional tillage system, but that was not observed in the no-till system.

Table 3. Statistical significance of tillage, seeding rate, and interactions on black bean productivity, Alburgh, VT, 2022.

	Tillage treatment	Dry bean seeding rate	Treatment x Seeding rate
Emergence population	***ł	***	*
Whole plant biomass	***	*	**
Weed biomass	***	NS	NS
White mold	NS§	NS	NS
Lodging	*	NS	NS
Harvest population	NS	***	NS
Harvest moisture	***	*	NS
Seed yield	***	**	NS

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

§NS; no significant difference between treatments.

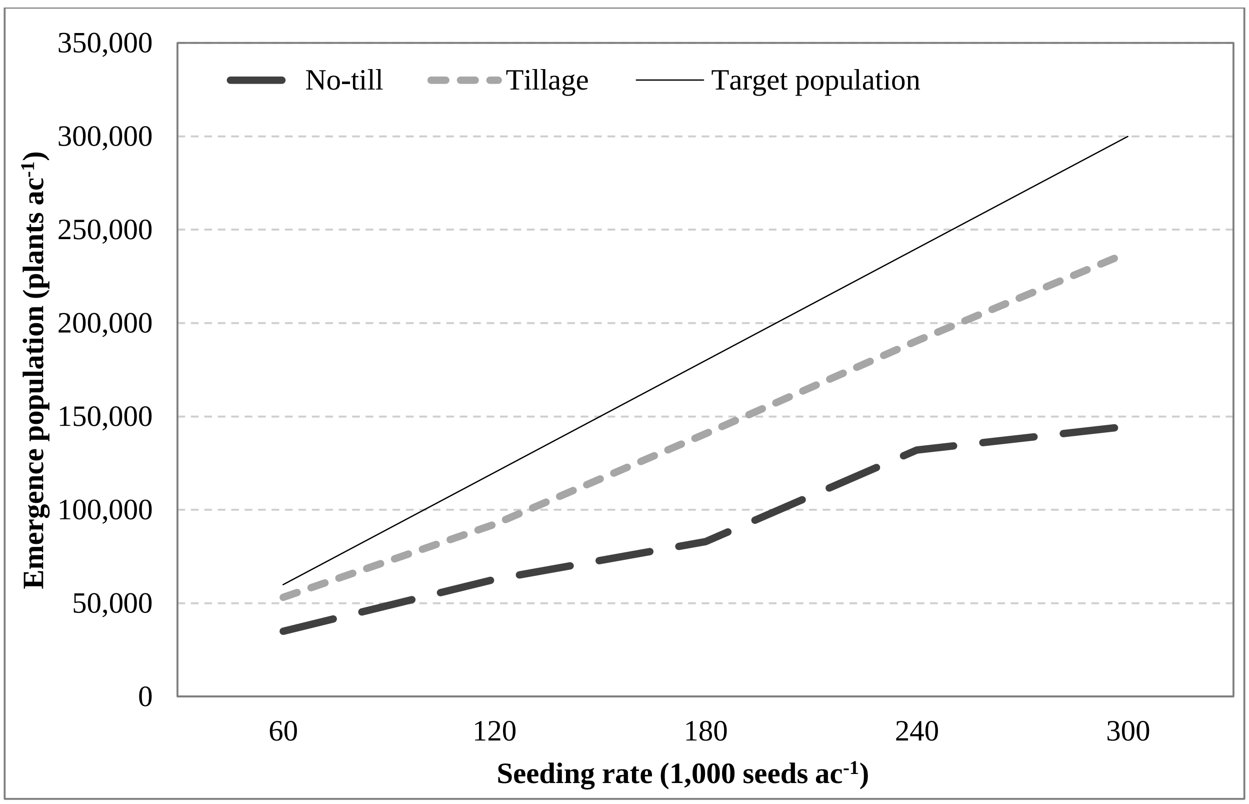

Figure 1. Tillage treatment by seeding rate interaction for dry bean emergence populations, Alburgh, VT, 2022. Solid black line represents the target population for each seeding rate.

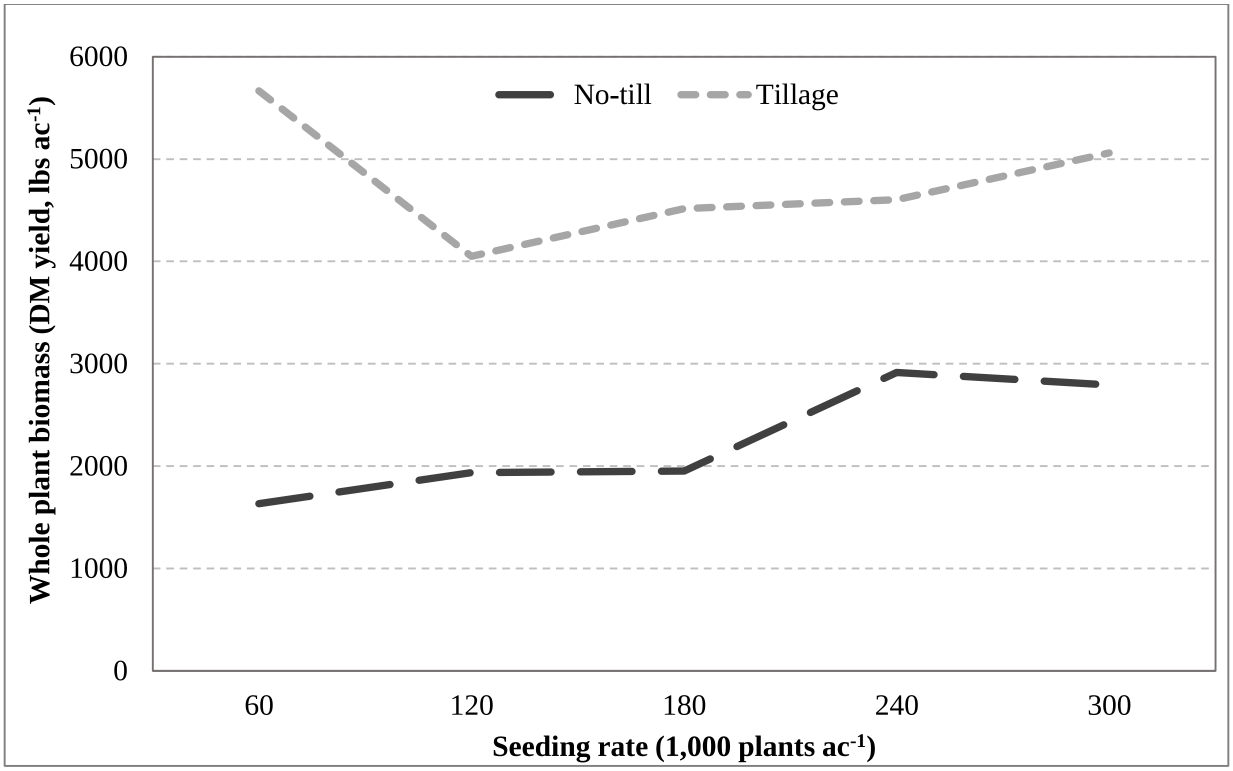

Figure 2. Tillage treatment by seeding rate interaction for whole bean plant biomass, Alburgh, VT, 2022.

Trial results by tillage treatment are summarized in Table 4. Dry bean emergence and whole plant biomass were both statistically greater in the tillage treatment compared to the no-till treatment. Average emergence was 142,861 plants ac^{-1} in the tilled plots compared to only 91,462 plants ac^{-1} in the no-till plots. Whole plant biomass was over 2X greater in the tilled plots (4779 lbs ac^{-1}) than the no-till plots (2246 lbs ac^{-1}). Weed biomass was over 40X higher in the no-till plots (441 lbs ac^{-1}) than in the tilled plots (10.4 lbs ac^{-1}). White mold incidence was very low in this trial, with a trial average of less than one plant in 20 with any signs of white mold, and there was no statistical difference between treatments. There was moderate lodging in this trial; the average score was 2.50. Lodging was statistically greater in the tillage treatment than in the no-till treatment. Despite the difference in emergence population, there was no significant difference in harvest population between treatments. Harvest moisture was statistically lower in the no-till plots than in the tilled plots, with moistures of 23.6% and 28.8% respectively. This is likely due to the later harvest date of the no-till plots. Both were quite high however and required additional drying prior to storage. Seed yield was statistically greater in the tilled plots (3079 lbs ac^{-1}) than in the no-till plots (1392 lbs ac^{-1}) despite the harvest populations being statistically similar.

Table 4. Results by tillage treatment for black bean seeding rate trial, Alburgh, VT, 2022.

Treatment	Emergence population	DM yield at R6/R7 growth stage[1]		White mold incidence[2]	Lodging[3]	Harvest population	Harvest moisture	DM seed yield
		Dry beans	Weeds					
	plants ac^{-1}	lbs ac^{-1}		# of affected plants	1-5 scale	plants ac^{-1}	%	lbs ac^{-1}
Tillage	**142861[a]**†	**4779[a]**	10.4[b]	0.03	2.70[b]	136880	28.8[b]	**3079[a]**
No-till	91462[b]	2246[b]	**441.5[a]**	0.03	**2.30[a]**	124937	**23.6[a]**	1392[b]
LSD (p=0.10)‡	14405	294.3	103.8	NS§	0.36	NS	1.24	207.4
Trial Mean	117162	3513	225.9	0.03	2.50	130909	26.2	2235

[1]Whole bean plant and weed biomass assessed at R6/R7 growth stage to capture peak biomass. R6/R7 growth stage characterized by oldest pods having developed seeds (other parts of plant have full-length pods with seeds almost as large as first pods; pods will be developed over whole plant).
[2]Incidence; Out of 20 plants, number of plants with signs of white mold.
[3]Lodging; visual assessment of entire plot; 1=almost all plants erect, 5=all plants down.
†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.

Trial results by black bean seeding rate are summarized in Table 5 below. Emergence population in the highest seeding rate was statistically higher than all other treatments and decreased as seeding rate decreased. Whole plant biomass was also statistically greater in the 300,000 seeds ac^{-1} treatment but was not significantly different from the 240,000 or 60,000 seeds ac^{-1} treatments. There were no statistical differences in weed biomass, white mold incidence, or plant lodging. Harvest populations were greatest in the 300,000 seeds ac^{-1} treatment, but not statistically different from the 240,000 seeds ac^{-1} treatment. Harvest moisture was lowest in the highest seeding rate (24.7%), but not statistically different from the 240,000 or 120,000 seeds ac^{-1} treatments. Seed yield was the highest in the 240,000 seeds ac^{-1} treatment, but this was not significantly different from the 300,000 or 180,000 seeds ac^{-1} treatments.

Table 5. Results by seeding rate treatment for black bean seeding rate trial, Alburgh, VT, 2022.

Seeding rate	Emergence population	DM yield at R6/R7 growth stage[1]		White mold incidence[2]	Lodging[3]	Harvest population	Harvest moisture	DM seed yield
		Dry beans	Weeds					
seeds ac^{-1}	plants ac^{-1}	lbs ac^{-1}		# of affected plants	1-5 scale	plants ac^{-1}	%	lbs ac^{-1}
60,000	44007[e]	3650[ab]	297.8	0.04	2.50	39167[d]	28.1[c]	1679[c]
120,000	77502[d]	2993[c]	242.3	0.02	2.00	86962[c]	26.2[abc]	2160[b]
180,000	111850[c]	3233[bc]	311.4	0.04	2.75	143389[b]	26.8[bc]	2270[ab]
240,000	161280[b]	3759[a]	138.3	0.00	2.63	181560[a]	25.2[ab]	**2557[a]**
300,000	**191170[a]**†	**3927[a]**	139.8	0.05	2.63	**203466[a]**	**24.7[a]**	2510[a]

LSD (p=0.10)‡	22777	465.4	NS§	NS	NS	34373	1.96	328.0
Trial Mean	117162	3513	225.9	0.03	2.50	130909	26.2	2235

[1]Whole bean plant and weed biomass assessed at R6/R7 growth stage to capture peak biomass. R6/R7 growth stage characterized by oldest pods having developed seeds (other parts of plant have full-length pods with seeds almost as large as first pods; pods will be developed over whole plant).
[2]Incidence; Out of 20 plants, number of plants with signs of white mold.
[3]Lodging; visual assessment of entire plot; 1=almost all plants erect, 5=all plants down.
†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.

Due to significant tillage treatment by seeding rate interactions, results by seeding rate were also analyzed separately. Results are summarized in Tables 6 and 7 below. In tilled plots, dry bean emergence was statistically highest in the highest seeding rate. While whole plant biomass was statistically highest in the lowest seeding rate, this did not lead to increased seed yield at harvest. Plants were able to grow larger at a lower seeding rate, but did not produce a greater number of seeds. Harvest population and seed yield were both statistically greater in the highest seeding rate.

In the no-till plots, black bean emergence was also greater in the higher seeding rates. There was no statistical difference in emergence between the 300,000 and 240,000 seeds ac^{-1} treatments. Whole plant biomass was highest in the 240,000 seeds ac^{-1} treatment, but not statistically different from the 300,000 seeds ac^{-1} treatment. Unlike the tilled plots, white mold incidence was statistically different between seeding rate treatments in no-till plots. The 120,000 and 240,000 seeds ac^{-1} treatments had no incidence of white mold, which was statistically lower than white mold incidence in the other three treatments. White mold incidence was quite low, and these differences may be due to plot location with the field rather than seeding rate. Harvest population and seed yield were both statistically greater in the 240,000 seeds ac^{-1} treatment. But harvest population in the 240,000 seeds ac^{-1} treatment was not statistically different from the 300,000 and 180,000 seeds ac^{-1} treatments. And although seed yield was highest in the 240,000 seeds ac^{-1} treatment, it was statistically similar to all but the lowest seeding rate.

Table 6. Results by seeding rate treatment for the tillage black bean seeding rate trial, Alburgh, VT, 2022.

Seeding rate	Emergence population	DM yield at R6/R7 growth stage[1]		White mold incidence[2]	Lodging[3]	Harvest population	Harvest moisture	DM seed yield
		Dry beans	Weeds					
seeds ac^{-1}	plants ac^{-1}	lbs ac^{-1}		# of affected plants	1-5 scale	plants ac^{-1}	%	lbs ac^{-1}
60,000	53108^{e}	**5667^{a}**	28.6	0.04	2.75	37174^{e}	29.6	2615^{b}
120,000	92276^{d}	4049^{c}	4.33	0.04	2.50	100901^{d}	28.9	3021^{b}
180,000	140737^{c}	4515^{bc}	6.96	0.04	3.00	144713^{c}	28.4	3211^{b}
240,000	190526^{b}	4604^{bc}	12.0	0.00	2.50	178568^{b}	28.8	3259^{b}
300,000	**237660^{a}**†	5061^{ab}	0.00	0.03	2.75	**223044^{a}**	28.1	**3289^{a}**

LSD (p=0.10)‡	16443	856.1	NS§	NS	NS	23433	NS	293.9
Trial Mean	142861	4779	10.4	0.03	2.70	136880	28.8	3079

[1]Whole bean plant and weed biomass assessed at R6/R7 growth stage to capture peak biomass. R6/R7 growth stage characterized by oldest pods having developed seeds (other parts of plant have full-length pods with seeds almost as large as first pods; pods will be developed over whole plant).
[2]Incidence; Out of 20 plants, number of plants with signs of white mold.
[3]Lodging; visual assessment of entire plot; 1=almost all plants erect, 5=all plants down.
†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. Results by seeding rate treatment for the no-till black bean seeding rate trial, Alburgh, VT, 2022.

Seeding rate	Emergence population	DM yield at R6/R7 growth stage[1]		White mold incidence[2]	Lodging[3]	Harvest population	Harvest moisture	DM seed yield
		Dry beans	Weeds					
seeds ac^{-1}	plants ac^{-1}	lbs ac^{-1}		# of affected plants	1-5 scale	plants ac^{-1}	%	lbs ac^{-1}
60,000	34905[c]	1633[b]	567.0	0.04[ab]	2.25	41159[c]	26.6[b]	743[b]
120,000	62729[bc]	1938[b]	480.2	**0.00[a]**	1.50	73024[bc]	23.4[ab]	1300[ab]
180,000	82964[b]	1951[b]	615.9	0.04[ab]	2.50	142065[ab]	25.3[b]	1330[ab]
240,000	132033[a]	**2914[a]**	264.7	**0.00[a]**	2.75	**184552[a]**	21.5[a]	**1854[a]**
300,000	**144680[a]†**	2793[a]	279.5	0.08[b]	2.50	183888[a]	**21.3[a]**	1731[a]
LSD (p=0.10)‡	46947	461.6	NS§	0.05	NS	69978	3.58	639.1
Trial Mean	91462	2246	441.5	0.03	2.30	124937	23.6	1392

[1]Whole bean plant and weed biomass assessed at R6/R7 growth stage to capture peak biomass. R6/R7 growth stage characterized by oldest pods having developed seeds (other parts of plant have full-length pods with seeds almost as large as first pods; pods will be developed over whole plant).
[2]Incidence; Out of 20 plants, number of plants with signs of white mold
[3]Lodging; visual assessment of entire plot; 1=almost all plants erect, 5=all plants down.
†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.

DISCUSSION

In the 2021-2022 growing season, the UVM Extension Northwest Crops and Soils Program initiated an organic black bean seeding rate trial to evaluate the impact of black bean seeding rate in two tillage systems: traditional tillage and no-till. A warm fall of 2021 resulted in very good winter rye cover crop establishment, and by the time the rye was rolled down in May 2022, it had produced over 3 tons of dry matter ac^{-1}. The thick layer of rolled down rye did present some challenges when no-till planting black beans. Multiple passes were made with the no-till planter to cut through the dense mat of winter rye, to ensure good seed to soil contact. However, there was still delayed germination and low stand counts in the no-till plots as well as increased weed pressure, particularly within the rows, between plants. The thick layer of winter rye did suppress weeds between rows. The temperatures were cooler than average from June through September 2022 and resulted in 139 less accumulated Growing Degree Days than normal. There was 20.5 total inches of rain, 5 inches above average, during the season, but timely weed management was not an issue in the tilled plots. Weed pressure was 40X lower in the tilled plots than in the no-till plots.

Planting black beans at increasingly higher seeding rates did increase emergence populations, but the effect varied in tilled versus no-till plots. Black bean emergence was below the target population for all seeding rates in both tillage treatments, but no-till planting black beans into rolled down rye resulted in even lower emergence. At the highest seeding rate (300,000 seeds ac^{-1}), emergence in the no-till plots was only 144,680 plants ac^{-1}, nearly half the target population, compared to 237,660 plants ac^{-1} in the tilled plots. Whole plant biomass was greater overall in the tilled system, likely due to better establishment. Interestingly, the lowest seeding rate produced the most biomass in the tilled system, indicating that black beans planted at low seeding rates will produce larger plants, likely due to increased space and resource availability. The increased biomass did not result in higher seed yields, however. Overall, black bean seed yield was greater in the tilled system and increased with seeding rate. Black beans planted at 300,000 seeds ac^{-1} in a tilled system produced yields that were statistically greater than all other seeding rate treatments. In the no-till system, while yields were greatest when planted at 240,000 seeds ac^{-1}, this was not statistically different from black beans planted at 120, 180, or 300,000 seeds ac^{-1}. This suggests that while improved seed yield will be observed from doubling the seeding rate from 60,000 to 120,000 seeds ac^{-1}, there will be little benefit to increasing black bean seeding rate above 120,000 seeds ac^{-1} in a no-till system. 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. The NWCS program will be repeating this research trial again in 2023.

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