NORTHWEST CROPS & SOILS PROGRAM

2023 No-Tillage and Dry Bean Variety Performance

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THE UNIVERSITY OF VERMONT EXTENSION

2023 No-Tillage and Dry Bean Variety Performance

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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. Currently, the demand for locally sourced dry beans has far exceeded the supply. Farmers are also looking for high-value crops to diversify their rotations. Modern breeding efforts have expanded the market classes that can be direct harvested, lowering the barrier to entry by reducing the need for specialized equipment. These alternative market classes are valued by consumers for their culinary characteristics and visual appeal. 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 in organic no-till systems and could reduce the negative impacts on soil health while still suppressing weeds. However, there has been little research on how other market classes perform in a no-till production system. To support and expand organic dry bean production throughout the northeast, the University of Vermont Extension Northwest Crops and Soils Program initiated a research trial to evaluate the performance of four dry bean market classes (black, navy, pinto, and small red) in an organic tilled system compared to an organic no-till system.

MATERIALS AND METHODS

The trial was conducted at Borderview Research Farm in Alburgh, VT during the 2022-2023 season. The experimental design was a randomized complete block with split plots and four replications. Main plots were two tillage treatments: traditional tillage and no-till. The sub-plot were four dry bean market classes (Table 1).

Table 1. Varietal information for the four dry bean varieties planted in Alburgh, VT, 2023.

Variety	Seed Source	Market class
Alpena	Central Bean Co.	Navy
Max	ADM Edible Bean Specialties, Inc.	Pinto
Rojo Chiquito	Central Bean Co.	Small Red
Zorro	Seneca Grain & Bean	Black

Trial management details can be found in Table 2. The entire area was planted with winter rye (var *ND Gardner*) on 17-Sep 2022 at a rate of 3 million pure live seeds ac^{-1} using a Sunflower no-till grain drill. For the tilled treatment, rye was terminated using a moldboard plow and then the seedbed was prepared using a Pottinger TerraDisc® on 28-Apr 2023. In the no-till plots, the rye was rolled down using an I&J Crop Roller Crimper (Camp Douglas, WI) on 31-May 2023. Dry beans were planted on 31-May with a John Deere no-till planter. The seeding rate varied by market class. Black, navy, and small red beans were planted at 125,000 seeds ac^{-1} and pinto beans were planted at 95,000 seeds ac^{-1}. Prior to planting, the seed was

treated with dry bean bacterial inoculant (*Rhizobium leguminosarum biovar phaseoli*). The plot size was 10ft x 20ft, with 4 rows at 30-inch spacing.

Table 2. Trial management information for the dry bean variety x tillage 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	
Seeding rates (pure live seeds ac^{-1})	Black, navy, & small red: 125,000 Pinto: 95,000	
Tillage operations	<u>Tillage</u>	<u>No-till</u>
	Moldboard plow Pottinger TerraDisc® 28-Apr 2023	Cereal rye (var ND Gardner) Planting date: 17-Sep 2022 Seed rate: 3 million live seeds ac^{-1} Roll/crimp 31-May 2023
Dry bean planting date	31-May 2023	
Dry bean harvest dates	14-, 28-Sep, and 2-Oct 2023	

Plant emergence was measured by counting the number of plants in two 1-m sections in each plot on 21-Jun. Starting in early July, plots were monitored for signs of flowering. Days to flower were recorded on the date at which approximately 50% of plants in a plot had at least one opened flower. To assess peak dry bean and weed biomass during the growing season, all above ground plant material was removed from within one 0.5 m^2 quadrat per plot using hand clippers when dry bean plants reached R6/R7 growth stage: 11-Aug for tilled plots and 17-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. Starting in late August, plants were scouted as they approached maturity. Days to maturity were recorded for each plot when 50% percent of plants in a plot had at least one dry pod. All plots were hand harvested as they reached maturity, about 5 days after 95% of pods were brown, on 14-, 28-Sep, and 2-Oct 2023. At harvest, lodging was measured by visual assessment for the whole plot on a scale of 1 to 5, where 1 meant all plants were erect and 5 meant all plants were horizontal. Pod height was measured by selecting 5 plants at random from two 1-m sections within the center two rows of each plot and measuring the distance from the soil surface to the bottom of the lowest pod. All plants within the two 1-m sections were hand-pulled and 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. Beans were then weighed to calculate yields and tested for harvest moisture and test weight using a DICKEY-John Mini-GAC Plus moisture and test weight meter. To capture differences in seed quality, two random samples of 100 seeds were taken from each plot and the number of unmarketable seeds was recorded. To assess differences in seed size, a 100-seeds were weighed 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 with a Davis Instruments Vantage Pro2 weather station, equipped with a WeatherLink data logger at Borderview Research Farm in Alburgh, VT (Table 3). 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 3. Weather data for Alburgh, VT, 2023.

	2023			
Alburgh, VT	June	July	Aug	Sep
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	6.27	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.

Interactions

There were significant interactions between main effects (variety x tillage treatment) for dry bean emergence, harvest moisture, seed yield, unmarketable seed, and adjusted seed yield (Table 4). Emergence populations were higher in the tilled plots for all varieties except Alpena (Figure 1). For Alpena, emergence

populations were about 10,000 plants ac^{-1} higher in the no-till plots. Populations were about 20,000 plants ac^{-1} lower in the no-till treatment for Rojo Chiquito and Zorro, and about 27,000 plants ac^{-1} lower for Max. The difference in percent emergence between tillage treatments was greatest for Max which had 28% less emergence in the no-till treatment than in the tilled treatment (Figure 2). Rojo Chiquito and Zorro only had about 16-17% reduction in emergence with the no-till treatment. Similar to emergence populations, Alpena had slightly higher percent emergence in the no-till treatment compared to the tilled treatment, but only by 8%. Figure 3 below shows the percentage of unmarketable seed by variety in the two tillage systems. Alpena, Rojo Chiquito, and Zorro all had relatively low amounts of unmarketable seeds and there was little difference between the tillage treatments. Max had much higher amounts of unmarketable seeds in both tillage systems compared to the other varieties. The percentage of unmarketable seeds increased from about 30% in the tilled treatment to 55% in the no-till treatment. This is reflected in the adjusted seed yield seen in Figure 4 below. Seed yields were higher overall in the tilled treatment. Rojo Chiquito had almost no difference in yield between the two tillage treatments. For Alpena, seed yield was reduced by about 800 lbs ac^{-1} in the no-till treatment. Zorro had a yield reduction of about 500 lbs ac^{-1} in the no-till treatment. The largest difference in adjusted seed yield was for Max, with a yield reduction of about 1500 lbs ac^{-1} in the no-till treatment.

Table 4. Significance of main effects and main effect interactions.

	Variety	Tillage Treatment	Variety x Tillage Treatment
Emergence population	***†	**	*
Percent emergence	NS‡	**	*
Flowering date	****	****	NS
Whole plant biomass	NS	****	NS
Weed biomass	NS	*	NS
Maturity date	****	****	NS
Pod height	****	*	NS
Lodging	****	NS	NS
Harvest moisture	*	**	**
Test weight	*	NS	NS
Seed yield	*	***	*
Unmarketable seed	****	**	**
Adjusted seed yield	****	***	*
100-seed weight	****	NS	NS

†****p<.0001; ***.0001<p<.001; **.001<p<.01; *.01<p<0.1

‡NS-No significant difference between treatments.

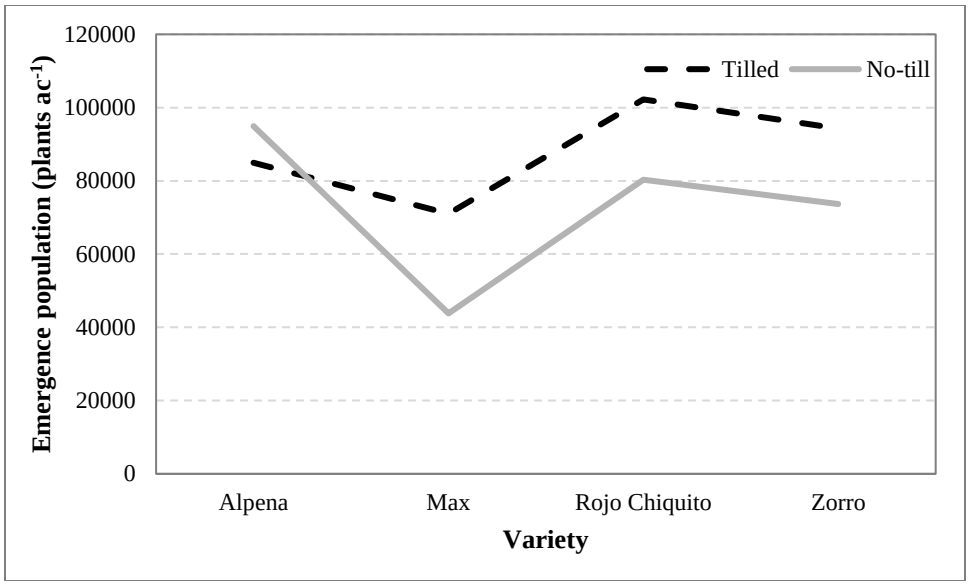

Figure 1. Emergence population by variety in tilled treatment compared to no-till treatment, Alburgh, VT, 2023.

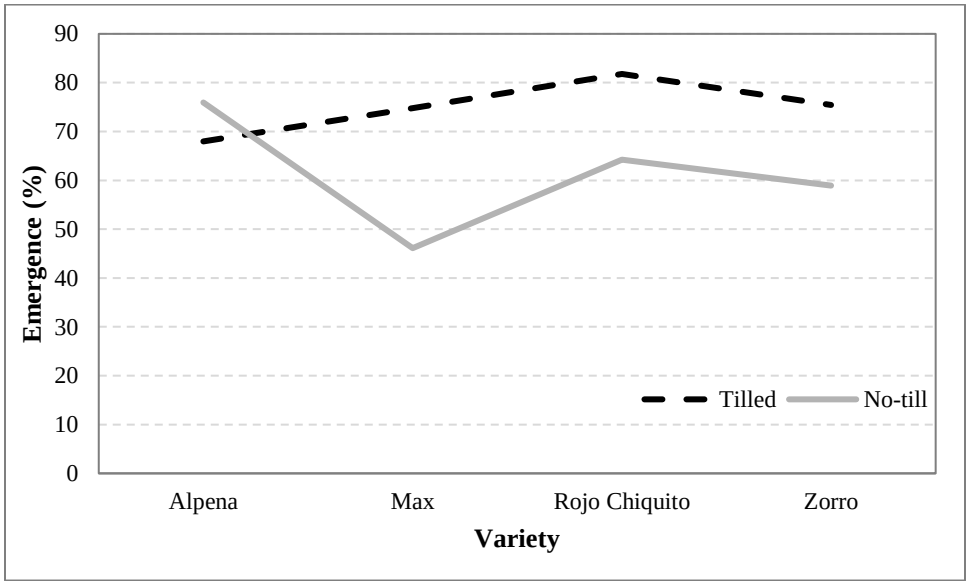

Figure 2. Percent emergence by variety in tilled treatment compared to no-till treatment, Alburgh, VT, 2023.

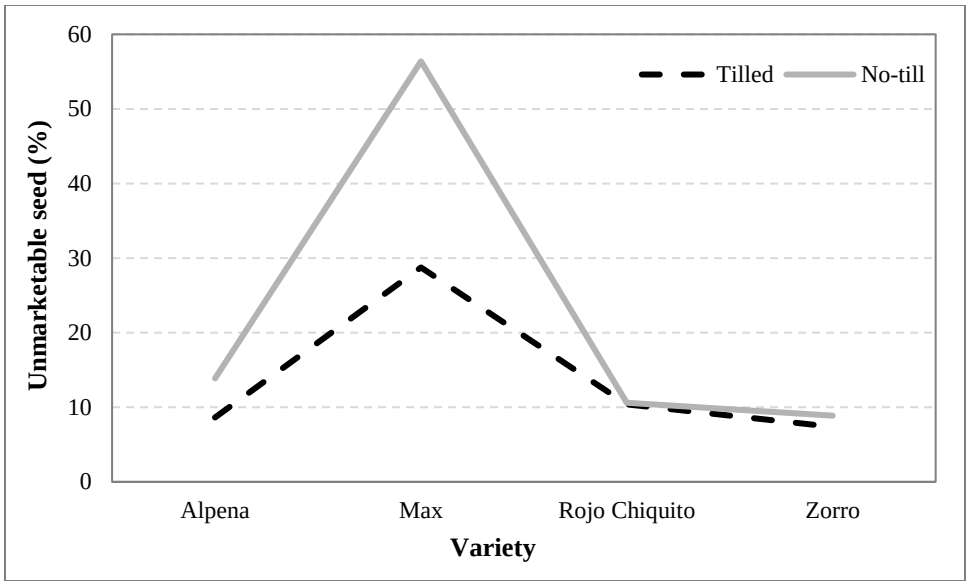

Figure 3. Unmarketable seed by variety in tilled treatment compared to no-till treatment, Alburgh, VT, 2023.

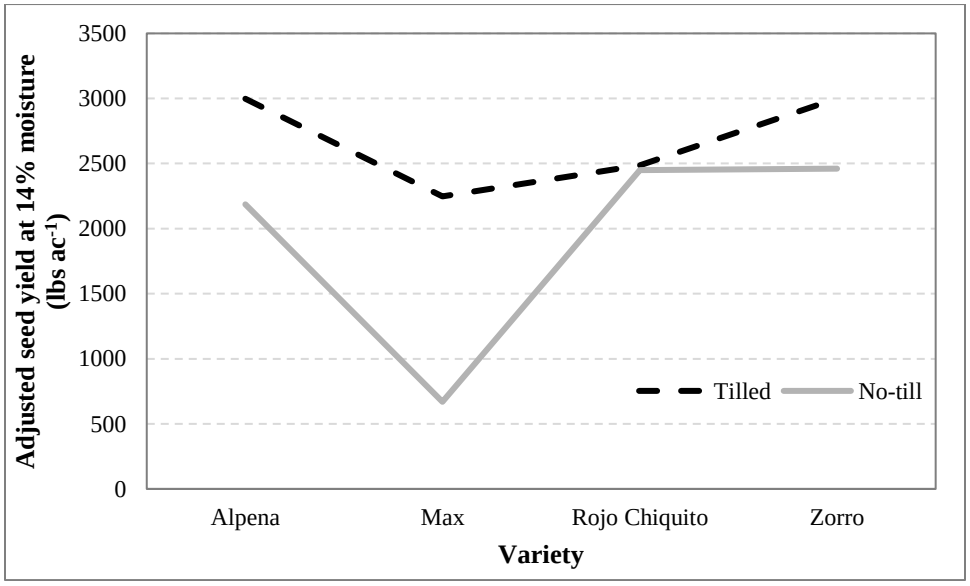

Figure 4. Adjusted seed yield by variety in tilled treatment compared to no-till treatment, Alburgh, VT, 2023.

Impact of dry bean variety

There was a statistically significant difference in emergence populations between varieties (Table 5), which is to be expected because they were planted at different seeding rates. Alpena, Rojo Chiquito, and Zorro were all planted at 125,000 seeds ac^{-1}, and these three varieties had statistically similar emergence populations. Max was planted at a lower seeding rate, 95,000 seeds ac^{-1}, and had a statistically lower emergence population than the other three varieties. There were no statistical differences in percent emergence and the trial average was 68.2% emergence. The variety Max had a flowering date of 11-Jul (192 days after 1-Jan), and this was statistically different from the other three varieties. Alpena, Rojo Chiquito, and Zorro started to flower 7-8 days later and were not statistically different from one another. Despite differences in emergence populations, there were no significant differences in whole plant biomass

or weed biomass between varieties. Similar to flowering date, Max reached maturity on 6-Sep, which was a week earlier than the next variety to reach maturity, Alpena. Rojo Chiquito and Zorro reached maturity 17 and 18 Sep and were not statistically different.

Table 5. Dry bean characteristics by variety, Alburgh, VT, 2023.

Variety	Market class	Emergence		Flowering date	Dry beans Dry matter biomass	Weeds Dry matter biomass	Maturity date
		plants ac^{-1}	%	Days after 1-Jan 23	lbs ac^{-1}		Days after 1-Jan 23
Alpena	Navy	89948^{a}†	72.0	200^{b}	3512	292	256^{b}
Max	Pinto	57421^{b}	60.4	**192^{a}**	3629	101	**249^{a}**
Rojo Chiquito	Small red	**91276^{a}**	73.0	199^{b}	3591	476	260^{c}
Zorro	Black	83973^{a}	67.2	199^{b}	3768	277	261^{c}
LSD (p = 0.10)‡	N/A§	11792	NS¥	0.95	NS	NS	3.71
Trial Mean		80654	68.2	197	3625	287	257

†Within a column, treatments marked with the same letter were statistically similar (p=0.10).
‡LSD-Least significant difference at the p=0.10.
§N/A-Not applicable.
¥NS-No significant difference between treatments.

Harvest characteristics were significantly impacted by variety (Table 6). Max had significantly higher lodging than the other varieties, with a rating of 5. Rojo Chiquito and Zorro had statistically similar lodging ratings of 2.38 and 2.50 respectively. Alpena had significantly lower lodging with a rating of 1.38. Rojo Chiquito had the greatest pod height (10.2 cm), but was not statistically different from Zorro (9.24 cm). Max had a pod height of 3.23 cm, which was significantly lower than the other varieties. Rojo Chiquito had a harvest moisture of 20% which was significantly higher than the other varieties, and the trial average was 18.4%. Max had the highest test weight of 54.2 lbs bu^{-1}, and this was statistically different from the other three varieties. The trial average seed yield at 14% moisture was 2744 lbs ac^{-1}. Zorro had the highest yield, 2963 lbs ac^{-1}, but was not significantly different from Alpena or Rojo Chiquito. To look for differences in seed quality, the percentage of unmarketable seed was calculated for each variety and then used to adjust the seed yield to represent clean, marketable seed. Max had significantly higher amounts of unmarketable seed, 42.6%, and was statistically greater than the other varieties which ranged from 8.13% (Zorro) to 11.3% (Alpena). After the seed yield was adjusted, the trial average was 2312 lbs ac^{-1}, and Max still had a significantly lower seed yield than the other varieties. There were no statistical differences in adjusted seed yield between Alpena, Rojo Chiquito, and Zorro. Max had the highest 100-seed weight, 46.3 grams, and was statistically greater than the other varieties.

Table 6. Harvest characteristics by dry bean variety, Alburgh, VT, 2023.

Variety	Market class	Lodging	Pod height	Harvest moisture	Test weight	Yield at 14% moisture	Unmarketable seed	Adjusted yield at 14% moisture	100-seed weight
		1-5 rating†	cm	%	lbs bu^{-1}	lbs ac^{-1}	%	lbs ac^{-1}	grams
Alpena	Navy	1.38[c]‡	6.67[b]	18.0[a]	53.3[a]	2900[a]	11.3[a]	2591[a]	19.9[d]
Max	Pinto	**5.00[a]**	3.23[c]	**17.5[a]**	47.9[b]	2358[b]	42.6[b]	1459[b]	**46.3[a]**
Rojo Chiquito	Small red	2.38[b]	**10.2[a]**	20.0[b]	**54.2[a]**	2754[a]	10.5[a]	2468[a]	25.5[b]
Zorro	Black	2.50[b]	9.24[a]	18.1[a]	53.8[a]	**2963[a]**	**8.13[a]**	**2730[a]**	24.4[c]
LSD (p = 0.10)§	N/A¥	0.48	1.86	1.25	1.72	363.8	6.37	378	0.74
Trial Mean		2.81	7.34	18.4	52.4	2744	18.1	2312	29

†Lodging scale: 1=all plants erect; 5=all plants horizontal.

‡Within a column, treatments marked with the same letter were statistically similar (p=0.10).

§LSD –Least significant difference at p=0.10.

¥N/A-Not applicable.

Impact of tillage treatment

Tillage treatment had a significant impact on dry bean emergence (Table 7). Emergence populations were significantly higher in the tilled plots. Percent emergence was also statistically greater in the tilled plot with 75% emergence, compared to 61.3% emergence in the no-till plots. Flowering date was significantly later in the no-till treatment compared to the tilled treatment. Dry beans started to flower 5 days earlier in the tilled plots. Dry bean and weed biomass were both significantly higher in the tilled treatment. The whole plant bean biomass was 4473 lbs ac^{-1} in the tilled treatment and only 2777 lbs ac^{-1} in the no-till treatment. Weed biomass was 450 lbs ac^{-1} in the tilled treatment but only 123 lbs ac^{-1} in the no-till treatment. Days to maturity was also significantly impacted by tillage treatment. Dry beans in the tilled plots reached maturity on 7-Sep (250 days after 1-Jan), which was 13 days earlier than in the no-till plots.

Table 7. Dry bean characteristics by tillage treatment, Alburgh, VT, 2023.

Treatment	Emergence		Flowering date	Dry beans / Weeds Dry matter biomass		Maturity date
	plants ac^{-1}	%	Days after 1-Jan 23	lbs ac^{-1}		Days after 1-Jan 23
Tillage	**88122[a]†**	**75.0[a]**	**195[a]**	**4473[a]**	**450[a]**	**250[a]**
No-Till	73186[b]	61.3[b]	200[b]	2777[b]	123[b]	263[b]
LSD (p = 0.10) ‡	8338	6.86	0.67	574	217	2.63
Trial Mean	80654	68.2	197	3625	287	257

†Within a column, treatments marked with the same letter were statistically similar (p=0.10).

‡LSD-Least significant difference at the p=0.10.

Lodging was not significantly different between tillage treatments (Table 8). Dry beans in the no-till plots had significantly higher pod height (8.41 cm) than in the tilled plots (6.27 cm). Harvest moisture was also significantly lower in the no-till plots which had an average harvest moisture of 17.6%, compared to 19.2%

in the tilled plots. Tillage treatment had no significant impact on test weight, and the trial average was 52.4 lbs bu^{-1}. Seed yield was significantly higher in the tilled plots (3098 lbs ac^{-1}) than in the no-till plots (2390 lbs ac^{-1}). There was 13.8% unmarketable seed in the tilled plots, and this was significantly lower than in the no-till plots, which had 22.4% unmarketable seed. Adjusted seed yield was significantly lower in the no-till plots (1941 lbs ac^{-1}) compared to the tilled plots (2683 lbs ac^{-1}). There were no significant differences in 100-seed weight between the treatments.

Table 8. Harvest characteristics by tillage treatment, Alburgh, VT, 2023.

Treatment	Lodging	Pod height	Harvest moisture	Test weight	Yield at 14% moisture	Unmarketable seed	Adjusted yield at 14% moisture	100-seed weight
	1-5 rating†	cm	%	lbs bu^{-1}	lbs ac^{-1}	%	lbs ac^{-1}	grams
Tillage	2.75	6.27[b]‡	19.2[b]	52.0	**3098[a]**	**13.8[a]**	**2683[a]**	29.2
No-Till	2.88	**8.41[a]**	**17.6[a]**	52.9	2390[b]	22.4[b]	1941[b]	28.9
LSD (p = 0.10) §	NS¥	1.32	0.89	NS	257.3	4.51	267.3	NS
Trial Mean	2.81	7.34	18.4	52.4	2744	18.1	2312	29.0

†Lodging scale: 1=all plants erect; 5=all plants horizontal.
‡Within a column, treatments marked with the same letter were statistically similar (p=0.10).
§LSD –Least significant difference at p=0.10.
¥NS-No Significant difference between treatments.

DISCUSSION

Dry bean varieties from four different market classes (navy, pinto, small red, and black) were grown in a tillage system and a no-till system to determine if they were suitable for a rolled-crimped rye mulch cropping system. Alpena (navy), Rojo Chiquito (small red), and Zorro (black) all performed well and were statistically similar to one another in this year's trial. Max (pinto) matured significantly earlier than the other three varieties. Growth habit was not measured in this trial, but Max had a prostrate growth habit and the most severe lodging. This variety also had significantly lower seed yields and higher amounts of unmarketable seed than the other varieties. Overall, dry beans in the no-till system had reduced emergence and delayed maturation compared to the tilled system. Seed yields were good in this trial, with an average yield at 14% moisture of 2312 lbs ac^{-1}, which was similar to other dry bean trials conducted at Borderview Research Farm in 2023. However, there was a significant yield reduction and increase in unmarketable seed in the no-till system.

There were some significant interactions between variety and tillage treatment. Emergence population and percent emergence were higher in the tilled system for Max, Rojo Chiquito, and Zorro, but not Alpena. Alpena also had the least difference in emergence populations and percent emergence between tillage treatments. The largest difference in percent emergence between the tilled and no-till treatments was for Max. Alpena, Rojo Chiquito, and Zorro all had similar amounts of unmarketable seed in both tillage systems, but for Max, the number of unmarketable seed increased from 28% in the tilled system to 56% the no-till system. The increase in unmarketable seed in addition to the reduced emergence, resulted in a yield

loss of almost 1500 lbs ac^{-1} for Max in the no-till system. While overall yields were good for the other three varieties, Rojo Chiquito had almost no difference in seed yield between the tillage treatments, suggesting that this variety may be well suited for a no-till cropping system. Results from a black bean seeding rate study conducted at Borderview Research Farm this season suggest that the black bean variety Zorro can also produce statistically similar yields in a no-till system when planted at 120,000 seeds ac^{-1}. The variety Max was included in the dry bean variety trial at Borderview Research Farm this season and had low yields and increased disease incidence, suggesting that it is not suitable for this northern climate. But there were other pinto bean varieties grown in the 2023 variety trial that produced high yields with low incidence of disease that may perform better in a no-till cropping system. Variety selection is very important, and more research needs to be done to understand how more varieties within these market classes perform in a no-till system. It is important to remember that these data represent only one year of data at one location and the UVM Extension NWCS program will be repeating this trial again in 2024.

ACKNOWLEDGEMENTS

This material is based upon work supported by the U.S. Department of Agriculture (USDA) National Institute of Food and Agriculture (NIFA) NE SARE under federal award number LNE22-444 and by the USDA NIFA Organic Agriculture Research and Extension Initiative (OREI) under federal award number 2022-51300-37881. The UVM Extension Northwest Crops and Soils Program would like to thank Roger Rainville and the staff at Borderview Research Farm for their generous help with the trial. We would like to acknowledge Anna Brown, John Bruce, Kellie Damann, Catherine Davidson, Hillary Emick, Lindsey Ruhl, Laura Sullivan, Sophia Wilcox Warren, and Sara Ziegler for their assistance with data collection and entry. This information is presented with the understanding that no product discrimination is intended and neither endorsement of any product mentioned, nor criticism of unnamed products, is implied.

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