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2024 INTEGRATING SOLAR CORRIDORS INTO CORN SILAGE PRODUCTION SYSTEMS

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Interseeding is a strategy to plant cover crops directly into a growing crop of corn silage providing for earlier planting to hopefully maximize the conservation and ecological benefits of the cover crop. However, there are several challenges limiting farmer adoption of interseeding cover crops. Interseeding when corn is between the V2 to V6 growth stage is preferable because after corn has reached the V6 stage, most seeding equipment is not tall enough, increasing the risk of damaging the corn crop. This requires owning or having access to specialized cover crop interseeding equipment. Another challenge is that typical row spacings create shade that limits cover crop establishment and growth. The solar corridor system is an alternative cropping system that is designed to increase the availability of sunlight to all rows, which can improve crop growth and nutrient cycling in the soil.

Since 2019, the UVM Extension Northwest Crops and Soils (NWCS) program has conducted research trials to investigate the impact of increased corn row spacing on corn yield and cover crop establishment and has found that cover crops consistently perform better in 60" rows compared to 30" rows. Increasing the row width of corn silage may improve interseeded cover crop growth, but it is still important to maintain cash crop yields. Based on past year's research done at Borderview Research Farm, increasing corn row width to 60" can result in yield reductions, likely due to decreased plant populations on a per acre basis. When planting in wider rows, seeding rates need to be increased to achieve the same number of plants per acre. For example, to achieve 30,000 plants ac^{-1} in 60" rows, the seeding rate must be doubled to 60,000 seeds ac^{-1}. It can be challenging to achieve these high seeding rates, which can result in a lower plant population at harvest and therefore reduced yields. Increasing corn row widths to 36" or 40" may minimize the yield loss while achieving the desired corn population. There is increasing interest from producers to incorporate alternative cropping systems, but these practices need to be fine-tuned, to maintain crop productivity. In 2024, the UVM Extension NWCS program initiated two trials to investigate 1) the impact of corn row spacing, and 2) the impact of corn row spacing and population on corn silage yield and quality.

MATERIALS AND METHODS

The trials were conducted at Borderview Research Farm in Alburgh, VT in 2024. Trial 1 evaluated the impact of five corn row widths on silage yield and quality. Trial 2 evaluated the impact of corn row width and population on corn yield and quality.

Trial 1- The impact of corn row width on silage productivity

The experimental design for Trial 1 was a randomized complete block design where the treatments were corn row widths (20", 30", 36", 40" and 60" row spacings) and were replicated four times (Table 1). Plots were 40' long and consisted of 4 rows. To accommodate wider row spacing, plot size was adjusted based on the corn row width. Plots were 7', 10', 12', 14' and 20' wide for 20", 30", 36", 40" and 60" spacing respectively. Corn was planted on 16-May. The 30" and 60" plots were planted using a 4-row cone planter with John Deere row units fitted with Almaco seed distribution units (Nevada, IA). The 20", 36" and 40" plots were planted with a custom-made planter that included John Deere plate row-units on an adjustable tool bar. All plots were planted to meet a target population of 30,000 plants ac^{-1}. To control weeds, all plots were treated with 1 qt ac^{-1} of Glystar Plus and 1.5 oz ac^{-1} of Resolve® Q on 28-May. On 17-Jun, plots were top-dressed with 30-0-20 plus the inhibitor ContaiN MAX™ at a rate of 300 lbs ac^{-1}. All plots were interseeded with a cover crop mixture of annual ryegrass (60%), red clover (30%) and tillage radish (10%). Corn was harvested on 12-Sep using a John Deere 2-row corn chopper and collected in a wagon fitted with scales to weigh the yield of each plot. An approximate 1 lb subsample was collected, weighed, dried, and weighed again to determine dry matter content and calculate yield. Cover crop biomass was not measured in this trial.

Table 1. Management details for Trial 1, Alburgh, VT, 2024.

Location	**Borderview Research Farm - Alburgh, VT**
Soil type	Benson rocky silt loam, over shaly limestone, 3-8% slopes
Previous crop	Corn silage
Replicates	4
Corn variety (Relative maturity)	Pioneer P8602AM (86 day)
Corn planting date	16-May
Tillage operations	Pottinger TerraDisc
Corn row widths (inches)	20, 30, 36, 40, 60
Target corn population (plants ac^{-1})	30,000
Herbicide (ac^{-1})	Glystar Plus (1qt) and Resolve® Q (1.5oz) on 28-May
Top dress fertilizer (lbs ac^{-1})	30-0-20 (300) plus ContaiN MAX™; 17-Jun
Date of interseeding	13-Jun
Cover crop seeding rate (lbs ac^{-1})	
Cover crop mixture	Annual ryegrass (60%) Red clover (30%) Tillage radish (10%)
Corn harvest date	12-Sep

The dried forage subsamples were ground to 2mm using a Wiley sample mill and then to 1mm using a cyclone sample mill (UDY Corporation). The samples were analyzed at the E. E. Cummings Crop Testing Laboratory at the University of Vermont (Burlington, VT) with a FOSS NIRS (near infrared reflectance spectroscopy) DS2500 Feed and Forage analyzer. The NIR procedures and corn silage calibration from Dairy One Forage Laboratories (Geneva, NY) were used to determine crude protein (CP), starch, ash corrected neutral detergent fiber (aNDFom), net energy lactation (NE_L), and neutral detergent fiber digestibility (NDFD; 30h). Milk per acre and milk per ton of harvested feed are two measurements used to combine yield with quality and arrive at a benchmark number indicating how much revenue in milk can be produced from an acre or a ton of corn silage. This calculation relies heavily on the NE_L calculation and can be used to generalize about data, but other considerations should be analyzed when including milk per ton or milk per acre in the decision-making process.

Trial 2- The impact of corn row width and population on silage productivity

The experimental design for Trial 2 was a randomized complete block with three replicates (Table 2). Corn was planted in 30” and 60” rows at populations ranging from 28,000 to 36,000 seeds ac^{-1}. Each plot was assigned a row width and a target population. Treatment descriptions are in Table 3. Plots were 20’ long and consisted of 4 rows. To accommodate wider row spacing, plot size was adjusted based on the corn row width. Plots were 10’ wide for 30” row spacing and 20’ wide for 60” row spacing.

Corn was planted on 16-May using a 4-row cone planter with John Deere row units fitted with Almaco seed distribution units (Nevada, IA). All plots were interseeded with a cover crop mixture of annual ryegrass (60%), red clover (30%) and tillage radish (10%). To control weeds, all plots were treated with 1 qt ac^{-1} of Glystar Plus and 1.5 oz ac^{-1} of Resolve® Q on 28-May. On 17-Jun, plots were top-dressed with 30-0-20 plus the inhibitor ContaiN MAX™ at a rate of 300 lbs ac^{-1}. Corn was harvested on 4-Sep as noted in Trial 1. An approximate 1 lb representative subsample was collected for each row width, weighed, dried, and weighed again to determine dry matter content. The dried forage subsamples were ground and analyzed as described in Trial 1. On 11-Oct, ground cover from the interseeded cover crop in each plot was measured using the Canopeo smartphone application. Cover crop biomass was not measured.

Table 2. Trial management details for Trial 2, Alburgh, VT, 2024.

Location	**Borderview Research Farm - Alburgh, VT**
Soil type	Benson rocky silt loam, over shaly limestone, 3-8% slopes
Previous crop	Corn silage
Replicates	4
Corn variety (Relative maturity)	Pioneer P8602AM (86 day)
Corn planting date	16-May
Tillage operations	Pottinger TerraDisc™
Corn row widths (inches)	30 and 60
Corn populations (thousand plants ac^{-1})	28, 30, 32, 34, and 36
Herbicide (ac^{-1})	Glystar Plus (1qt) and Resolve® Q (1.5oz) on 28-May
Top dress fertilizer (lbs ac^{-1})	30-0-20 (300) plus ContaiN MAX™; 17-Jun
Date of interseeding	13-Jun
Cover crop seeding rate (lbs ac^{-1})	
Cover crop mixture	Annual ryegrass (60%) Red clover (30%) Tillage radish (10%)
Corn harvest date	4-Sep

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 genetics, soil, weather, and other growing conditions can result in variations in yield and quality. Statistical analysis makes it possible to determine whether a difference between treatments is significant or whether it is due to natural variations in the plant or 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. This means that when the difference between two treatments within a column is equal to or greater to the LSD value for the column, there is a real difference between the treatments 90% of the time. Treatments within a column that have the same letter are statistically similar. In this example, treatment C was significantly different from treatment A, but not from treatment B. The difference between C and B is 1.5, which is less than the LSD value of 2.0 and so these treatments were not significantly different in yield. The difference between C and A is equal to 3.0, which is greater than the LSD value of 2.0 indicating the yields of these treatments were significantly different from one another. The letter 'a' indicates that treatment B was not significantly lower than the top yielding treatment, indicated in bold.

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 Instrument Vantage Pro2 weather station, equipped with a WeatherLink data logger at Borderview Research Farm in Alburgh, VT (Table 3). Conditions were warm and dry at planting and through the rest of May. However, for the rest of the summer temperatures remained approximately normal with above normal precipitation although less severe than in the 2023 growing season. But excessive rainfall persisted from June through August and there was a total of 24.0 inches of precipitation accumulated over the course of the trial period, 4.7 inches above normal. With warmer temperatures than in 2023, a total of 2707 Growing Degree Days (GDDs) accumulated, which is 158 GDDs more than the 30-year average.

Table 3. Weather data for Alburgh, VT, 2024.

Alburgh, VT	May	June	July	August	Sept
Average temperature (°F)	61.9	68.5	73.7	69.2	64.7
Departure from normal	3.47	0.95	1.33	-1.45	2.02
Precipitation (inches)	2.27	6.65	6.67	5.78	2.61
Departure from normal	-1.49	2.39	2.61	2.24	-1.06
Growing Degree Days (50-86°F)	388	548	732	595	444
Departure from normal	87	25	37	-47	56

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.

<u>Trial 1- The impact of corn row width on silage productivity</u>

Corn harvest characteristics for Trial 1 are summarized in Table 4. Corn silage yield did not vary significantly across row spacing treatments ranging from 18.9 to 25.0 tons ac^{-1} and averaging 21.5 tons ac^{-1}. Spacing did significantly impact corn quality in respect to crude protein, fiber, starch content, and net energy contents. Crude protein was highest in the 40" treatment at 7.95%, however, this was statistically similar to the 36" and 60" treatments. Crude protein was the lowest in the 20" treatment at 7.28%. Interestingly, the fiber contents were lowest in the 20" treatment but were similar to the 30" and 60" treatments. While there were differences in fiber content, there were no differences in fiber digestibility across the spacing treatments. Starch content was highest in the 20" treatment at 42.9% but was statistically similar to the 30" treatment. With these differences in quality parameters, the 20" treatment had the highest net energy of lactation content at 0.723 Mcal lb^{-1} and the highest predicted milk production potential at 3511 lbs ton^{-1}. These were statistically higher than all other spacing treatments.

Table 4. Corn harvest and quality characteristics for Trial 1, Alburgh, VT, 2024.

Treatment	Yield, 35% DM	CP	ADF	aNDFom	Starch	30-hr NDFD	NE_L	Milk	
	tons ac^{-1}	--------------% of DM----------------				% of NDF	Mcal lb^{-1}	lbs. ton^{-1}	lbs. ac^{-1}
20	**25.0**	7.28c†	**18.4a**	**32.0a**	**42.9a**	**53.7**	**0.723a**	**3511a**	**30727**
30	23.9	7.38bc	20.1ab	34.5ab	39.7ab	52.8	0.694b	3365b	28111
36	18.9	7.88a	20.8bc	36.1bc	38.5bc	51.8	0.689bc	3321b	21748
40	19.1	**7.95a**	22.6c	38.7c	36.2c	51.5	0.668c	3256b	21624
60	20.6	7.78ab	19.8ab	34.9ab	39.5b	53.6	0.694b	3360b	24202
LSD (p = 0.10)‡	NS§	0.454	2.21	3.23	3.14	NS	0.023	127	NS
Trial mean	21.5	7.65	20.3	35.2	39.3	52.7	0.694	3363	25283

†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.

<u>Trial 2- The impact of corn row width and population on silage productivity and cover crop establishment</u>

In this trial, when comparing just two row spacings, 30- and 60-inch, yields were significantly greater when the typical 30-inch row spacing was used regardless of plant population (Table 5). Yields were reduced by 9 tons ac^{-1} when spacing was increased to 60 inches. However, we know that light infiltration through the canopy increases with increasing row spacing so interseeded cover crops would have greater access to light in these wider row spacings. Post-harvest assessments of cover crop ground cover, however, found no statistical difference between the two treatments suggesting that increasing row spacing did not significantly improve cover crop establishment. Interseeding success remains variable even when row spacings are increased to maximize light infiltration.

Table 5. Corn harvest and cover crop characteristics by row spacing treatment, Alburgh, VT, 2024.

Row spacing	Yield, 35% DM	Ground cover
	tons ac^{-1}	%
30-inch	**25.4a**†	**51.6**
60-inch	16.3b	35.7
LSD (p = 0.10)‡	1.63	NS§
Trial mean	20.8	43.7

†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.

Corn quality metrics also did not differ significantly between the two spacing treatments (Table 6). The row spacing alone did not impact the plants' ability to produce ears or biomass that would translate into different protein, fiber, or energy concentrations. The difference in predicted milk yield per acre is due to the difference in silage yield shown in Table 5.

Table 6. Corn quality by row spacing treatment, Alburgh, VT, 2024.

Row spacing	CP	ADF	aNDFom	Starch	30-hr NDFD	NE_L	Milk	
	--------------% of DM----------------				% of NDF	Mcal lb^{-1}	lbs. ton^{-1}	lbs. ac^{-1}
30-inch	**7.01**	**24.1**	**41.2**	**35.2**	50.7	**0.652**	**3172**	**28166a**†
60-inch	6.92	25.0	42.8	34.2	**51.6**	0.642	3162	18061b
LSD (p = 0.10)‡	NS§	NS	NS	NS	NS	NS	NS	2014
Trial mean	6.96	24.6	42	34.7	51.2	0.647	3167	23114

†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.

Corn population also did not significantly impact corn yield or cover crop ground cover regardless of row width (Table 7). Yields decreased by approximately 2 tons ac^{-1} when populations were reduced to 32,000 or less, but were statistically similar to the higher population treatments. Similarly, ground cover was similar across populations varying little from 40.9 to 46.7%. Corn quality also did not differ by population treatment regardless of row width (Table 8). As populations increase, competition may impact ear development, size, and thus corn quality. However, this was not observed in this trial.

Table 7. Corn and cover crop characteristics by population treatment, Alburgh, VT, 2024.

Population	Yield, 35% DM	Ground cover
	tons ac^{-1}	%
28,000	20.0	**46.7**
30,000	20.6	42.3
32,000	20.0	40.9
34,000	21.4	44.2
36,000	**22.1**	44.3
LSD (p = 0.10)‡	NS†	NS
Trial mean	20.8	43.7

‡LSD; least significant difference at the p=0.10); top performer is in **bold.**
†NS; no significant difference between treatments.

Table 8. Corn quality by population treatment, Alburgh, VT, 2024.

Population	CP	ADF	aNDFom	Starch	30-hr NDFD	NE_L	Milk	
	--------------% of DM----------------				% of NDF	Mcal lb^{-1}	lbs. ton^{-1}	lbs. ac^{-1}
28,000	**7.01**	25.1	42.8	33.6	**51.8**	0.644	3166	22280
30,000	7.01	26.0	44.1	31.8	51.5	0.630	3112	22376
32,000	6.95	23.8	40.9	35.6	51.7	0.654	**3200**	22457
34,000	6.99	24.4	41.6	35.3	50.4	0.650	3181	23917
36,000	6.85	**23.6**	**40.6**	**37.2**	50.4	**0.656**	3175	**24537**
LSD (p = 0.10)‡	NS†	NS	NS	NS	NS	NS	NS	NS
Trial mean	6.96	24.6	42	34.7	51.2	0.647	3167	23114

‡LSD; least significant difference at the p=0.10; top performer is in **bold.**
†NS; no significant difference between treatments.

DISCUSSION

Trial 1 investigated the productivity of corn silage grown in 20”, 30”, 36”, 40”, and 60” rows. With populations held constant at 30,000 plants ac^{-1} across all row widths, there were no statistical differences in yield between row width treatments. The 20” treatment significantly reduced the protein content but increased starch, energy content, and milk potential per ton compared to wider row spacings. To achieve a target population of 30,000 plants ac^{-1} with 60” row widths, corn is planted at a rate of 60,000 seeds ac^{-1}, increasing the density of plants within a row. Corn plants may alter growth characteristics like plant height and ear development, thus impacting corn silage quality. While the number of plants on a per acre basis is the same (i.e. 30,000 plants ac^{-1}), there are 2X as many plants within a 60” compared to a 30” row. In previous years, this density has negatively impacted silage yields, however, that was not observed in 2024.

Trial 2 investigated the impact of row width and population on silage productivity. Corn silage yield and quality were not significantly different across populations ranging from 28,000 to 36,000 plants ac^{-1}. This suggests that farmers could incorporate wider row spacings into their corn silage systems without negatively impacting corn silage yield or quality. However, cover crop establishment, which would be the main benefit to increasing row spacing when interseeding, was not significantly increased. It is important to remember that these data represent only one year at one location.

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