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SARE Interseeding Cover Crops in Corn Silage Cropping Systems

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INTERSEEDING COVER CROPS IN CORN SILAGE CROPPING SYSTEMS

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With increasing focus on minimizing environmental impacts from agriculture, farmers are looking for strategies that are good for farm and environmental viability. Cover cropping is one strategy that has been promoted to help farms improve soil health and minimize soil and nutrient losses to the environment. However, with a short growing season it is often difficult to get an adequate cover cropping following corn silage harvest. Therefore, farmers are interested in using interseeding techniques to establish cover crops into an actively growing corn crop. Being successful with this practice will likely require changes to other aspects of the cropping system such as corn populations, corn relative maturity, and the timing of cover crop seeding. The University of Vermont Extension's Northwest Crops and Soils Team implemented two field experiments in 2020 to help identify best interseeding practices that support successful cover crop establishment without sacrificing corn silage yields.

MATERIALS AND METHODS

The field trials were conducted at Borderview Research Farm in Alburgh, VT (Tables 1 and 2). Trial 1 evaluated the impact of corn variety and population on cover crop establishment and corn yields. Trial 2 evaluated the impact interseed timing on cover crop establishment and corn yields. All plots were 10' x 20', consisting of four rows of corn spaced 30" apart, and replicated three times.

The experimental design for Trial 1 was a randomized complete block with split plot design. Main plots were corn population (28,000, 34,000, and 38,000 plants ac^{-1}) and split plots were corn varieties. The plots were interseeded with a cover crop mixture of annual ryegrass (60%), tillage radish (10%) and red clover (30%) when the corn reached the V6 growth stage. In Trial 2, the experimental design was a randomized complete block design where treatments were interseed timing (V2, V4, and V6 corn growth stages).

Corn was planted on 13-May and 6-May in Trial 1 and 2 respectively. In Trial 1, plots were originally seeded at 40,000 seeds ac^{-1} and thinned to the appropriate treatment populations on 9-Jun. The amount of photosynthetic active radiation (PAR) reaching the ground under the corn canopy was measured using a LI-COR LI-191R line quantum light sensor equipped with a LI-1500 data logger. Light was measured approximately weekly from the time of interseeding through August. To understand how much the corn canopy was obstructing the total available light, a light measurement was taken outside of the corn canopy and then under the corn canopy in the center of each plot. The data were then used to calculate the percent of light infiltrating the corn canopy. Corn was harvested 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. The samples from Trial 1 were then ground to 2mm using a Wiley sample mill and then to 1mm using a cyclone sample mill (UDY Corporation). The samples were analyzed for forage quality via Near Infrared Reflectance Spectroscopy at the UVM Cereal Grain Testing Laboratory (Burlington, VT) using a FOSS DS2500 NIRS. No quality analyses were conducted on the corn from Trial 2.

Following harvest, on 20-Oct, ground cover was measured in Trial 1 by processing photographs using the Canopeo© smartphone application. On 27-Oct, cover crop biomass was measured by collecting biomass within a 0.25m^2 area in each plot in the trial. Samples were weighed and dried to determine dry matter content and calculate yield. The samples were also ground using the same procedures for the corn samples and analyzed for %C, %N, and C:N ratio at the University of Vermont Agricultural and Environmental Testing Laboratory (Burlington, Vermont). In Trial 2, cover crop establishment and growth post-harvest was minimal with higher weed incidence than in Trial 1. In order to capture the ground cover contributed by cover crops and weeds separately, ground cover in this trial was measured using the beaded string method on 28-Sep. Cover crops were too small to collect biomass samples and therefore, yield and quality is not reported.

Table 1. Trial 1 management, Alburgh, VT, 2020.

Location	Borderview Research Farm – Alburgh, VT	
Soil type	Cabot extremely stony fine sandy loam	
Corn variety treatments (relative maturity)	B94T73R (94RM) B94T73SX (94 RM) B97T04SXE (97 RM) CP3499VT2P (94 RM) P9608R (96 RM)	SW3768 (95 RM) SW4010 (100 RM) 38N85 (92 RM) 9070AM (90 RM)
Corn population treatments (plants ac^{-1})	28,000 34,000 38,000	
Corn planting date	13-May	
Cover crop mixture	25 lbs ac^{-1} Annual ryegrass (60%) Red clover (30%) Tillage radish (10%)	
Cover crop planting date	22-Jun	
Harvest date	17-Sep	

Table 2. Trial 2 management, Alburgh, VT, 2020.

Location	Borderview Research Farm – Alburgh, VT
Soil type	Cabot extremely stony fine sandy loam
Interseed timing treatments (dates of interseeding)	V2 (2-Jun) V4 (10-Jun) V6 (22-Jun)
Corn planting date	6-May
Cover crop mixture	25 lbs ac^{-1} Annual ryegrass (60%) Red clover (30%) Tillage radish (10%)
Harvest date	9-Sep

Data were analyzed using mixed model analysis using the mixed procedure of SAS (SAS Institute, 1999). Replications in the trial were treated as random effects and treatments were treated as fixed. Mean comparisons were made using the Tukey-Kramer adjustment procedure when the F-test was considered significant (p<0.10). Because few significant interactions were observed between year and other variables, data were combined across years prior to the employing the mean comparisons procedure.

RESULTS

Weather data was recorded with a Davis Instrument Vantage Pro2 weather station, equipped with a WeatherLink data logger at Borderview Research Farm in Alburgh, VT (Table 3). The season began with cooler than normal temperatures, but temperatures quickly increased and remained above normal for much of the season. Rainfall was below normal for much of the season with the region being designated as D0 or abnormally dry (Drought.gov) throughout the season. Much of the rain that fell throughout the season came in short duration storms. For example, in August there were only 6 rain events that accumulated at least 0.1". Of these, 2 events totaled 1.53" and 2.98", contributing 67% of the month's entire accumulation. Furthermore, temperatures remained above normal for much of the mid-summer. In July, of 75% of the month saw temperatures climb above 80° F with some days reaching above 90° F. These temperatures contributed to above normal Growing Degree Days (GDDs) accumulations of 2485, 140 above the 30-year normal.

Table 3. 2020 weather data for Alburgh, VT.

	May	Jun	Jul	Aug	Sep
Average temperature (°F)	56.1	66.9	74.8	68.8	59.2
Departure from normal	-0.44	1.08	4.17	0.01	-1.33
Precipitation (inches)	2.35	1.86	3.94	6.77	2.75
Departure from normal	-1.04	-1.77	-0.28	2.86	-0.91
Growing Degree Days (base 50°F)	298	516	751	584	336
Departure from normal	6	35	121	2	-24

Based on weather data from a Davis Instruments Vantage Pro2 with WeatherLink data logger.
Historical averages are for 30 years of NOAA data (1981-2010) from Burlington, VT.

Trial 1 – Impact of Corn Population and Variety

Interactions

There was only one significant interaction between main effects (Table 4). A significant interaction between corn population and variety for cover crop dry matter yield indicates that the cover crop produced differing amounts of biomass when interseeded into the same corn variety planted at different populations. Figure 1 displays these differences. For most varieties, a lower seeding rate resulted in higher cover crop biomass; however, 38N85, 9070AM, and SW4010 did not follow this trend. These 3 varieties had similar or higher cover crop biomass when corn populations were higher. This may be due to plant architecture. The lack of other significant interactions indicates that corn varieties responded similarly in terms of yield and quality parameters when planted at different populations.

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

	Population	Variety	Population x Variety
Population	***	NS	NS
Corn yield	**	***	NS
Fall ground cover	***	*	NS
Cover crop dry matter	*	NS	NS
Cover crop yield	***	NS	*
Corn dry matter	NS	***	NS
Corn crude protein	NS	***	NS
Corn ADF	NS	*	NS
Corn NDF	NS	*	NS
Corn NFC	NS	NS	NS
Corn lignin	NS	**	NS
Corn ash	NS	*	NS
Corn fat	NS	***	NS
Corn starch	NS	**	NS
Corn digestible starch	NS	***	NS
Corn WSC	NS	*	NS
Corn uNDF30	NS	***	NS
Corn uNDF120	NS	***	NS
Corn uNDF240	NS	***	NS
Corn TDN	NS	**	NS
Corn NEL	NS	**	NS
Corn VFA	NS	***	NS
Milk yield (lbs ton^{-1})	NS	**	NS
Milk yield (lbs ac^{-1})	**	***	NS

* 0.1 < p > 0.05
** 0.05 < p > 0.01
*** p < 0.01
NS- Not statistically significant

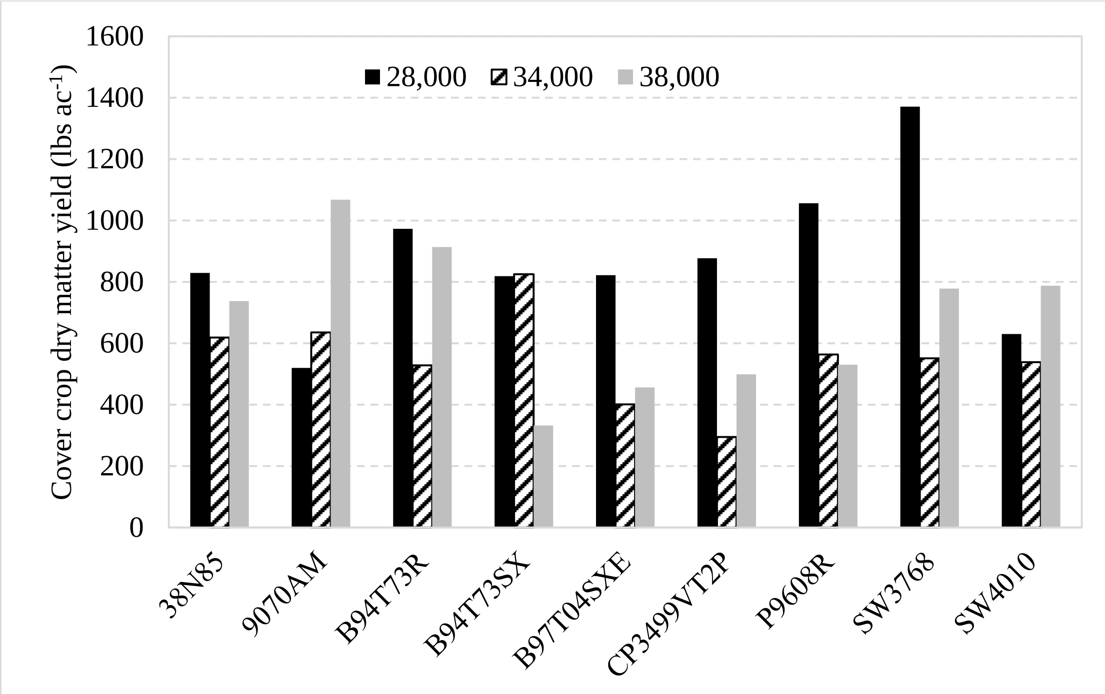

Figure 1. Population x variety interaction for cover crop dry matter yield.

Impact of Population

Corn population significantly impacted yield (Figure 2). Corn yields were significantly lower when populations of 28,000 and 34,000 plants ac^{-1} were used compared to 38,000. However, no additional yield benefit was observed from increasing from 28,000 to 34,000 plants ac^{-1}. Population did not impact corn silage quality.

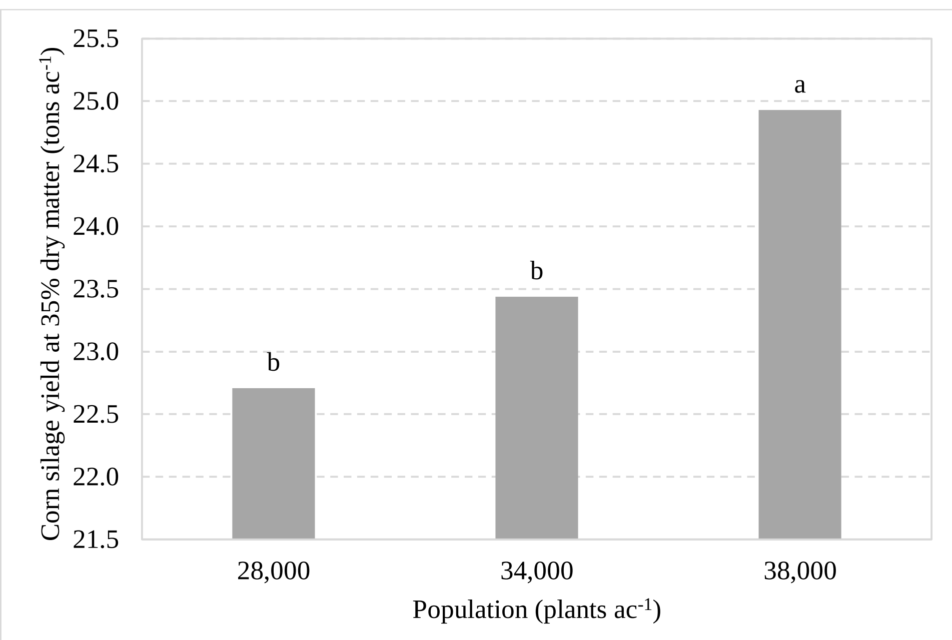

Figure 2. Corn silage yield by plant population.
Treatments that share a letter performed statistically similarly to one another.

By two weeks after cover crop interseeding, the corn canopy had significantly closed reducing approximately 80% of the potential light infiltrating to the ground (Figure 3). Therefore, the newly planted cover crop had approximately 2-3 weeks from the time of seeding to germinate and establish prior to full canopy closure, in which very little light penetrated to the ground level for the remainder of the season. This demonstrates the challenge interseeding presents as any delay in seed germination or establishment (i.e. limited moisture, low vigor, etc.) significantly reduces the time available to the cover crop to properly establish increasing the chance of survival through the rest of the growing season.

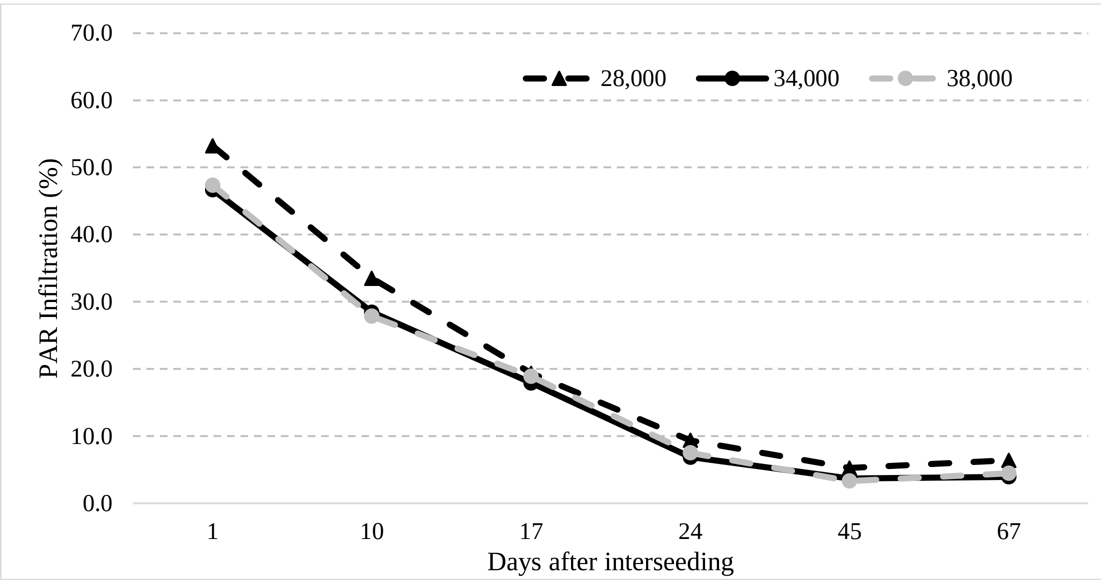

Figure 3. PAR infiltration over the season across corn populations.

Cover crop establishment also differed significantly by population (Table 5). Cover crops produced higher ground cover and biomass when interseeded into lower corn population stands. Ground cover significantly increased from 23.7% to 42% when populations were reduced below 34,000 plants ac^{-1}. However, ground cover was not further impacted when populations increased from 34,000 to 38,000 plants ac^{-1}. Similarly, cover crops produced over 300 lbs ac^{-1} more biomass when interseeded into corn at 28,000 plants ac^{-1} compared to corn at 34,000 plants ac^{-1}. Cover crop biomass was not further impacted when populations were increased from 34,000 to 38,000 plants ac^{-1}.

Table 5. Cover crop characteristics by population.

Population	Ground cover	Cover crop dry matter	Cover crop dry matter yield
plants ac^{-1}	%	%	lbs ac^{-1}
28,000	42.0a†	10.9b	877a
34,000	23.7b	12.3a	551b
38,000	25.6b	11.9ab	678b
LSD (p=0.10)‡	5.67	1.13	134
Trial Mean	30.4	11.7	702

†Treatments that share a letter performed statistically similarly to one another.
‡LSD; least significant difference at the p=0.10 level.

Impact of variety

Variety significantly impacted corn yield and quality parameters (Tables 6 and 7). Corn silage yields ranged from 20.7 to 27.9 tons ac^{-1} with the top performing variety, B94T73R, yielding similarly to only one other variety, B94T73SX. Crude protein (CP) averaged 8.23% with the top performing variety, 38N85, containing 8.80% protein. Protein levels were decent despite dry conditions that could limit nitrogen availability and negatively impact protein levels. Acid detergent fiber (ADF) and neutral detergent fiber (NDF) contents averaged 23.4% and 41.0% respectively. The lowest ADF and NDF contents were produced by variety B97T04SXE which had 21.1% ADF and 37.8% NDF. Four other varieties also performed statistically similarly to this variety in terms of both ADF and NDF content. Starch varied widely by variety ranging from 27.8% to 36.2% with the top performing variety, B97T04SXE, containing 3.6% more starch than the next highest variety. Water soluble carbohydrates (WSC) ranged from 5.99% to 7.81%. Total digestible nutrients (TDN) ranged from 61.9% to 64.6% with four other varieties performing similarly to the top performer. uNDF240 is the portion of the NDF fiber that remains undigested after 240 hours of exposure to rumen fluid. uNDF240 ranged from 10.2% to 12.8%. Net energy of lactation (Nel) ranged from 0.625 to 0.679 Mcal lb^{-1}.

Table 6. Corn silage quality parameters by variety.

Variety	Yield at 35% dry matter	CP	ADF	NDF	Lignin	Ash	Fat	Starch	WSC	TDN	uNDF240	Nel
	tons ac^{-1}					% of DM					% of NDF	Mcal lb^{-1}
B94T73R	**27.9**	8.01	24.8	42.7	3.13	4.55	2.99*	29.7	7.21*	63.2	12.2	0.647
B94T73SX	25.6*	8.06	26.0	44.5	3.28	4.83	2.66	27.8	6.76	61.9	12.8	0.625
B97T04SXE	24.2	8.19	**21.1**	**37.8**	**2.73**	**4.11**	**3.25**	**36.2**	5.99	**64.6**	**10.2**	**0.679**
CP3499VT2P	23.6	8.12	24.7	42.3	3.01*	4.75	2.87	30.4	6.83	62.8	11.7	0.641
P9608R	23.1	8.39	23.0*	40.1*	2.95*	4.61	3.20*	32.6*	6.59	63.8*	10.5*	0.664*
SW3768	23.2	8.47*	22.6*	39.8*	2.83*	4.87	3.10*	31.1	**7.81**	64.1*	11.0*	0.665*
SW4010	21.6	8.04	24.2	42.1	2.98*	4.85	2.66	30.5	6.93	62.8	12.0	0.641
38N85	20.7	**8.80**	21.7*	38.7*	2.79*	4.56	3.20*	32.3	6.93	64.2*	10.6*	0.671*
9070AM	23.3	7.94	22.9*	40.8*	2.82*	4.56	2.86	32.3	7.32*	63.7*	11.5	0.659*
LSD (p=0.10)	2.30	0.374	2.66	3.62	0.289	0.401	0.286	3.78	0.859	1.32	1.06	0.026
Trial Mean	23.7	8.23	23.4	41.0	2.95	4.63	2.98	31.4	6.93	63.4	11.4	0.655

* Varieties with an asterisk performed statistically similarly to the top performer in **bold**

Translating corn silage yield and quality into predicted milk yield outcomes can be a helpful way to compare corn silage varieties. Table 7 below shows the predicted milk yield per dry matter ton of corn silage and per acre of corn silage. Both these parameters varied by variety. The highest milk yield per ton of 3405 lbs ton^{-1} was produced by variety B97T04SXE which was statistically similar to four other varieties. The highest milk yield per acre of 31808 lbs ac^{-1} was produced by variety B94T73R which was significantly higher than all other varieties. A comparison between varieties for these two milk yield indicators can be visualized in Figure 4. Varieties falling into the top left quadrant would indicate higher than average yield but lower than average quality. Varieties falling in the bottom right quadrant would indicate higher than average quality but lower than average yield. Varieties falling in the bottom left quadrant would indicate lower than average yield and quality whereas varieties falling in the top right quadrant would indicate higher than average yield and quality. Comparing varieties in this way we can see that variety B97T04SXE was the only variety that performed above average in both yield and quality.

Table 7. Predicted milk yield by variety.

Variety	Milk yield	
	lbs ton^{-1}	lbs ac^{-1}
B94T73R	3275	**31808**
B94T73SX	3175	28534
B97T04SXE	**3405**	28935
CP3499VT2P	3267	27015
P9608R	3359*	27125
SW3768	3369*	27366
SW4010	3238	24617
38N85	3402*	24599
9070AM	3298*	26843
LSD (p=0.10)	111	2756
Trial Mean	3310	27427

* Varieties with an asterisk performed statistically similar to the top performer in **bold.**

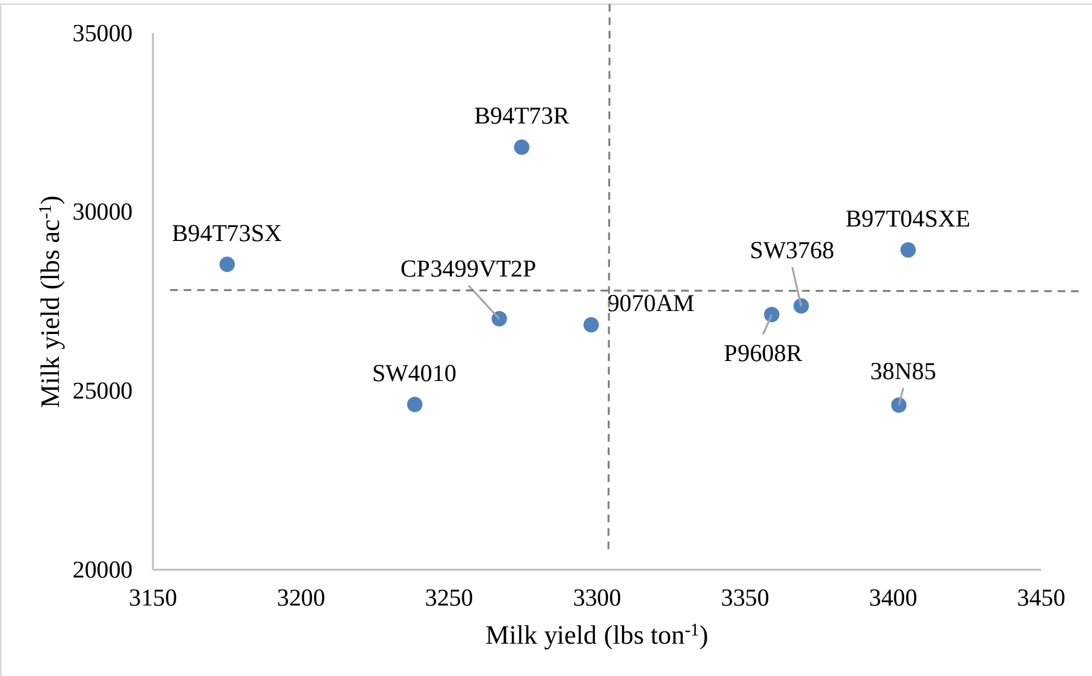

Figure 4. Predicted milk yield per ton vs milk yield per acre by variety.

Post-harvest ground cover was also significantly impacted by corn variety, however, cover crop biomass was not (Table 8). Ground cover ranged from 20.2% in plots with variety CP3499VT2P to 38.4% in plots with variety SW3768. Interestingly, high corn yield was not clearly associated with lower ground cover. For example, the second highest yielding variety, B94T73SX, had a statistically similar level of ground cover as variety SW3768 which had the highest ground cover but yielded almost 2.5 tons ac^{-1} less than

B94T73SX. This is important as it demonstrates that interseeding cover crops can be successful without compromising the yield of the corn crop (Figure 5).

Table 8. Cover crop characteristics by variety.

Variety	Ground cover	Cover crop dry matter yield
	%	lbs ac^{-1}
B94T73R	26.5bcd	805
B94T73SX	31.1abc	658
B97T04SXE	24.7cd	560
CP3499VT2P	20.2d	557
P9608R	36.0ab	717
SW3768	**38.4a**	**900**
SW4010	29.3abcd	652
38N85	32.7abc	728
9070AM	35.0ab	741
LSD (p=0.10)	9.82	NS
Trial Mean	30.4	702

Treatments that share a letter performed statistically similarly to one another.
The top performing treatment is indicated in **bold**.
NS – No significant difference.

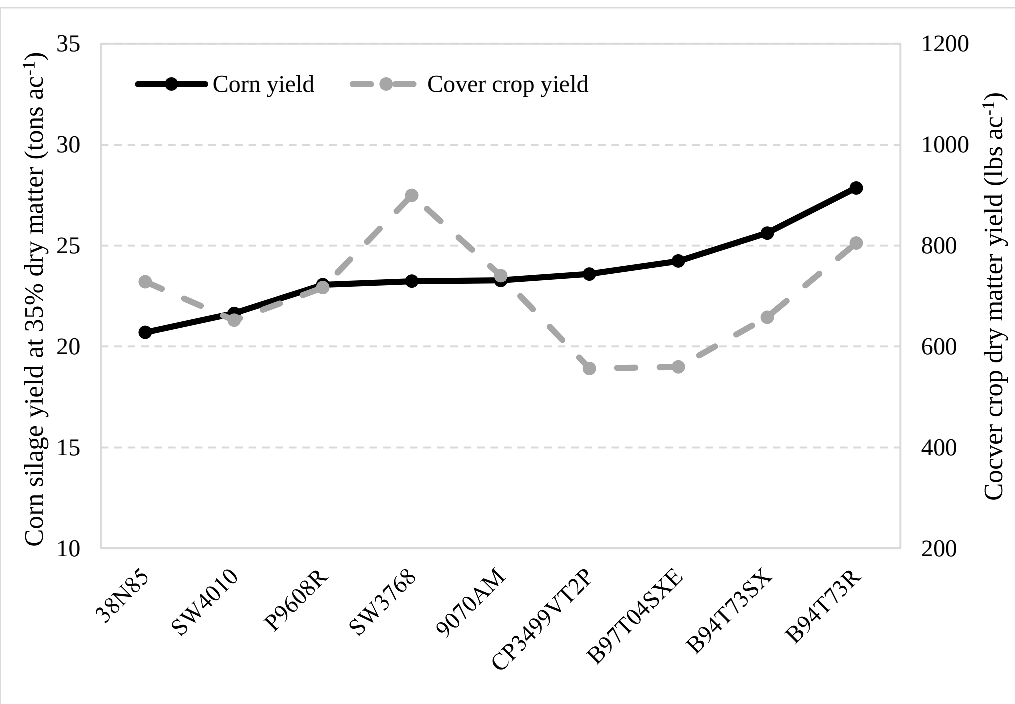

Figure 5. Corn silage and cover crop yield by variety.

Trial 2 – Impact of Cover Crop Interseed Timing

Deciding when to interseed a cover crop is challenging. On one hand you want to allow the cover crop time to establish before the corn blocks the light, but on the other hand, you don't want the cover crop to compete with the establishing corn for resources. In addition, you want to make sure that corn herbicides do not impact the interseeded cover crop. Generally, corn can be interseeded anywhere from the V2 to V6 growth stage. After V6, most interseeding equipment is not tall enough, increasing the risk of damaging the corn crop.

Light available at the time of interseeding varied dramatically across the timing treatments (Figure 6). The arrows indicate the date the corn was interseeded corresponding to the V2, V4, and V6 growth stages. At the V2 and V4 growth stages, virtually none of the PAR was being obstructed by the corn canopy. However, by the time the corn reached the V6 stage, the canopy was already obstructing almost 50% of the light. Light infiltration continued to decline by approximately 10% each week until only 10% of the total light was infiltrating the canopy. This is the level that remained through the remainder of the season.

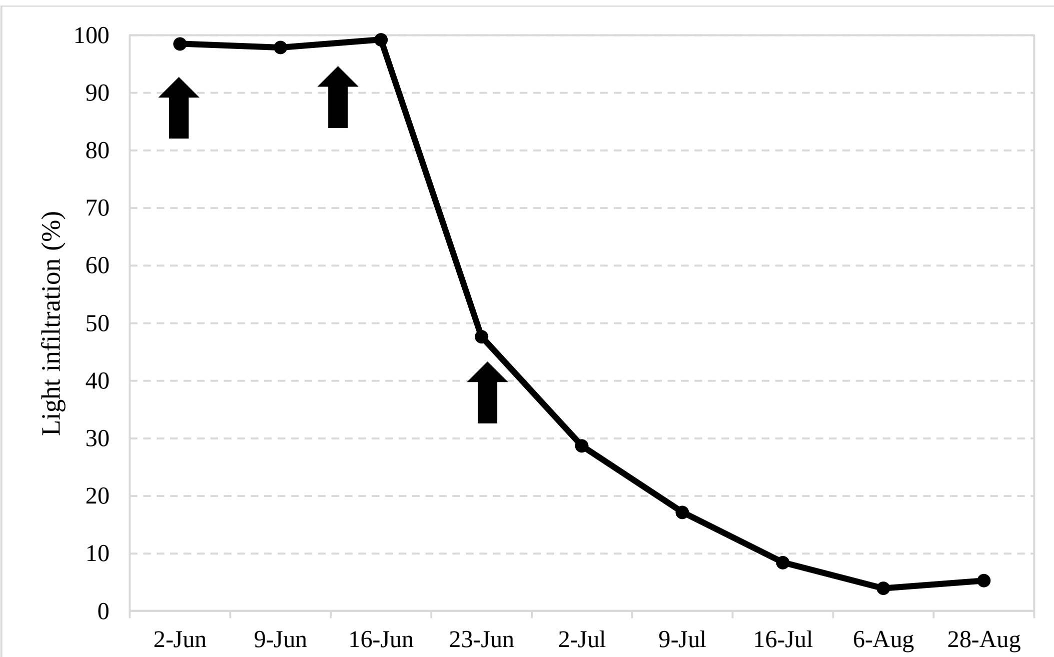

Figure 6. PAR across the season. *Arrows indicate the V2, V4, and V6 growth stages at which cover crops were interseeded.*

Despite the significant reduction in light available to the germinating cover crop in later interseedings, all timings supported similar cover crop establishment (Table 9). Post-harvest ground cover averaged 29.2% across the three timings and did not differ statistically. However, the majority of the ground cover was contributed by weeds, not interseeded cover crop species. This suggests that weed pressure throughout the season may have contributed to poor cover crop establishment and performance. As shown in Image 1, the dominant species that established and survived was the tillage radish. This is likely due to its large taproot that allowed it to access the limited moisture in the soil that the clover and annual ryegrass could not. Its wide leaves also allow it to compete for light resources better than the other species. Although the cover crops were assessed approximately 20 days after the corn was harvested, cover crop biomass was still too small to adequately sample. The corn in the trial yielded well averaging 23.7 tons ac^{-1} and did not vary across interseed timings. It is important to note that no damage was caused to the corn crop either from equipment at later interseedings or competition from the cover crop.

Table 9. Corn and cover crop characteristics by interseed timings, 2020.

Interseed timing	Yield at 35% dry matter	Dry matter	Ground cover		
	tons ac^{-1}	%	% cover crop	% weeds	Total %
V2	22.9	36.8	**6.55**	28.3	**34.8**
V4	**24.2**	**36.2**	4.76	23.2	28.0
V6	23.9	37.2	5.95	**18.8**	24.7
LSD (p=0.10)	NS†	NS	NS	NS	NS
Trial Mean	23.7	36.7	5.75	23.4	29.2

†NS; Not statistically significant at the p=0.10 level.

Image 1. Post-harvest cover crop.

DISCUSSION

Interseeding cover crops into corn silage systems is challenging and may have higher success given changes to corn variety selection, populations, and the timing of interseeding. Determining the best combination of characteristics that support high yielding corn crops, and successful cover crops, requires multiple years of data to better understand how these variables interact under varying conditions. More data needs to be collected to better understand the interaction of these corn hybrid characteristics with crop management.

ACKNOWLEDGEMENTS

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