Interseeding Cover Crops into Wide-Row Corn Silage

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2020 INTERSEEDING COVER CROPS INTO WIDE-ROW CORN SILAGE

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There has been increased interest in interseeding cover crops into corn. Cover cropping is a way to prevent soil erosion, maintain and/or improve soil nutrients, improve soil aggregation, prevent nutrient loss from runoff, and increase water retention. Such soil improvements can promote conditions that add resiliency to a crop, especially considering extreme weather patterns that may affect yields. Interseeding can be beneficial by providing year-round ground coverage and maximizing a short growing season by interseeding early to allow for full cover crop growth. It can be difficult to grow a successful cover crop, given other demands from a farm operation and weather limitations. One challenge that farmers face when trying to implement interseeding is establishing the cover crops into dense rows of corn. Shading by corn plants restricts cover crop growth especially as the season progresses. Traditionally, corn is planted in dense 30-in. rows to maximize yields and decrease weed pressure. In 2018 and 2019, Practical Farmers of Iowa has conducted on-farm research trials to study the effect of wide rows (60-inch) on grain corn yields and cover crop biomass. Cover crop biomass was significantly increased when planted into 60-in. corn, but results were mixed when it came to corn yields. Over half the farms saw reduced corn yields in 60-in. corn compared to 30-in. rows (Gailans, 2018, 2019). This innovative practice may be a viable solution for farmers, but research needs to be done in the Northeast to determine the impact of wide rows on corn silage yield and quality, cover crop biomass, and soil health. In 2020, the University of Vermont Extension Northwest Crops and Soils Program conducted the second year of this trial to examine the impact of corn row spacing and population on interseeded cover crop success, as well as corn yield and quality here in the Northeast.

MATERIALS AND METHODS

The trial was conducted at Borderview Research Farm, Alburgh, VT in 2020. The experimental design was a randomized complete block design with split plots and four replications (Table 1). Main plots were 2 row-widths, 30- and 60-inch spacing (Table 2). Subplots were 3 different cover crop treatments, cowpeas, Summer Solar mix, and a mix of annual ryegrass, tillage radish, and red clover; varietal information and seeding rate are provided in Table 3 below. There were 4 rows per plot. To account for the difference in row-width, plots with 30-in. spacing were 10’ x 20’and plots with 60-in. spacing were 20’ x 30’.

Table 1. Wide row corn agronomic and trial information, Alburgh, VT, 2020.

Location	Borderview Research Farm Alburgh, VT
Soil type	Covington silty clay loam
Previous crop	Winter rye
Plant population (seeds ac^{-1})	56,000 – 60 in 32,000 – 30 in 30,000 – 30 in
Corn variety	NK8618 (Roundup Ready) 86RM
Plot size (ft.)	20 x 30 – 60 in. 10 x 30 – 30 in.

Planting date	Corn: 14-May Cover crop: 18-Jun
Tillage operations	Spring disk, spike tooth harrow
Starter fertilizer (at planting)	200 lbs. ac^{-1} 10-20-20
Chemical weed control	1 qt. ac^{-1} Roundup Power Max® and ½ oz. ac^{-1} Resolve® Q, 26-May
Additional fertilizer (side dress)	200 lbs. ac^{-1} 46-0-0, 23-Jun
Harvest date	Corn: 9-Sep

Table 2. Treatment descriptions for wide row corn trial, Alburgh, VT, 2020.

Row widths in.	**Corn populations** plants ac^{-1}
60	56,000
30	30,000 32,000

Table 3. Cover crop information for wide row corn trial, Alburgh, VT, 2020.

Cover crop	**Seeding rate** lbs. ac^{-1}	**Species**
Cowpeas	60	'Iron & Clay' mixed cowpeas
Summer solar mix	60	cowpeas 'Iron & Clay', buckwheat 'VNS', sunn hemp ''VNS', Peredovik sunflower
AR/TR/RC Mix	30	Annual ryegrass, tillage radish, red clover

Plots were planted on 14-May with a 4-row cone planter with John Deere row units fitted with Almaco seed distribution units (Nevada, IA) at a rate of 56,000 seeds ac^{-1}. After planting, plots with 30-in. spacing were thinned to either 30,000 or 32,000 plants ac^{-1} depending on treatment, however there were no statistically significant differences between the two populations. Results presented below represent all plots with 30-inch row spacing, regardless of plant population. Plots with 60-inch spacing were not thinned. Cover crops were interseeded into corn on 18-Jun. Photosynthetic Active Radiation (PAR) was measured using a LI-COR LI-191R Line Quantum Sensor equipped with a LI-1500 GPS (Lincoln, NE) enabled data logger. In each plot two readings were taken, one above the corn canopy to capture the total available sunlight, and one under the canopy at approximately ground level in the center of the plot. These two measurements were used to calculate PAR canopy infiltration (%). On 3-Sep, cover crop samples were taken, by collecting two 0.25 m^2 quadrats per plot in 30-in. plots, and one 0.25 m^2 quadrat per plot in 60-in. plots. Only one quadrat sample was taken from 60-in. plots due to a greater amount of cover crop biomass present. Samples were weighed and dried to determine yield and dry matter content. On 9-Sep, the corn was harvested with a John Deere 2-row chopper and a wagon fitted with scales. An approximate 1 lb. subsample was taken from each plot and dried to calculate dry matter content. The dried subsamples were ground on a Wiley sample mill to a 2mm particle size and to 1mm particle size on a cyclone sample mill from the UDY Corporation. The samples were then analyzed for quality at the University of Vermont Cereal Testing Lab (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, lignin, ash, total fatty acids (TFA), ash corrected neutral detergent fiber (aNDFom), and neutral detergent fiber digestibility (NDFD).

Mixtures of true proteins, composed of amino acids, and non-protein nitrogen make up the crude protein (CP) content of forages. The CP content is determined by measuring the amount of nitrogen and multiplying by 6.25. The bulky characteristics of forage come from fiber. Forage feeding values are negatively associated with fiber since the less digestible portions of plants are contained in the fiber fraction. The detergent fiber analysis system separates forages into two parts: cell contents, which include sugars, starches, proteins, non-protein nitrogen, fats and other highly digestible compounds; and the less digestible components found in the fiber fraction. The total fiber content of forage is contained in the neutral detergent fiber (NDF). Chemically, this fraction includes cellulose, hemicellulose, and lignin. Because of these chemical components and their association with the bulkiness of feeds, NDF is closely related to feed intake and rumen fill in cows. Recently, forage testing laboratories have begun to evaluate forages for NDF digestibility (NDFD). This analysis can be conducted over a wide range of incubation periods from 30 to 240 hours. Research has demonstrated that lactating dairy cows will eat more dry matter and produce more milk when fed forages with optimum NDFD. Forages with increased NDFD will result in higher energy values and, perhaps more importantly, increased forage intakes. Forage NDFD can range from 20 – 80% NDF. Neutral detergent fiber expressed on an organic matter basis (aNDFom) is used when high ash content leads to ash remaining in the fiber residue. Net energy lactation (NEL) is estimated energy value of feed used for maintenance plus milk production during dairy cow lactation or last two months of gestation for dry, pregnant cows.

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, a 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 was recorded with a Davis Instrument Vantage Pro2 weather station, equipped with a WeatherLink data logger at Borderview Research Farm in Alburgh, VT (Table 4). The region experienced drought and warmer than average temperatures this season. While May was cooler than average, from June to August, temperatures were higher than normal. In July, the average temperature in Alburgh, VT was 4.17° F higher than normal. Above average temperatures coincided with little rainfall from May to July. In both May and June, there were periods without rain that lasted nearly two weeks. July was particularly hot and dry. But in August there were a two significant rain events and the average monthly precipitation was 2.86 in. above normal. However, this season's warm conditions did provide optimal Growing Degree Days (GDDs) through the season with a total of 2484 GDDs accumulated May-Sep, 139 above normal.

Table 4. Weather data for Alburgh, VT, 2020.

Alburgh, VT	May	June	July	August	Sept
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 (50-86°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.

Measurements of photosynthetically active radiation (PAR) through the corn canopy to the soil surface was measured four times during the growing season, 16-Jul, 24-Jul, 6-Aug, and 26-Aug 2020. There were significant differences in the percent PAR infiltration between 60-inch and 30-inch row-widths (Figure 1). On all four sample dates, the percent canopy infiltration was significantly higher in 60-inch row spacing. The difference in light infiltration between the 60-inch and 30-inch treatments decreased as the season progressed and corn canopy closed. There were no significant differences in the percent PAR infiltration between cover crop types on the first (16-Jul) and last (26-Aug), sampling dates (Figure 2). The Summer Solar mix had significantly greater PAR infiltration than the other two cover crops on 24-Jul. On 6-Aug, again the Summer Solar mix had the greatest PAR infiltration, but that was statistically similar to the cow peas.

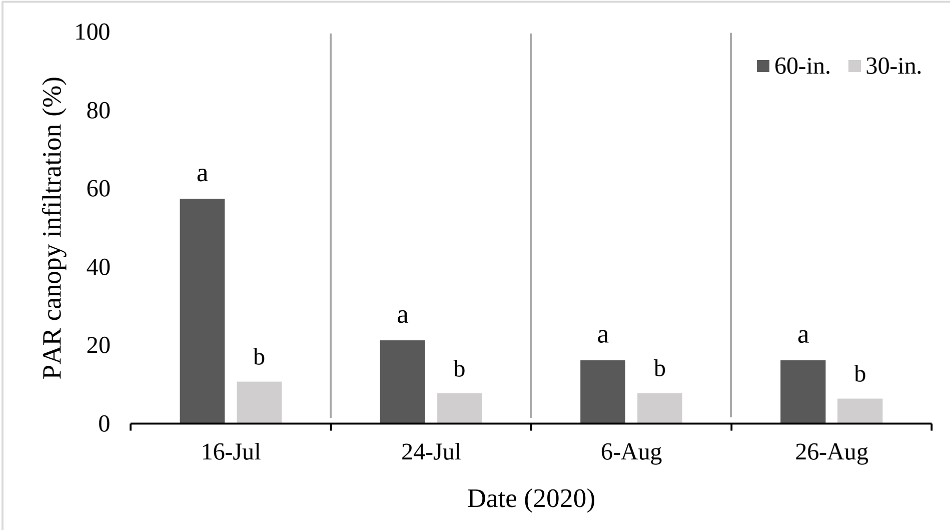

Figure 1. Percent PAR infiltration through corn canopy to soil surface in 60-in. and 30-in. row-widths, Alburgh, VT, 2020. Within a column, treatments marked with different lowercase letters are statistically different (p=0.10).

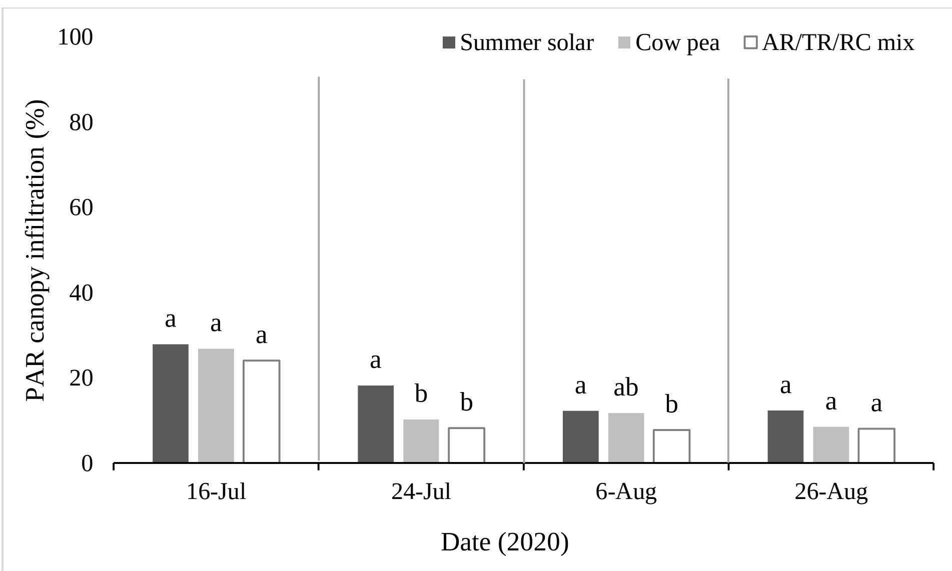

Figure 2. Percent PAR infiltration through corn canopy to soil surface in different interseeded cover crops, Alburgh, VT, 2020. Within a column, treatments marked with different lowercase letters are statistically different (p=0.10).

Soil Health Results

After corn was harvested, soil samples were collected on 22-Sep and were submitted to the Cornell Soil Health Laboratory for the Comprehensive Assessment of Soil Health analysis (Ithaca, NY). Five soil samples within each plot were collected six inches in depth with a 3-inch diameter auger, thoroughly mixed, put in a labeled gallon bag, and mailed to the lab for analysis. Percent aggregate stability was measured by Cornell Sprinkle Infiltrometer and indicates ability of soil to resist erosion. Active carbon (mg C kg^{-1}) is measured by quantifying potassium permanganate oxidation with a spectrophotometer. Soil respiration

(CO_2 mg/soil g) is measured by amount of CO_2 released over a four-day incubation period and is used to quantify metabolic activity of the soil microbial community. Surface (0-6 in.) and subsurface (6-18 in.) hardness are measured using a field penetrometer. The Soil Health Score is a weighted calculation of different soil quality parameters

The 30-inch rows did not differ significantly from the 60-inch rows in terms of wet aggregate stability, active carbon, soil respiration or overall soil health score (Table 5). Surface and subsurface hardness were significantly reduced in the 60-inch rows compared to the 30-inch rows. In terms of cover crop type, there were also no significant differences in wet aggregate stability, active carbon, soil respiration or overall soil health score (Table 6). The AR/TR/RC mix had significantly lower surface and subsurface hardness than the other two cover crops.

Table 5. Impact of row width on soil quality in corn silage, Alburgh, VT, 2020.

Row width	Wet aggregate stability	Active carbon	Soil respiration	Surface hardness (0-6 in.)	Subsurface hardness (6-18 in.)	Overall
	%	mg C kg^{-1}	CO_2 mg g^{-1}	Psi	Psi	Score
30-in.	38.8	1101	0.923	146[b]†	285[b]	72.5
60-in.	35.2	1077	0.985	**124[a]**	**273[a]**	74.9
LSD (0.10) ‡	NS§	NS	NS	14.6	11.0	N/A
Trial Mean	37.0	1089	0.954	135	279	73.7

†Treatments within a column with the same letter are statistically similar. Top performers are in **bold**.
‡LSD –Least significant difference at p=0.10.
§ NS – There was no statistical difference between treatments in a particular column (p=0.10).

Table 6. Impact of cover crop type on soil quality in corn silage, Alburgh, VT, 2020.

Cover crop	Wet aggregate stability	Active carbon	Soil respiration	Surface hardness (0-6 in.)	Subsurface hardness (6-18 in.)	Overall
	%	mg C kg^{-1}	CO_2 mg g^{-1}	psi	psi	Score
Cow pea	37.3	1110	0.962	140[b]†	280[b]	73.5
Summer solar mix	36.7	1086	1.004	148[b]	294[c]	72.3
AR/TR/RC mix	36.9	1070	0.897	**117[a]**	**264[a]**	75.3
LSD (0.10) ‡	NS§	NS	NS	17.9	13.5	N/A
Trial Mean	37.0	1089	0.954	135	279	73.7

†Treatments within a column with the same letter are statistically similar. Top performers are in **bold**.
‡LSD –Least significant difference at p=0.10.
§ NS – There was no statistical difference between treatments in a particular column (p=0.10).

Cover Crop Results

The row width of the corn crop significantly impacted the dry matter yield of the interseeded cover crops (Table 7). Cover crop yield was significantly higher in the corn with 60-in. spacing (2166 lbs. ac^{-1}). Dry matter yield was more than four times greater than the yield of cover crops in 30-in. rows (518 lbs. ac^{-1}). There were also significant differences in dry matter yield amongst the different cover crops (Table 8). The Summer solar mix had the greatest dry matter yield (1430 lbs. ac^{-1}) but was not statistically different from the cow peas (929 lbs. ac^{-1}). The AR/TR/RC mix had the lowest yield, 844 lbs. ac^{-1}.

Table 7. Impact of row-width on cover crop dry matter yield, Alburgh, VT, 2020.

Row width	Dry matter yield
	lbs. ac^{-1}
30-in.	518[b]†
60-in.	**2166[a]**
‡LSD (*p*=0.10)	503
Trial mean	1068

†Treatments within a column with the same letter are statistically similar.
Top performers are in **bold**.
‡LSD –Least significant difference at p=0.10.

Table 8. Impact of cover crop type on dry matter yield, Alburgh, VT, 2020.

Cover crop	Dry matter yield
	lbs. ac^{-1}
Cow pea	929[ab]†
Summer Solar mix	**1430[a]**
AR/TR/RC mix	844[b]
‡LSD (*p*=0.10)	581
Trial mean	1068

†Treatments within a column with the same letter are statistically similar.
Top performers are in **bold**.
‡LSD –Least significant difference at p=0.10.

Corn Results

There was a significant impact of row spacing on corn dry matter and yield (Table 9). Corn in 30-inch rows had statistically higher dry matter (38.5%) and yield at 35% DM (24.1tons ac^{-1}) than corn in 60-inch rows (36.7%; 18.6 tons ac^{-1}). The 30-inch rows produced an average of 5.5 more tons of corn silage per acre than 60-inch rows. The cover crop type had an impact on the corn dry matter but not on the yield (Table 10). Corn that was interseeded with cow peas had significantly higher dry matter (38.7%) than the corn interseeded with the Summer solar mix (37.4%) or the AR/TR/RC mix (37.7%). Corn interseeded with the AR/TR/RC mix had the highest yield at 35% DM (23.1 tons ac^{-1}) but this was not statistically different from the other two cover crops.

Table 9. Impact of row width on corn yield, Alburgh, VT, 2020.

Row width	DM	Yield, 35% DM
	%	tons ac^{-1}
30-in.	**38.5**[a]	**24.1**[a]
60-in.	36.7[b]	18.6[b]
‡LSD (p=0.10)	0.843	1.65
Trial mean	37.9	22.2

†Treatments within a column with the same letter are statistically similar. Top performers are in **bold**.
‡LSD –Least significant difference at p=0.10.

Table 10. Impact of cover crop type on corn yield, Alburgh, VT, 2020.

Cover crop	DM	Yield, 35% DM
	%	tons ac^{-1}
Cow pea	**38.7**[a†]	21.2
Summer Solar mix	37.4[b]	22.3
AR/TR/RC mix	37.7[b]	**23.1**
LSD (p=0.10)‡	0.973	NS§
Trial mean	37.9	22.2

†Within a column, treatments marked with the same letter were statistically similar (p=0.10).
Top performers are in **bold.** ‡LSD –Least significant difference at p=0.10.
§ NS – There was no statistical difference between treatments in a particular column (p=0.10).

Row width had a few significant impacts on corn harvest quality (Table 11). Crude protein was significantly greater in 60-in. rows (9.28%) compared to 30-in. row (8.49%). Ash content was significantly lower in 30-in. rows with 3.69% compared to 4.25% in 60-in. rows. The 24-hr NDFD was statistically greater in 60-in. rows than 30-in. rows with 50.9% and 49.1% respectively. Predicted milk (lbs.) per ton and per acre were statistically different between row widths. For predicted milk in lbs. ton^{-1}, 60-in. rows had a greater yield, 3414 lbs. ton^{-1}. Inversely, for predicted milk in lbs. per acre, 30-in. rows had a greater yield, 27,655 lbs. ac^{-1}. All other quality parameters were not statistically different between row-widths. Cover crop type had almost no impact on corn harvest quality (Table 12). The only statistically significant difference between treatments was in predicted milk (lbs) per acre. The AR/TR/RC mix had the highest yield, 26,968 lbs. ac^{-1}, and that was not significantly different from the Summer Solar mix.

Table 11. Impact of row width on corn quality, Alburgh, VT, 2020.

Row width	Starch	Crude protein	ADF	aNDF	Lignin	Ash	24-hr NDFD	48-hr NDFD	NE$_L$	Milk	
	-------------------------% DM-------------------------						-----% NDF-----		Mcal lb.$^{-1}$	lbs. ton^{-1}	lbs. ac^{-1}
30-in.	**31.3**	8.49[b]†	23.4	43.1	**2.84**	**3.69**[a]	49.1[b]	62.5	0.667	3277[b]	**27655**[a]
60-in.	29.7	**9.28**[a]	**23.2**	**42.9**	2.93	4.25[b]	**50.9**[a]	**62.9**	0.667	**3414**[a]	22161[b]
LSD‡ (p=0.10)	NS§	0.231	NS	NS	NS	0.281	0.762	NS	NS	74.188	2107.1
Trial mean	30.8	8.75	23.3	43.1	2.87	4.06	49.7	62.7	0.667	3323	25824

†Within a column, treatments marked with the same letter were statistically similar (p=0.10). Top performers are in **bold.**
‡LSD –Least significant difference at p=0.10.
§ NS – There was no statistical difference between treatments in a particular column (p=0.10).

Table 12. Impact of cover crop type on corn quality, Alburgh, VT, 2020.

Cover crop	Starch	Crude protein	ADF	aNDF	Lignin	Ash	24-hr NDFD	48-hr NDFD	NE_L	Milk	
	--------------------------% DM--------------------------						-----% NDF-----		Mcal lb.$^{-1}$	lbs. ton^{-1}	lbs. ac^{-1}
Cow pea	31.0	8.68	**22.9**	**42.8**	**2.78**	**4.00**	**49.9**	**62.8**	**0.671**	3309	24527[b]†
Summer solar mix	**31.1**	8.74	23.8	43.6	2.96	4.01	49.4	62.6	0.663	3322	25976[ab]
AR/TR/RC mix	30.3	**8.84**	23.2	42.8	2.87	4.17	49.8	62.7	0.667	**3337**	**26968[a]**
LSD (*p*=0.10)‡	NS§	NS	NS	NS	NS	NS	NS	NS	NS	NS	2433.1
Trial mean	30.8	8.75	23.3	43.1	2.87	4.06	49.7	62.7	0.667	3323	25824

†Treatments within a column with the same letter are statistically similar. Top performers are in **bold**.
‡LSD –Least significant difference at p=0.10.
§ NS – There was no statistical difference between treatments in a particular column (p=0.10).

DISCUSSION

In 2020, corn planted in 30-inch rows produced an average of 5.5 more tons ac^{-1} than corn planted in 60-inch rows. On the other hand, cover crop biomass greatly increased when interseeded into 60-inch corn rows compared to 30-inch rows. Cover crop yield was more than 4 times greater in the 60-inch rows across all three cover crop types. This makes sense because the photosynthetically active radiation (PAR) was significantly higher in 60-inch rows. Increased light infiltration to the soil surface and lack of shading from the corn canopy allowed for better establishment and growth of interseeded cover crops when corn is planted with 60-in. row spacing. This can be beneficial for farms where weed suppression is an issue. It may be challenging to cultivate or spray herbicides onto corn fields if equipment is not set up for wider rows. This increased biomass production of the cover crops in 60-inch rows can suppress weeds when traditional cultivation or herbicide application is not available. In this year's trial, soil health samples were taken approximately two weeks after corn harvest, and there were minimal differences between the 30- and 60-inch rows. The plots that had been planted with 60-inch row spacing did have reduced soil surface and subsurface hardness compared to the 30-inch spacing. The cover crop mixture with annual ryegrass, tillage radish, and red clover also had reduced soil surface and subsurface hardness compared to cow peas, and the Summer Solar mix. Compaction occurs when large pores in the soil are packed closely together, particularly in wet soils, because of tillage or traffic with heavy equipment. Surface compaction can prevent roots from accessing water and nutrients, and after rain events may result in ponding, runoff, and erosion. One way to manage soil compaction is by incorporating deep tillage or deep rooting cover crops into the crop rotation. The 60-inch spacing allows for better establishment of cover crops, as seen in the year's trial, and likely resulted in reduced soil surface and subsurface hardness compared to 30-inch rows, where cover crops cannot establish as well. Additionally, the cover crop mixture that included tillage radish outperformed the other two cover crop treatments, which makes sense because tillage radish is a way to manage soil compaction in the field, without the use of tillage equipment.

The results from this season are consistent with what was observed last season in 2019. Corn planted in 30-inch rows produced higher yields than 60-inch rows, but only by an average of 2.9 tons ac^{-1}, which was less of a difference than what seen this season. In both years, cover crop type had no impact on corn yield. Last year, cover crop biomass was also greater when interseeded into 60-inch rows; the average yield was 3.3

times greater than in 30-inch rows. Over the past two seasons, row spacing, and cover crop type have had little to no impact on corn silage quality. These data highlight the trade-offs that farmers must consider when making management decisions with respect to row spacing and interseeding cover crops. These results indicate that wider row spacing can decrease silage yield, but not impact the quality of the corn. Farmers may have to plant corn at a higher seeding rate in 60-in. rows to account for the decrease in rows per acre and resulting decrease in corn yields. Further investigation on other corn row widths should be investigated as yield decline may be less severe in 36 or 42 in rows. Additionally, more research can be done on corn hybrid selection in order to see if farmers can make up for wider rows by planting a corn hybrid that produces high yields even when seeded at a lower rate per acre, and maintain silage yields that would be comparable to traditional row spacing. Overall, cover crop selection has not been shown to impact corn quality, but may improve soil health, particularly soil compaction. It is important to remember that these data only represent two years of research at one location.

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