1st Question: Do We Need to Apply Additional Phosphorus for Corn Succeeding Sugarbeet?

2nd Question: Should We Incur a Loss by Interseeding in Sugarbeet (Beta vulgaris) ?

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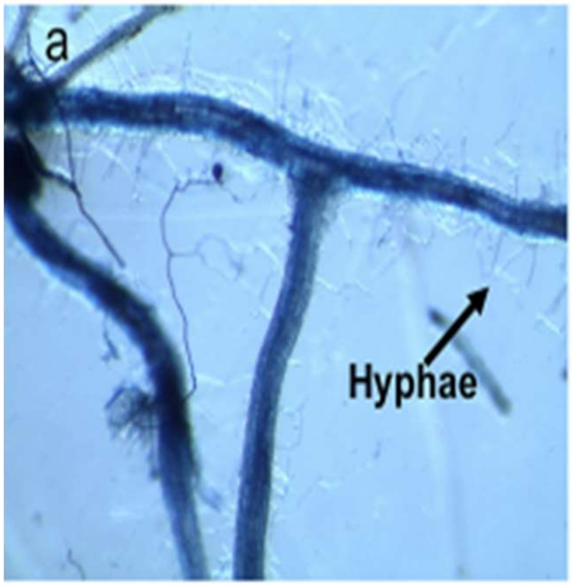
Do We Need to Apply Additional Phosphorus for Corn Succeeding Sugarbeet?

Phosphorus deficiency in corn at early growth stages are common

Fallow syndrome is linked it to decreased colonization of roots by vesicular-arbuscular mycorrhizae (VAM), common after non-mycorrhizal crops like sugarbeet, canola in rotation preceding corn

Do We Need to Apply Additional Phosphorus for Corn Succeeding Sugarbeet?



Arbuscular mycorrhizal fungi growing on corn

Figure 1. Arbuscular mycorrhizal fungi (AMF), an obligate symbiont infecting wheat roots. (Photo by J. Goos, NDSU)

Do We Need to Apply Additional Phosphorus for Corn Succeeding Sugarbeet?

Different crop species and varieties have different levels of dependency on VAM. The P and Zn status of the soil will also have an impact on whether crop growth is affected when VAM levels are low

Mycorrhizal dependency	Crop
Very high	Maize, Pigeon pea, cotton, Faba bean
High	Sunflower, soybean, sorghum, navy bean, chickpea
Low	Field peas, oat, wheat, Triticale
Very low	Barley
Independent (non-hosts)	Canola, Lupins, Sugarbeet

Most pulses and oilseed crops (except lupins and canola) have high to very high dependency and will therefore suffer more than a winter cereal if VAM levels are low. Canola and lupins are not hosts of the VAM fungi and thus do not breed up inoculum and are unaffected by VAM levels. As these non-host crops do not contribute to building up VAM levels, they are not as beneficial as say wheat or sorghum in the rotation for a future VAM dependent crop.

Do We Need to Apply Additional Phosphorus for Corn Succeeding Sugarbeet?

Six treatments, 4 replications, four site-year (2018- Casselton and Sabin, 2019- Chaffee and Downer)

1. No P (only recommended N and K)
2. NPK (Recommended)
3. 100 kg P_2O5 ac^{-1} (+recommended N and K)
4. Starter (In-furrow 10-34-0@ 3 gpa + recommended N and K)
5. Myco (Mycorrhiza inoculant + recommended N and K)
6. Myco + Starter (+recommended N and K)

Do We Need to Apply Additional Phosphorus for Corn Succeeding Sugarbeet?

TABLE 1 Location, initial nutrient availability, crop and fertilizer management of experimental sites during 2018 and 2019 growing seasons

	2018		2019	
Soil and management indices	**Casselton, ND**	**Sabin, MN**	**Chaffee, ND**	**Downer, MN**
Location	46°56′0.5″ N, 97°11′56.3″ W	46°51′52.2″ N, 96°31′5.8″ W	46°56′89.5″ N, 97°12′10.5″ W	46°46′21.4″ N, 96°32′53.7″ W
Soil series	Kindred–Bearden	Wyndmere	Glyndon	Wyndmere
Soil organic matter, g kg^{-1}	50	26	42	35
pH (1:2.5)	7.4	8.7	7.9	7.5
Texture	Silty clay loam	Sandy loam	Sandy loam	Loamy fine sand
Soil NO_3–N,kg ha^{-1}[a]	27	12	13	15
Olsen P, mg kg^{-1}	17	7	14	11
Available K, mg kg^{-1}	207	89	193	170
Planting date	1 May	2 May	11 May	2 May
Harvesting date	26 Oct.	23 Oct.	15 Oct.	23 Oct.
Recommended fertilizers, kg ha^{-1}				
N	250	250	250	250
P_2O_5	10	87	58	58
K_2O	0	100	100	100

[a]Soil available NO_3 was measured for 90-cm depth.

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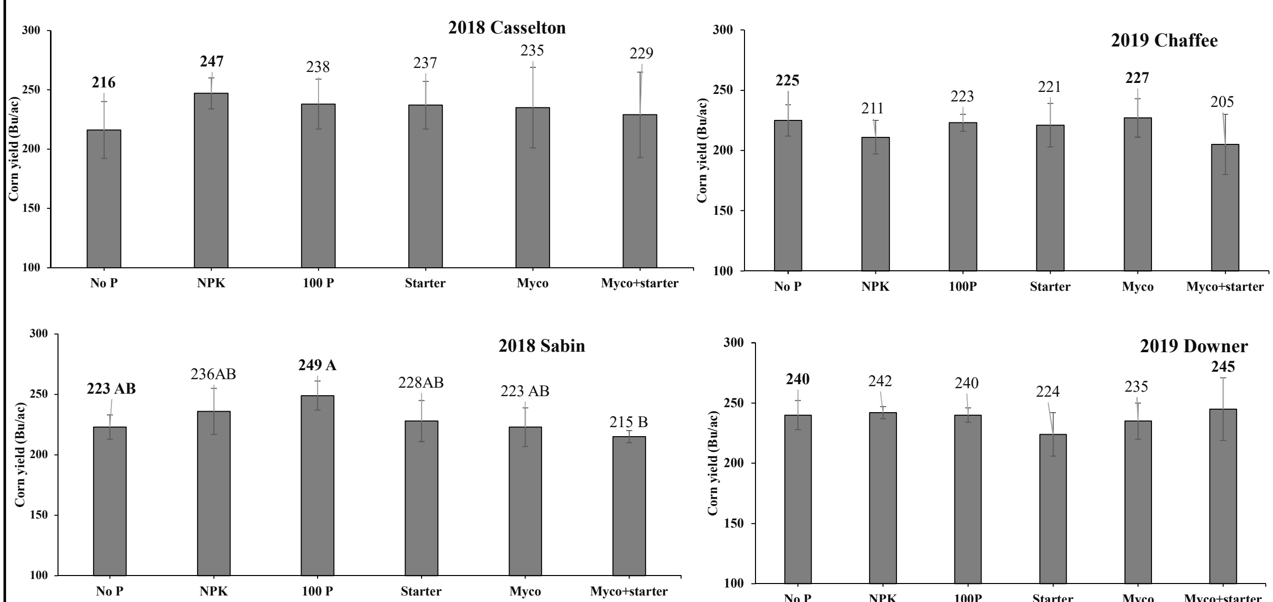


Do We Need to Apply Additional Phosphorus for Corn Succeeding Sugarbeet?

TABLE 3 Soil available P (mg kg^{-1}) in response to P treatments for fields with sugarbeet as preceding crop in the Red River of North Dakota and Minnesota during 2018–2019 seasons *At harvest for 2018 and at V4 growth stages, June 19, 2019*

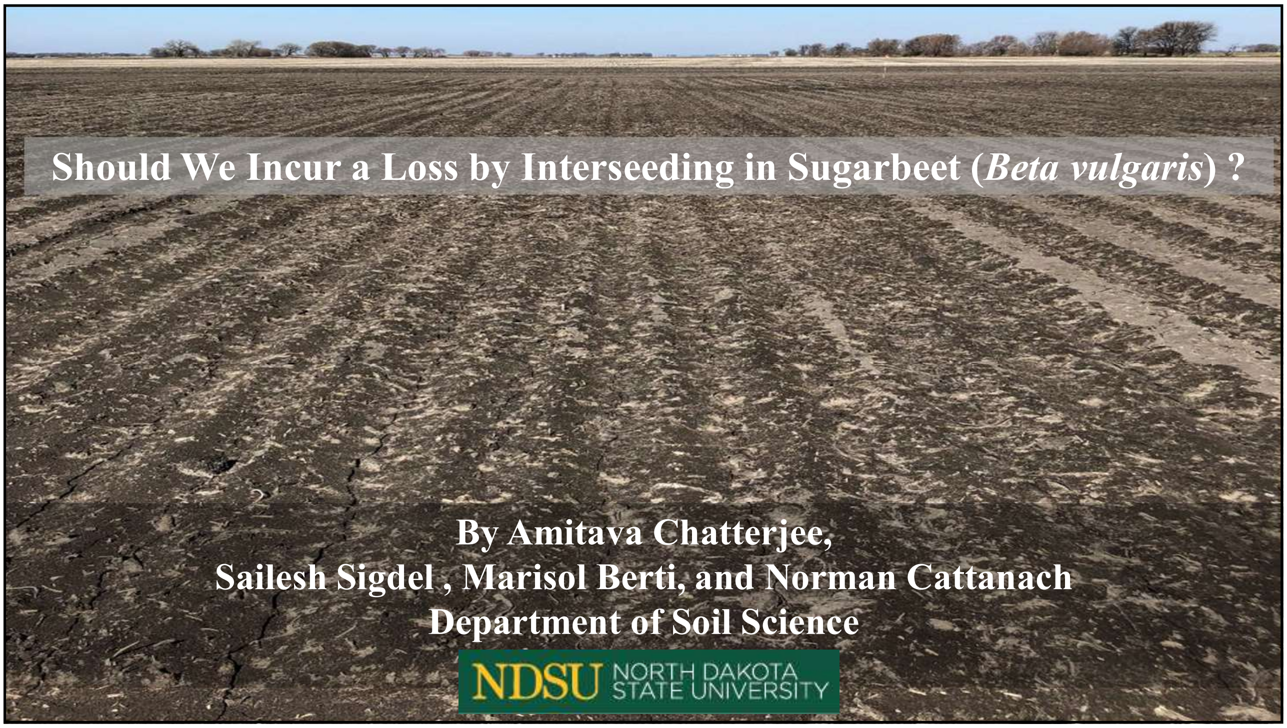
	2018		2019	
Treatments	**Casselton, ND**	**Sabin, MN**	**Chaffee, ND**	**Downer, MN**
NoP	8.07 (2.6[a])	6.69 (5.6)	36.5 (5.74)B[b]	15.5 (4.43)B
NPK	9.89 (4.5)	7.67 (3.2)	42.3 (10.3)AB	33.5 (12.2)AB
112P	12.1 (4.8)	6.76 (1.6)	55.0 (6.32)A	26.0 (10.3)AB
Starter	8.48 (5.3)	6.89 (1.4)	41.3 (13.6)AB	69.3 (39.1)A
Myco	5.85 (1.2)	6.69 (1.2)	35.8 (4.57)B	15.0 (2.94)B
Myco+Starter	7.13 (2.1)	6.79 (2.1)	46.3 (14.8)AB	31.5 (16.6)AB
$P > F$	.12	.91	.03	.01

AMF Population on June, 2019

Treatments	Chaffee, ND	Downer, MN
NoP	0.79 (0.11[a])B[b]	2.30 (0.60)
NPK	1.79 (0.52)A	1.31 (0.17)
112P	1.31 (0.36)AB	2.28 (0.62)
Starter	1.08 (0.07)AB	2.13 (0.32)
Myco	1.38 (0.76)AB	1.83 (0.53)
Myco+Starter	1.21 (0.33)AB	2.39 (0.81)
$P > F$	.03	.11

Do We Need to Apply Additional Phosphorus for Corn Succeeding Sugarbeet?

- Recommended P for corn is sufficient for corn succeeding sugarbeet
- Commercial mycorrhizal inoculum did not increase yield over fertilizer P
- Higher than recommended P and starter had no negative effect on mycorrhiza
- Growers can opt for cover crops (barley, oat) that promote VAM growth



Should We Incur a Loss by Interseeding in Sugarbeet (*Beta vulgaris*) ?

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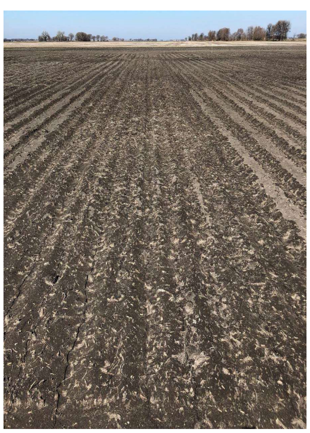
Interseeding cover crop can protect soil after beet harvest and at early spring of the following year



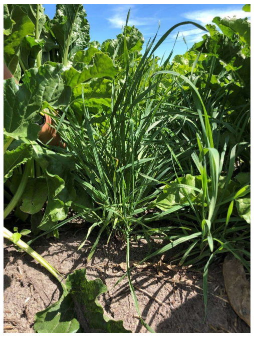
Beet field at late fall

Interseeded rye

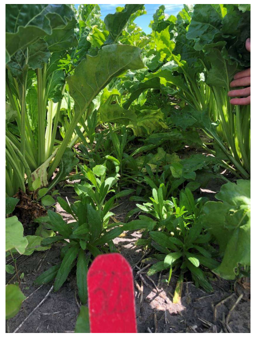
Rye plot soon after beet harvest

Over-wintered rye

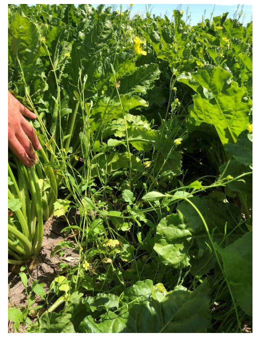
Cover crop species



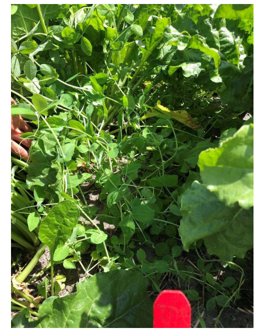
Winter Rye (20 lb. ac^{-1})



Camelina (6 lb. ac^{-1})



Mustard (10 lb. ac^{-1})



Pea (20 lb. ac^{-1})

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Interseeding time

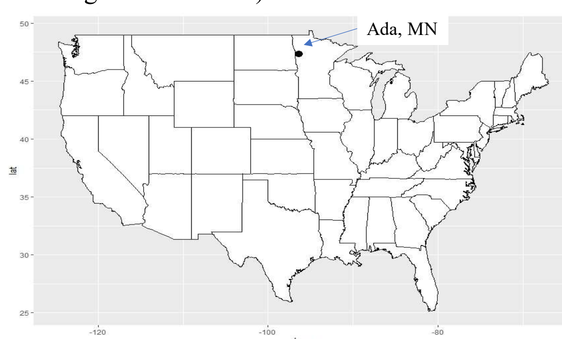
2018 Growing Season	2019 Growing Season	2020 Growing Season
Early: June 21	Early: June 13	Early: June 18
Late: July 11	Late: June 24	Late: June 26

Experiment plan

Experimental Design: RCBD (4 cover crop species × 2 interseeding time + control)

Plot size: 30 ft × 11 ft

Site	Ada, MN		
Year	**2018**	**2019**	**2020**
Previous crop	Spring Wheat	Spring Wheat	Spring Wheat
Texture	sandy clay loam	sandy clay loam	loam
pH	8.4	7.6	8.2
NO_3-N (lb. N ac^{-1})	8.3	14.4	33.3
OM (%)	2.4	3.1	2.2
Sugarbeet planting	7-May	13-May	11-May
Harvesting	26-Sep	16-Sep	17-Sep

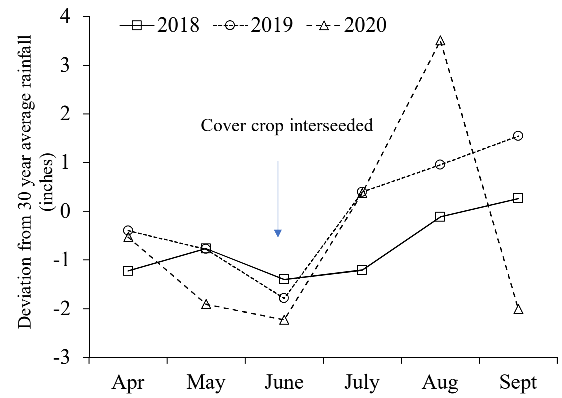


Observations- (i) Cover crop biomass at harvest (2×2 sq ft), (ii) sugarbeet root yield and sugar content (the center two rows of each plot), (iii) economic return

Statistical Analyses: RCBD (4 cover crop species × 2 interseeding time + control) and also factorial RCBD (4 cover crop species × 2 interseeding time) using SAS 9.4. Interseeding date and cover crop species were considered fixed effects and year and rep (year) as random effects. Main effects and interactions were evaluated at 95% level of significance.

Cover Crop Interseeding

Results and Discussion: Weather during growing season



Picture taken on August 28, 2019

Year	Total precipitation
2018	13.54 inches
2019	17.09 inches
2020	15.35 inches

Results and Discussion: 2018-2020 Growing Season

Main and interaction effects of cover crop species and interseeding time on cover crop biomass yield (lb. ac^{-1}), sugarbeet yield (ton ac^{-1}), sugar concentration (%), and recoverable sugar yield (ton ac^{-1})

Source of variation	**Cover crop Biomass**	**Sugarbeet root yield**	**Sugar concentration**	**Recoverable sugar yield**
Interseeding time (I)	ns	ns	ns	ns
Cover crop species (CC)	ns	ns	ns	ns
I*CC	ns	ns	ns	ns
Year*I	<0.01*	<0.01*	0.04*	<0.01*
Year*CC	<0.01*	ns	ns	ns
Year*I*CC	0.04*	ns	0.04*	ns

“ * ” indicates significant at the p≤ 0.05

Results and Discussion: Aboveground cover crop biomass

Interseeding time effect on cover crop biomass yield during 2018-20 growing seasons

Interseeding time	2018	2019	2020	3 yr avg
		---------(lb. ac^{-1})--------		
Early	148 a	1784 a	894 a	942
Late	84 b	479 b	378 b	313

Cover crop species effect on cover crop biomass yield during 2018-20 growing seasons

Cover crop species	2018	2019	2020	3 yr avg
		------------- (lb. ac^{-1}) ------------		
Austrian Pea	79	1344 a	1087 a	836
Camelina	135	598 b	256 b	329
Mustard	123	1082 ab	584 ab	597
Rye	126	1503 a	617 ab	749

Sugarbeet root yield and sugar content in response to interseeding

Planting	Cover crop	2018		2019		2020	
		Yield (ton ac^{-1})	Sugar (%)	Yield (ton ac^{-1})	Sugar (%)	Yield (ton ac^{-1})	Sugar (%)
	No cover crops	37.6	16.2	30.9 abc	16.3 abc	32.0	16.6
Early	Rye	36.1	16.6	21.6 d	17.0 a	24.8	17.0
	Camelina	37.0	16.7	27.0 bcd	16.8 ab	27.7	16.7
	Pea	36.3	16.8	25.5 cd	16.3 abc	22.9	16.5
	Brown mustard	39.0	16.6	22.4 d	16.2 abc	26.8	16.7
Late	Rye	38.1	16.6	30.8 abc	16.4 abc	29.5	16.7
	Camelina	38.2	16.5	34.2 a	16.0 bc	27.2	16.7
	Pea	38.4	16.4	33.5 ab	15.9 c	29.1	16.8
	Brown mustard	37.1	16.8	32.1 abc	16.5 abc	24.9	16.8
P-value		ns	ns	<0.001*	0.008*	ns	ns

Should we incur a loss by interseeding?

Planting	Cover crop	2018 ($ ac^{-1})		2019 ($ ac^{-1})		2020 ($ ac^{-1})	
	No cover crops	$1,425		$906 ab†		$1,324	
Early	Rye	$1,452	+27*	$737 cd	-209*	$1,093	-230*
	Camelina	$1,513	+88	$903 abc	-44	$1,157	-166
	Pea	$1,522	+97	$774 bcd	-172	$934	-389
	Brown mustard	$1,584	+159	$664 d	-283	$1,136	-188
Late	Rye	$1,545	+120	$942 ab	-4	$1,236	-88
	Camelina	$1,509	+83	$986 a	+39	$1138	-185
	Pea	$1,511	+86	$938 ab	-9	$1,234	-89
	Brown mustard	$1,541	+116	$1,019 a	+72	$1,067	-257
	$LSD_{0.05}$	ns		115		ns	

*Difference in profit from without cover crop

Economic return: $ ac^{-1} = {(sugar% - SLM%)*20-Other Sugar Losses}*Price per Pound + Agri Products - Operation Cost

Conclusion

- Late interseeding of cover crops had no negative effect on economic return from sugarbeet.
- Amount of biomass: pea=rye>brown mustard> camelina
- Depending on amount of cover crop biomass produced, early interseeding, particularly by rye and pea, can reduce the economic return.
- Cost involved with interseeding, and ecosystem services from cover crops are not considered.

Acknowledgments

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