Effects of mycorrhizal inoculation, rock phosphate and composted manure in pulse-flax rotations

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2018-04-10

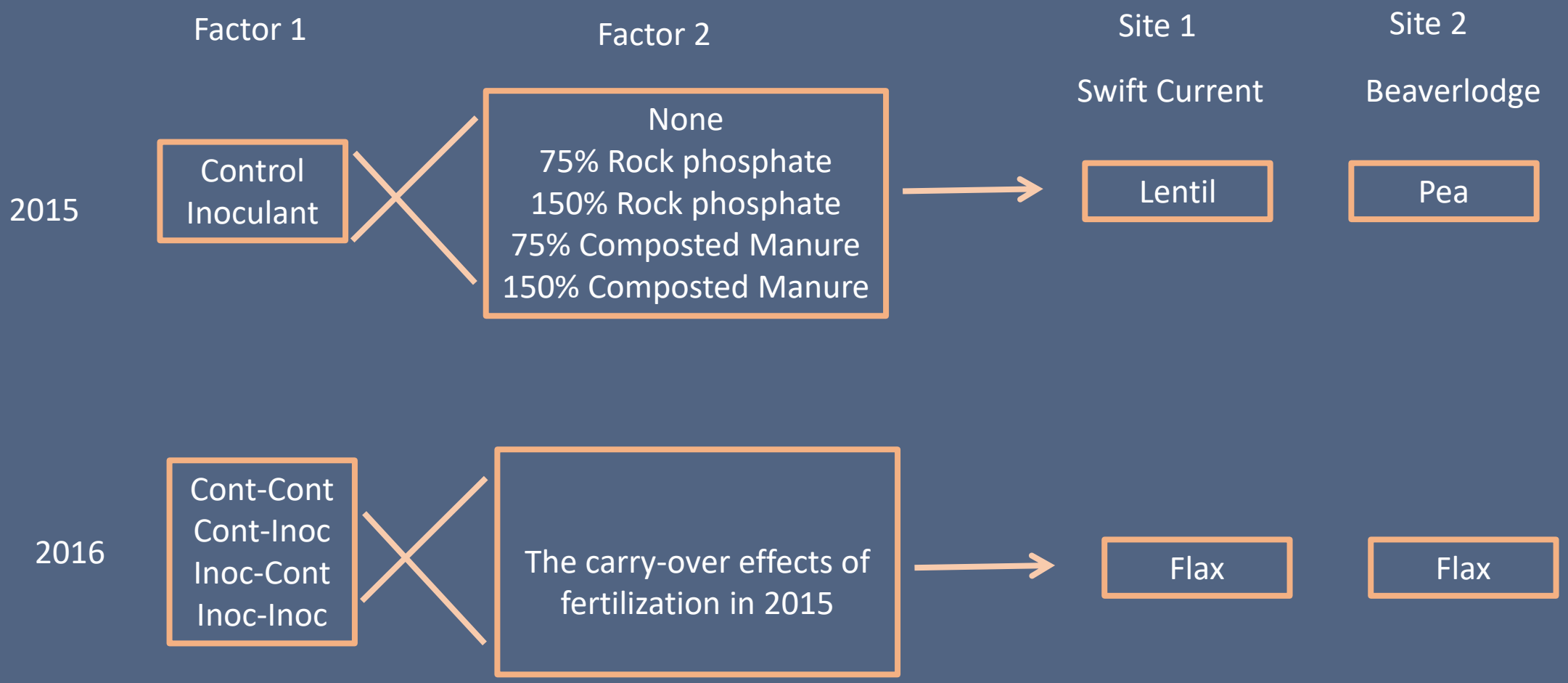
Background

- Arbuscular mycorrhizal fungi (AMF) assist plants to absorb phosphorus (P) and other elements from soil
- In organic grain farming systems of the Prairie, soil phosphorus is often low
- Inoculation with AMF had increased lentil production by 30% on an organic farm

Hypotheses

- Finely gound rock phosphate ammended with humic acid can increase the level of available soil P and plant production
- Composted manure can increase the level of available soil P and plant production
- The arbuscular mycorrhizal fungi (AMF) help plants extract phosphorus from the soil

Experiment Design



Part1：

Effects of AMF inoculation and two certified P sources (rock phosphate and composted manure) on agronomic traits and soil properties

Swift Current, 2015, Lentil

	Yield (kg/ha)	Biomass (kg/ha)	Grain_N (%)	Grain_P (%)	Straw_N (%)	Straw_P (%)	Soil_N (kg/ha)	Soil_P (kg/ha)	Root Colonization (%)
Control	4053 ± 24	1134±85	3.88±0.02	0.32±0.00	1.25±0.07	0.09±0.00	9.35±0.21	8.34±0.49	73.03±1.31
Inoculant	370 ± 24	1100 ± 85	3.88±0.02	0.32±0.00	1.31±0.07	0.1±0.00	8.98±0.21	8.14±0.49	76.48±1.31
P-value	0.0858	0.5285	0.9546	0.9615	0.3193	0.2903	0.0545	0.6118	0.0673
None	403 ± 30 a	1061 ± 97	3.86±0.03 ab	0.31±0.01 b	1.2±0.08 b	0.09±0.01 bc	9.47±0.27	7.01±0.59 c	74±2.07
75% RP	421 ± 30 a	1045 ± 97	3.88±0.03 ab	0.31±0.01 b	1.09±0.08 b	0.08±0.01 c	9.04±0.27	7.62±0.59 bc	72.31±2.07
150% RP	417 ± 30 a	1131 ± 97	3.85±0.03 b	0.32±0.01 ab	1.19±0.08 b	0.09±0.01 bc	8.91±0.27	7.47±0.59 bc	75.88±2.07
75% CM	388 ± 30 ab	1213 ± 97	3.85±0.03 b	0.32±0.01 ab	1.32±0.08 b	0.1±0.01 b	9.35±0.27	8.98±0.59 ab	74.75±2.07
150% CM	310 ± 30 b	1136 ± 97	3.95±0.03 a	0.34±0.01 a	1.61±0.08 a	0.13±0.01 a	9.03±0.27	10.12±0.59 a	76.81±2.07
P-value	**0.0044**	0.3113	**0.023**	**0.0089**	**<.0001**	**<.0001**	0.2813	**<.0001**	0.5956

- Introduced AMF had no effect on agronomic traits and soil properties
- Composted manure at 150% recommended P level reduced lentil yield, but increased N, P level in grain and straw, and soil test P level.
- Rock phosphate had no effect

Note: The interaction effect of inoculation and fertilization was not significant

Beaverlodge, 2015, Pea

	Yield (kg/ha)	Biomass (kg/ha)	Grain_N (%)	Grain_P (%)	Grain_K (%)	Grain_C (%)	Straw_N (%)	Straw_P (%)	Straw_K (%)	Straw_C (%)	Soil_N (kg/ha)	Soil_P (kg/ha)	Root Colonization (%)
Control	4267 ± 219	6324 ± 355	3.27±0.06	0.26±0.01 a	0.85±0.01	41.01±0.05	0.65±0.02	0.04±0.00	1.51±0.09	40.92±0.08	22.73±1.87	30.35±2.51	52.43±1.68
Inoculant	4394 ± 219	6424 ± 355	3.35±0.06	0.25±0.01 b	0.86±0.01	41.1±0.05	0.67±0.02	0.05±0.00	1.54±0.09	40.97±0.08	23.72±1.87	27.95±2.51	54.5±1.68
P-value	0.3305	0.6627	0.1288	**0.0344**	0.5571	0.1741	0.1741	0.0623	0.5955	0.7115	0.2365	0.1405	0.4752
None	4218 ± 243 a	6251 ± 406 ab	3.28±0.07	0.26±0.01 a	0.86±0.02	40.99±0.08	0.65±0.03	0.04±0.00	1.47±0.1 bc	40.83±0.13	24.32±2	31.52±2.87 ab	56.5±2.65
75% RP	4246 ± 243 a	6019 ± 406 b	3.34±0.07	0.25±0.01 ab	0.87±0.02	41.07±0.08	0.66±0.03	0.04±0.00	1.36±0.1 c	41.02±0.13	22.54±2	24.19±2.87 c	49.56±2.65
150% RP	4217 ± 246 a	6056 ± 406 b	3.24±0.07	0.26±0.01 ab	0.83±0.02	41.16±0.08	0.66±0.03	0.04±0.00	1.44±0.1 bc	41.14±0.13	21.32±2	26.44±2.87 bc	55.13±2.65
75% CM	4235 ± 243 a	6317 ± 406 ab	3.3±0.07	0.24±0.01 b	0.86±0.02	41.05±0.08	0.67±0.03	0.04±0.00	1.59±0.1 ab	40.97±0.13	24.35±2	29.53±2.87 abc	56.44±2.65
150% CM	4737 ± 243 a	7226 ± 406 a	3.4±0.07	0.25±0.01 ab	0.86±0.02	41.01±0.08	0.67±0.03	0.04±0.00	1.78±0.1 a	40.76±0.13	23.6±2	34.07±2.87 a	49.69±2.65
P-value	**0.0396**	**0.0082**	0.332	**0.0232**	0.681	0.6242	0.6242	0.7075	**<.0001**	0.248	0.1124	**0.0018**	0.1397

- Inoculation with AMF reduced % P grain
- Composted manure increased soil mineral P content at harvest, and pea biomass, straw % K and yield, but the low rate reduced % P grain
- Rock phosphate reduced soil test P

Note: No interaction of inoculation and fertilization is significant, except for on mycorrhizal colonization (p=0.0485)

Swift Current, 2016, Flax

Aims: 1. Test the carry-over effect vs continuous effect of inoculation with AMF
2. The carry-over effect of composted manure and rock phosphate on crop and soil mineral N and P levels

	Yield (kg/ha)	Biomass (kg/ha)	plant_N (%)	plant_P (%)	Plant_K (%)	Plant_C (%)	Grain_N (%)	Grain_P (%)	Straw_N (%)	Straw_P (%)	Soil_N (kg/ha)	Soil_P (kg/ha)	Root Colonization (%)
Cont-Cont	464±52.92	1696±157.17	0.73±0.03	0.18±0.01	1.48±0.07	45.08±0.12	1.98±0.02	0.6±0.01	0.27±0.03	0.09±0.01	7.99±1.33	9.43±0.93	61.6±2.83
Cont-Inoc	432±52.92	1705±157.17	0.69±0.03	0.16±0.01	1.37±0.07	45.17±0.12	2.02±0.02	0.59±0.01	0.3±0.03	0.1±0.01	8.57±1.33	7.79±0.93	61.95±2.83
Inoc-Cont	426±52.92	1537±157.17	0.7±0.03	0.17±0.01	1.45±0.07	44.89±0.12	2±0.02	0.6±0.01	0.28±0.03	0.09±0.01	8.27±1.33	9.47±0.93	62.25±2.83
Inoc-Inoc	467±52.92	1669±157.17	0.67±0.03	0.17±0.01	1.34±0.07	45±0.12	1.98±0.02	0.6±0.01	0.26±0.03	0.09±0.01	7.4±1.33	9.83±0.93	60.2±2.83
P-value	0.8059	0.7601	0.5455	0.37	0.2455	0.2201	0.416	0.8721	0.7462	0.9794	0.2699	0.0752	0.8735
None	505±56.02	1822±169.01	0.73±0.04	0.17±0.01	1.45±0.08	44.98±0.13	2.01±0.03	0.56±0.01 b	0.28±0.03	0.08±0.01	8.53±1.35	9.26±0.98 b	59.94±2.98
75% RP	440±56.02	1627±169.01	0.71±0.04	0.17±0.01	1.38±0.08	45.08±0.13	2±0.03	0.59±0.01 ab	0.28±0.03	0.08±0.01	7.6±1.35	6.74±0.98 b	59.06±2.98
150% RP	434±56.02	1693±169.01	0.74±0.04	0.19±0.01	1.51±0.08	45.04±0.13	2±0.03	0.6±0.01 ab	0.29±0.03	0.1±0.01	7.43±1.35	8.61±0.98 b	61.19±2.98
75% CM	457±56.02	1619±169.01	0.65±0.04	0.16±0.01	1.38±0.08	45.07±0.13	1.97±0.03	0.61±0.01 ab	0.26±0.03	0.09±0.01	8.42±1.35	9.03±0.98 b	63.06±2.98
150% CM	400±56.02	1499±169.01	0.66±0.04	0.17±0.01	1.32±0.08	45.02±0.13	1.99±0.03	0.62±0.01 a	0.28±0.03	0.11±0.01	8.3±1.35	12.02±0.98 a	64.25±2.98
P-value	0.4812	0.5812	0.3606	0.1137	0.3901	0.9629	0.8811	**0.0093**	0.7778	0.5426	0.5037	**<.0001**	0.3922

- No significant effect of any inoculation treatment
- The carry-over effect of compost manure at 150% recommended P significantly increased grain P level of flax, and soil P level
- Rock phosphate had no effect

Beaverlodge, 2016, Flax

Treatment	Yield (kg/ha)	Biomass (kg/ha)	Plant_N (%)	Plant_P (%)	Plant_K (%)	Plant_C (%)	Grain_N (%)	Grain_P (%)	Grain_K (%)	Grain_C (%)	Straw_N (%)	Straw_P (%)	Straw_K (%)	Straw_C (%)	Soil_N (kg/ha)	Soil_P (kg/ha)	Root Colonization (%)
Cont-Cont	1348±136	3793±311	1.72±0.11	0.28±0.01	1.79±0.08	43.46±0.26	2.56±0.04	0.62±0.02	0.82±0.04	59.3±0.20	0.45±0.01	0.09±0.01	1.12±0.03	45.01±0.11	10.82±0.8	24.92±2	44.65±4.85
Cont-Inoc	1362±136	3914±311	1.77±0.11	0.27±0.01	1.75±0.08	43.28±0.26	2.66±0.04	0.6±0.02	0.8±0.04	59.2±0.20	0.47±0.01	0.09±0.01	1.15±0.03	44.93±0.11	11.33±0.8	21.95±2	39±4.85
Inoc-Cont	1407±136	3934±311	1.78±0.11	0.27±0.01	1.75±0.08	43.51±0.26	2.63±0.04	0.59±0.02	0.79±0.04	59.19±0.20	0.47±0.01	0.09±0.01	1.15±0.03	44.8±0.11	10.87±0.8	24.98±2	41.25±4.85
Inoc-Inoc	1372±136	3882±311	1.8±0.11	0.27±0.01	1.75±0.08	43.63±0.26	2.62±0.04	0.59±0.02	0.79±0.04	59.2±0.20	0.45±0.01	0.08±0.01	1.09±0.03	44.97±0.11	11.04±0.8	23.91±2	35.15±4.85
P-value	0.8955	0.9017	0.6135	0.0964	0.9191	0.1301	0.094	0.0573	0.6952	0.9529	0.5644	0.5823	0.5594	0.4814	0.3779	0.4776	0.0921
None	1451±139 ab	4075±319 ab	1.8±0.11 ab	0.27±0.01	1.69±0.08	43.32±0.27	2.62±0.04	0.6±0.02	0.79±0.04	59.33±0.21	0.46±0.01	0.09±0.01	1.14±0.04	44.95±0.12	10.98±0.8	23.97±2.14	35.63±5.03
75% RP	1156±139 c	3267±319 c	1.67±0.11 b	0.27±0.01	1.68±0.08	43.37±0.27	2.64±0.04	0.6±0.02	0.79±0.04	59.41±0.21	0.48±0.01	0.09±0.01	1.07±0.04	44.81±0.12	10.47±0.8	24.34±2.14	42.56±5.03
150% RP	1293±139 bc	3700±319 bc	1.78±0.11 ab	0.27±0.01	1.78±0.08	43.66±0.27	2.6±0.04	0.6±0.02	0.83±0.04	59.31±0.21	0.45±0.01	0.09±0.01	1.1±0.04	44.82±0.12	11.08±0.8	23.55±2.14	43.19±5.03
75% CM	1393±139 abc	3887±319 abc	1.67±0.11 b	0.27±0.01	1.76±0.08	43.55±0.27	2.6±0.04	0.61±0.02	0.81±0.04	59.01±0.21	0.47±0.01	0.09±0.01	1.17±0.04	45.02±0.12	11.46±0.8	23.53±2.14	41.31±5.03
150% CM	1568±139 a	4473±319 a	1.92±0.11 a	0.28±0.01	1.89±0.08	43.45±0.27	2.63±0.04	0.59±0.02	0.8±0.04	59.04±0.21	0.44±0.01	0.08±0.01	1.16±0.04	45.03±0.12	11.08±0.8	24.3±2.14	37.38±5.03
P-value	**0.0003**	**<.0001**	**0.0037**	0.8372	0.0687	0.2455	0.8755	0.9224	0.5489	0.3694	0.3667	0.5049	0.2665	0.4777	0.1087	0.9698	0.2965

Note: Plant_ N, P, K, and C measured at bloom stage

- As in Swift Current, all AMF inoculation treatments had not effects on plant and soil variables
- Composted manure at 150% recommended rate tended to increase flax yield, biomass and flax N level
- Low level of rock phosphate reduced flax yield and biomass

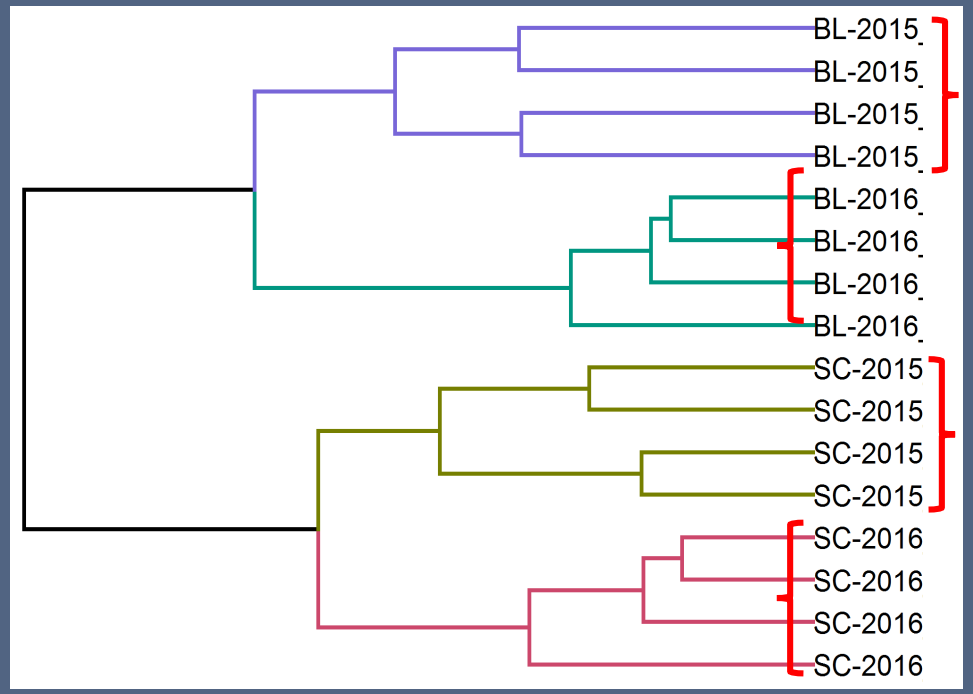
Conclusions

- AMF inoculation did not improve crop yield or plant nutrition on research farms
- Composted manure increased crop productivity in Beaverlodge, and soil P level at both sites
- Rock phosphate had no positive effect on crop productivity and soil properties in our experiments, and sometimes even had negative effects on crop yield and biomass

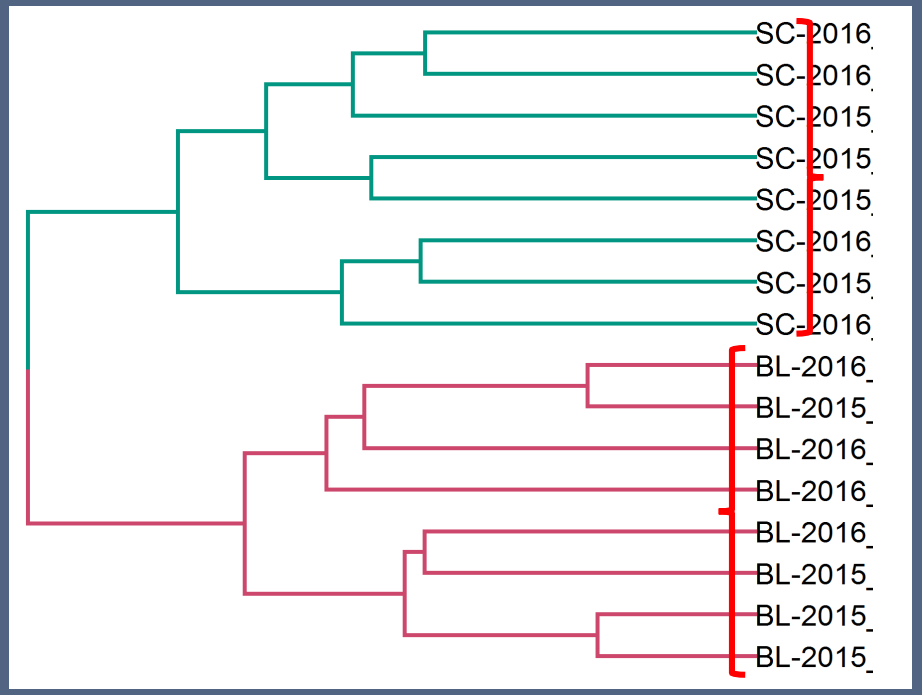
Part II

Effects of AMF inoculation and two certified P sources (rock phosphate and composted manure) on the communities of rhizosphere AMF, fungi, and bacteria

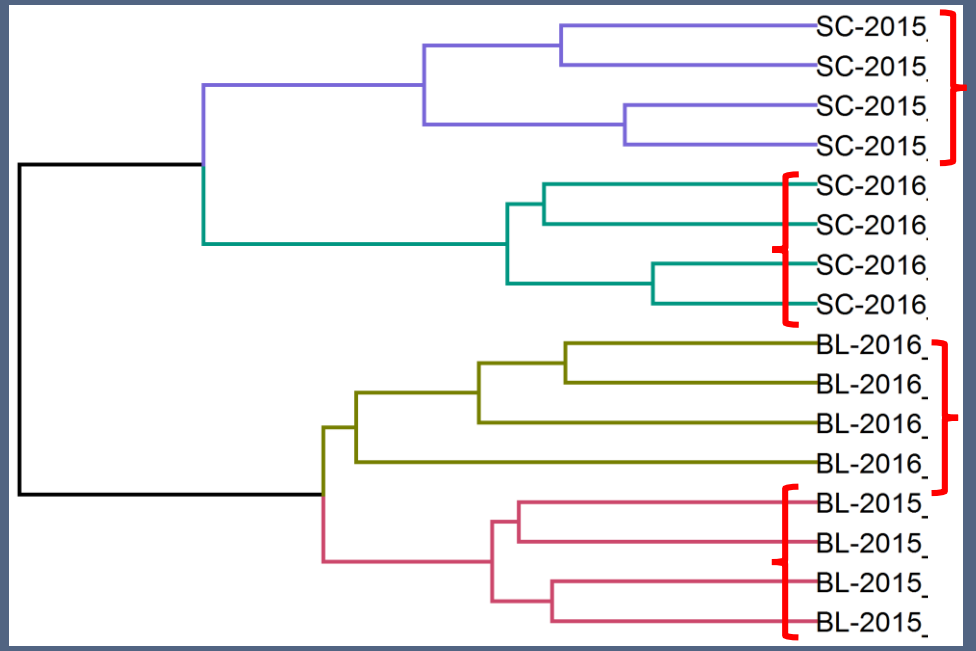
Bacteria



AMF



Fungi



- Hierarchical clustering analysis showing that communities of bacteria and fungi were similar among sites and years indicating the large influence of the environmental conditions;
- The community of AMF is influenced by site and not so much by year.

Effects of introduced AMF and organic fertilizer on soil microbial community structure

Treatment	AMF						Fungi						Bacteria					
	2015_Swift Current			2015_Beaverlodge			2015_Swift Current			2015_Beaverlodge			2015_Swift Current			2015_Beaverlodge		
	Df	F	Pr(>F)	Df	F	Pr(>F)	Df	F	Pr(>F)	Df	F	Pr(>F)	Df	F	Pr(>F)	Df	F	Pr(>F)
Inoculation	1	1.186	0.289	1	1.054	0.383	1	1.145	0.255	1	0.912	0.618	1	1.079	0.278	1	1.079	0.278
Fertilizer	4	0.990	0.500	4	0.810	0.720	4	0.963	0.557	4	1.171	0.071	4	0.785	0.934	4	0.785	0.934
Inoculation:Fertilizer	4	0.933	0.614	4	1.551	0.069	4	1.055	0.322	4	1.130	0.136	4	0.904	0.657	4	0.904	0.657
	2016_Swift Current			2016_Beaverlodge			2016_Swift Current			2016_Beaverlodge			2016_Swift Current			2016_Beaverlodge		
	Df	F	Pr(>F)	Df	F	Pr(>F)	Df	F	Pr(>F)	Df	F	Pr(>F)	Df	F	Pr(>F)	Df	F	Pr(>F)
2015_Inoc	1	0.501	0.935	1	0.862	0.557	1	0.706	0.945	1	0.774	0.912	1	0.561	0.984	1	0.561	0.984
2016_Inoc	1	0.936	0.499	1	1.395	0.174	1	0.789	0.840	1	1.096	0.271	1	1.265	0.171	1	1.265	0.171
Fertilizer	4	0.919	0.620	4	1.129	0.265	4	0.953	0.668	4	1.160	0.054	4	0.798	0.827	4	0.798	0.827
2015_Inoc:2016_Inoc	1	0.704	0.773	1	0.554	0.832	1	1.415	0.051	1	1.056	0.331	1	1.259	0.193	1	1.259	0.193
2015_Inoc:Fertilizer	4	0.887	0.694	4	1.185	0.259	4	0.817	0.968	4	1.024	0.387	4	0.770	0.867	4	0.770	0.867
2016_Inoc:Fertilizer	4	1.024	0.438	4	0.780	0.805	4	1.020	0.425	4	0.977	0.599	4	0.804	0.804	4	0.804	0.804
2015_Inoc:2016_Inoc:Fertilizer	4	0.997	0.460	4	0.896	0.610	4	0.801	0.974	4	1.102	0.154	4	0.735	0.914	4	0.735	0.914

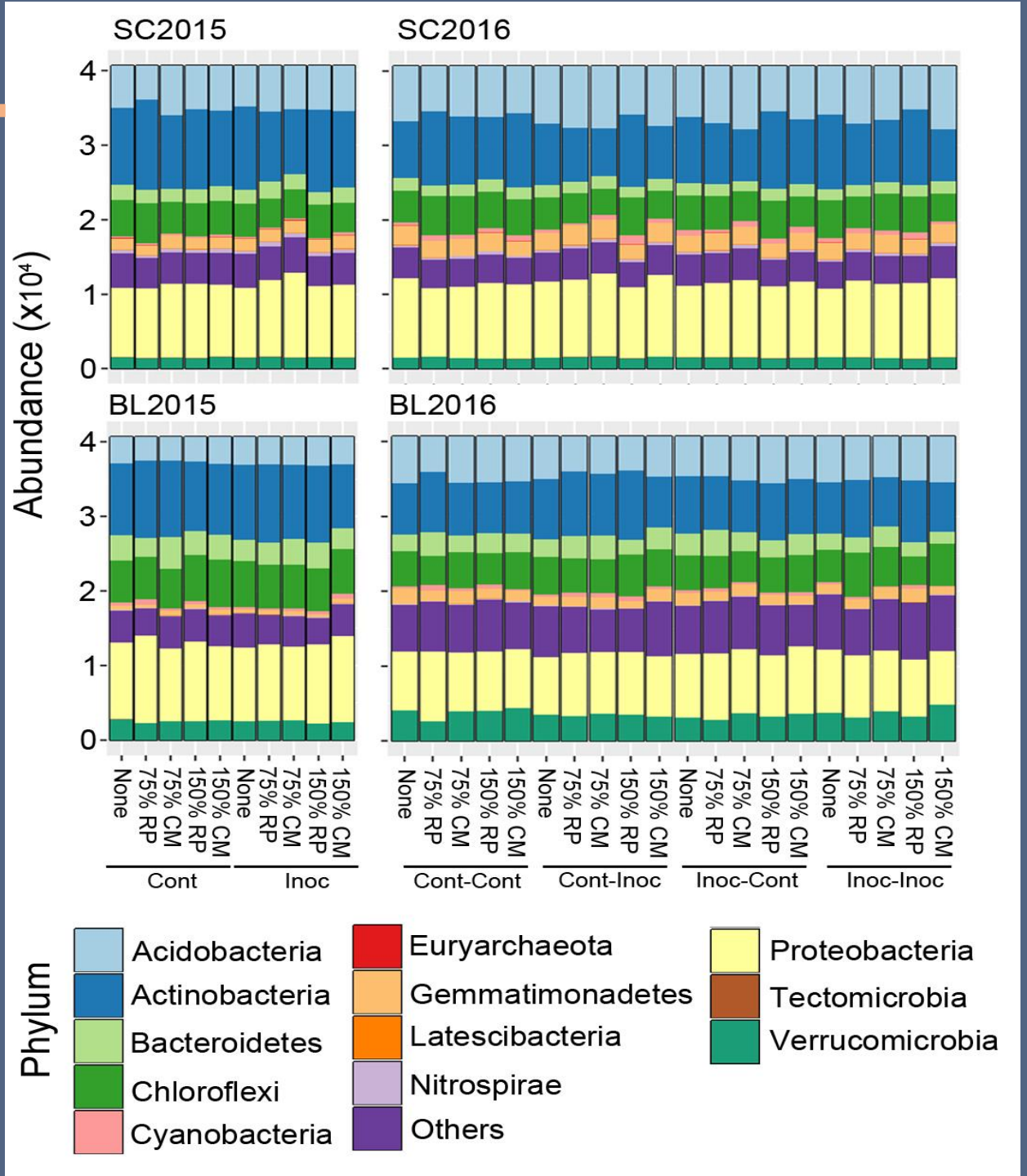
No significant effect on the structure of AMF, fungi or bacteria communities

Bacteria

Swift Current

Beaverlodge

- Inoculation and fertilization had no effect on bacterial phyla
- The shift between the two rotation years in each site is obvious, as it is between two sites



	Treatment	*Acidobacteria*	*Actinobacteria*	*Bacteroidetes*	*Chloroflexi*	*Proteobacteria*	*Gemmatimonadetes*	*Verrucimicrobe*
SC2015	Control	9.717 ± 0.072	10.202 ± 0.04	9.086 ± 0.049	9.44 ± 0.049	10.296 ± 0.036	8.83 ± 0.059	8.578 ± 0.056
	Inoculant	9.792 ± 0.072	10.202 ± 0.04	9.143 ± 0.049	9.422 ± 0.049	10.356 ± 0.036	8.938 ± 0.059	8.695 ± 0.056
	P-value	0.345	0.997	0.376	0.643	0.235	0.193	0.082
	none	9.747 ± 0.099	10.252 ± 0.05	9.166 ± 0.074	9.489 ± 0.059	10.358 ± 0.056	8.89 ± 0.093	8.623 ± 0.08
	75 RP	9.721 ± 0.099	10.25 ± 0.05	9.147 ± 0.074	9.5 ± 0.059	10.331 ± 0.056	8.894 ± 0.093	8.652 ± 0.08
	150 RP	9.735 ± 0.099	10.189 ± 0.05	9.035 ± 0.074	9.398 ± 0.059	10.282 ± 0.056	8.851 ± 0.093	8.637 ± 0.08
	75 CP	9.757 ± 0.099	10.123 ± 0.05	9.058 ± 0.074	9.336 ± 0.059	10.302 ± 0.056	8.873 ± 0.093	8.593 ± 0.08
	150 CP	9.811 ± 0.099	10.198 ± 0.05	9.166 ± 0.074	9.432 ± 0.059	10.357 ± 0.056	8.911 ± 0.093	8.679 ± 0.08
	P-value	0.959	0.131	0.563	0.064	0.844	0.993	0.945
SC2016	Cont-Cont	8.808 ± 0.082	9.112 ± 0.077	7.368 ± 0.043	8.489 ± 0.085	9.2 ± 0.03	7.731 ± 0.038	7.258 ± 0.031
	Cont-Inoc	8.964 ± 0.082	8.947 ± 0.077	7.357 ± 0.043	8.31 ± 0.085	9.255 ± 0.03	7.771 ± 0.038	7.332 ± 0.031
	Inoc-Cont	8.866 ± 0.082	9.043 ± 0.077	7.346 ± 0.043	8.391 ± 0.085	9.208 ± 0.03	7.68 ± 0.038	7.265 ± 0.031
	Inoc-Inoc	8.876 ± 0.082	9.078 ± 0.077	7.319 ± 0.044	8.43 ± 0.085	9.221 ± 0.03	7.696 ± 0.038	7.269 ± 0.031
	P-value	0.284	0.327	0.774	0.189	0.457	0.332	0.306
	none	8.88 ± 0.086	9.076 ± 0.084	7.393 ± 0.047	8.422 ± 0.09	9.206 ± 0.033	7.745 ± 0.042	7.3 ± 0.035
	75 RP	8.907 ± 0.086	9.029 ± 0.084	7.306 ± 0.047	8.403 ± 0.09	9.209 ± 0.033	7.748 ± 0.042	7.33 ± 0.035
	150 RP	8.748 ± 0.086	9.177 ± 0.084	7.342 ± 0.047	8.515 ± 0.09	9.197 ± 0.033	7.611 ± 0.042	7.204 ± 0.035
	75 CP	8.942 ± 0.086	8.939 ± 0.084	7.322 ± 0.047	8.376 ± 0.09	9.236 ± 0.033	7.763 ± 0.042	7.292 ± 0.035
	150 CP	8.915 ± 0.086	9.005 ± 0.084	7.374 ± 0.047	8.309 ± 0.09	9.256 ± 0.033	7.731 ± 0.042	7.279 ± 0.035
	P-value	0.244	0.217	0.482	0.277	0.586	0.091	0.144
BL2015	Control	8.131 ± 0.069 b	9.189 ± 0.041	8.082 ± 0.122	8.67 ± 0.049	9.252 ± 0.049	6.319 ± 0.076	7.843 ± 0.074
	Inoculant	8.226 ± 0.069 a	9.192 ± 0.041	8.007 ± 0.122	8.686 ± 0.049	9.248 ± 0.049	6.216 ± 0.076	7.808 ± 0.074
	P-value	**0.022***	0.932	0.29	0.713	0.936	0.142	0.478
	none	8.204 ± 0.078	9.191 ± 0.049	8.018 ± 0.136 ab	8.685 ± 0.062	9.214 ± 0.062	6.146 ± 0.097	7.883 ± 0.086
	75 RP	8.14 ± 0.078	9.256 ± 0.049	7.902 ± 0.136 b	8.662 ± 0.062	9.304 ± 0.062	6.228 ± 0.097	7.781 ± 0.086
	150 RP	8.189 ± 0.078	9.185 ± 0.05	8.068 ± 0.136 ab	8.689 ± 0.062	9.268 ± 0.062	6.173 ± 0.097	7.772 ± 0.086
	75 CP	8.159 ± 0.078	9.213 ± 0.049	8.241 ± 0.136 a	8.63 ± 0.062	9.189 ± 0.062	6.377 ± 0.097	7.855 ± 0.086
	150 CP	8.198 ± 0.078	9.109 ± 0.049	7.995 ± 0.136 ab	8.726 ± 0.062	9.272 ± 0.062	6.413 ± 0.097	7.838 ± 0.086
	P-value	0.837	0.073	**0.045***	0.71	0.482	0.056	0.559
BL2016	Cont-Cont	8.682 ± 0.052 a	8.867 ± 0.037 b	7.819 ± 0.111	8.411 ± 0.06	9.002 ± 0.033	7.346 ± 0.086	8.224 ± 0.087
	Cont-Inoc	8.528 ± 0.052 b	9.011 ± 0.037 a	7.882 ± 0.111	8.5 ± 0.06	9.004 ± 0.033	7.158 ± 0.086	8.144 ± 0.087
	Inoc-Cont	8.645 ± 0.052 ab	8.906 ± 0.037 b	7.924 ± 0.111	8.421 ± 0.06	9.065 ± 0.033	7.205 ± 0.086	8.085 ± 0.087
	Inoc-Inoc	8.681 ± 0.052 a	8.876 ± 0.037 b	7.635 ± 0.111	8.515 ± 0.06	8.982 ± 0.033	7.205 ± 0.086	8.219 ± 0.087
	P-value	**0.002****	**0.001****	0.09	0.294	0.097	0.198	0.222
	0Fert	8.676 ± 0.054	8.901 ± 0.04 ab	7.778 ± 0.118	8.443 ± 0.064	9.001 ± 0.035	7.313 ± 0.092	8.185 ± 0.091 ab
	75RP	8.553 ± 0.054	8.969 ± 0.04 a	7.955 ± 0.118	8.446 ± 0.064	9.072 ± 0.035	7.156 ± 0.092	7.979 ± 0.091 b
	150RP	8.645 ± 0.054	8.977 ± 0.04 a	7.692 ± 0.119	8.433 ± 0.064	8.989 ± 0.035	7.195 ± 0.092	8.14 ± 0.091 ab
	75CP	8.627 ± 0.054	8.882 ± 0.04 ab	7.874 ± 0.118	8.445 ± 0.064	9.017 ± 0.035	7.337 ± 0.092	8.243 ± 0.091 a
	150CP	8.667 ± 0.054	8.846 ± 0.04 b	7.776 ± 0.118	8.541 ± 0.064	8.987 ± 0.035	7.142 ± 0.092	8.292 ± 0.091 a
	P-value	0.1	**0.015***	0.326	0.578	0.17	0.202	**0.008****

- ANOVA shows no treatment effects on the abundance of major bacterial phyla Swift Current in 2015 or 2016.
- But in Beaverlodge, inoculation and fertilization modified the abundance of *Acidobacteria*, *Actinobacteria*, *Bacteroidetes*, and *Verrucimicrobia*

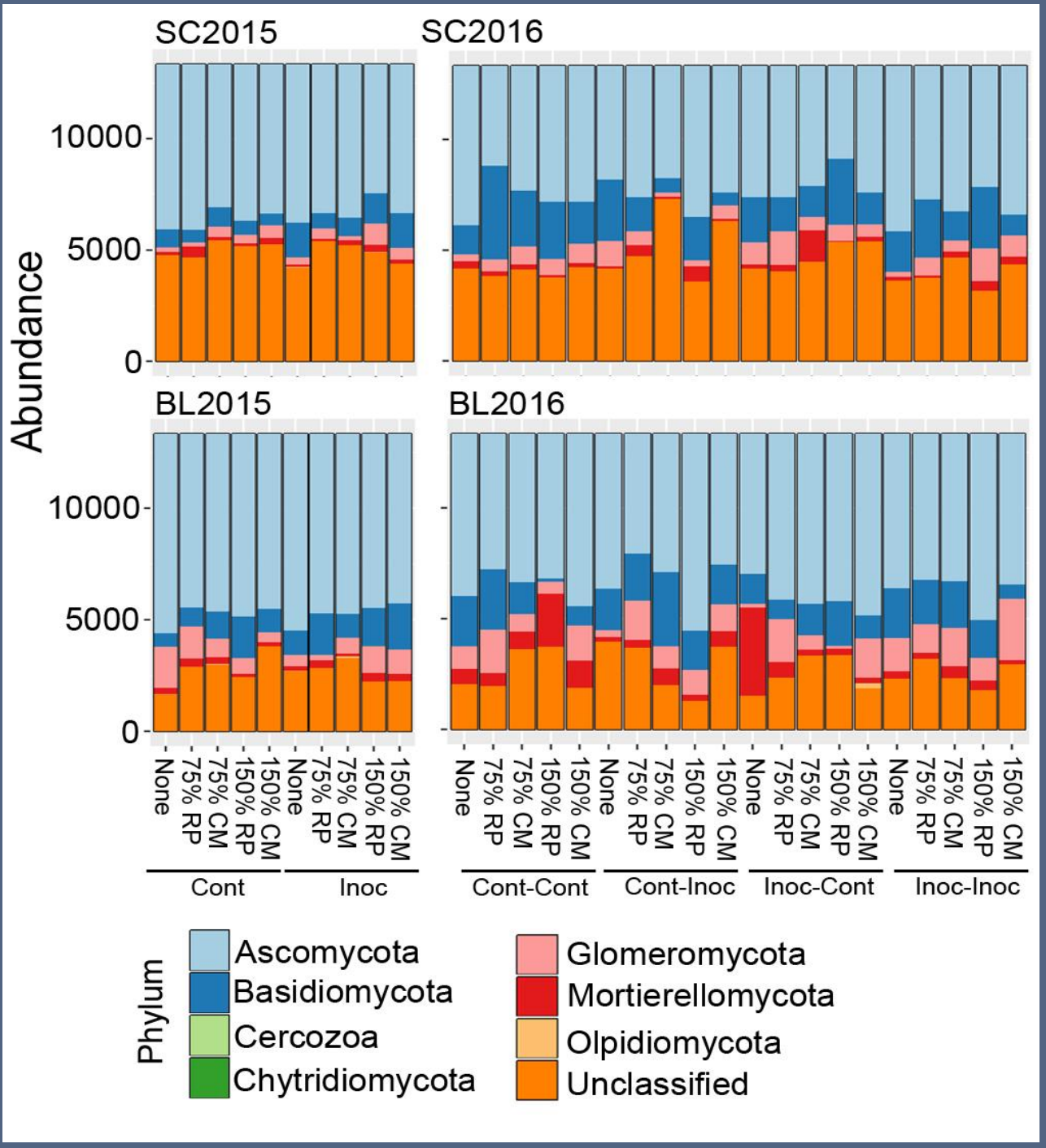
Note: The abundance of bacterial phyla was log2 transformed

Fungi

Swift Current

Beaverlodge

- Shifts between years and sites can be seen
- But the variation within each of the four panels is mostly noise



	Treatment	*Ascomycota*	*Basidiomycota*	*Glomeromycota*	*Mortierellomycota*
SC2015	Control	8.855 ± 0.054	6.515 ± 0.191 b	5.814 ± 0.287	5.24 ± 0.533
	Inoculant	8.799 ± 0.054	7.063 ± 0.191 a	6.097 ± 0.285	5.209 ± 0.501
	P-value	0.464	0.048*	0.482	0.959
	none	8.89 ± 0.085	7.031 ± 0.299	5.499 ± 0.447	4.688 ± 0.729
	75 RP	8.861 ± 0.085	6.469 ± 0.299	5.666 ± 0.454	5.551 ± 0.727
	150 RP	8.767 ± 0.085	6.821 ± 0.299	6.459 ± 0.431	5.436 ± 0.716
	75 CP	8.807 ± 0.085	6.778 ± 0.301	5.827 ± 0.441	5.004 ± 0.771
	150 CP	8.812 ± 0.085	6.845 ± 0.301	6.325 ± 0.429	5.445 ± 0.675
	P-value	0.863	0.78	0.438	0.89
SC2016	Cont-Cont	8.683 ± 0.067	7.832 ± 0.193	6.525 ± 0.275	5.408 ± 0.452
	Cont-Inoc	8.66 ± 0.067	7.206 ± 0.194	6.294 ± 0.283	5.713 ± 0.474
	Inoc-Cont	8.601 ± 0.067	7.526 ± 0.191	6.755 ± 0.272	5.84 ± 0.475
	Inoc-Inoc	8.768 ± 0.067	7.465 ± 0.19	6.653 ± 0.278	5.599 ± 0.449
	P-value	0.369	0.169	0.684	0.927
	0Fert	8.763 ± 0.075	7.676 ± 0.217 a	6.565 ± 0.318	5.327 ± 0.505
	75RP	8.635 ± 0.075	7.769 ± 0.213 a	6.732 ± 0.303	5.561 ± 0.5
	150RP	8.637 ± 0.075	7.854 ± 0.213 a	6.649 ± 0.309	5.754 ± 0.523
	75CP	8.646 ± 0.075	7.202 ± 0.214 a	6.224 ± 0.307	6.148 ± 0.529
	150CP	8.709 ± 0.075	7.035 ± 0.213 a	6.612 ± 0.302	5.409 ± 0.498
	P-value	0.686	**0.035***	0.821	0.796
BL2015	Control	9.003 ± 0.046	6.906 ± 0.196	6.784 ± 0.384	5.562 ± 0.273
	Inoculant	8.995 ± 0.046	7.331 ± 0.193	6.522 ± 0.382	5.593 ± 0.273
	P-value	0.871	0.051	0.485	0.936
	none	9.089 ± 0.066	6.641 ± 0.264	6.941 ± 0.487	5.534 ± 0.422
	75 RP	8.972 ± 0.066	7.088 ± 0.265	6.401 ± 0.49	5.895 ± 0.421
	150 RP	8.992 ± 0.066	7.525 ± 0.263	6.903 ± 0.488	5.564 ± 0.43
	75 CP	8.989 ± 0.066	7.039 ± 0.263	6.541 ± 0.48	5.385 ± 0.429
	150 CP	8.953 ± 0.066	7.3 ± 0.262	6.48 ± 0.484	5.509 ± 0.423
	P-value	0.547	0.123	0.786	0.93
BL2016	Cont-Cont	8.84 ± 0.112	7.213 ± 0.336	7.01 ± 0.407	6.842 ± 0.467
	Cont-Inoc	8.798 ± 0.112	7.682 ± 0.326	6.939 ± 0.413	6.171 ± 0.454
	Inoc-Cont	8.921 ± 0.112	7.229 ± 0.331	6.499 ± 0.418	6.768 ± 0.496
	Inoc-Inoc	8.861 ± 0.112	7.399 ± 0.325	7.442 ± 0.409	5.789 ± 0.447
	P-value	0.892	0.71	0.477	0.245
	0Fert	8.842 ± 0.125	7.581 ± 0.364	6.436 ± 0.464	6.881 ± 0.557
	75RP	8.76 ± 0.125	7.562 ± 0.369	7.561 ± 0.459	6.005 ± 0.493
	150RP	8.969 ± 0.125	7.23 ± 0.375	6.465 ± 0.463	6.51 ± 0.495
	75CP	8.827 ± 0.125	7.583 ± 0.363	6.883 ± 0.451	6.329 ± 0.498
	150CP	8.877 ± 0.125	6.947 ± 0.364	7.517 ± 0.455	6.238 ± 0.499
	P-value	0.829	0.699	0.266	0.771

ANOVA shows no effect on major fungal phyla except for weak effects of inoculation and fertilization on *Basidiomycota* in Swift Current.

Effects of AMF inoculation and fertilization on microbial diversity indices

	AMF				Fungi				Bacteria			
	2015_Swift Current		2015_Beaverlodge		2015_Swift Current		2015_Beaverlodge		2015_Swift Current		2015_Beaverlodge	
	Shannon Index	Evenness	Shannon Index	Evenness	Shannon Index	Evenness	Shannon Index	Evenness	Shannon Index	Evenness	Shannon Index	Evenness
Cont	1.45 ± 0.68	0.51 ± 0.18	1.44 ± 0.65	0.44 ± 0.26	2.58 ± 0.46	0.67 ± 0.1	2.77 ± 0.44	0.67 ± 0.06	6.47 ± 0.22	0.88 ± 0.02	5.95 ± 0.36	0.82 ± 0.05
Inoc	1.48 ± 0.85	0.47 ± 0.22	1.40 ± 0.67	0.56 ± 0.3	2.74 ± 0.52	0.69 ± 0.07	2.71 ± 0.45	0.65 ± 0.07	6.49 ± 0.47	0.87 ± 0.05	5.95 ± 0.29	0.82 ± 0.04
None	1.43 ± 0.8	0.47 ± 0.21	1.32 ± 0.63	0.5 ± 0.25	2.83 ± 0.46	0.71 ± 0.06	2.62 ± 0.49	0.63 ± 0.07	6.56 ± 0.26	0.88 ± 0.01	5.98 ± 0.24	0.83 ± 0.03
75% R.P.	1.52 ± 0.76	0.5 ± 0.19	1.26 ± 0.64	0.57 ± 0.25	2.67 ± 0.62	0.67 ± 0.12	2.86 ± 0.51	0.68 ± 0.06	6.48 ± 0.29	0.87 ± 0.02	5.86 ± 0.33	0.81 ± 0.04
150% R.P.	1.5 ± 0.88	0.51± 0.23	1.46 ± 0.64	0.53 ± 0.38	2.58 ± 0.49	0.66 ± 0.08	2.74 ± 0.41	0.67 ± 0.06	6.43 ± 0.3	0.88 ± 0.02	5.88 ± 0.33	0.81 ± 0.05
75% C.M.	1.35 ± 0.74	0.47 ± 0.21	1.6 ± 0.74	0.46 ± 0.28	2.53 ± 0.48	0.67 ± 0.1	2.93 ± 0.3	0.69 ± 0.04	6.4 ± 0.6	0.87 ± 0.07	6.13 ± 0.24	0.85 ± 0.03
150% C.M.	1.55 ± 0.75	0.5 ± 0.17	1.46 ± 0.67	0.44 ± 0.26	2.68 ± 0.41	0.68 ± 0.07	2.56 ± 0.42	0.64 ± 0.09	6.53 ± 0.28	0.88 ± 0.02	5.89 ± 0.41	0.81 ± 0.05
	2016_Swift Current		2016_Beaverlodge		2016_Swift Current		2016_Beaverlodge		2016_Swift Current		2016_Beaverlodge	
Cont-Cont	1.55 ± 0.48	0.64 ± 0.15	**1.36 ± 0.35 a**	**0.55 ± 0.13 a**	3.04 ± 0.45	0.71 ± 0.05	2.43 ± 0.43	0.71 ± 0.09	6.69 ± 0.19	0.86 ± 0.02	**5.69 ± 0.32 ab**	**0.856 ± 0.015 ab**
Cont-Inoc	1.66 ± 0.59	0.66 ± 0.14	**1.14 ± 0.38 ab**	**0.48 ± 0.15 ab**	3.03 ± 0.62	0.7 ± 0.08	2.57 ± 0.36	0.71 ± 0.06	6.76 ± 0.23	0.86 ± 0.02	**5.76 ± 0.27 a**	**0.859 ± 0.013 a**
Inoc-Cont	1.31 ± 0.6	0.6 ± 0.17	**1.33 ± 0.46 a**	**0.53 ± 0.18 a**	3.14 ± 0.67	0.7 ± 0.09	2.2 ± 0.83	0.63 ± 0.22	6.73 ± 0.24	0.86 ± 0.02	**5.73 ± 0.26 ab**	**0.860 ± 0.014 a**
Inoc-Inoc	1.51 ± 0.41	0.66 ± 0.1	**0.95 ± 0.46 b**	**0.39 ± 0.18 b**	3.08 ± 0.62	0.73 ± 0.08	2.44 ± 0.51	0.71 ± 0.07	6.72 ± 0.26	0.86 ± 0.01	**5.53 ± 0.18 b**	**0.848 ± 0.012 b**
None	1.41 ± 0.64	0.6 ± 0.19	**0.96 ± 0.41 b**	**0.39 ± 0.17 b**	3.14 ± 0.56	0.72 ± 0.06	2.48 ± 0.76	0.69 ± 0.2	6.71 ± 0.23	0.86 ± 0.01	**5.55 ± 0.22 b**	**0.851 ± 0.013 b**
75% R.P.	1.67 ± 0.58	0.69 ± 0.11	**1.08 ± 0.38 ab**	**0.45 ± 0.14 ab**	2.9 ± 0.61	0.67 ± 0.09	2.42 ± 0.39	0.68 ± 0.07	6.74 ± 0.21	0.86 ± 0.02	**5.88 ± 0.29 a**	**0.865 ± 0.013 a**
150% R.P.	1.35 ± 0.41	0.63 ± 0.14	**1.17 ± 0.52 ab**	**0.47 ± 0.19 ab**	3.05 ± 0.59	0.71 ± 0.08	2.14 ± 0.79	0.63 ± 0.18	6.63 ± 0.24	0.86 ± 0.02	**5.61 ± 0.25 b**	**0.851 ± 0.016 b**
75% C.M.	1.65 ± 0.47	0.65 ± 0.12	**1.47 ± 0.29 a**	**0.59 ± 0.08 a**	3.09 ± 0.74	0.72 ± 0.11	2.55 ± 0.38	0.73 ± 0.07	6.74 ± 0.26	0.86 ± 0.02	**5.72 ± 0.25 ab**	**0.859 ± 0.014 ab**
150% C.M.	1.46 ± 0.5	0.63 ± 0.14	**1.31 ± 0.46 ab**	**0.55 ± 0.18 a**	3.2 ± 0.42	0.72 ± 0.04	2.47 ± 0.31	0.71 ± 0.05	6.8 ± 0.19	0.86 ± 0.02	**5.63 ± 0.26 b**	**0.853 ± 0.013 ab**

ANOVA shows inoculation and fertilization effect on the diversity indices of AMF and bacteria in 2nd rotation year in Beaverlodge, only. Inconsistency reflects complex relationships among, microbes, crops, and environmental factors

Conclusions

Microbial community structure

- The microbial communities were driven by the conditions at the sites and year. There was very little influence of fertilization and inoculation on phyla.

Diversity indices

- Repeated inoculation with AMF reduced the diversity of resident AMF and bacteria
- Composted manure increased the diversity of resident AMF, and low level of rock phosphate increased that of bacteria

Abundance of phyla

- Very little treatment effects