Long-term effect of N fertilization and crop rotation on soil microbial community structure and functionality

Atul-Nayyar [1,2*], Chantal Hamel [1,2], Keith Hanson [2] and Jim Germida [1]

[1]Department of Soil Science, University of Saskatchewan, Saskatoon, SK S7N 5A8
[2]Agriculture and Agri-Food Canada, Semiarid Prairie Agriculture Research Centre, Swift Current, SK, S9H 3X2

INTRODUCTION Crop rotation is an important practice to maintain and improve soil physical, chemical and biological quality. Numerous studies have reported the beneficial effect of legumes on subsequent cereal crops but there are relatively few studies that document the influence of cereals on succeeding legume crops. The objective of this study was to evaluate the impact of a wheat rotation crop and nitrogen fertilization of pea on pea root rot incidence and soil microbial community structure and functionality.

MATERIALS AND METHODS

➢The experiment is a ten-year old long-term field study located in Indian Head, Saskatchewan.

➢Treatments were:

•Three N rates (0, 20 and 40 kg N ha^{-1})

•Two cropping systems (wheat-pea rotation and continuous-pea)

•Three sampling times (June, August & September) (Figure 1)

➢Soil (depth 0-7.5 cm), plant and root samples were taken from four locations in plots and bulked together before analyses (Table 1) Nitrate and phosphate fluxes were monitored in situ with anion exchange membranes (AEM).

Table 1. Variables measured and methods

Variables	Evaluation and Method
NO_3 and PO_4 fluxes	Anion Exchange Membranes (Modified from Ziadi et al. 1999)
Root colonized with AMF (%)	Root Colonization Staining (Vierheilig et al. 1998) Grid intersection measurement (Giovanetti and Mosse, 1980)
Plant N	Digest tissue and autoanalyze (Noel and Hambleton, 1976)
Microbial abundance (FAME)	Phospholipid fatty acids (Hamel et al. 2006)
Microbial activity	Dehydrogenase (Casida et al, 1964)
	Phosphatase (Eivazi and Tabatabai, 1977)
	Urease (Modified from Kandeler and Gerber, 1988)

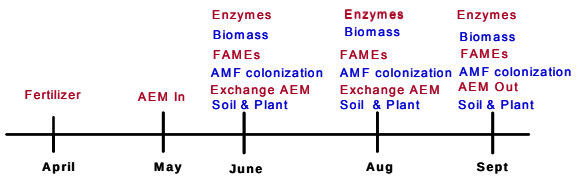

Figure 1. Fertilization, sampling time and parameters analyzed for * AEM= Anion exchange membranes inserted in May were replaced in June and August and finally removed in September

➢The significance of treatment effects on soil-related variables was assessed using repeated-measures analysis of variance (PROC MIXED) and that of plant related variables using ANOVA through SAS. The LSD test was used for treatment means comparisons at p=0.05. Differences in soil microbial community composition were determined using discriminant analysis.

RESULTS

➢ Long-term N fertilization had very little influence, it only reduced AMF root colonization.

➢The NO_3 flux was lower but plant %N was higher in rotation plots as compared to continuous pea plots, but phosphate flux was not affected by crop rotation (Table 2).

➢The effect of crop rotation on disease suppression was significant (Table 2).

Table 2. Soil fertility , root rot , AMF root colonization and enzyme activities in two crop rotations (n=72)

Crop	AEM NO_3 ($\mu g\ g^{-1}\ cm^2\ day^{-1}$)	AEM PO_4 ($\mu g\ g^{-1}\ cm^2\ day\ -1$)	Plant N (%)	Root rot (rating 0-9)	RC (%)	Dase (μg TPF day^{-1})	Phosphatase (μg p-nitrophenol produced $g^{-1}\ hr^{-1}$)	Urease ($\mu g\ g^{-1}\ ha^{-1}$)
Continuous pea	0.006113	0.000078	2.83	2.52	30.94	78.64	24.64	4.32
Rotation pea	0.003612	0.000095	3.17	1.90	34.22	96.97	31.09	4.56
p values	0.0001	ns	0.002	<0.0001	0.002	0.003	0.0001	0.001

AEM = Anion exchange membranes, RC= root colonization, Dase= dehydrogenase

➢Arbuscular mycorrhizal root colonization was 4% higher in rotation pea than continuous pea (Table 2)

➢Soil microbial community composition varied with cropping systems (P= 0.003). The largest changes in biomarkers abundance were the increase in Gram-ve biomarker C18:1c and AMF biomarker C16 1:ω5, and the decrease in saprophytic fungi C18:2 (Table 3).

➢The NLFA/PLFA ratio for C16:1ω5 was low (0.45) indicating a predominant bacterial contribution to this biomarker which thus overestimates impact of rotation on AMF.

➢ Overall soil microbial biomass was increased by 11% with rotation pea (p<0.0001, data not shown).

➢Microbial activity, as assayed by three enzymes, was higher in rotation pea than continuous pea (Table 2).

➢Pea dry matter yield increased in rotation plots compared to continuous plots (Figure 2).

Table 3. Percentage increase or decrease in phospholipid biomarker in soil of rotation pea over continuous pea. Means with different letters are significantly different (n=72)

Type of microorganism	Microbial biomarker	Percent change
AMF	c16:1w5	80 a
fungi	c18:2	-38 c
Gram +ve bacteria	c17:0	-8 b
Gram +ve bacteria	c18:0	-6 b
Gram +ve bacteria	iso c17:0 + c170	-4 b
Gram +ve bacteria	iso c16:0	5 b
Gram +ve bacteria	c14:0	7 b
Gram +ve bacteria	ante c15:0	11 b
Gram +vebacteria	c15:0	13 b
Gram +ve bacteria	c16:0	17 b
Gram +ve bacteria	iso c15:0	19 b
Gram –ve bacteria	c18:1t	-12 c
Gram –ve bacteria	2OH c16:0	-11 b
Gram –ve bacteria	3OH c14:0	-0 b
Gram –ve bacteria	2OH c14:0	16 b
Gram –ve bacteria	3OH c12:0	18 b
Gram –ve bacteria	c18:1c	79 a

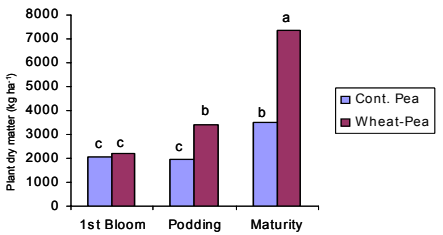

Figure 2. Effect of cropping system and sampling time on dry matter yield of pea. Mean with different letters are different (n=72)

DISCUSSION

➢Including wheat in rotation with pea changed the soil microbial community in favor of bacteria and decreased root rot organisms.

➢ Plant N uptake was impaired in continuous pea as shown by lower plant N% despite higher NO_3 flux in continuous pea.

➢Higher plant biomass in rotation pea leads to larger residue return to soil, a source of carbon and energy for microorganisms. Higher plant productivity was concurrent with higher soil microbial biomass and activity in rotation pea.

CONCLUSIONS

❖Practicing crop rotation of wheat with pea not only increases pea plant productivity but also increases soil microbial activity and functionality, which are two indicators of soil quality.

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REFERENCES

•Eivazi, F. and Tabatabai, M. A. 1977. Phosphatases in soils. Soil Biol. Biochem. 9, 167-172.

•Giovanetti, M., and Mosse, B. 1980. An evaluation of techniques for measuring vesicular-arbuscular mycorrhizal infection in roots. New Phytol. 84, 489-500.

•Hamel, C., Hanson, K., Selles, F., Cruz, A. F., Lemke, R., McConkey, B. and Zentner, R. 2006. Seasonal and long-term resource-related variations in soil microbial communities in wheat-based rotations of the Canadian prairie. Soil Biol. Biochem. 38, 2104-2116.

•Kandeler, E. and Gerber, H. 1988. Short-term assay of soil urease activity using colorimetric determination of ammonium. Biol. Fert. Soil 6, 68-72

•Noel, R.J and Hambleton, L..G. 1976. Collaborative study of a semi-automated method for the determination of crude protein in animal feeds. J. Assoc. Off. Anal. Chem. 59, 134-140.

•Vierheilig, H., Coughlan, A. P., Wyss, U. and Piche, Y. 1998. Ink and vinegar, a simple staining technique for arbuscular-mycorrhizal Fungi. Appl. Environ. Microbiol. 64, 5004-5007.

•Ziadi, N., Simard, R. R., Allard, G. and Lafond, G. 1999. Field evaluation of anion exchange memberans as a N soil testing method for grasslands. Can. J. Soil Sci. 79, 281-294.

nayyara@agr.gc.ca