Landscape- and Micro-Scale Variability of Nitrogen Fixation by Chickpea

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Abstract

A landscape-scale study was conducted near Biggar, SK, to estimate N_2 fixation by chickpea *(Cicer arietinum)* using the natural ^{15}N abundance method. The spatial variability of N_2 fixation was investigated at both the landscape- and micro-scale.

Percentage of N derived from atmosphere (%Ndfa) in chickpea seed and residue ranged from 41.1%-69.5 %and 31.9%-88.4% , respectively. Total kgNdfa (residue plus seed) was estimated as 8.2 - 83.8 kg N ha^{-1}.

Soil moisture, mineral N and pH were characterized by a distinct spatial pattern. Symbiotic N_2 futation, however, was not associated with a regular spatial pattern. Soil properties and N_2 fixation were poorly correlated. Symbiotic N_2 futation was highly variable at both the landscape- and micro-scale.

Introduction

Legumes can fix atmospheric N in association with nodule-formin *Rhizobium* bacteria. Factors known to influence N_2 fixation include soil nutrient status, moisture, pH and salinity. These factors are known to vary over a toposequence (Honeycutt at al., 1990; Stevenson et al., 1995); thus, it is expected that N_2 futation will vary accordingly. Stevenson et al. (1995) and Androsoff et al. (1995) reported that the estimates of N_2 fixation by pea in a natural landscape using the natural ^{15}N abundance and enriched ^{15}N method were poorly correlated. They hypothesized that N_2 fixation by pea was controlled not only at the landscape-scale but also at the micro-scale.

Chickpea is a recently introduced pulse crop to Saskatchewan. Estimation of N_2 futation by chickpea is an important step to understanding its contribution to soil N-cycle. Moreover, there is a need to understand how N_2 fixation by chickpea is influenced by soil variability.

Objectives

1. To estimate N_2 fixation by chickpea in a natural landscape.
2. To investigate the spatial variability of N_2 fixation by chickpea at both the landscape- and micro-scale.

Materials and Methods

Landscape-Scale Study

The study field was surveyed and stratified into different landform element complexes, i.e., shoulders and footslopes (Pennock et al., 1994). The first phase of two crop rotations, i.e., chickpea-wheat and wheat-wheat, was established in 1996. Three 14-sampling-point transects were established in each rotation. The sampling distance was 14.25 m. Canola was used as reference crop for N_2-fixation estimation.

Micro-Scale Study

A 33-m transect was established in a footslope position for the micro-scale study. The sampling distance was 0.3 m. Wheat was used as reference crop for N_2-fixation estimation and was seeded in the neighboring transect of chickpea.

Sampling and Analysis

Spring soil (O-15 cm) moisture, mineral N, pH and EC were measured. Yield, total N and ^{15}N content for crops were measured at harvest. Natural ^{15}N abundance method was used to estimate N_2 fixation for both landscape- and micro-scale study.

Statistical *Analysis*

Because the data were skewed and were highly variable, non-parametric statistics were used to summarize the data, i.e., Mann-Whitney U test was used to test the difference of soil properties and N_2 fixation between shoulders and footslopes (a= 0.20); Spearman coefficient was used to test the correlation between N_2 futation, soil properties and chickpea variables. The semivariance was used to determine the spatial structure of soil properties and N_2 futation.

Results and Discussion

Landscape-Scale Study

Soil properties and N_2 futation were highly variable (Table 1). Footslopes had a higher moisture and mineral N content than shoulders, but a lower pH, whereas EC did not differ between shoulder and footslope positions (Table 2).

Although total biomass yield was significantly higher in footslopes, there is no detectable difference in seed yield between landscape positions. Similarly, estimates of N_2 fixation revealed few differences between landscape positions with the exception of fixed N in chickpea residue (Table 3), probably due to the interrelationship and combined effects of influencing factors.

Residue, seed and total kgNdfa were significantly correlated with soil moisture, but not with mineral N (Table 4). The %Ndfa of residue and seed were not significantly correlated with soil properties. Not surprisingly, %Ndfa and kgNdfa were correlated significantly with chickpea yields.

Micro-Scale Study

Soil properties and %Ndfa along the micro-scale transect were highly variable (Table 5 and Figure 1). No significant correlation between soil properties and N_2 fixation was found. The landscape- and micro-scale variability of N_2 fixation was probably caused by the high variability of soil properties, even though poor correlation between N_2 fixation and soil properties existed in the study field. The range (spatial dependence distance) for moisture and mineral N was about 1 l-m and 4.5-m, respectively (Figure 2). The range for pH, EC and %Ndfa was not detected, indicating that their variability within this data set was random. Symbiotic N_2 fixation can not be easily predicted due to both the high variability of soil properties and the limitations of the estimating approaches.

Summary

At the landscape scale, total N_2 fixation by chickpea ranged from ***8-84*** kg N ha-‘. Data suggest strong topographic controls on soil moisture, mineral N and pH, but not on EC and N_2 fixation. At the micro-scale, the range for moisture and mineral N was about 1 l-m and 4.5-m, respectively. But the range for pH, EC and N_2 fixation was not detected. Symbiotic N_2 fixation was highly variable at both the landscape- and micro-scale. Unknown factors are contributing to this variability, thus, more studies are required.

Acknowledgments

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Table 1 Descriptive statistics for soil properties and N_2 fixation (landscape-scale)

	n	Min.	Max.	Median	IQR	Std Dev	Skewness
Moisture (%)	40	14.8	39.0	8.2	9.7	6.2	-0.29
Mineral N (ppm)	40	2.4	18.0	7.9	3.7	2.9	0.75
pH	40	6.9	8.6	8.0	0.7	4.0	-0.28
EC ($mS\ cm^{-1}$)	40	0.11	0.83	0.28	0.1	0.13	2.54
Seed yield (kg ha^{-1})	40	843	2530	1738	584	417	-0.07
Total yield (kg ha^{-1})	40	960	7420	4105	1505	1128	0.46
Residue %Ndfa	40	31.9	88.4	67.2	17.4	13.4	-0.74
Seed %Ndfa	40	41.1	69.5	58.3	12.1	7.5	-0.4 1
Residue kg Ndfa	40	2.8	24.0	9.1	5.9	5.2	1.00
Seed kg Ndfa	40	3.3	59.9	35.2	17.8	10.9	0.31
Total kg Ndfa	40	8.2	83.8	44.4	22.3	15.0	0.61

Note: IQR = Interquartile range

Table 2 Median values and the results of Mann-Whitney U test for soil properties and chickpea yields related to the landform element complexes, (LEC)

LEC	n	Moisture (%)	Mineral N (ppm)	pH	EC (mS cm-')	Seed yield (kg ha-')	Total yield (kg ha^{-1})
Shoulder	13	23.7a	7.2a	8.2a	0.29a	1726a	3690a
Footslope	27	31.2b	9.4b	7.7b	0.27a	1826a	4210b

Note: Within columns, medianvalues followed by the same letter are not significantly different (a = 0.20).

Table 3 Median values and the results of Mann-Whitney U test for N_2 fixation related to the landform element complexes (LEC)

LEC	n	.....% Ndfa.....		.....kg Ndfa.....		Total Ndfa
		Residue	Seed	Residue	Seed	
Shoulder	13	67.3a	62.7a	6.58a	33.3a	42.5a
Footslope	27	67.2a	57.6a	9.88b	35.8a	46.5a

Note: Within columns, median values followed by the same letter are not significantly different (a = 0.20).

Table 4 Spearman coefficients for %Ndfa, kgNdfa and total kgNdfa of chickpea correlated with soil properties and chickpea yields

	.....%Ndfa.....		.....kg Ndfa.....		Total kg Ndfa
	Residue	Seed	Residue	Seed	
Moisture (%)	N S	NS	0.45***	0.31*	0.39**
Mineral N (ppm)	NS	NS	NS	NS	NS
PI-I	NS	NS	-0.44***	NS	NS
EC (mS cm“)	NS	0.35**	NS	0.27*	NS
Seed yield (kg ha-‘)	NS	0.28*	0.51***	0.89***	0.82***
Total Yield (kg ha^{-1})	-0.27*	0.26*	0.70***	0.83***	0.85***

Note: *,** and *** significant at a = 0.10, 0.05 and 0.01
NS = not significant

Table 5 Descriptive statistics for soil properties and %Ndfa (micro-scale)

	n	Min.	Max.	Median	IQR	Std Dev	Skewness
Moisture (%)	110	17.0	34.2	28.3	3.4	2.5	-0.77
Mineral N (ppm)	110	5.7	19.2	11.8	3.3	2.5	0.10
pH	110	6.8	8.1	7.2	0.1	0.1	1.69
EC (mS cm-‘)	110	0.05	0.32	0.23	0.08	0.06	-0.63
%Ndfa (Residue)	110	20.2	73.6	51.1	12.2	9.3	-0.48
%Ndfa (Seed)	110	33.3	65.6	51.4	7.2	5.5	-0.47

Note: IQR = Interquartile range

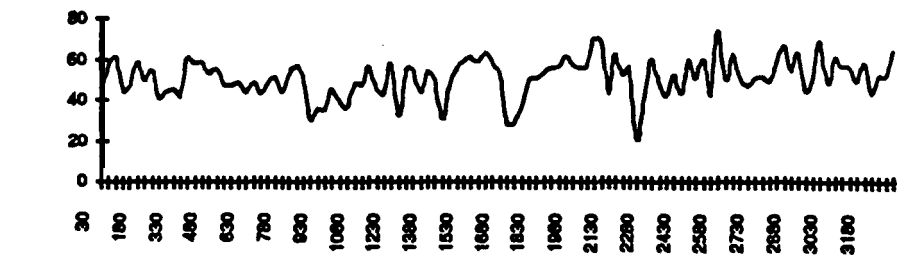

Figure 1 Spatial distribution of chickpea residue %Ndfa along the micro-scale transect

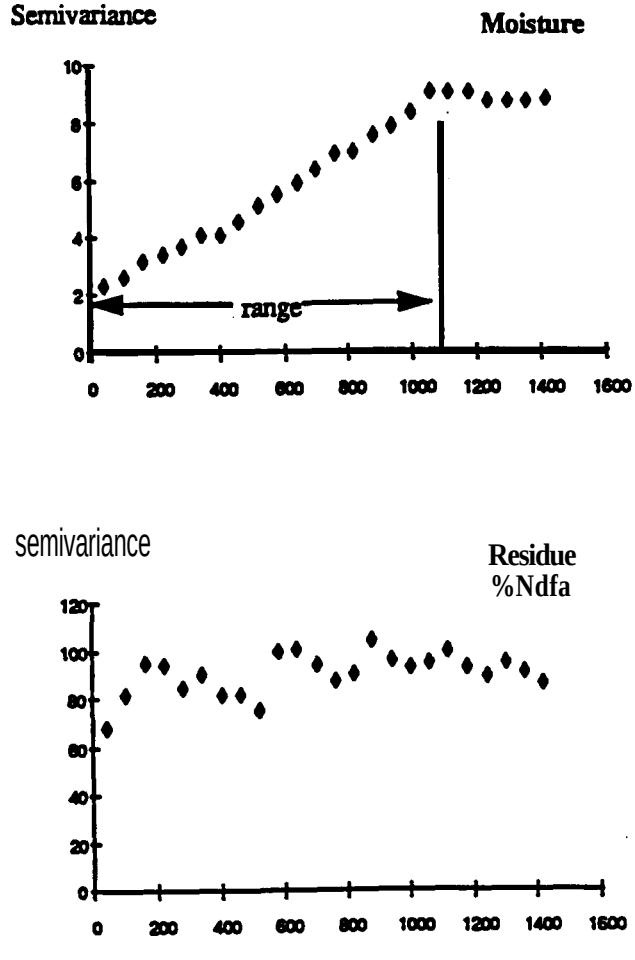

Figure 2 The semivariogram of soi lmoisture and residue %Ndfa