Nitrogen Accumulation by Pea as Affected by Topography

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Abstract

Field peas grown under normal field conditions are exposed to variable soil and environmental conditions that will affect both crop yield and nitrogen (N) uptake. Topography and slope position may play an important role in governing soil and environmental factors that influence N accumulation.

In 1991, a field experiment was initiated to examine the effects of landscape position on the yield and N accumulation by field pea (var. Marofat). A two hectare site was located in the Black soil zone on land with gently sloping to roughly undulating slopes (2-5%). Six landform elements were identified at the site location. The site was managed at a farm scale using typical cultural practices.

Spring levels of inorganic nitrogen ($NO_3 + NH_4$) ranged from 19.0 to 57.4 kg/ha (0-60 cm depth). Differences in levels of inorganic nitrogen between landform elements were observed ($p = 0.03$). Volumetric moisture content of the soil (0-120 cm) was consistently highest in footslopes throughout the growing season. Water stress was not a limiting factor to plant growth in any landform until 50-55 days after planting.

Total yield (seed + straw) of the pea crop ranged from 2310 to 8100 kg/ha while seed yield varied from 960 to 3940 kg/ha. Significant differences between landforms were detected for total yield ($p = 0.02$) but not seed yield. Seed nitrogen content ranged from 31-133 kg/ha but no differences were observed between landforms.

Introduction

Soil and environmental factors and their influence on accumulation of nitrogen by legume crops has not been well studied. Research with cereal grains has indicated that soil stored available water, growing season precipitation/evaporation and fertilizer N explain most of the variations in yield of grain N (Entz and Fowler, 1988; Bole and Pittman, 1980). Environmental stresses affecting grain N yield are most influential when they occur early in the growing season and up until plant flowering stage (Entz and Fowler, 1988).

Quantitative measurement of any process in a natural landscape will exhibit spatial variability. Soil landscape analysis techniques allow distinct portions of the landscape (i.e. landform elements) to be identified. The ability to quantify landform elements and randomly select replicates results in an unbiased experimental design (Pennock et al., 1987). Non-parametric statistical tests can then be carried out with respect to landform element.

A field experiment was designed in 1991 to test whether topography affects nitrogen accumulation in a temperate climate, undulating prairie landscape. Objectives were to measure the amount and variability of nitrogen accumulation occurring in a heterogeneous natural landscape, and determine which soil and/or environmental factors associated with nitrogen accumulation are most influenced by topography and slope position.

Materials and Methods

The experimental site is located in the Black soil zone of Saskatchewan on land with gently sloping to roughly undulating slopes (2-5%). Soil parent materials are of glacio-fluvial and glacio-lacustrine origin. Surface soils have a fine sandy loam texture. The site was cropped to spring wheat in 1990.

In early May, a representative area of the landscape (approximately 200 metres by 200 metres) was selected. A 10 metre square grid design was imposed and grid intersection points were surveyed with a theodolite. Information from the survey was entered into a computer surface interpolation program in order to determine landform elements. Six landform elements were identified within the landscape and include; 1) converging footslope (CFS), 2) converging shoulder (CSH), 3) diverging footslope (DFS), 4) diverging shoulder (DSH), 5) lower level (LL) and 6) upper level (UL). Ten replicates of each landform element were then randomly selected to provide a total of 60 sites.

On May 12, soil was collected from each of the 60 sites to a depth of 120 cm. Samples were collected to determine mineral nitrogen (NH4 + NO3), gravimetric moisture, bulk density, available water holding capacity, pH, soil electrical conductivity and particle size.

On May 27, the field was seeded by the cooperating farmer to green pea (var. Marofat) at a rate of 134 kg/ha. Prior to seeding, the field had been treated with ethalfluralin and supplied with 17 kg/ha of N and 17 kg/ha of P from a blend of 46-0-0 and 12-51-0 dry fertilizer.

During the growing season soil was collected (0-120 cm) biweekly from 30 of the 60 sites for gravimetric moisture determination. Surface soils (60 sites) were measured in situ for pH and analyzed for NH_4 and NO_3 at regular intervals from early May until September.

Weed plants were removed throughout the growing season from pea plots to prevent any N transfers between species.

At physiological maturity (August 26), pea was harvested. The crop was dried, threshed and weighed to determine total yield (seed + straw) and seed yield. Total % nitrogen of pea seed was determined by micro-Kjeldahl methods (Bremner and Mulvaney, 1982).

Results

Data presented hereafter (Tables 1-5) has been grouped according to landform element and tested to determine whether differences exist between the six landforms. The Kruskal-Wallis one-way analysis of variance by ranks is a non-parametric test that is designed to determine if differences exist between the median values of at least one pair of groups (Siegel and Castellan, 1988). The level of significance used for the data is $\propto = 0.2$. If a significant difference is observed, a multiple comparison method between groups was carried out.

Prior to seeding (May 12), levels of mineral nitrogen and volumetric water content of the soil in early spring were determined (Table 1). Mineral nitrogen was highest at the UL position with a median value of 45 kg/ha and is significantly different ($p = 0.03$) from the LL (29 kg/ha) and DFS (34 kg/ha) landscape positions.

Volumetric water content is expressed as centimetres (cm) of water in the 0 to 120 cm depth of the soil profile. The footslope positions (CFS and DFS) had significantly higher moisture levels ($p = 0.0002$) while the DSH has the lowest moisture level (Table 1).

Table 1: Pre-seeding mineral N and volumetric water by landform element

Land form	Mineral N (kg/ha)*		Land form	cm Water (0-120 cm)	
LL	29	a**	DSH	25	a**
DFS	34	a	UL	28	ab
CFS	36	ab	CSH	29	abc
DSH	37	ab	LL	29	bc
CSH	37	ab	CFS	32	c
UL	45	b	DFS	33	bc

* includes 0-60 cm depth

** Medians followed by same letter are not significantly different

Volumetric water content was measured biweekly over the duration of the growing season (Table 2). The first sampling date (June 11) roughly corresponds with period in which pea seedling emergence began to occur. Differences between landform element medians during the growing season were detected on four sampling dates (June 11, July 10, July 22 and

August 7). Data in Table 2 shows a general pattern of soil water content to be present throughout the growing season. Footslopes (DFS and CFS) generally had a higher moisture content while shoulders (CSH and DSH) were generally the driest landforms.

By July 22nd, some sites (especially shoulders) began to dry out to a level below that of permanent wilting point (PWP) in the top 30 cm of the profile. No water would be available to the plant when moisture content is below PWP. Most landform elements had sites with moisture contents below PWP in the upper 45 cm of the soil profile at the August 7th sampling date. By August 22nd, shoulder element moisture contents were all below PWP in the upper 60 cm of the profile.

Soil pH was measured in situ with a pH probe. The pH in the 0 to 15 cm depth did not change between the two measurement periods (Table 3). A difference in pH (p = 0.08) was detected between the DSH (8.02) and CFS (7.18) landform elements.

Table 2: Growing season moisture by landform element from June 11 to August 22 (cm of water in 0-120 cm depth)

Land form	June 11	June 25	July 10	July 22	Aug 7	Aug 22
DFS	34	33	30	27	26	22
CFS	32	33	31	25	23	20
UL	29	30	29	24	23	21
LL	29	30	27	24	20	20
CSH	31	31	28	21	19	18
DSH	29	30	26	22	18	16

The CSH landform element had the highest total yield (7185 kg/ha) and was significantly different (p = 0.02) than DFS (4950 kg/ha) and UL (5310 kg/ha) elements (Table 4). The median yield for the CFS element (5185 kg/ha) is lower than that of UL, but no difference was detected between it and the CSH.

Table 3: Soil pH in different landform elements measured in the spring and fall (0-15 cm depth)

Landform	Spring		Fall	
CFS	7.18	a *	7.18	a *
CSH	7.46	ab	7.46	ab
DFS	7.49	ab	7.49	ab
LL	7.55	ab	7.55	ab
UL	7.80	ab	7.80	ab
DSH	8.02	b	8.02	b

* Medians followed by same letter are not significantly different

Table 4: Total yield of pea in different landform elements

Landform	*Total Yield (kg/ha)	
DFS	4950	a **
CFS	5185	ab
UL	5310	a
DSH	5725	ab
LL	6135	ab
CSH	7185	b

* Total Yield = Seed + Straw

** Medians followed by same letter are not significantly different

Table 5: Seed yield, harvest index and seed N of pea in different landform elements

Land form	Seed Yield* (kg/ha)	H.I. *	Seed N* (kg/ha)	Spring Mineral N (kg/ha)
UL	2350	0.48	73	45 b **
CFS	2575	0.48	81	36 ab
DFS	2615	0.46	78	34 a
DSH	2690	0.48	88	37 ab
CSH	2880	0.44	94	37 ab
LL	2880	0.48	91	29 a

* No significant differences observed for this variable

** Medians followed by same letter not significantly different

No differences between landform elements was found to exist with respect to seed yield, H. I. or seed N (Table 5). Seed protein content was very consistent (20-21 %) across the entire field when grouped as landforms.

Discussion

In a temperate climate, prairie region, the amount of precipitation (and soil moisture) may be expected to have the greatest impact on crop growth. Rainfall was well above average in 1991. Growing conditions were excellent and crop yields at the site were very good. Water stress was not apparent in any landform until 50-55 days after planting.

The preliminary pH data (Table 4) does not suggest that differences present would affect N accumulation to any great extent. Soil inorganic N would be plant available within this range and most legume/rhizobia associations in temperate areas require a neutral or slightly alkaline pH for maximum N fixation (Gibson, 1977).

When seed yield and seed N are compared to spring levels of mineral N, a general pattern is apparent. Seed yield and seed N values are high when mineral N is low (CSH and LL). It would be reasonable to speculate that higher rates of N fixation in the CSH and LL would account for high levels of seed N yield in these landforms. In any case, N would not appear to be limiting plant growth.

Total seed N was not significantly different between landform positions. It does not appear that environmental/soil stresses influenced seed yield or N accumulation in pea seed with respect to topography or slope position. Growing conditions were optimal, especially in the early part of the season, when plants would be most susceptible to stress.

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