Representative sampling size and number of required samples for soil testing in direct seeding fields

Wei Hu[1], Bing C. Si[1], Jeff. J. Schoenau[1]

[1]Department of Soil Science, University of Saskatchewan, 51 Campus Drive, S7N 5A8, Saskatoon, SK

Key Words: representative sampling size, strip sampling, nitrogen, phosphorus, direct seeding

Abstract

Direct seeding is widely utilized in the southern Canadian prairies. The associated band application of fertilizers makes conventional soil testing problematic. Strip sampling was suggested in direct seeding fields, but little is known about the optimum strip length. The objective of this study was (1) to identify the representative sampling size (RSS) of a sampling strip and (2) to determine the number of required samples (NRS) in a field in terms of point-based random sampling. Soil samples of 0-10 cm and 10-20 cm were collected from two 10 acre farm fields near Central Butte in the Brown soil zone of Saskatchewan. For strip sampling, five 160 cm long and 10 cm wide sampling strips were selected in these two fields. Different samples with sampling lengths ranging from 5 cm to 155 cm were obtained. For random sampling, 30 and 45 samples using a 4 cm diameter tubular probe were collected in these two fields. The results showed that RSSs differed with fields, nutrient types and soil layers. On average, the RSSs were 60 cm, 65 cm and 35 cm, respectively for testing NO_3^--N, NH_4^+-N and extractable P. The NRSs differed with sampling fields but not with nutrient types and soil layers. With a confidence level of 95%, about 30 and 80 random samples are needed in these two fields, respectively, to achieve mean estimate of soil nutrients with a relative error of 10%. This study provided a reference of soil sampling for soil nutrient tests in direct seeding fields.

Introduction

Soil testing is a useful tool for determining crop fertilizer requirements for crops. However, the value of the soil test is only as good as the method used to take the soil samples. It is important to be representative in collecting the samples.

Common methods for soil sampling are to take soil samples at a few points from a field and then mix them for testing. The assumption is that each sample represents locally a relatively uniform area and the composite sample evens out field-scale variability. Direct seeding and conservation tillage has been widely adopted in the Canadian prairies (McKenzie et al., 2001). For this cropping system, because fertilizers are usually band-applied and there is little soil disturbance, the location where the sample is taken is of importance for soil testing. If samples are taken along the fertilizer band from the previous year, the value of the soil sample will be much higher than the field average. Furthermore, after a few years' direct seeding, it is hard to identify and locate fertilizer bands visually, because the location of the fertilizer band varies each year. Therefore, there is a challenge as how one can take representative samples for soil testing from such a field.

To overcome the soil sampling problem associated with band fertilization, some laboratories (such as Western Ag Laboratories) suggest strip sampling for soil testing. However, there is no

research on what is the representative strip length, in order to alleviate the effect of non-uniform fertilizer application on soil testing. Alternatively, random sampling with enough point-based samples should be feasible to get the field average (Yan and Cai, 2008). The number of required samples (NRS) for random sampling depends on spatial variability of a nutrient in a field. However, little is known about the spatial variability of soil nutrients and the NRS in direct seeded fields.

The objective of this study was (1) to identify the representative sampling size (RSS) of a sampling strip and (2) to determine the NRS in terms of random sampling in direct seeded fields.

Materials and methods

Soil samples were collected from two farm fields near Central Butte (50° 47′ 31″ N latitude, 106° 30′ 28″ W longitude) in south-central Saskatchewan. The soil is dominated by Brown Chernozems of Haverhill, Ardill and Kettlehut soil associations (Saskatchewan Soil Survey, 1989) with loamy texture. This area is characterized by moderately sloping (0–10%) topography (Kar et al., 2012).

Two 10 acre fields were selected for soil sampling (Table 1). These two fields are termed as 2011 fall field and 2012 spring field, respectively, according to their different sampling time. In the 2011 fall field, two sampling strips located 40 m apart were selected at the upper slope and lower slope of a catena. In the 2012 spring field, three sampling strips located 30 m apart were equidistantly distributed at different locations along a toposequence. Each strip was 160 cm long and 10 cm wide. Small segments of 5 cm length were dissected, thus 32 soil samples were obtained for each strip. At the same time, 30 (2011 fall) and 45 (2012 spring) random samples were collected with a tubular probe (4 cm in diameter) in these two fields. Soil samples from 0-10 cm and 10-20 cm were obtained for both sampling methods. For each sample, concentration of NO_3^--N, NH_4^+-N and extractable P was measured by Technicon automated colorimetry (Noorbakhsh et al., 2008).

Table 1. Sampling Fields Description in Central Butte.

Legal location/ Sampling time	Field description	Strip location	Strip name	Fertilization	Number of random sample cores /measured nutrient
NE36-20-4-3rd /2011 fall	wheat seeded in 2011 with row spacing of 25 cm, 2.5 cm spread (disc)	Upper slope	2011fall_Upper	15kg N & 25 kg P_2O_5/ha in seed row, 60 kg N/ha in mid row	30 cores (4 cm in diameter) in 10 acres /NO_3^--N, NH_4^+-N and extractable P
		Lower slope	2011fall_Lower	24 kg N & 39 kg P_2O_5 /ha in seed row, 70 kg N/ha in mid row	
NW30-20-R3-wf3rd /2012 spring	wheat seeded in 2011 with row spacing of 30 cm, 7.5 cm spread (sweep)	Upper slope	2012spring_Upper	50 kg N & 20 kg P_2O_5/ha all in seed row	45 cores (4 cm in diameter) in 10 acres /NO_3^--N, NH_4^+-N and extractable P
		Middle slope	2012spring_Middle		
		Lower slope	2012spring_Lower		

The samples from strips were used to explore the RSSs. The measured soil nutrients were averaged over consecutive 2 to 31 segments, so that the average represents measurement over a 10 cm to 155 cm long sample size. For each sample size, statistics such as mean, variance and coefficient of variation (CV) were obtained. We expected that the CV values would decrease with increasing sample size. The corresponding sampling length when CV<0.1 was treated as the RSS

of a strip for a given soil nutrient test because spatial variability is weak in case where CV<0.1 (Zhang et al., 2007).

The random samples were used to determine the NRS in a field. Under the assumption that the soil nutrients are normally distributed, the NRS in a field is given by (Garten et al., 2007):

$$\text{NRS}=t^2\frac{\sigma^2}{d^2} \qquad (1)$$

where t is the value of the Student's t-distribution for NRS-1 degrees of freedom and $\alpha = 0.05$ (confidence level of 95%), σ is standard deviation, d is the acceptable error which was defined as 5%, 10%, 15% and 20% of the mean values determined in this study.

Results and Discussion

Statistics for soil nutrients at the strip (microscale) and field scales are listed in Tables 2 and 3, respectively. Extractable P concentration was usually higher than NO_3^--N and NH_4^+-N, while concentrations of NO_3^--N and NH_4^+-N were comparable. Soil nutrient concentrations differed among fields, slope locations and soil layers. They were usually lower in the 2012 spring field than in the 2011 fall field. No major trends of soil nutrients were found along the toposequence. While the concentrations of NO_3^--N and NH_4^+-N were comparable between two soil layers, the extractable labile P concentration at 0-10 cm depth was usually much higher than that at 10-20 cm. This may due to that fertilizers were usually applied in the top 10 cm layer and weathering of primary mineral P to secondary labile P forms is greater at the surface. As well P is not highly mobile in the soil profile.

Table 2. Summary of Statistics of Soil Nutrients for Different Sampling Strips (N=32).

		0-10 cm			10-20 cm		
Strip name	**Soil nutrients**	**Mean (ug/g)**	**Variance (ug^2/g^2)**	**CV (%)**	**Mean (ug/g)**	**Variance (ug^2/g^2)**	**CV (%)**
2011fall_Upper	NO_3^--N	6.5	5.8	36.6	5.0	2.3	30.7
	NH_4^+-N	3.7	10.2	84.3	3.7	9.0	80.8
	P	24.0	29.2	22.3	7.3	3.6	25.9
2011fall_Lower	NO_3^--N	4.9	2.6	33.3	3.4	1.4	33.9
	NH_4^+-N	4.2	1.7	30.6	4.1	1.2	26.6
	P	20.1	14.4	19.0	8.2	4.4	25.1
2012spring_Upper	NO_3^--N	1.8	0.4	31.1	2.2	0.4	27.1
	NH_4^+-N	4.3	5.3	55.1	5.8	4.4	35.7
	P	11.6	5.8	20.5	4.2	0.4	14.9
2012spring_Middle	NO_3^--N	1.9	0.5	35.5	2.5	0.4	23.7
	NH_4^+-N	2.8	0.3	19.3	2.7	0.5	25.9
	P	15.6	2.9	10.8	8.6	4.8	25.1
2012spring_Lower	NO_3^--N	1.8	0.2	21.2	2.3	0.2	17.9
	NH_4^+-N	6.9	3.6	27.6	6.3	1.0	16.4
	P	10.1	2.3	14.5	5.2	0.8	17.2

The CV values of all soil nutrients fell into the range of 0.1 to 1.0, indicating a moderate variability for all nutrients. Spatial variability differed with nutrient types, sampling locations and soil layers, but no trends were observed. At the field scale, variability of soil nutrients was similar

between different nutrient types and soil layers, but the relative variability in the 2012 spring field was greater than that in the 2011 fall field.

Of particular note is that variability of soil nutrients for some strips was comparable to that encountered at the field scale. The field area (10 acres) is 2.5×10^5 times of that of a strip (0.16 m^2), and the sample volume at the field scale (126 cm^3 for a sample) is about one fourth of that in the strip (500 cm^3). Therefore, our result disagree with the general findings that spatial variability increased with increasing sampling area and decreasing sampling volume (Grigal et al., 1991). This is likely related to the band application of fertilizers creating considerable microscale variability. The comparable variations between 1.6 m-strip and 10 acre-field indicate a possibility to scale up variation and mean value of soil nutrients from smaller to larger spatial areas in case of band application of fertilizers.

Table 3. Summary of Statistics of Soil Nutrients for Random Sampling in the Two Fields (N=30 in 2011fall and N=45 in 2012spring).

Field	Soil nutrients	0-10 cm			10-20 cm		
		Mean (ug/g)	Variance (ug^2/g^2)	CV (%)	Mean (ug/g)	Variance (ug^2/g^2)	CV (%)
2011 fall	NO_3^--N	6.2	2.9	27.8	6.1	2.9	27.7
	NH_4^+-N	7.5	6.3	32.7	7.5	6.3	34.0
	P	12.3	16.0	32.5	10.3	8.4	27.8
2012 spring	NO_3^--N	2.2	1.0	45.5	2.6	1.2	42.3
	NH_4^+-N	2.8	1.7	45.9	2.8	1.7	46.0
	P	11.3	28.1	46.7	9.2	20.3	49.3

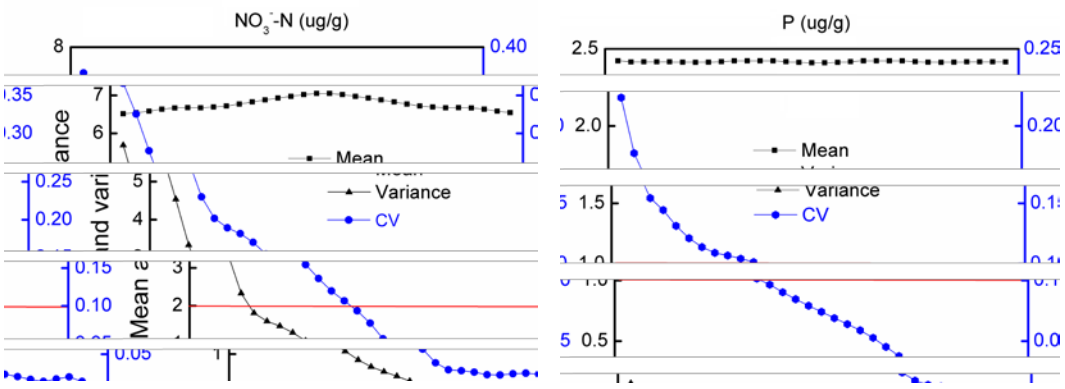

Figure 1. Mean, variance and coefficient of variance (CV) of soil nutrients versus strip length at 0-10 cm (2011fall_Upper).

The mean value of soil nutrients generally kept stable with different strip length, while variance and CV decreased sharply with increasing strip length (Fig. 1). Beyond a certain strip length, they decreased very slowly or kept stable. The RSS differed with sampling locations, soil layers and nutrient types (Fig. 2). On average, the RSS roughly ranked in the order of upper slope > lower slope for both fields. The RSS values for NO_3^--N and NH_4^+-N were slightly greater at 0-10 cm than those at 10-20 cm, while it was reverse for extractable P. The trends of RSSs among sampling locations and soil layers were closely related to the variability of soil nutrients at

the strip scale (Table 2). In addition, the RSS for extractable P was usually smaller than that of NO_3^--N and NH_4^+-N. On average, the RSS for NO_3^--N, NH_4^+-N and extractable P was 60 cm, 65 cm and 35 cm, respectively.

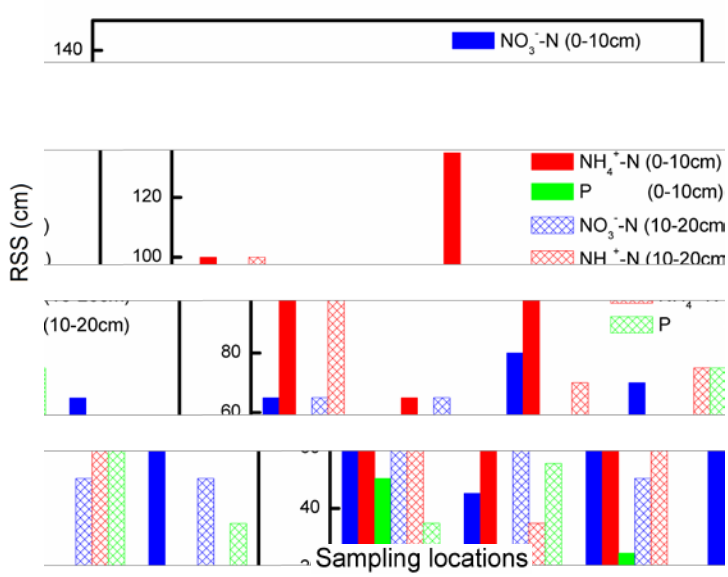

Figure 2. Representative sampling size (RSS) of a strip at different sampling locations.

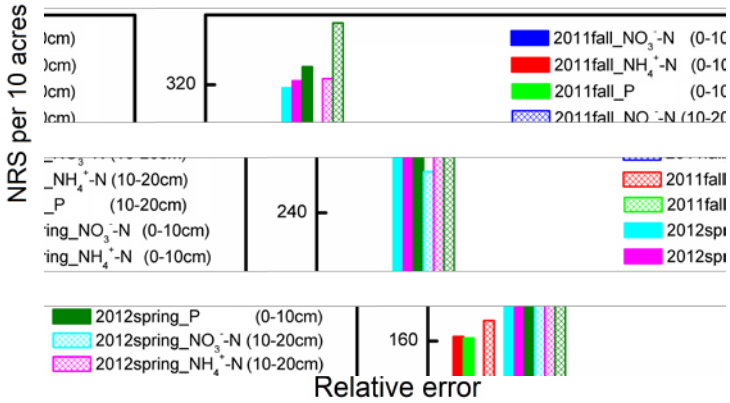

Figure 3. Number of required samples (NRS) to achieve different relative errors with a confidence level of 95%.

The NRS did not show difference between different nutrient types and soil layers for a given field (Fig. 3). However, it differed with sampling fields. This is because the relative variability as indicated by the CV value in the 2012 spring field was much stronger than that in the 2011 fall field. Therefore, if the same absolute error was defined for both fields, the NRS for NO_3^--N and

NH_4^+-N measurement would be smaller in the 2012 spring field than that in the 2011 fall field because of the less variance of NO_3^--N and NH_4^+-N in the 2012 spring field.

Furthermore, the NRS values in a 10 acre sampling field differed largely with relative error (Fig. 3). For relative error of 5%, a very large number (over 100) of sample cores is needed, being much larger than the number of our samples. For relative error of 20%, the NRS was only about 10 to 25. In this study, a relative error of 10% was suggested for soil testing in the field. As such, it is determined that about 30 and 80 samples would be required for the 2011 fall and 2012 spring fields, respectively. It is noteworthy that the 2011 fall field had variable rate application of fertilizer made on it in 2011 while the 2012 spring field had a constant rate of fertilizer applied across the field in 2011.

According to this study, both the RSS and NRS were related to the spatial variability of soil nutrients. Therefore, the cropping systems and associated nutrient management which can influence the variability of soil nutrients should be considered in determining the RSS and NRS. Although this study showed that the variability of soil nutrients at strip and field scales were comparable, the average level could differ with these two contrasting scales. Further study should focus on identifying a "benchmark" strip or determining the number of representative strip to achieve a reliable estimate of field average of soil nutrients.

Acknowledgements

The financial support of Agriculture Development Fund (ADF) is appreciated. Thanks to Cory Fatteicher, Tom King, Brett Ewen and Ron Urton for their assistance in sampling collection and sample analysis and to Yonge Farms for providing a field for sampling.

References

Garten, C. T., Kang, S., Brice, D. J ., Schadt, C. W. and Zhou, J. 2007. Variability in soil properties at different spatial scales (1 m-1 km) in a deciduous forest ecosystem. Soil Biol. Biochem. 39: 2621-2627.

Grigal, D. F., McRoberts, R. E. and Ohmann, L. F. 1991. Spatial variation in chemical properties of forest floor and surface mineral soil in the North Central United States. Soil Sci. 151: 282-290.

Kar, G., Derek, P. and Schoenau, J. J. 2012. Spatial distribution and chemical speciation of soil phosphorus in a band application. Soil Sci. Am. J. 76: 2297-2306.

McKenzie, R. H., Middleton, A. B. and Zhang, M. 2001. Optimal time and placement of nitrogen fertilizer with direct and conventionally seeded winter wheat. Can. J. Soil Sci. 81: 613-621.

Saskatchewan Soil Survey. 1989. Rural Municipality of Humboldt No. 370. Preliminary soil map and report. Saskatchewan Institute of Pedology, Univ. of Saskatchewan, Saskatoon, SK, Canada.

Yan, X. Y. and Cai, Z. C. 2008. Number of soil profiles needed to give a reliable overall estimate of soil organic carbon storage using profile carbon density data. Soil Sci. Plant Nutr. 54: 819-825.

Zhang, X. Y., Sui, Y. Y., Zhang, X. D., Meng, K. and Herbert, S. J. 2007. Spatial variability of nutrient properties in black soil of northeast China. Pedosphere 17: 19-29.