Soil nitrogen and phosphorus were greater in overlapping areas of fields in Alberta, Saskatchewan, Manitoba, and Ontario

Authors: Crittenden, S.J., Fitzmaurice, J., Lewis, M., Reid, K., and Irvine, B.

Source: Canadian Journal of Soil Science, 101(1) : 168-171

Published By: Canadian Science Publishing

URL: https://doi.org/10.1139/cjss-2020-0052

NRC Research Press

SHORT COMMUNICATION

Soil nitrogen and phosphorus were greater in overlapping areas of fields in Alberta, Saskatchewan, Manitoba, and Ontario

S.J. Crittenden, J. Fitzmaurice, M. Lewis, K. Reid, and B. Irvine

Abstract: A total of 344 soil cores were taken in annually cropped fields of Alberta, Saskatchewan, Manitoba, and Ontario from 2011 to 2013 in areas where the field shapes, or obstacles within fields, required the driving pattern of farm operations to overlap. Soil nitrate-N concentrations in overlapping areas were 60% greater, soil Olsen-P concentrations were 23% greater, and pH was 0.5 units greater at 0–15 cm depth compared with non-overlapping areas, suggesting smaller nutrient use efficiency and potential for greater nutrient loss.

Key words: nitrogen, phosphorus, soil organic matter content, overlap, spatial distribution.

Résumé : De 2011 à 2013, les auteurs ont prélevé 344 carottes de sol dans des champs cultivés annuellement en Alberta, en Saskatchewan, au Manitoba et en Ontario. L'échantillonnage a été effectué là où le relief ou un obstacle quelconque nécessitait un chevauchement des travaux agricoles. Dans la couche de 0 à 15 cm de profondeur du sol, à ces endroits, la concentration de N-nitrate était plus élevée de 60 %, celle de P extrait par la méthode d'Olsen était plus élevée de 23 % et le pH était de 0,5 unité plus haut qu'aux endroits où les travaux ne se chevauchaient pas. Ces résultats donnent à penser que les oligoéléments y sont moins bien assimilés et que la perte des éléments nutritifs pourrait y être plus grande. [Traduit par la Rédaction]

Mots-clés : azote, phosphore, teneur en matière organique du sol, chevauchement, répartition spatiale.

Introduction

Crop nutrient use efficiency (NUE) is an important consideration in annual cropping systems, so that crop production is maximized, whereas environmental impact is minimized. Fertilization rate is often considered to maximize production for crops; however, placement of nutrients within the field is also key to improving crop NUE spatially. Shapes of agricultural fields and obstacles within fields will determine driving patterns for farm operations such as seeding, fertilization, and harvesting. Overlap of seed, fertilizer, and pesticide applications increase with smaller field size and when fields are irregularly shaped, and the amount of overlap depends on size of the farm implement, obstacles in the field, field shape, and field size (Shockley et al. 2012). Automatic section control (ASC) can reduce excess application of seed, fertilizer, or pesticide by turning off parts of equipment where application to land has already occurred. The profitability of ASC depends on field size and field shape (Larson et al. 2016). Though technology exists to reduce overlap application, there is a lag in adoption. A survey of western Canadian producers reflecting the 2016 crop year found that ASC was available on 73% of respondents' equipment, but that only 36% used it for fertilizer application, 26% for seeding, and 70% for spraying, whereas 27% did not have ASC (Steele 2017). It should be noted that the survey respondents were generally younger, had larger farm sizes, and had greater revenues than average western Canadian farms, which may have

Received 16 April 2020. Accepted 10 August 2020.

S.J. Crittenden, J. Fitzmaurice, and B. Irvine. Agriculture and Agri-Food Canada, Brandon Research and Development Centre, 2701 Grand Valley Road, Brandon, MB R7A 5Y3, Canada.

M. Lewis. Agriculture and Agri-Food Canada, 107 Science Place, Saskatoon, SK S7N 0X2, Canada.

K. Reid. Agriculture and Agri-Food Canada, 174 Stone Road West, Guelph, ON N1G 4S9, Canada.

Corresponding author: Stephen Crittenden (email: Stephen.Crittenden@Canada.ca).

Can. J. Soil Sci. **101**: 168–171 (2021) dx.doi.org/10.1139/cjss-2020-0052

skewed the results towards greater adoption of newer technologies. Tractor guidance systems can also improve efficiency by reducing equipment overlap and gaps (Kharel et al. 2020). In addition to double application in overlap areas, when farm equipment turns, more product is applied on the inside of the turn than the outside because the tangential velocity increases with distance from the axis of rotation, and thus more nutrients are applied per unit area (Sama et al. 2015). Nutrient applications should match crop uptake as closely as possible to minimize potential losses through leaching, runoff, or gaseous emissions. However, landscape features, such as water bodies, roadways, electrical towers, or odd or non-symmetric field shapes may force complex driving patterns for farm equipment that create uneven nutrient applications with areas of overlap in excess of crop requirement. One-pass fertilizer and seeding equipment, ASC, and variable control of sprayers and planters at the individual row or nozzle level are technologies that are currently available to improve efficiency, though the return on investment is inconsistent depending on field size, shape, and crop (Smith and Dhuyvetter 2016). The objective of the current work was to quantify the amount of nutrient buildup in areas of agricultural fields that experience overlap from driving patterns of farm equipment relative to adjacent non-overlap areas.

Materials and Methods

Sites were selected based on crop type, soil class, farm equipment used, and size of overlap area. Crops were either cereal, canola (*Brassica napus* L.), or soybean (*Glycine max* L.) in the year of sampling, and sites must have been cropped each year for the previous 5 yr. Soils had uniform texture, low salinity, and no manure in the previous 15 yr. Topography was near level with no water ponding issues. The same seeder width must have been used for the previous 5 yr (though changes could have occurred previously) with a minimum 3 m wide overlap. Soil samples were taken on 118 fields of 68 farms in total: nine farms in Alberta, 33 in Saskatchewan, 18 in Manitoba, and eight in Ontario, Canada. There were 90 samples taken in 2011, 552 in 2012, and 390 in 2013 for a total of 1032 over three depths (0–15, 15–30, and 30–60 cm) from 344 soil cores. Soil samples were taken in paired clusters in autumn after harvest. The first cluster was in “overlap” locations where obstacles forced the producer to drive twice over the same area each seeding pass, compared with the second cluster where there were no obstacles present (“no overlap”). Stubble from the harvested crop must have been present at double the rate in the overlap compared with the no overlap areas. The three major groups of obstacles present were fixed interior, fixed exterior, and riparian. Interior obstacles were inside of the field (e.g., electrical poles), exterior obstacles were at the edges of the production fields (e.g., irregular field shapes, headlands, or margins), and riparian obstacles were water bodies contained within, or passing through, a field. Five soil cores (each 5 cm diameter) were taken within a cluster and combined. Cores within a cluster were less than 2 m apart. There was a 5–10 m gap between sampling clusters in the overlap and the non-overlap areas, depending on the size of the seeding equipment and obstacle shape. A total of 188 cores were taken in fixed interior, 116 in fixed exterior, and 40 in riparian areas. Samples were also classified into soil group (i.e., Brown, Dark Brown, and Black Chernozem and Gray Brown Luvisol). Soil was air-dried immediately after sampling, ground at 2 mm, and sent to a commercial laboratory (Agvise Laboratories, Northwood, OH, USA) for analysis of nitrate-N, Olsen-P, pH (1:1 soil to water), and soil organic matter content (SOM) by loss-on-ignition (Nathan and Gelderman 2015), and particle size (Gee and Or 2002). From the original 1032 samples, all were analyzed for nitrate-N, 772 for SOM, 304 for Olsen-P, 208 for pH, and 129 for soil texture. Olsen-P was analyzed only for the 0–15 cm depth. Paired treatment comparisons were done separately for each depth using Student’s t tests in R (R Core Team 2019) at $P < 0.05$.

Results and Discussion

Statistically significant greater concentrations of nitrate-N and Olsen-P, and greater soil pH were found in overlap than non-overlap areas (Table 1). Soil nitrate-N concentrations in overlap areas were 60% greater at 0–15 cm depth, 90% greater at 15–30 cm depth, and 135% greater at 30–60 cm depth. Soil Olsen-P concentrations were 23% greater, and soil pH was 0.5 units greater in overlap compared with non-overlap areas at the 0–15 cm depth. The significantly greater nitrate-N and Olsen-P in the 0–15 cm depth in overlap compared with adjacent non-overlap areas indicates consistent over-application of nutrients in these areas. Nitrate-N concentrations were also greater at 15–30 and 30–60 cm depths in overlap compared with non-overlap areas, indicating that nitrogen applied at or near the soil surface tended to move downward and accumulate lower in the soil profile. The build-up of nitrate-N and Olsen-P concentrations during at least the previous 5 yr period where equipment size did not change, suggests consistent over-application that was not compensated for by uptake and export of plant biomass in these double-seeded overlap areas. The greater pH values in overlap areas were likely due to tillage operations in the overlap areas bringing alkaline subsoil to the surface. Not all fields were consistently under no-till management. Overlapping areas of fields would have received excess tillage operations, as they did for fertilization, and therefore, subsoil mixing and the pH increase could be greater in overlapping areas. However, in contrast to pH, SOM remained equal between overlap and non-overlap areas at all depths. The lack of difference in SOM between overlap and non-overlap areas suggests

Table 1. Mean soil organic matter content (SOM), nitrate-N, Olsen-P, clay content, and pH values by depth for overlap versus non-overlap areas, number of samples (*n*), and significance of *t* tests comparing overlap to non-overlap areas at all sites.

Depth (cm)	SOM ($g{\cdot}kg^{-1}$)			Nitrate-N ($mg{\cdot}kg^{-1}$)			Olsen-P ($mg{\cdot}kg^{-1}$)			Clay content ($g{\cdot}kg^{-1}$)			pH		
	n	No overlap	Overlap	*n*	No overlap	Overlap	*n*	No overlap	Overlap	*n*	No overlap	Overlap	*n*	No overlap	Overlap
0–15	344	42.8 (1.4)	42.5 (1.4)	344	9.0 (0.8)	14.4* (1.2)	298	11.1 (0.9)	14.1* (0.9)	67	307 (38)	268 (13)	124	6.82 (0.65)	7.30* (1.59)
15–30	214	24.4 (1.3)	25.1 (1.2)	344	4.3 (0.3)	8.6* (0.9)	—	—	—	28	357 (44)	356 (45)	38	7.16 (1.64)	7.23 (1.66)
30–60	214	16.0 (1.0)	16.9 (1.1)	344	5.9 (0.4)	14.3* (2.5)	—	—	—	28	361 (44)	361 (46)	38	7.74 (1.78)	7.65 (1.76)

Note: Standard errors are shown in parentheses after the mean. The asterisks (*) indicate a significant difference at $P < 0.05$ by Student's *t* test.

that the additional nitrogen and phosphorus left in overlapping areas of fields did not lead to a similar increase in crop residue and (or) root inputs that would be expected to increase SOM (Jackson et al. 2017). Differences in fertilization due to overlap likely would not have influenced SOM to a large extent given that the size of farm equipment had remained constant for at least the previous 5 yr (Gregorich et al. 1996). Clay content was also similar between overlap and non-overlap areas (Table 1) indicating no difference in soil formation processes. Although crop yield was not measured, it can be assumed that the double-seeded overlapping areas did not increase crop yield linearly (i.e., double) relative to the single-seeded areas because the overlap areas accumulated nitrate-N and Olsen-P over time, suggesting that uptake was unbalanced with fertilization.

Data were further broken down into types of overlapped situations (data not shown). Nitrate-N and Olsen-P were greater in overlap areas compared with non-overlap areas for all types (i.e., field interior, exterior, and riparian areas) in a similar pattern to the overall analysis. For field exterior overlap areas, nitrate-N was 30% greater at 0–15 cm depth, 50% greater at 15–30 cm depth, and 65% greater at 30–60 cm (though not significantly greater at 30–60 cm due to variability in overlap nitrate-N concentrations) compared with non-overlap areas. For field interior overlap areas, nitrate-N was 44% greater at 0–15 cm depth, 53% greater at 15–30 cm depth, and 61% greater at 30–60 cm compared with non-overlap areas. Although not significant, nitrate-N was 21% greater at 0–15 cm depth, 18% greater at 15–30 cm depth, and 6% less at 30–60 cm depth in overlap compared with non-overlap areas in riparian zones. Although not significant, Olsen-P at 0–15 cm depth was between 20% and 25% greater in overlap areas of interior, exterior, and riparian zones. Paired *t* test comparisons were also made for nitrate-N, Olsen-P, and SOM by soil group (i.e., Black, Dark Brown, or Brown Chernozem and Gray-Brown Luvisol) (data not shown). Patterns in nitrate-N, Olsen-P, and SOM between overlapping and non-overlapping areas were similar to those for the overall data when separated by soil group.

Technological options for producers to reduce overlapping areas of fields include both software (e.g., guidance systems) and hardware (e.g., ASC of seeder); however, the return on investment of these technologies is site specific depending on farm characteristics (Shockley et al. 2012). It should be noted that because this study is observational in nature, causal links between greater amounts of nutrients in overlapping areas cannot be attributed exclusively to excess nutrient applications. Another explanation for the greater nitrogen and phosphorus contents in overlapping areas could also be smaller plant uptake due to soil constraints such as compaction.

Conclusions

These data show that nitrogen and phosphorus are present in greater amounts in areas of arable fields in the Canadian Prairie region and Ontario where, due to field configuration, driving patterns overlap. Producers, consultants, and researchers should avoid sampling in overlap areas because they do not represent typical field conditions. Greater care must be taken in overlapping areas of arable fields to fully reach yield potential by maximizing NUE through fertilization and minimizing losses to the environment which should lessen production costs. Technologies currently available such as ASC and one-pass fertilizers and seeders can be employed to reduce over-applications of nutrients thus reducing nutrient losses to the environment and improving agronomic and economic efficiency.

Acknowledgements

We would like to acknowledge Terry Kowalchuk, Dale Hicks, Jillian Smith, Anthony Masich, Myles Kopytko, and Jeff Thiele for helping to organise the soil samplings. In addition, constructive comments from reviewers greatly improved the manuscript.

References

Gee, G.W., and Or, D. 2002. Particle-size analysis. Pages 255–293 in J.H. Dane and C.G. Topp, eds. Methods of soil analysis. Part 4. Physical methods. SSSA Book Series 5.4. SSSA, Madison, WI, USA.

Gregorich, E.G., Ellert, B.H., Drury, C.F., and Liang, B.C. 1996. Fertilization effects on soil organic matter turnover and corn residue C storage. Soil Sci. Soc. Am. J. **60**: 472–476. doi:10.2136/sssaj1996.03615995006000020019x.

Jackson, R.B., Lajtha, K., Crow, S.E., Hugelius, G., Kramer, M.G., and Piñeiro, G. 2017. The ecology of soil carbon: pools, vulnerabilities, and biotic and abiotic controls. Annu. Rev. Ecol. Evol. Syst. **48**: 419–445. doi:10.1146/annurev-ecolsys-112414-054234.

Kharel, T.P., Ashworth, A.J., Shew, A., Popp, M.P., and Owens, P.R. 2020. Tractor guidance improves production efficiency by reducing overlaps and gaps. Agric. Environ. Lett. **5**: e20012. doi:10.1002/ael2.20012.

Larson, J.A., Velandia, M.M., Buschermohle, M.J., and Westlund, S.M. 2016. Effect of field geometry on profitability of automatic section control for chemical application equipment. Precision Agric. **17**: 18–35. doi:10.1007/s11119-015-9404-y.

Nathan, M.V., and Gelderman, R.H. 2015. Recommended chemical soil testing procedures for the north central region. North Central Regional Research Publication No. 221 (revised). Missouri Agricultural Experiment Station SB 1001. Columbia, MO, USA. pp. 75.

R Core Team. 2019. R: a language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. [Online]. Available from https://www.R-project.org/.

Sama, M.P., Luck, J.D., and Stombaugh, T.S. 2015. Scalable control architecture for variable-rate turn compensation. Appl. Eng. Agric. **31**(3): 425–435. doi:10.13031/aea.31.10848.

Shockley, J., Dillon, C.R., Stombaugh, T., and Shearer, S. 2012. Whole farm analysis of automatic section control for agricultural machinery. Precision Agric. **13**: 411–420. doi:10.1007/s11119-011-9256-z.

Smith, C.M., and Dhuyvetter, K.C. 2016. Determining the economically optimal level of control on sprayers and planters. J. ASFMRA, 1–21. doi:10.22004/ag.econ.236651.

Steele, D. 2017. Analysis of precision agriculture adoption & barriers in western Canada. [Online]. Available from https://www.realagriculture.com/wp-content/uploads/2017/04/Final-Report-Analysis-of-Precision-Agriculture-Adoption-and-Barriers-in-western-Canada-April-2017.pdf [10 Sep. 2020].