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Effect of subsoiling and injection of pelletized organic matter on soil quality and productivity

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Leskiw, L. A., Welsh, C. M. and Zeleke, T. B. 2012. **Effect of subsoiling and injection of pelletized organic matter on soil quality and productivity**. Can. J. Soil Sci. **92**: xxx–xxx. Subsoil compaction is a widespread problem in most reclamation and other industrial operations. The objective of our research was to evaluate effectiveness of coupling deep subsoiling with injection of 20 Mg ha^{-1} organic matter pellets. Research was conducted at seven sites on a pipeline right-of-way in central Alberta. Treatments were subsoiling, subsoiling with pellets and a compacted right-of-way (control), established in spring and fall 2009. Treatment effects on soil physical properties and nutrient status were assessed in fall 2009 for spring-established sites and on all sites in fall 2010. Density and height of canola plants were determined in late summer 2010. Relative to the control, subsoiling with pellet treatments had lower bulk density in the 20- to 40-cm depth interval (up to 40%) in 2010, particularly in clay-loam soils. This treatment often had higher available phosphorus and total organic carbon in 2010, and total nitrogen in spring treated sites in 2009. Relative to the control, subsoiling with pellets had 46% higher canola plant density in clay loam soils of fall-treated sites. Subsoiling with pellets is recommended on heavy-textured, compacted soils to alleviate compaction and increase plant productivity.

Key words: Compaction, subsoiling, organic pellets, available nutrients, soil amendments

Leskiw, L. A., Welsh, C. M. et Zeleke, T. B. 2012. **Incidence du sous-solage et de l'injection d'agglomérés de matière organique sur la qualité et la productivité des sols**. Can. J. Soil Sci. **92**: xxx–xxx. Le compactage du sous-sol est un problème largement répandu dans la plupart des activités de restauration du sol et d'autres activités industrielles. La recherche devait évaluer si combiner le sous-solage à l'injection de 20 Mg d'agglomérés de matière organique par hectare a une quelconque efficacité. L'étude s'est déroulée à sept endroits le long de la servitude de passage d'un pipeline, dans le centre de l'Alberta. Les traitements étaient les suivants : sous-solage, sous-solage avec agglomérés et témoin (servitude compactée), au printemps et à l'automne 2009. On a évalué l'incidence du traitement sur les propriétés physiques du sol et sur le bilan nutritif à l'automne 2009 pour les sites aménagés au printemps, et à l'automne 2010 pour l'ensemble des sites. La densité et la hauteur des plants de canola ont été établies à la fin de l'été 2010. Comparativement au site témoin, le sous-solage avec injection d'agglomérés avait engendré une moins grande densité apparente dans la couche de 20 à 40 cm de profondeur (jusqu'à 40 %) en 2010, principalement dans les sols loameux-argileux. Ce traitement a souvent donné lieu à une concentration plus élevée de phosphore disponible et de carbone organique en 2010, tandis que la concentration totale d'azote était plus élevée aux sites traités au printemps 2009. Toujours comparativement au site témoin, le sous-solage avec injection d'agglomérés a augmenté la densité des plants de canola de 46 % dans les loams argileux des sites aménagés à l'automne. Les auteurs recommandent le sous-solage avec injection d'agglomérés pour les sols compactés à texture lourde, afin d'atténuer le compactage et d'accroître le rendement des cultures.

Mots clés: Compactage, sous-solage, agglomérés organiques, éléments nutritifs disponibles, amendements du sol

Subsoil compaction is an on-going concern in most reclamation and industrial sites such as well sites, pipeline corridors, forestry, mining and construction operations. In agriculture and forestry practices, repeated traffic from machinery with axle loads in excess of 10–18 Mg is a common occurrence (Häkansson 1994; Abu-Hamdeh 2003; Berli et al. 2004; Munkholm et al. 2005). This heavy trafficking on the soil surface causes soil deformation, which is transmitted from surface to subsurface layers, resulting in major and persistent compaction. The problem becomes more serious in clay and Solonetzic soils and when construction and reclamation are practiced while the soil is wet and most susceptible to compaction (Schwenke et al. 1999).

Research shows that subsoil compaction leads to a very persistent and often permanent loss in soil productivity, which is often reflected in yield reductions (Håkansson 1994). Subsoil compaction impedes root growth and significantly reduces aeration, water infiltration, macroporosity and availability of nutrients (Unger and Kaspar 1994; Motavalli et al. 2003). Ishaq et al. (2001) reported a 12–35% reduction in nitrogen uptake by wheat (*Triticum aestivum* L.) and a 23% reduction by sorghum (*Sorghum bicolor* L. Moench) due to subsoil compaction. Lower crop yields may be a result of lower soil nitrogen availability under compacted conditions. Subsoil compaction also contributes to increases in rates of denitrification or nitrous oxide

(N_2O) production during wet periods (Linn and Doran 1984; Torbert and Wood 1992).

Subsoiling is one of the most common methods used to alleviate soil compaction. It breaks up dense soil layers, improves water infiltration and movement, enhances root growth and development and increases crop production (Díaz-Zorita 2000). In southern Illinois, Varsa et al. (1997) used deep tillage to break up clay pans in the soil, which led to increased rooting depth and yield of corn (*Zea mays* L.). However, other studies have shown the opposite and stressed a recompaction problem (Larney and Fortune 1986; Munkholm et al. 2005). In north Alabama, Raper et al. (2005) found no increase in cotton (*Gossypium hirsutum*) with either annual, biennial or triennial subsoiling treatments. The argument by the latter group was that mechanically loosened subsoil is prone to recompaction as a recently tilled soil has substantially lower strength. In Alberta, subsoiling treatments did not significantly increase yield of wheat (*Triticum aestivum* L. var. Neepawa) on solonetzic soils from that of irrigation alone (Chang et al. 1986), nor was subsoiling successful in fracturing compacted layers of haul roads in the Alberta boreal forest over a wide range of soil types (McNabb 1994).

Techniques that permanently improve soil physical quality, such as organic matter incorporation, can be coupled with subsoiling operations if the benefits, feasibility and cost justify the practice. Research to date has shown that organic materials reduce compressibility of a soil by increasing resistance to deformation, elasticity of the soil and biological activities (Soane 1990). In the high-rainfall zone of southern Australia, grain yield of wheat (*Triticum aestivum* L. var. Ambrook) increased by up to 1.7 times through incorporation of organic amendments into the upper layers of the B horizon (Gill et al. 2008). This was attributed to the resulting decrease in bulk density and greater access to subsoil water with organic amendment treatments. Organic amendments also had better soil aggregation due to increased microbial activity (Gill et al. 2009). In South Carolina, Khalilian et al. (2002) reduced the soil hardpan of a sandy-loam soil and increased the yield of cotton with deep tillage and organic pellet amendment treatments. In general, subsoiling with deep incorporation of organic amendments has improved soil physical, chemical and biological properties in the zone of incorporation. Long term effects of this treatment, however, have yet to be determined.

Based on the above observations we hypothesized that coupling deep subsoiling with organic pellet injection would have a greater long-term effect on subsoil compaction than subsoiling alone. The alleviation of compaction would in turn improve productivity of impacted lands. The main objective of this study was to evaluate the effect of subsoiling in conjunction with pellet injection on soil physical properties, nutrient status and crop productivity in Alberta, one and two growing seasons after treatment application.

MATERIALS AND METHODS

Study Sites

The study sites were located approximately 100 km southeast of Edmonton, Alberta, Canada. Seven research sites were established along a TransCanada PipeLines Ltd. (TCPL) right-of-way that had been compacted by pipeline construction, which occurred in 2006. Sites ranged from approximately 2 km apart (sites 1, 2 and 3; sites 5 and 6; and sites 4 and 7), 30 km apart (sites 1, 2 and 3 to sites 5 and 6; sites 5 and 6 to sites 4 and 7) and 50 km apart (sites 1, 2 and 3 to sites 4 and 7). The pipeline was installed using full right-of-way stripping and the trench was excavated with a wheel trencher. The soil conditions were quite wet during reclamation. The pipe was buried approximately 1.2 m below the soil surface and the right-of-way was 40 m wide. Soil was an imperfectly drained Humic Gleysol at site 1, a moderately well drained Black Solodized Solonetz at site 3, and well drained Black Chernozems on the remaining sites (Soil Classification Working Group 1998). Parent material at all sites is morainal. Soil texture ranges from sandy loam to clay loam and land use at each site includes grazing of a grass and legume mix (sites 1–4) with free range beef cows and calves and crop production of canola (*Brassica napus*) (sites 5–7) (Table 1). Normal annual precipitation is 483 mm (Canadian Climate Normal 1971–2000 for Stettler, Alberta; Environment Canada 2011) of which most falls as rain in June to August. Study year 2009 was a relatively dry year and 2010 was relatively wet (Fig. 1).

Table 1. Geographic locations, site characteristics and sampling periods of the study sites

Site	Location	Soil texture	Land use	Treatment year	Sampling year
1	52°34′3″N 113°01′34″W	Loam	Grazing	Spring 2009	Fall 2009 and 2010
2	52°34′3″N 113°1′34″W	Loam	Grazing	Spring 2009	Fall 2009 and 2010
3	52°33′46″N 113°0′11″W	Sandy loam	Grazing	Spring 2009	Fall 2009 and 2010
4	52°26′38″N 112°16′28″W	Clay loam	Grazing	Spring 2009	Fall 2009 and 2010
5	52°31′23″N 112°33′36″W	Clay loam	Canola	Fall 2009	Fall 2010
6	52°32′11″N 112°37′9″W	Clay loam	Canola	Fall 2009	Fall 2010
7	52°26′17″N 112°15′35″W	Sandy loam	Canola	Fall 2009	Fall 2010

Author: Check date of Chang et al. 1986 (1994 in reference list).

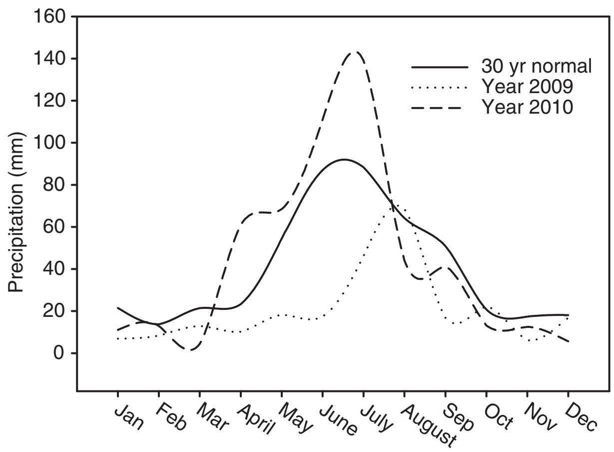

Fig. 1. Mean monthly precipitation in 2009 and 2010 at the closest climate station to the sites (Environment Canada 2011). Broken lines show 30 yr normal precipitation.

Treatments

Each site was approximately 40 m wide by 100 m long and consisted of three treatments with three replicates (Fig. 2). Treatments were a compacted control, subsoiling alone and subsoiling with pellet injection. An undisturbed reference, located off the pipeline right-of-way on an adjacent farm field and not subjected to compaction, was used as a benchmark for crop production of canola on sites 5–7. At each site, the control was located within the compacted area overlying the trenchline and extending about 3 m to either side of the trench for a combined width of 6 m, and was not treated with subsoiling or pellet injection. The subsoiling with pellets treatment was applied along the remaining compacted right-of-way on both work and spoil sides of the control, except for three random 3 m by 10 m areas per site that were subject to only subsoiling. Subsoiling and subsoiling with pellets treatments were established in spring 2009 for sites 1–4 and in fall 2009 for sites 5–7.

For subsoiling and subsoiling with pellets treatments, a paratill subsoiler (Bigham Brothers Inc., Lubbock, TX) with a specially designed pellet delivery and injector system (Patent pending) which could inject pellets while ripping the subsoil layer was used for deep ripping of the subsoil layer to relieve compaction. The subsoiler shank has a vertical, straight upper shank with the lower part curved to one side. The base is raised towards the back and produces a slight soil lift. For this study, shanks were spaced 61 cm apart and set to 30 to 40 cm depth of subsoiling (from the surface). Pellets were applied at 20 Mg ha^{-1} based on initial calibration results from bench scale greenhouse tests (data not shown). The pellets were produced by a private clean technology company called EarthRenew Corporation (Calgary, Alberta). To construct the pellets, manure was subjected to a flash drying process at very high temperatures (approximately 800°C), which breaks down and destroys fungi and bacteria, plant seeds and chemicals including pesticide and herbicide residues. The pellets are 0.32 cm long and have an average bulk density of 0.78 Mg m^{-3} (Table 2). Extractable metals and microbial content were within environmentally acceptable ranges, and meet the category A compost standard of the Canadian Council of Ministers of the Environment (2005).

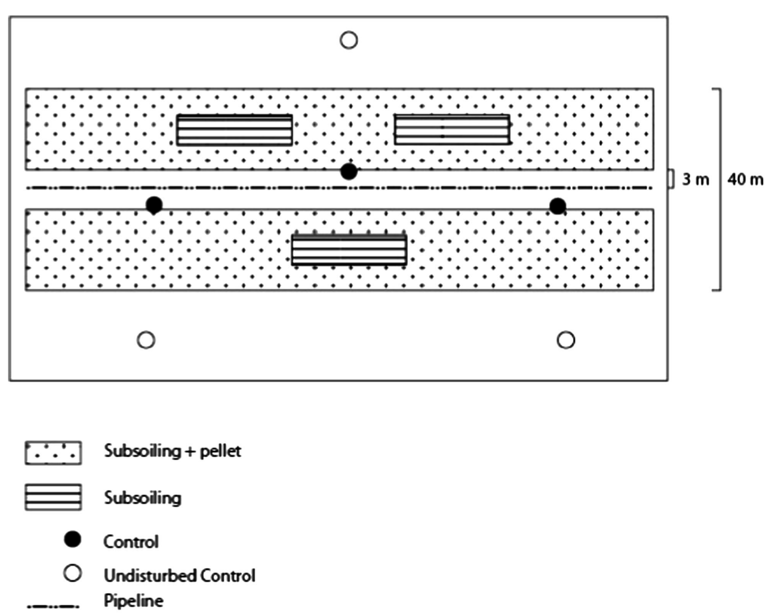

Fig. 2. Treatment layout representative of sites 1–7.

Table 2. Properties of organic matter pellets

Property	Value
Bulk density (Mg m^{-3})	0.78
Organic matter (g kg^{-1})	510
Total nitrogen (g kg^{-1})^{z}	18
Phosphorus (g kg^{-1})^{z}	5.2
Potassium (g kg^{-1})^{z}	12.4

^{z}Concentration is presented on a dry weight basis.

Soil Chemical and Physical Analyses

For sites 1–4, soil samples were taken on 2009 Oct. 06 (4 mo. after establishment) and 2010 Oct. 20 (two growing seasons after establishment). For sites 5–7, soil samples were taken 2010 Oct. 20 (1 yr after establishment). Three random soil samples were taken for each treatment at each site at 0- to 20-cm depth interval for topsoil and 20- to 40-cm depth interval for subsoil. All analyses were performed by Exova Inc. Chemical analyses included total organic carbon, total nitrogen, and available nutrients including nitrate, phosphorus and potassium. A 2 M potassium chloride extract was used to determine nitrate nitrogen (Maynard et al. 2008), and the modified Kelowna method (Ashworth and Mrazek 1995) was used to determine phosphorus and potassium (Carter 1993). Total carbon and total nitrogen concentrations were determined by catalytic tube combustion at 900°C by an elemental analyzer (Vario MAX CN, Elementar Americas, Inc., Mt. Laurel, NJ). Total organic carbon was determined by loss on ignition, which involved subtracting total inorganic carbon (determined after burning off organic carbon) from total carbon (Blume et al. 1990). Bulk density of topsoil and subsoil was determined (after drying at 105°C for 24 h) from undisturbed samples collected in duplicates using metal cores of 72 mm (inside) diameter and 75 mm height (Hao et al. 2008). Soil texture analysis was conducted using the hydrometer method (Kroetsch and Wang 2008) to determine percent sand, silt and clay.

Plant and Root Density

To determine treatment effect on crop yield, plant density (number of plants per 1 m row), plant height, health and vigour were determined at ripening stage for canola in late summer on three replicates of each control, reference and subsoiled with pellets treatments. Plant density was not determined on sites 1–4 as these were used for grazing and not crop production; however, health and vigour of pasture grasses were recorded. Root density was determined in a soil pit at the 20- to 40-cm depth interval by counting number of exposed roots per 100 cm^2 (Day 1982).

Data Analyses

Analysis of variance (ANOVA) with multiple comparisons was used to determine if treatments had a significant effect on soil physical and chemical properties. For sites 5–7 canola densities were used to determine effect of treatment on crop production. Sites 1–4 were combined to analyze results of spring treatments on soil properties. Data were then combined to determine effect of year on soil physical and chemical properties. Sites 5–7 were combined to analyze effect of fall treatments on soil physical and chemical properties and plant density and height of canola. All sites were combined to determine overall treatment effect on soil physical and chemical properties. A two-way ANOVA was used to determine significance of site, treatment and site × treatment for spring- and fall-established samples at $P = 0.05$, $\alpha = 0.05$. A three-way ANOVA was used to determine significance of site, treatment, year, site × treatment, treatment × year and site × year on spring-established samples. If significant differences were detected, the Holm-Sidak test was used to compare results of individual treatments. The Shapiro-Wilk normality test was used to check for normal distribution. All statistical tests in this study were conducted using the General Linear Models (GLM) procedure in R Statistics (R-stat 2010) and Sigma Plot Version 11.2 (Systat 2010).

RESULTS AND DISCUSSION

Subsoil Bulk Density

When all sites were combined, bulk density in the subsoil (20- to 40-cm depth interval) was significantly lower in the subsoiling with pellets treatment (1.20 Mg m^{-3}) than in control (1.40 Mg m^{-3}) and subsoiling (1.37 Mg m^{-3}) treatments (Fig. 3). The subsoiling treatment, however, was not significantly different from the control. No site × treatment interactions were detected, indicating the subsoiling with pellets treatment was more effective in lowering bulk density than the subsoiling alone.

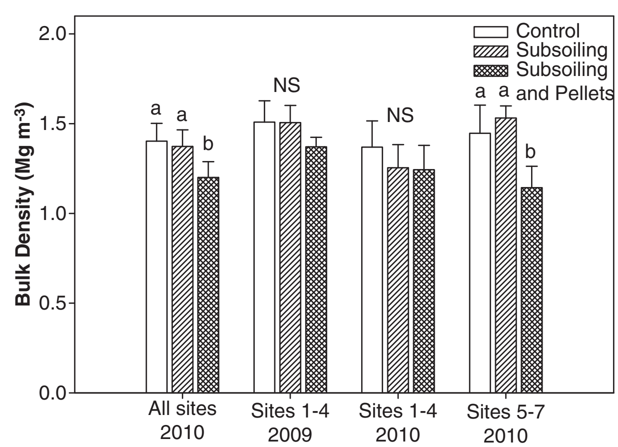

Fig. 3. Mean subsoil (20- to 40-cm depth interval) bulk density of all sites combined in 2010. Error bars represent the standard error of the mean. NS = non-significant.

Author: Carter 1993 is not in the reference list.

When spring-established sites were combined, no significant differences between treatments were observed for bulk density in 2009 or 2010 due to high variability among sites (Fig. 3). No interactions occurred between site and treatment. However, site had a significant effect on bulk density for both 2009 and 2010. Site 4, which has a clay loam soil (Table 1), had significantly higher bulk density (1.49 and 1.39 Mg m^{-3} in 2009 and 2010, respectively) than site 1 (1.24 and 1.06 Mg m^{-3}) and site 2 (1.23 and 1.10 Mg m^{-3}) (loams), but not significantly different than site 3 (1.58 and 1.61 Mg m^{-3}) (sandy loam). This suggests that for this study, clay loam and sandy loam soils were more susceptible to compaction than loam soils. Loam soils may have had better soil aggregation, which made them more resistant to compaction.

When the effect of year was introduced by combining results from 2009 and 2010 sampling (4 mo and 16 mo after treatment), 2009 had significantly higher bulk density (1.46 Mg m^{-3}) than 2010 (1.29 Mg m^{-3}) for sites 1–4. However, there was a significant year × site effect, affecting results interpretation. For example, bulk density was lower in 2010 for clay loam (site 4) and loam (sites 1 and 2) soils, whereas in the sandy loam soil (site 3), bulk density was biologically, but not statistically higher in 2010 than 2009. The higher values in sandy loam soils may have been due to higher precipitation in 2010. In Wyoming, Abdel-Magid et al. (1987) also found an increase in bulk density of grazed sandy loam soils with increased precipitation. Overall, there was no significant increase in bulk density from 2009 to 2010 in either the subsoiling or subsoiling with pellets treatment. An increase in bulk density over the 2-yr study period suggests that soils are settling and recompacting.

When fall-established sites were combined (sites 5–7), subsoiling with pellets had significantly lower subsoil bulk density (1.14 Mg m^{-3}) than control (1.45 Mg m^{-3}) and subsoiling (1.53 Mg m^{-3}) treatments in 2010 (12 mo after treatment) (Fig. 3). An interaction occurred between site and treatment, again likely due to soil texture. In this case, the numerical difference in bulk density between subsoiled with pellets and subsoiled treatments was greater in site 5 (0.43 Mg m^{-3}) and site 6 (0.46 Mg m^{-3}), which were clay loam soils, than site 7 (0.28 Mg m^{-3}), which was a sandy loam. Thus, for fall-established sites, the effect of the subsoiling with pellets on reducing bulk density was enhanced in clay loam soils. According to MacEwan (2007), root growth is inhibited in clay soils with bulk density as low as 1.45 Mg m^{-3}, whereas in sandy soils, it can be as high as 1.70 Mg m^{-3} before root growth is inhibited. The subsoiling with pellets treatment is therefore recommended specifically for fine-textured soils with compacted subsoil.

Available and Total Nutrient Content

Available phosphorus in subsoil (20- to 40-cm depth interval) of all sites combined was significantly higher

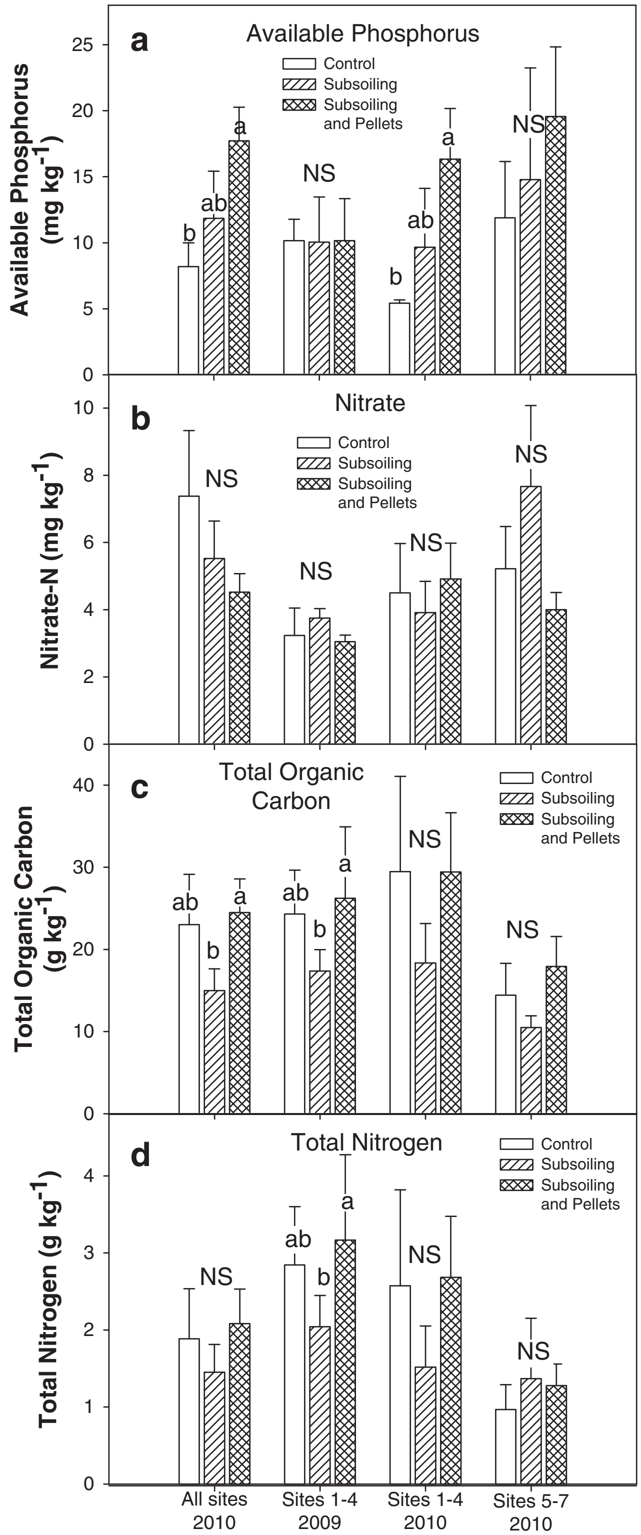

Fig. 4. Available and total nutrient content in subsoil (20- to 40-cm depth interval) of spring 2009 (1–4) and fall 2009 (5–7) established sites during first year (2009) and second year (2010) sampling. Error bars represent the standard error of the mean. NS = non-significant.

in the subsoiling with pellets treatment (17.7 mg kg^{-1}) than the control (8.19 mg kg^{-1}) (Fig. 4a). There was no significant effect of site on available phosphorus nor were there site × treatment interactions. Available phosphorus in the subsoil of spring-established sites (1–4) was significantly higher in the subsoiling with pellets treatment (16.3 mg kg^{-1}) than the control (5.4 mg kg^{-1}) in 2010 (16 mo after treatment) (Fig. 4a). No significant differences in available phosphorus were found in 2009 (4 mo after treatment). As 2009 was a very dry year, there was likely not much decomposition of the pellets and therefore no increase in available phosphorus with the subsoiling with pellets treatment. The increase in available phosphorus in this treatment in 2010, however, suggests phosphorus was mineralized during the 2010 growing season. As 2010 was a relatively wet year, it is likely that the increased soil water would have led to increased microbial activity and therefore more decomposition of organic matter pellets. This, in turn, could have increased available phosphorus concentrations. In an incubation study of soils ranging in texture from fine-silty to coarse-loamy, Laboski and Lamb (2003) found phosphorus availability increased in soils applied with liquid swine manure over a 9-mo period, whereas fertilizer phosphorus became less available. They postulated that the decomposition of manure released organic acids that reduced phosphorus sorption to the soil, which in turn increased phosphorus availability.

No significant differences in nitrate were found in any treatments for 2009 or 2010 (Fig. 4b). After one and two growing seasons for spring- and fall-established sites, respectively, available nitrate released from the pellets may have been taken up by crops thereby reducing the amount left in the soil. According to Brady (1990), the first crops planted following manure application will utilize one-fifth to one-half of the nutrients supplied by animal manure. In field observations, a high root density was seen clustered around the injected pellets, particularly with canola plants in fall-established sites. These crops were likely taking advantage of increased nitrogen released from the pellets. In Australia, Gill et al. (2008) observed a higher nitrate uptake in shoots of wheat during all stages of growth on clay soils treated with subsoil organic amendments than soils that were untreated. They attributed the increase in plant nitrate uptake as one of the major reasons for the higher yield of wheat in organic amendment treatments versus unamended.

For all sites combined, subsoil total organic carbon was higher in subsoiled with pellets than subsoiled, but not control treatments (Fig. 4c). Overall, total nitrogen was not significantly different among treatments. When spring-established sites were pooled, the subsoiling with pellets treatment was significantly higher in subsoil total organic carbon and total nitrogen than the subsoiling treatment in 2009 (Fig. 3c and d). Other studies have documented significant increases in total organic carbon and nitrogen with solid organic waste application (Khalilian et al. 2002; Motavalli et al. 2003). The control was not significantly different from the subsoiling with pellets treatment. However, the closer the sampling points to the pipeline trench, the higher the total organic carbon and nitrogen. As the control plots extended about 3 m on either side of the pipeline, the relatively high concentrations may have been related to soil replacement activities during pipeline construction. For spring-established sites in 2010, no significant differences were detected in either total organic carbon or nitrogen for any treatments, although results were comparable to 2009. No significant differences in total and available nutrients were observed when fall-established sites were combined. Available nutrients released from the pellets were likely already taken up by crops at the time of sampling. There was no interaction between site and treatment for any of the nutrients in 2009 or 2010.

No significant differences in available potassium were observed between treatments in either spring or fall 2009 sites for topsoil or subsoil (data not shown). No significant differences in the topsoil (0–20 cm depth interval) were observed in any nutrient either in 2009 or 2010 (data not shown). This was expected as treatments were applied to the subsoil.

Plant Response to Subsoiling and Injection of Pellets

For fall-established sites (5–7), canola plant density was almost twice as high in the subsoiling with pellets treatment (22 plants m^{-1} row) as the control (12 plants m^{-1} row), but not significantly different from undisturbed control (21 plants m^{-1} row) in 2010 at ripening stage (Fig. 5). Canola plants were significantly taller in the subsoiling with pellets treatment (112 cm) than the control (99 cm) for sites 5 and 6. Sites were not significantly different from one another and there was no site × treatment interaction.

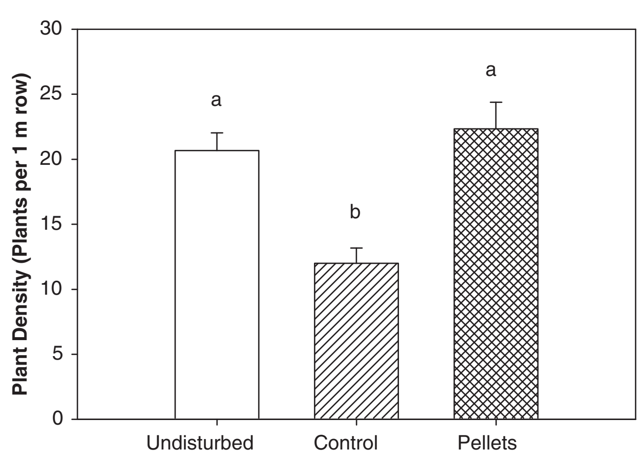

Fig. 5. Canola plant densities in fall 2009 established sites (5–7). Error bars represent the standard error of the mean.

Deep root density was higher in the subsoiling with pellets treatment (>100 roots dm^{-1}) than either subsoiling or control (~10 to 100 roots dm^{-1}) at the 20- to 40-cm depth interval across all sites and for all plants (canola, grasses, legumes). Plants had the same root density on the subsoiling with pellets treatments in all three soil types (clay-loam, loam, sandy-loam); whereas for subsoiling and control treatments, lowest root density was on clay-loam soils (~10 roots dm^{-1}) and highest on loam soils (~100 roots dm^{-1}). The higher deep root density in the subsoiling with pellets treatment was related to the proliferation of roots in the presence of available nutrients from the organic pellets. This was confirmed by visual observation of the high cluster of roots surrounding the pellets. Higher densities of roots in the subsoil of fields with incorporation of organic pellets than in untreated soils were also observed in the high rainfall zone of southern Australia by Gill et al. (2008).

The large difference in plant density between the subsoiling with pellets and control treatments can be attributed to soil improvement, such as lower bulk density and higher nutrient availability (Figs. 2 and 3) resulting from pellet injection. Higher plant density of subsoiling with pellets treatments relative to control is consistent with results from an earlier study (Leskiw and Zeleke 2009), in which barley (*Hordeum vulgare* L.) yield was up to 84% higher in 2009 on soils treated the previous year with subsoiling and pellet injection compared with the untreated and compacted control. In South Carolina, Khalilian et al. (2002) reported increased cotton yield of up to 44% after injection of solid municipal waste into B horizon of a compacted soil.

Gill et al. (2008) found greater biomass and increased deep root growth of wheat (*Triticum aestivum* L.) in subsoil amended treatments versus unamended during all stages of growth. They attributed increased crop productivity to improved soil structure and increased root growth through the rip lines in subsoil amended treatments. They found an increased ability to extract subsoil water and available nitrogen. In the current study, according to field observations, canola, grasses and legumes growing in the subsoiling with pellets treatment were greener than those growing in the compacted control. This could indicate either a higher uptake of nitrogen or water from the subsoil.

Application of subsoiling with pellets is proving to be a cost-effective reclamation technique for compacted industrial sites such as well sites and pipeline corridors. In addition to the research sites reported in this paper, several well sites and pipeline rights- of-way have been successfully ameliorated recently by this method in Alberta.

CONCLUSIONS

Subsoiling with pellet injection improved subsoil structure and rooting, increased availability of some nutrients and contributed to higher crop yields. The yields on the treated right-of-way are comparable with those on undisturbed farm fields. The subsoiling and pellet injection offers a cost effective method for ameliorating compacted industrial sites, thereby reclaiming the land to match capability of adjoining undisturbed lands.

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