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SOIL NUTRIENT LEVELS AND CROP PERFORMANCE AT VARYING POSITIONS RELATIVE TO MANURE BANDS

B. Assefa

Department of Biosystems Engineering, University of Manitoba, Winnipeg, Manitoba R3T 5V6

Y. Chen

Department of Biosystems Engineering, University of Manitoba, Winnipeg, Manitoba R3T 5V6

K. Buckley

Brandon Research Center, Agriculture & Agri-Food Canada, Brandon, Manitoba R7A 5Y3

W. Akinremi

Department of Soil Science, University of Manitoba, Winnipeg, Manitoba R3T 5V6

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A field experiment was carried out to investigate nutrient distribution in the soil and crop response at different lateral positions relative to injected manure bands. Liquid swine manure was injected at three micro-rates (r_1 = 1.2 × 10 $^{-3}$ m^3 m^{-1} $tool^{-1}$, r_2 = 2.4 × 10 $^{-3}$ m^3 m^{-1} $tool^{-1}$, and r_3 = 3.6 ×10 $^{-3}$ m^3 m^{-1} $tool^{-1}$) achieved by varying the spacing between manure bands. Manure application at each of the micro-rates was performed using two types of injection tools (Coulter and Furrower). Manure nutrient distribution was characterised using measured levels of soil inorganic nitrogen and phosphorus at varying positions relative to the centre line of manure band during the growing season. Soil pH and EC were also determined at the same positions. Plant development characteristics (number of tillers, number of heads, and stem length) and biomass were used as parameters for measuring and comparing crop performance at varying positions relative to the centre line of manure band. Results indicate that nutrient levels and crop performance could be reduced with greater distance away (farther position) from the center line of manure bands, especially at the highest micro-rate.

INTRODUCTION

Injection of liquid manure into soils adds to levels of soil nutrients present in the soil prior to injection of the manure. This brings about sharp difference in soil nutrient levels between the spread (reach) of manure band and lateral positions beyond. Manure band is defined as the manure that has been placed in a slot formed by an injection tool in the soil along the direction of travel during the injection operation. Following injection, the manure nutrients move both laterally and vertically within the soil. To some extent, the lateral movement (towards the middle of two successive bands) of the manure nutrients within the soil will change the sharp nature of difference in soil nutrient levels mentioned above to a more gradual one. This process, which varies with soil type, contributes to manure nutrient distribution in the soil.

Distribution of manure nutrients in soil is also affected by the width of the manure bands initially placed into the soil. The width of the manure bands in turn depends on the injection tool to be used and soil conditions. Sweep-type tools place manure in wider bands as compared to disc and knife types (Chen 1999; Hultgreen and Stock 1999; Sawyer et al. 1991; Warner and Godwin 1988). Such placement of manure in the soil favours uniform distribution of nutrients within the soil. Thus the width of manure band at the time of injection and the lateral movement of the manure nutrients after injection determine the extent of manure nutrients distribution in the soil and hence the availability of nutrients to plants.

This needs to be substantiated with scientific findings. However, there is little documentation in the literature to address this issue and it would be appropriate to carry out relevant experiments. Therefore, the objective of this study was to investigate nutrient distribution in the soil and crop response at different lateral positions relative to injected manure bands based on field experiment. The first year results of a three-year field experiment were reported in this paper.

MATERIAL AND METHODS

Site description

The field site is located at the Brandon Research Centre, Brandon, Manitoba, Canada. The experiment for which results are included in this paper was conducted in the growing season of 2002. The soil is classified as the Janick series in the Orthic Black soil zone with clay loam surface texture that was developed on moderately to strongly calcareous silty clay to clay lacustrine deposits (Fitzmaurice et al. 1999). The field was pre-seeding burnt-off with Roundup at an average rate of 1.55 L/ha.

Experimental design

A 2 by 3 factorial experiment set up in a randomized complete block design was used. The factors were two types of injection tools: Furrowers (120 mm wide) and Coulters (460 mm diameter) and three micro-rates: $r_1 = 1.2 \times 10^{-3}$ m^3 m^{-1} $tool^{-1}$, $r_2 = 2.4 \times 10^{-3}$ m^3 m^{-1} $tool^{-1}$, and $r_3 = 3.6 \times 10^{-3}$ m^3 m^{-1} $tool^{-1}$. Detailed definition and explanation of micro-rate was presented in Rahman et al. (2004). The manure flow rate was kept constant by maintaining constant pumping rate during the entire manure injection operation. Thus, on a per hectare basis, the same manure application rate (34 m^3/ha) was applied to all the plots and this was considered as a macro-rate. The target micro-rates were achieved by adjusting the forward speed of the injector and varying the spacing between individual tools. Descriptions of equipment used and field operation procedure have been given in detail in Assefa et al. (2004).

Sampling procedures

Soil and manure properties Soil sampling was done to a depth of 150 mm with copper core samplers of 52 mm diameter before manure application. This was done to determine the soil moisture content and bulk density immediately prior to manure injection. The soil samples were collected from five random plots across the entire field site. Representative manure samples were collected at the time of manure loading into the applicator for characterization of the manure used in the study. Soil properties determined and characteristics of the manure used were presented in Assefa et al. (2004).

Soil nutrients Following manure injection, soil sampling for nutrient analyses was performed at various positions relative to manure bands (Fig. 1). One sampling position (labelled as A_1, A_2, and A_3) was located on the centre lines of the manure bands for the r_1, r_2, and r_3 micro-rate treatments, respectively. One (B_1), two (B_2 & C_2), and three (B_3, C_3, & D_3) sampling positions were located between the bands for the r_1, r_2, and r_3 treatments, respectively. Positions within a given treatment were spaced 150 mm apart. The sampling was done at three random locations along each position in each plot. The samples collected from the three random locations were mixed together to form a composite sample of the respective position.

The first soil sampling was carried out to a depth of 300 mm, three weeks after the manure application. By then the crop had reached a state of full emergence. During the first sampling, the sampling locations were flag-marked for use in subsequent samplings. Thereafter, four successive samplings were carried out every two weeks giving a total of five sampling times. The samples were analysed for NO_3-N, NH_4-N, P, pH, and electrical conductivity (EC).

Plant development characteristics Whole plant samples were collected by randomly uprooting 40 plants per plot for the r_3 treatment, 20 from each of the plant rows (B_3 and D_3) between any two random but consecutive manure bands. Row B_3 represents a plant row close to a reference manure band whereas row D_3 represents plant row farther from the reference manure band but mid way between the reference and an adjacent manure band. This was done to study if there are any differences in the plant development characteristics, that is, number of tillers, number of heads, and stem length due to the varied positions of plant rows relative to manure bands. Schematic description of the plant rows relative to manure bands and soil sampling positions are given in Fig. 1. Another set of plant samples was collected to determine plant biomass. This set of plant samples consists of 500-mm long crop rows cut at three random locations from each of two different crop rows in the r_3 treatments between consecutive manure bands. The samples for each row from the three locations were combined to form a composite sample for that row. This means that each sample represents for the biomass from a row length of 1.5 m. The samples were labelled as B_3 or D_3. Samples with the label B_3 represented rows close to the manure band whereas those with label D_3 represented midway crop row between the manure bands. This was done to examine difference in biomass, if any, due to crop position relative to manure bands. Plant biomass was determined on the dry matter of the plant samples using the oven-dry method, at 60ºC for 72 h (ASAE 2002).

Statistical analyses

The data were analysed using SAS software (SAS Institute Inc. 2001). Analysis of Variance (ANOVA) using the general linear model (GLM) procedure was carried out to calculate mean values of variables of interest at different positions within each treatment. Least Significant Difference (LSD) test was employed to determine within treatment mean differences at different positions. All comparisons were made at a 0.1 level of significance.

RESULTS AND DISCUSSION

Inorganic nitrogen

Levels of soil NO_3-N as influenced by position relative to manure band placement at varying micro-rates using Coulter tool are given in Table 1. Three weeks after injection, there was no significant difference in the level of soil NO_3-N between positions A_1 and B_1 within r_1 treatment. Within r_2 and r_3 treatments, the levels of soil NO_3-N decreased with position away from manure band. Five weeks after injection, soil NO_3-N decreased with distance away from manure band within r_1 and r_3 treatments whereas it remained unaffected by position within r_2 treatment. Seven to eleven weeks after injection, soil NO_3-N remained unaffected by position within r_1 and r_2 treatments. Within r_3 treatment, the previous trend, decreasing in soil NO_3-N with distance away from manure band was observed at seven and nine weeks after injection whereas there was no difference at eleven weeks after the injection.

Levels of soil NO_3-N at varying positions relative to manure band following manure placement at different micro-rates using Furrower tool are shown in Table 1. Within r_1 treatment, the level of soil NO_3-N was lower at position B_1 than at A_1 at three weeks after injection. For the same treatment, there was no difference in soil NO_3-N between the positions at five to eleven weeks after injection. Within the r_2 treatment, there were no differences in soil NO_3-N between any of the positions throughout the measurement. Within r_3 treatment, soil NO_3-N decreased with distance away from the manure band when measured at three, five, seven, and nine weeks after injection.

Concentrations of soil NH_4-N did not vary between any of the positions within the r_1, r_2, and r_3 treatments at all times of measurement when the manure was injected using Coulter tool (Table 2). Similarly, when applied using Furrower, there were no differences in soil NH_4-N concentration between the positions except at five and seven weeks after injection where the concentration at position B_2 was higher than at positions A_2 and C_2 and that at position B_3 was higher than at A_3 and D_3, respectively (Table 2).

Phosphorus

Phosphorous concentrations in the soil at varying positions relative to manure bands placed using Coulter tool are shown in Table 3. There were no differences in soil P concentration between positions A_1 and B_1 at all times of measurement within r_1 treatment. Similarly, there was no P concentration difference among positions A_2, B_2, and C_2 within r_2 treatment at the times of measurement except eleven weeks after injection, where the concentration was higher at position C_2 than A_2 and B_2. In addition, within r_3 treatment, soil P concentration was about the same among the positions. When manure was injected using Furrower, as shown in Table 3, soil P concentration at position B_1 within r_1 treatment was higher than that at position A_1 three weeks after injection, however there was no difference during the rest of the measurements between the positions. Within r_2 and r_3 treatments, there was no difference in soil P concentration among the positions at all times of measurement.

pH and EC

An overall observation of positional differences in soil pH indicates that there is an increasing trend in soil pH with distance away from the center line of manure band (Table 4). A detailed look at the results reveals that, seven weeks after manure injection using Coulter tool, position A_1 had a lower soil pH than position B_1 within r_1 treatment. Similarly, in the r_2 treatment position A_2 had lower pH than both positions B_2 and C_2, three weeks after the manure injection. Within r_3 treatment the soil pH at position A_3 was lower than those at B_3, C_3, and D_3 three weeks after injection. At that same time of sampling, position B_3 had a lower soil pH than positions C_3 and D_3 which were similar to each other. Five weeks after injection, soil pH at positions A_3 and B_3 were lower than those at C_3 and D_3 whereas at the time of last sampling soil pH at position A_3 was lower than those at B_3, C_3, and D_3.

Within the r_1 treatment where manure was injected using the Furrower tool the soil pH at position A_1 was lower than that at position B_1 three and five weeks after injection but not at other times of sampling. Within the r_2 treatment the pH remained unaffected by position at all sampling times except at nine weeks after injection whereby position A_2 had lower soil pH than B_2 and C_2. Similarly, differences in soil pH within the r_3 treatment were not consistent. Three weeks after the injection position A_3 had lower soil pH than the rest and position B_3 had lower pH than C_3 and D_3. Seven weeks after injection, position A_3 had lower pH than B_3, C_3, and D_3.

Unlike soil pH, soil EC followed decreasing trend with position away from the center of manure band (Table 5). Though the general trend still holds true, within the r_1 treatment where manure was injected using Coulter tool there was no significant difference observed between positions A_1 and B_1 at all sampling times. A more obvious difference was evidenced within the r_3 treatment where EC at position A_3 was much higher than the rest positions three and five weeks after injection. In contrast, in plots where manure was injected using Furrower tool, soil EC at position A_1 was higher than that at B_1 at all sampling times, within the r_1 treatment whereas no difference was observed between positions within the r_2 treatment. Within the r_3 treatment, position A_3 had higher EC than the rest at three, five and seven weeks after manure application. Moreover position B_3 had higher EC than C_3 and D_3 at three and five weeks after injection.

Plant development characteristics

A consistent trend of higher plant performance at plant rows closer to manure bands was evidenced in all the plant development characteristics (Table 6). This is expected and may mean availability of nutrients more in close proximity to the manure bands than in the middle. Significantly higher number of tillers and heads were observed at position B_3 than at D_3 within r_3 treatment where the manure was injected using Furrower tool. For stem length, similar difference was observed when manure was applied using Coulter tool. Plant biomass was significantly higher at B_3 than at D_3 within r_3 treatment while manure was injected using either of the tools.

SUMMARY

The study reported in this paper was carried out to understand the effect of lateral position on soil nutrient availability and crop performance. The lateral positions were defined relative to manure bands placed into the soil at different micro-rates. The micro-rates were obtained by adjusting the forward speed of the injector and varying the spacing between individual injection tools. The results suggest that injection of liquid manure could lead to considerable difference in nutrient availability at varying positions relative to manure bands. This was especially true for NO_3-N when manure was injected at the highest micro-rate (r_3 = 3.6 $\times 10^{-3}$ m^3 m^{-1} $tool^{-1}$). That is, the availability was reduced with farther position from the center of the manure bands. This was also supplemented by the crop development characteristics that generally showed a consistently decreasing trend in crop performance with increasing distance in crop rows away from the manure bands. However, the results of this study are subject to comparison and verification with the other two years data within the same experiment and the literature.

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Table 1. Levels of soil **NO_3-N** concentration at varying positions relative to manure band.

Micro-rate	Position relative to manure band	Weeks after injection				
		3	5	7	9	11
		---------------------------- NO_3-N (kg ha^{-1}) ------------------------				
Coulter						
r_1	A_1	199.1a*	91.0a	46.2a	16.7a	7.6a
	B_1	107.8a	46.6b	23.2a	30.7a	12.0a
r_2	A_2	171.9a	25.8a	7.8a	10.3a	4.8ab
	B_2	59.0b	18.8a	8.3a	10.6a	4.5b
	C_2	34.0b	17.4a	24.0a	8.7a	7.0a
r_3	A_3	310.9a	143.1a	36.2b	15.7ab	6.9a
	B_3	108.4b	67.2b	89.3a	26.2a	6.8a
	C_3	67.8b	11.9c	18.2c	8.8ab	6.0a
	D_3	56.7b	7.5c	20.3b	6.4b	4.5a
Furrower						
r_1	A_1	191.5a	80.8a	62.8a	12.3a	8.7a
	B_1	86.1b	22.5a	36.4a	14.0a	10.7a
r_2	A_2	82.3a	66.3a	8.0a	4.9a	4.5a
	B_2	108.5a	62.6a	17.4a	9.5a	4.8a
	C_2	89.8a	38.4a	12.7a	8.0a	4.8a
r_3	A_3	299.8a	160.6a	190.4a	38.0a	10.5a
	B_3	116.9b	78.4b	23.4ab	14.2b	17.0a
	C_3	66.2bc	24.9c	13.3b	14.0b	7.2a
	D_3	34.0c	15.5c	9.0b	7.6b	6.6a

* Values within a column for the same tool and same micro-rate followed by the same letter are not significantly different (P = 0.1).

Table 2. Levels of soil **NH_4-N** concentration at varying positions relative to manure band.

Micro-rate	Position relative to manure band	Weeks after injection		
		3	5	7
		----------------- NH_4-N (kg ha^{-1}) -----------------		
Coulter				
r_1	A_1	1.90a*	5.65a	2.15a
	B_1	2.15a	5.57a	2.14a
r_2	A_2	2.38a	3.84a	2.78a
	B_2	2.33a	4.02a	2.51a
	C_2	2.43a	4.41a	3.20a
r_3	A_3	1.88a	4.84a	2.86a
	B_3	1.90a	5.80a	2.98a
	C_3	1.90a	5.42a	2.37a
	D_3	2.05a	5.88a	2.26a
Furrower				
r_1	A_1	2.03a	5.65a	2.60a
	B_1	2.13a	9.13a	2.34a
r_2	A_2	2.28a	3.45b	2.10a
	B_2	1.90a	5.20a	2.71a
	C_2	2.65a	3.36b	2.09a
r_3	A_3	2.10a	5.05a	2.16b
	B_3	2.10a	6.78a	3.45a
	C_3	2.23a	5.65a	2.41ab
	D_3	2.43a	5.09a	2.24b

* Values within a column for the same tool and same micro-rate followed by the same letter are not significantly different (P = 0.1).

Table 3. Levels of soil **P** concentration at varying positions relative to manure band.

Micro-rate	Position relative to manure band	Weeks after injection				
		3	5	7	9	11
		---------------------------- P (kg ha^{-1}) ----------------------------				
Coulter						
r_1	A_1	191.7a*	144.6a	159.3a	171.0a	180.8a
	B_1	190.4a	156.7a	161.6a	181.0a	174.0a
r_2	A_2	220.4a	172.7a	185.2a	130.3a	145.8b
	B_2	207.9a	169.4a	140.5a	127.7a	145.8b
	C_2	200.0a	181.0a	345.7a	170.3a	162.7a
r_3	A_3	219.2a	176.3ab	452.0a	173.7a	166.1ab
	B_3	196.6a	177.4ab	440.7a	178.0a	153.7b
	C_3	195.5a	194.4a	453.1a	172.1a	171.8a
	D_3	194.6a	170.6b	440.7a	182.6a	171.8a
Furrower						
r_1	A_1	205.3a	186.6a	347.9a	130.0a	168.4a
	B_1	214.7b	184.2a	353.7a	161.9a	178.5a
r_2	A_2	185.3b	163.9a	154.6a	148.0a	169.5a
	B_2	204.5a	172.7a	145.2a	152.6a	169.4a
	C_2	195.5ab	180.0a	166.9a	146.2a	177.4a
r_3	A_3	230.3a	191.8a	460.4a	218.8a	191.0ab
	B_3	231.7a	166.7a	213.5a	150.6a	180.7b
	C_3	221.8a	203.9a	201.7a	215.2a	203.4a
	D_3	221.4a	175.2a	115.0a	194.6a	200.0a

* Values within a column for the same tool and same micro-rate followed by the same letter are not significantly different (P = 0.1).

Table 4. Levels of soil **pH** at varying positions relative to manure band.

Micro-rate	Position relative to manure band	Weeks after injection				
		3	5	7	9	11
		---------------------------- pH	----------------------------			
Coulter						
r_1	A_1	7.63a*	7.63a	7.70b	7.85a	7.75a
	B_1	7.68a	7.68a	7.85a	7.80a	7.80a
r_2	A_2	7.43a	7.58a	7.75a	7.73a	7.83a
	B_2	7.55b	7.63a	7.75a	7.68a	7.80a
	C_2	7.60b	7.68a	7.75a	7.70a	7.80a
r_3	A_3	7.35c	7.53b	7.68a	7.63a	7.75a
	B_3	7.50b	7.55b	7.60a	7.65a	7.68b
	C_3	7.55ab	7.65a	7.63a	7.68a	7.65b
	D_3	7.63a	7.65a	7.70a	7.65a	7.68b
Furrower						
r_1	A_1	7.53b	7.58b	7.73a	7.63a	7.85a
	B_1	7.60a	7.73a	7.78a	7.65a	7.83a
r_2	A_2	7.68a	7.70a	7.75a	7.75b	7.78a
	B_2	7.68a	7.73a	7.75a	7.83a	7.78a
	C_2	7.70a	7.75a	7.78a	7.83a	7.78a
r_3	A_3	7.40c	7.68a	7.60b	7.65a	7.83a
	B_3	7.53b	7.50a	7.68a	7.65a	7.80a
	C_3	7.58ab	7.58a	7.65ab	7.73a	7.80a
	D_3	7.60a	7.65a	7.68a	7.70a	7.75a

* Values within a column for the same tool and same micro-rate followed by the same letter are not significantly different (P = 0.1).

Table 5. Levels of soil **EC** at varying positions relative to manure band.

Micro-rate	Position relative to manure band	Weeks after injection				
		3	5	7	9	11
		---------------------------- EC (dS m^{-1})	----------------------------			
Coulter						
r_1	A_1	0.84a*	0.71a	1.61a	0.52a	0.50a
	B_1	0.62a	0.63a	0.60a	0.55a	0.49a
r_2	A_2	0.79a	0.63a	0.60ab	0.53a	0.50a
	B_2	0.56a	0.56a	0.57b	0.49a	0.48ab
	C_2	0.55a	0.61a	0.62a	0.50a	0.44b
r_3	A_3	1.20a	0.78a	0.63a	0.54a	0.48ab
	B_3	0.59b	0.64b	1.31a	0.53a	0.47a
	C_3	0.56b	0.60b	0.66a	0.53a	0.39a
	D_3	0.54b	0.58b	0.61a	0.51a	0.43a
Furrower						
r_1	A_1	0.83a	0.71a	0.64a	0.53b	0.52a
	B_1	0.63b	0.55b	0.57b	0.57a	0.48b
r_2	A_2	0.62a	0.66a	0.63a	0.55a	0.55a
	B_2	0.66a	0.69a	0.62a	0.55a	0.53a
	C_2	0.63a	0.60a	0.62a	0.51a	0.47a
r_3	A_3	1.12a	0.85a	0.75a	0.61a	0.50a
	B_3	0.70b	0.68b	0.65b	0.55ab	0.54a
	C_3	0.60c	0.58c	0.61b	0.50b	0.49a
	D_3	0.55c	0.55c	0.61b	0.49b	0.50a

* Values within a column for the same tool and same micro-rate followed by the same letter are not significantly different ($P = 0.1$).

Table 6. Plant characteristics within the r_3 micro-rate treatment.

Plant characteristic	Position	Coulter	Furrower
Number of tillers	B_3	2.97a*	3.04a
	D_3	2.69a	2.40b
Number of heads	B_3	2.71a	2.60a
	D_3	2.52a	2.16b
Stem length (mm)	B_3	594.5a	563.7a
	D_3	575.1b	549.7a
Biomass (g/m)	B_3	214.0a	218.7a
	D_3	129.2b	135.7b

* Values within a column and same plant characteristic followed by the same letter are not significantly different (P = 0.1).

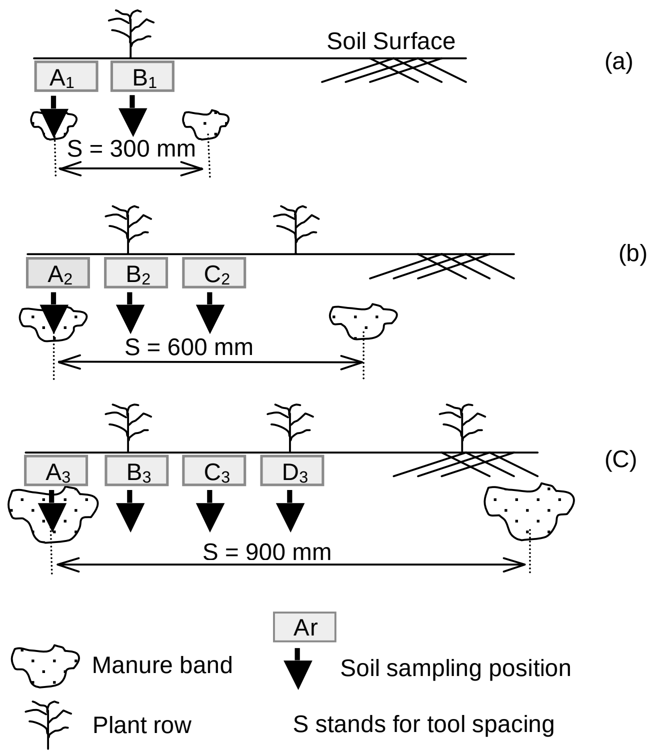

Figure 1. A schematic diagram of manure band, soil sampling position, and plant rows: (a) micro-rate r_1, (b) micro-rate r_2, and (c) micro-rate r_3.