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Effect of Placement and Timing of Nitrogen Fertilizer Sources on Efficiency of Nitrogen Use by Durum Wheat and Canola Under Reduced and Conventional Tillage Systems

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Abstract

Efficient fertilizer management is necessary to optimize the economics of production and to avoid excess nutrient carry-over in the soil, reducing the potential for environmental damage. Crop yield was influenced by source, timing and placement of fertilizer N, with effects differing with tillage system. Initial effects on stand density, Cd concentration in the seed, and weed populations were also determined. Detailed soil sampling was completed at the end of the study to evaluated effects of management on nitrate accumulation in the profile and nutrient and pH stratification.

Background

Efficient fertilizer management is critical to maintain economic crop production, long-term environmental quality and sustainability of the soil resource. Efficient applications of fertilizers which are in balance with the nutrient requirements for crop production contribute to maintenance or improvement in soil quality, by increasing residue cover and the amount of organic matter returned to the soil. This aids in reducing erosion and in maintaining organic matter levels within the soil (Campbell et al. 1990). The increased organic residues produced with proper fertilizer management act as nutrient reserves for enhanced biomass production. Nitrogen fertilizer, when used as recommended by soil testing, has been shown to reduce nitrate leaching by encouraging effective root development and crop utilization of N from the soil profile (Campbell et al. 1990). However, excessive N fertilization or the use of ineffective fertilizer application techniques are not only economically inefficient, but can also create environmental problems, by nitrate leaching into the ground water or emission of nitrous oxide, nitric oxide or ammonia to the atmosphere.

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Efficient fertilizer management considers four major factors:
1) Rate of application
2) Timing of application
3) Placement of fertilizer
4) Source of fertilizer

Optimum rate, timing, placement and source of fertilizer nutrients depends on soil type, climatic conditions, tillage systems and type of crop grown. Other management considerations specific to the particular farming unit, such as equipment availability, time and labour constraints through the growing season, and taxation and cash flow situation, may also strongly impact on a producer's fertilizer management decisions. Therefore, it is important for a farm manager to have comparative information on a range of application techniques and fertilizer sources under varying soil, climatic and management situations, in order to select the fertilizer management package best suited to his particular situation.

Objectives

This study was designed to evaluate the effect of nitrogen fertilizer source, placement and timing under reduced (ZT) and conventional tillage (CT) systems on:
1) Seed yield and quality of durum wheat and canola
2) Nutrient accumulation and efficiency of fertilizer use
3) Soil quality, as indicated by bulk density, penetration resistance, soil pH, and nitrate accumulation in the soil profile
4) Weed density and distribution

Materials and Methods

The study was located on two Chernozemic soils in the Black Soil Zone of the Canadian prairies, a fine sandy loam and a clay loam. Both soils are calcareous and both tested low in available N and P. Field experiments were initiated in the spring of 1992, with spring-applied fertilizer treatments. In the fall of 1992, fall fertilizer applications were added to the experiment for the 1993 and 1994 growing seasons. These treatments were applied on extra plots which had received spring banded UAN, urea and NH_3. The fertilizer treatments are as follows:

Fall Applications

1. Anhydrous ammonia (NH_3), banded; P seed-placed
2. Urea ammonium nitrate (UAN), banded; P seed-placed
3. Urea, banded; P seed-placed

Spring Applications

4. Anhydrous ammonia, banded; P seed-placed
5. Urea ammonium nitrate, banded; P seed-placed
6. Urea, banded; P seed-placed
7. Urea ammonium nitrate, dual banded

8. Urea, dual banded
9. Urea ammonium nitrate, spoke application; P seed-placed
10. Urea ammonium nitrate, dribble band; P seed-placed
11. Urea, dribble band; P seed-placed
12. Ammonium nitrate (AN), dribble banded; P seed-placed
13. Ammonium nitrate, broadcast; P seed-placed
14. Urea, broadcast; P seed-placed
15. Control - no N, no P
16. Control - no N, P seed-placed
17. Control - no N, P banded
18. Control - no N, no P, banding action

Nitrogen was applied at 55 lbs per acre, a rate chosen to provide a reasonable crop, yet allow differences in efficiency of fertilizer use among treatments to be measurable. Phosphorus, as monoammonium phosphate (MAP), was applied at 27 lbs P_2O_5 per acre, in a band 3/4 inch to the side and 1.5 inch below the seed. This rate of fertilizer was generally not sufficient to produce optimum crop yields. An overall application of 50 lbs per acre of S and elemental sulphur was applied in April in each year, to prevent S deficiencies. Pre-seed band urea ammonium nitrate (UAN) and urea were applied at the three- to four-inch depth using a 7-foot plot seeder with 0.5 inch points on 8 inch spacing, equipped with both a dry fertilizer box and fluid dispensing apparatus. The anhydrous ammonia was applied at the three- to four-inch depth with a 7 foot cultivator with 1 inch points on 8 inch spacing. Fall bands were applied in mid-October, after the soil temperature drops below 10 C. Spring bands were applied the day before seeding. Broadcast applications were spread by hand immediately prior to seeding. Surface dribble bands were applied through the drill the day after seeding, by raising the openers out of the ground and dribbling the fertilizer on the soil surface. Spoke wheel applications were applied the day after seeding, using a Pattison Brothers spoke applicator, which nests the fertilizer at 8 inch spacings.

No tillage operations were conducted on the zero till plots, but the stubble were mowed with a gyro-mower to simulate the effects of a straw chopper. The conventional tillage treatments receive two passes in the fall and one pass in the spring with a cultivator equipped with tine harrows.

The crops grown were Legend canola (*Brassica napus*) and Sceptre durum wheat (*Triticum durum*). Seeding occurred in late April to mid-May, with a 7 foot plot seeder equipped with 0.5 inch hoe-type openers. Canola was seeded to a depth of 0.5 inch at 6 lbs per acre, while the durum was seeded to a depth of 1.0 inch at 95 lb per acre.

A fall treatment of glyphosate was applied to control quackgrass and winter annual weeds. A treatment of glyphosate was also applied in 1992, immediately after seeding and prior to spring fertilizer banding in 1993 and 1994. Weed control in the canola was accomplished with applications of Poast (1.54 litres per acre), Muster (0.01 lb per acre) and Lontrel (0.60 litre per acre) in 1992 on both sites, Poast in 1993 on the fine sandy loam and Poast and Lontrel in 1993 on the clay loam soil. In 1994 and 1995, both canola sites received Poast and Muster (0.65 litres/acre and 0.01 kg/acre). Canola was desiccated prior to harvest with Reglone at 0.8 litres per acre on both sites in all three years. In the durum, weeds were controlled with Achieve (0.9 lb per acre) and Buctril M (0.405 litres per acre) in 1992, with Stampede CM (1.11 litres per acre) in 1993 and with Hoe-Grass 284 (1.01 litres/acre), Estaprop (0.71 litres/acre) and Buctril M/MCPA (0.405 litres/acre and 0.22 litres/acre) on the fine sandy loam and Buctril M/MCPA (0.405 litres/acre and 0.22 litres/acre) and Refine Extra (0.008 kg/acre) on the clay loam in 1994. In 1995, durum on both sites were treated with Achieve extra (Achieve 0.40 kg/ha and Buctril 0.405 l/ha). Herbicide rotation was practised to slow the build up of herbicide resistance. Weed counts were taken immediately after herbicide application.

Temperature and rainfall data were collected throughout the growing season, using an automated weather station. Stand counts were taken on selected treatments in the durum and canola in mid-June. Mid-season samples collected at heading for the durum and at full flowering for the canola were dried, weighed and analysed for N, P, Zn and Cd. Plots were harvested at late August to mid-September using a Wintersteiger plot combine, yields of seed and straw were measured and samples submitted to the laboratory for analysis of N, P, Zn and Cd content. Laboratory analysis of the samples is in progress due to a heavy sample load and equipment problems.

At the initiation of the study and after harvest in 1995, detailed soil samples were taken at 0-5, 5-10, 10-15, 15-30, 30-60 and 60-120 cm. The surface three depths were analysed for N, P, K, Cd, pH and conductance. The lower depths were analysed for N. This will allow assessment of the effect of the different management systems on nutrient stratification, soil acidification and nitrate distribution in the profile. Analysis of these samples is still in progress.

Experimental design was a split plot with four replicate for each crop species and location, for a total of 576 plots. Tillage treatments were the main plots and fertilizer treatments the sub-plots. Statistical analysis was conducted using contrast analysis with the GLM procedure of SAS (Statistical Analysis Systems Institute 1985).

RESULTS

Canola Seed Yield

Table 1: Canola grain yield (bu/acre) as a function of fertilizer source, placement and time of application under zero and conventional tillage management on a Marringhurst Fine Sandy Loam and a Newdale Clay Loam soil (1992-95).

Treatment	Marringhurst FSL		Newdale CL	
	CT	ZT	CT	ZT
NH_3 Fall Band (PS)	31.9	33.9	29.2	29.6
UAN Fall Band (PS)	27.3	23.8	29.0	23.9
Urea Fall Band (PS)	27.6	26.8	26.8	26.1
NH_3 Spring Band (PS)	28.9	32.4	32.1	29.8
UAN Spring Band (PS)	28.2	28.7	31.6	27.5
Urea Spring Band (PS)	27.5	28.2	31.3	25.9
UAN Dual Band	31.2	25.6	29.1	26.4
Urea Dual Band	28.1	27.2	28.0	26.5
UAN Spoke (PS)	31.1	28.0	29.9	27.1
UAN Dribble (PS)	28.3	24.2	29.0	25.8
Urea Dribble (PS)	28.7	28.5	29.5	23.7
A.N. Dribble (PS)	29.6	26.1	26.8	27.0
A.N. Broadcast (PS)	25.6	28.6	29.3	27.7
Urea Broadcast (PS)	24.1	26.8	30.0	24.9
No N, No P	16.4	13.5	23.5	16.9
No N, P Seed-placed	17.7	17.6	20.8	18.7
No N, P Banded	18.5	13.9	21.2	18.4
No N, No P, Band	17.6	15.5	19.3	17.0
CV	18.7		15.8	

Canola yields over the 4-year study were generally lower than the area average, ranging from 25-34 bu $acre^{-1}$ in the fertilized treatments. The low yields can be attributed to the relatively low N level and to shelling which occurred in some years. Problems with shelling will be corrected in future studies, as a plot swather is currently being fabricated. Yields in 1995 were depressed due to a 6 week lack of rainfall, associated with temperatures in the 30-35°C range, which reduced canola seed set.

Marringhurst Fine Sandy Loam: On the fine sandy loam soil, tillage did not influence yield of canola, when averaged over treatments and years (Tables 1 and 2). However, there was a tendency toward a tillage by treatment interaction ($p<0.0758$). Canola yield tended to be higher under CT than ZT in the control treatments and when UAN was the fertilizer source.

Under CT, dribble-banded applications of UAN or urea produced higher canola yield than broadcast applications; Under ZT, broadcast and dribble-banded applications produced comparable yields. Fall-banded NH_3 produced higher canola yield than did fall-banded UAN, with the differential being greater under ZT than CT. Under ZT, fall-applied NH_3 also produced higher canola yield than fall-applied urea.

Table 2: P-values for significance of effects of tillage and tillage by treatment interactions for grain yield of canola and durum on a Newdale Clay Loam and Marringhurst Fine Sandy Loam (1992-95)

Source of Variation	Marringhurst FSL		Newdale CL	
	Canola	Durum	Canola	Durum
Tillage	ns	ns	0.0008	0.0001
MSE (tillage)	436.2	493.9	81.53	129.1
Tillage x Treatment	0.0758	0.0296	0.0160	0.0001
MSE-(Till x Treat)	22.7	31.5	17.1	22.2

Newdale Clay Loam: On the clay loam soil, yield was consistently higher under CT than ZT. The Newdale site tended to be moister and cooler than the Marringhurst soil, conditions where ZT may be at a disadvantage to CT in terms of early spring growth and stand establishment. A significant tillage by treatment interaction existed, with CT having the greatest yield advantage over ZT when urea was surface applied or UAN was used as the fertilizer source. The CT advantage was also large when urea was spring-banded with P seed-placed or when no fertilizer was applied. Yields were equivalent between CT and ZT with fall-banded NH_3 or urea and with surface applied ammonium nitrate. Canola yields were reduced by conducting a banding pass, without addition of fertilizer, under CT but not under ZT.

Table 3: F-values for contrast analysis of effects of fertilizer source, timing and placement on yield of canola under zero and conventional tillage management on a Marringhurst Fine Sandy Loam and Newdale Clay Loam soil (1992-95).

Contrast	Marringhurst FSL		Newdale CL	
	CT	ZT	CT	ZT
No N vs. N	0.0001	0.0001	0.0001	0.0001
Band vs. surface N	ns	ns	0.0655	0.0467
Urea vs. UAN	ns	ns	ns	ns
Broadcast vs. Dribble	0.0230	ns	ns	ns
Am.N vs. Urea, Surface	ns	ns	ns	0.0018
P seed vs. P dual	ns	ns	0.0144	ns
NH_3 vs. Urea, Spring	ns	ns	ns	0.0051
NH_3 vs. UAN, Spring	ns	ns	ns	0.0961
NH_3 vs. UAN, Fall	0.0896	0.0034	ns	0.0001
NH_3 vs. urea, Fall	ns	0.0369	ns	0.0096
Urea vs. UAN, Fall	ns	ns	ns	ns
UAN Band vs. Spoke	ns	ns	ns	ns
UAN in soil vs Dribble	ns	ns	ns	ns
Banding effect - no N	ns	ns	0.0126	ns
P vs. no P check	ns	ns	ns	ns
C.V.	21.8	28.9	17.1	15.7

Under both CT and ZT, canola yield was higher with in-soil band as compared to surface applications of urea or UAN. Under ZT, ammonium nitrate produced higher yields than urea, but the same effect did not occur under CT. Loss of surface applied urea may have been greater under ZT than CT, due to higher volatilization and immobilization losses associated with surface crop residue.

Under ZT, NH_3 showed a consistent advantage over urea or UAN, when applied either in the fall or the spring. Banded NH_3 may remain in the NH_4^+ form for longer than either urea or UAN, and so be less prone to denitrification losses in saturated microsites that could occur in the ZT system.

Seed-placed P with spring-banded urea or UAN produced higher canola yields than P dual banded with these N sources under CT. The same trend occurred on this soil with durum, under CT.

Durum Seed Yield

Durum seed over the 4-year study was slightly below the area average, due to the restricted N application rate. Dry conditions and high temperatures during the spring and summer of 1995 reduced yields on both sites. However, a good response to fertilizer N was still observed.

Marringhurst Fine Sandy Loam: On the fine sandy loam soil, there was no consistent difference in yield between the CT and ZT treatments, although a tillage by treatment interaction occurred (Tables 2 and 4). The CT management produced higher durum yield than ZT when no fertilizer was applied, due presumably to the greater release of N from soil organic matter with tillage. The CT also outyielded ZT when UAN or urea were fall-banded, possibly because of greater denitrification and/or leaching losses under ZT as compared to CT. The CT also outyielded ZT when UAN or urea were dual-banded, although the reason is not readily apparent.

Under CT, application of P, whether seed-placed or banded increased durum yield. Yield was greater when P was dual-banded rather than seed-placed with UAN or urea, in contrast to the trend in CT canola on the Newdale soil. The lower yield with seed-placed P may reflect some seedling damage on the light-textured soil.

Under ZT, there were no significant differences in durum yield among N sources, placements and timings.

Newdale Clay Loam: On the clay loam soil, durum yield was consistently higher under CT than ZT, but there was an interaction between tillage and treatment. The smallest differential in yield between CT and ZT occurred with spring-banded applications of N, regardless of source. Fall-banded, spring spoke and surface-applied N all produced much higher durum yields under CT as compared to ZT. Yields were also much higher under CT than ZT when no N was applied.

Yield was increased under both CT and ZT with P application. Durum yield was higher under CT when P was seed-placed and urea or UAN banded away from the seed than when P and the N sources were dual banded. This is in contrast to the effect on the fine sandy loam soil but reflects the pattern observed in canola on the clay loam. The seed-placed P may perform better than the dual-banded applications because of the cool, moist conditions that occur on the clay loam soil, but one would then expect to see a similar effect under ZT conditions.

Table 4: Durum grain yield (bu/acre) as a function of fertilizer source, placement and time of application under zero and conventional tillage management on a Marringhurst Fine Sandy Loam and a Newdale Clay Loam soil (1992-95).

Treatment	Marringhurst FSL		Newdale CL	
	CT	ZT	CT	ZT
NH_3 Fall Band (PS)	39.8	42.6	46.7	36.8
UAN Fall Band (PS)	43.5	38.9	42.3	29.9
Urea Fall Band (PS)	43.4	41.2	44.0	30.5
NH_3 Spring Band (PS)	41.6	45.9	44.4	39.8
UAN Spring Band (PS)	37.9	41.7	46.6	39.9
Urea Spring Band (PS)	39.0	41.2	44.4	41.0
UAN Dual Band	45.7	43.0	43.3	39.8
Urea Dual Band	43.6	39.7	43.5	41.1
UAN Spoke (PS)	42.0	39.9	45.5	34.4
UAN Dribble (PS)	40.0	42.0	45.7	34.7
Urea Dribble (PS)	38.8	41.3	44.6	33.6
A.N. Dribble (PS)	37.2	37.4	44.4	33.2
A.N. Broadcast (PS)	41.3	40.1	43.5	32.2
Urea Broadcast (PS)	40.7	38.3	44.9	32.9
No N, No P	28.2	24.7	33.0	22.4
No N, P Seed-placed	32.2	29.5	35.1	25.9
No N, P Banded	33.1	27.1	35.8	27.5
No N, No P, Band	28.5	27.8	30.4	25.6
CV	14.7		12.5	

Durum yield was higher with NH_3 than UAN under both ZT and CT and higher with NH_3 than urea under ZT. The NH_3 appears to be less subject to denitrification and/or leaching losses than urea or UAN when applied as a fall band. Losses of fall-applied N on the clay loam soil appear to be greater under ZT than CT. The nested application of UAN was less effective under ZT than was the spring banded application, both of which received seed-placed P.

Table 5: F-values for contrast analysis of effects of fertilizer source, timing and placement on yield of durum under zero and conventional tillage management on a Marringhurst Fine Sandy Loam and Newdale Clay Loam soil (1992-95).

Contrast	Marringhurst FSL		Newdale CL	
	CT	ZT	CT	ZT
No N vs. N	0.0001	0.0001	0.0001	0.0001
Band vs. surface N	ns	ns	ns	0.0001
Urea vs. UAN	ns	ns	ns	ns
Broadcast vs. Dribble	ns	ns	ns	ns
Am.N vs. Urea, Surface	ns	ns	ns	ns
P seed vs. P dual	0.0013	ns	0.0799	ns
NH_3 vs. Urea, Spring	ns	ns	ns	ns
NH_3 vs. UAN, Spring	ns	ns	ns	ns
NH_3 vs. UAN, Fall	ns	ns	0.0096	0.0006
NH_3 vs. urea, Fall	ns	ns	ns	0.0017
Urea vs. UAN, Fall	ns	ns	ns	ns
UAN Band vs. Spoke	ns	ns	ns	0.0058
UAN in soil vs Dribble	ns	ns	ns	ns
Banding effect - no N	ns	ns	ns	ns
P vs. no P check	0.0216	ns	0.0018	0.0556
C.V.	16.7	21.1	11.2	16.8

Cadmium Concentration

Cadmium analysis for the 1994-94 growing seasons are not completed due to heavy sample load and equipment breakdowns in the laboratory. Sample analysis should be completed in the near future.

Table 6: Cadmium content of canola seed as a function of fertilizer source, placement and time of application on a Newdale Clay Loam soil.

Treatment	Conventional Till		Zero Till	
	1992	1993	1992	1993
NH_3 Fall Band (PS)	.	53.1	.	45.0
UAN Fall Band (PS)	.	61.5	.	53.4
Urea Fall Band (PS)	.	62.9	.	54.2
NH_3 Spring Band (PS)	32.9	66.1	29.4	59.6
UAN Spring Band (PS)	38.1	60.3	32.2	49.0
Urea Spring Band (PS)	32.2	61.3	30.1	52.3
UAN Dual Band	33.1	58.7	39.3	53.0
Urea Dual Band	32.1	55.0	35.8	52.6
UAN Spoke (PS)	33.5	54.8	38.3	60.9
UAN Dribble (PS)	32.4	63.5	33.3	51.7
Urea Dribble (PS)	37.1	61.9	40.7	53.9
A.N. Dribble (PS)	32.2	59.6	31.2	50.7
A.N. Broadcast (PS)	32.0	64.4	33.4	57.0
Urea Broadcast (PS)	35.5	59.1	33.3	50.5
No N, No P	39.0	62.4	47.7	52.6
No N, P Seed-placed	40.3	66.5	46.6	56.0
No N, P Banded	46.1	63.5	39.5	56.6
No N, No P, Band	38.9	55.2	46.3	59.2

Canola

Clay Loam: In 1992, under CT, fertilizer management had little effect on Cd content of canola seed (Tables 6 and 7). Cadmium content was lower with N applications than where no N had been added. The same result occurred under ZT. This is in contrast to previous observations in barley and durum wheat. Under ZT, Cd content in canola seed was also slightly higher with surface N applications than with in-soil applications of urea and UAN and where the P was dual banded as compared to seed-placed.

Table 7: F-values for contrast analysis of effects of fertilizer source, timing and placement on cadmium content of canola seed on a Newdale Clay Loam Soil.

Contrast	Conventional Till		Zero Till	
	1992	1993	1992	1993
Band vs. surface N	ns	ns	0.0648	ns
Urea vs. UAN	ns	ns	0.0919	ns
Broadcast vs. Dribble	ns	ns	ns	ns
No N vs. N	0.0611	ns	0.0001	ns
Am.N vs. Urea, Surface	ns	ns	ns	ns
P seed vs. P dual	ns	ns	0.0429	ns
NH_3 vs. Urea, Spring	ns	ns	ns	0.0583
NH_3 vs. UAN, Spring	ns	ns	ns	0.0080
NH_3 vs. UAN, Fall	.	ns	.	0.0296
NH_3 vs. urea, Fall	.	0.0703	.	0.0176
Urea vs. UAN, Fall	.	ns	.	ns
UAN Band vs. Spoke	ns	ns	ns	0.0030
UAN in soil vs Dribble	ns	ns	ns	ns
Banding effect - no N	ns	ns	ns	0.0840
P vs. no P check	ns	ns	ns	ns
C.V.	22.6	12.4	17.0	9.8

Table 8: Cadmium content of canola seed as a function of fertilizer source, placement and time of application on a Marringhurst Fine Sandy Loam soil.

Treatment	Conventional Till		Zero Till	
	1992	1993	1992	1993
NH_3 Fall Band (PS)	.	72.9	.	70.3
UAN Fall Band (PS)	.	76.9	.	73.3
Urea Fall Band (PS)	.	74.4	.	75.1
NH_3 Spring Band (PS)	79.3	75.4	69.2	76.5
UAN Spring Band (PS)	71.1	82.2	67.4	66.1
Urea Spring Band (PS)	70.3	76.7	71.2	77.1
UAN Dual Band	70.1	74.6	82.2	90.9
Urea Dual Band	68.1	86.8	73.2	71.4
UAN Spoke (PS)	69.8	72.4	73.9	64.1
UAN Dribble (PS)	86.5	71.0	87.3	74.3
Urea Dribble (PS)	71.5	73.2	74.9	89.3
A.N. Dribble (PS)	65.8	73.4	73.0	68.0
A.N. Broadcast (PS)	68.3	77.3	63.8	57.2
Urea Broadcast (PS)	72.4	79.7	61.6	63.8
No N, No P	75.2	78.3	73.2	74.4
No N, P Seed-placed	88.7	81.0	75.8	83.5
No N, P Banded	76.8	115.6	84.1	83.3
No N, No P, Band	78.2	75.4	86.5	74.0

In 1993, there were again few differences in Cd concentration under CT. Seed Cd content was lower with fall applied NH_3 than with urea. Under ZT, fall applied NH_3 also produced lower Cd content in the grain as compared to UAN or urea, but when spring-applied, levels were higher with NH_3 than with the other sources. Cadmium content in the seed was also higher when UAN was applied as a spoke wheel application than as a band. But, in the absence of fertilizer addition, a banding operation increased Cd content of the seed.

<u>Fine Sandy Loam:</u> In 1992, under CT, Cd content of canola seed tended to be lower with applied N than in its absence Tables 8 and 9). Surface dribble banded UAN produced higher Cd than did the in-soil band applications. Under ZT the surface dribble banded treatment were also higher in Cd than the in-soil banded or broadcast applications.

Table 9: F-values for contrast analysis of effects of fertilizer source, timing and placement on cadmium content of canola seed on a Marringhurst Fine Sandy Loam Soil.

Contrast	Conventional Till		Zero Till	
	1992	1993	1992	1993
Band vs. surface N	0.0278	ns	0.0416	ns
Urea vs. UAN	ns	ns	ns	ns
Broadcast vs. Dribble	ns	ns	0.0530	0.0187
No N vs. N	0.0934	ns	ns	ns
Am.N vs. Urea, Surface	ns	ns	ns	0.0684
P seed vs. P dual	ns	ns	ns	ns
NH_3 vs. Urea, Spring	ns	ns	ns	ns
NH_3 vs. UAN, Spring	ns	ns	ns	ns
NH_3 vs. UAN, Fall	.	ns	.	ns
NH_3 vs. urea, Fall	.	ns	.	ns
Urea vs. UAN, Fall	.	ns	.	ns
UAN Band vs. Spoke	ns	ns	ns	ns
UAN in soil vs Dribble	0.0084	ns	0.0252	ns
Banding effect - no N	ns	ns	ns	ns
P vs. no P check	ns	0.0061	ns	ns
C.V.	16.7	19.0	15.3	20.2

In 1993, under CT, N applications did not significantly influence Cd levels in canola seed, but applications of P, either seed-placed or banded led to higher Cd levels than in its absence. Under ZT, dribble banded applications of UAN or urea led to higher Cd levels than broadcast applications. Urea produced higher seed Cd levels than did ammonium nitrate.

Generally, in canola, Cd levels in the seed were low and the effect of fertilizer management on Cd level was inconsistent. There was no indication that N applications led to an increase in Cd level in the seed. In fact, in contrast to the observations in barley and durum wheat, N applications tended to reduce Cd levels in canola seed, with the effect being significant in some instances. Phosphorus application also had no consistent effect on Cd level in canola seed, although there was a significant increase in Cd with P application on the fine sandy loam soil under CT in 1993 and a tendency towards higher levels with P application under ZT in this site-year. Effects of P in other site-years was minimal.

<u>**Durum Wheat**</u>

Cadmium concentration in durum wheat is of concern, as levels in the Canadian crop may exceed the proposed limit for trade suggested by Codex Alimentarus. Durum wheat tends to accumulate higher levels of Cd than hard red spring wheat and genetic variation occurs among durum cultivars in the level of Cd accumulated in the grain. A breeding program is underway to reduce the concentration of Cd in Canadian cultivars, but fertility and crop management practices may influence Cd concentration in crops and long-term accumulation in the soil.

<u>Clay Loam:</u> In 1992, under CT, N application did not significantly influenced Cd content in durum seed, although Cd concentration tended to be higher with N as compared to without (Tables 10 and 11). Seed Cd concentration was higher when P was seed-placed than when it was dual banded with urea or UAN, under both CT and ZT. Under ZT, P applications increased Cd content. Under ZT, seed Cd levels were also higher with surface as compared to in-soil applications of N.

In 1993, application of N increased Cd level in the seed under both CT and ZT. Under CT, spring banded NH_3 produced very high concentrations of Cd in the seed - higher than either urea or UAN applied as a spring band. Under ZT, the same tendency occurred, but it was not statistically significant. Under CT, a banding operation in the absence of fertilizer application reduced Cd in the seed. The same tendency occurred in 1992 in both CT and ZT, but the differences were not significant. Under ZT, in-soil band applications led to higher Cd levels than surface applications, primarily due to low concentrations with surface dribble band applications. Yield was low with surface dribble bands in this site-year, indicating that the N was not utilized effectively. The low Cd accumulation in the seed in this placement may reflect the low N availability.

Table 10: Cadmium content of durum grain as a function of fertilizer source, placement and time of application on a Newdale Clay Loam soil.

Treatment	Conventional Till		Zero Till	
	1992	1993	1992	1993
NH_3 Fall Band (PS)	.	96.6	.	84.2
UAN Fall Band (PS)	.	88.1	.	73.2
Urea Fall Band (PS)	.	91.5	.	84.5
NH_3 Spring Band (PS)	48.4	112.2	45.8	86.8
UAN Spring Band (PS)	49.4	86.4	50.8	78.9
Urea Spring Band (PS)	53.5	88.5	48.8	75.4
UAN Dual Band	42.1	85.8	47.3	80.9
Urea Dual Band	40.3	84.0	48.5	73.4
UAN Spoke (PS)	51.0	91.0	50.7	72.7
UAN Dribble (PS)	49.1	86.4	52.4	66.2
Urea Dribble (PS)	53.2	88.5	53.5	62.7
A.N. Dribble (PS)	47.5	88.0	51.8	65.0
A.N. Broadcast (PS)	49.4	97.8	52.9	76.6
Urea Broadcast (PS)	49.0	89.2	51.4	74.3
No N, No P	41.0	76.2	39.7	58.2
No N, P Seed-placed	43.2	71.6	47.7	66.4
No N, P Banded	41.5	70.8	41.7	71.7
No N, No P, Band	33.0	63.0	33.9	64.5

Fine Sandy Loam: On this soil, N application increased Cd concentration in durum seed on both tillage systems in both years (Tables 12 and 13). Application of P also consistently increased Cd in the seed, although effects were significant only in 1993. Placement of P had varying effects, with seed-placed P increasing Cd in the grain as compared to dual banded P under CT in 1992 and under ZT in 1993, while the reverse was true under ZT in 1992. Under CT in 1992 and ZT in 1993, UAN as a spoke wheel application led to lower Cd in the seed as compared to UAN as a spring band application, with P seed-placed in both cases. Under ZT in 1993, spring band applications of UAN and urea produced higher Cd levels than dribble band applications. Fall-banded NH_3 produced very high Cd levels as compared to any other treatment.

Table 11: F-values for contrast analysis of effects of fertilizer source, timing and placement on cadmium content of durum grain on a Newdale Clay Loam Soil.

Contrast	Conventional Till		Zero Till	
	1992	1993	1992	1993
Band vs. surface N	ns	ns	0.0648	0.0188
Urea vs. UAN	ns	ns	0.0919	ns
Broadcast vs. Dribble	ns	ns	ns	0.0312
No N vs. N	ns	0.0001	ns	0.0057
Am.N vs. Urea, Surface	ns	ns	ns	ns
P seed vs. P dual	0.0558	ns	0.0468	ns
NH_3 vs. Urea, Spring	ns	0.0010	ns	ns
NH_3 vs. UAN, Spring	ns	0.0004	ns	ns
NH_3 vs. UAN, Fall	.	ns	.	ns
NH_3 vs. urea, Fall	.	ns	.	ns
Urea vs. UAN, Fall	.	ns	.	ns
UAN Band vs. Spoke	ns	ns	ns	ns
UAN in soil vs Dribble	ns	ns	ns	ns
Banding effect - no N	ns	0.0588	ns	ns
P vs. no P check	ns	ns	0.0714	ns
C.V.	22.4	11.1	17.4	14.3

Table 12: Cadmium content of durum grain as a function of fertilizer source, placement and time of application on a Marringhurst Fine Sandy Loam soil.

Treatment	Conventional Till		Zero Till	
	1992	1993	1992	1993
NH_3 Fall Band (PS)	.	126.4	.	161.3
UAN Fall Band (PS)	.	114.5	.	115.0
Urea Fall Band (PS)	.	127.1	.	104.7
NH_3 Spring Band (PS)	88.6	130.7	91.0	126.6
UAN Spring Band (PS)	95.8	124.4	72.1	120.5
Urea Spring Band (PS)	91.7	114.0	76.0	118.8
UAN Dual Band	64.4	126.5	85.7	103.4
Urea Dual Band	72.1	122.8	94.9	96.9
UAN Spoke (PS)	73.1	123.5	68.1	99.5
UAN Dribble (PS)	71.6	130.9	76.6	96.4
Urea Dribble (PS)	93.1	122.7	67.2	113.8
A.N. Dribble (PS)	84.5	132.1	73.7	122.5
A.N. Broadcast (PS)	71.3	111.6	75.3	104.7
Urea Broadcast (PS)	81.5	119.8	71.2	102.7
No N, No P	49.9	96.3	43.3	72.0
No N, P Seed-placed	56.0	105.8	65.2	91.2
No N, P Banded	52.4	104.5	65.3	111.6
No N, No P, Band	44.7	81.9	60.7	71.5

Table 13: F-values for contrast analysis of effects of fertilizer source, timing and placement on cadmium content of durum grain on a Marringhurst Fine Sandy Loam Soil.

Contrast	Conventional Till		Zero Till	
	1992	1993	1992	1993
Band vs. surface N	ns	ns	ns	0.0971
Urea vs. UAN	ns	ns	ns	ns
Broadcast vs. Dribble	ns	ns	ns	ns
No N vs. N	0.0001	0.0004	0.0006	0.0001
Am.N vs. Urea, Surface	ns	ns	ns	ns
P seed vs. P dual	0.0012	ns	0.0534	0.0275
NH_3 vs. Urea, Spring	ns	ns	ns	ns
NH_3 vs. UAN, Spring	ns	ns	ns	ns
NH_3 vs. UAN, Fall	.	ns	.	0.0004
NH_3 vs. urea, Fall	.	ns	.	0.0001
Urea vs. UAN, Fall	.	ns	.	ns
UAN Band vs. Spoke	0.0357	ns	ns	0.0905
UAN in soil vs Dribble	ns	ns	ns	ns
Banding effect - no N	ns	ns	ns	ns
P vs. no P check	ns	0.0422	ns	0.0012
C.V.	20.3	13.1	21.6	16.0

Weed populations

By 1994, some interesting trends were beginning to show up in the weed populations, although high variability in weed distribution was a problem. In the canola on the clay loam soil, green foxtail and wild buckwheat tended to be higher with NH_3 as compared to UAN or urea as fall or spring band applications. Wild buckwheat populations tended to somewhat higher with banding applications, with most of the difference occurring under ZT. Wild buckwheat populations were higher under CT than ZT in canola on the clay loam.

In the canola on the fine sandy loam, green foxtail population was higher with fall banded as compared to spring banded fertilizer. Green foxtail was also higher with NH_3 as compared to urea or UAN, under CT. Russian thistle and thyme-leaf spurge populations were higher with broadcast as compared to banded fertilizer applications.

In the durum on the clay loam soil, volunteer canola was substantially higher under ZT as compared to CT. Under ZT, volunteer canola populations were higher with broadcast as compared to banded fertilizer applications and were lower with spring banded NH_3 as compared to other spring banded N sources. Cleavers population was lower with applied P as compared to where no P was applied, particularly under ZT. Green foxtail populations were higher with UAN as compared to urea applications and higher with urea as compared to ammonium nitrate.

In the durum on the fine sandy loam soil, foxtail populations tended to be higher under CT than ZT, although differences were not statistically significant due to the high variability in the population distribution. Volunteer canola populations were higher under ZT than CT, as observed on the clay loam soil. Under ZT, volunteer canola populations also were higher with spring as compared to fall banded N applications and higher with surface as compared to banded application. Under CT, volunteer canola populations were higher with urea as compared to ammonium nitrate. In contrast to the canola, thyme-leaf spurge populations were higher with fall as compared to spring band N applications. Thyme-leaf spurge also was lower with N application than when no N was applied.

Discussion

The first two years of this study was cooler than normal while the third year was average in temperature. Higher than normal effective precipitation occurred in all three years. In the fourth year of the study, early spring conditions were extremely wet and cold. However, after seeding, rainfall ceased and temperatures increased, leading to a 6-week period with no significant precipitation and temperatures frequently in the 30-35°C range. The high temperatures and lack of precipitation reduced crop yields in this year.

Differences among timing, placement and source of N differed between sites and years, indicating that relative performance of the fertilizer management options varies with environmental conditions. When applied as a fall-band, NH_3 generally produced higher yields of both canola and durum than did UAN or urea. No consistent difference occurred among N sources when banded in the spring. Although in-soil band applications tended to produce higher yields than surface applications, differences were not always large or significant, indicating that surface N applications may be a reasonable management practice under some conditions.

Stand density was not greatly influenced by tillage system. Differences in stand density of canola and durum occurred due to N applications, but the effects varied from year to year and site to site. Application of P tended to increase stand density of durum on both soils and of canola on the clay loam soil.

Cadmium concentration in durum seed was consistently increased with N application, but placement, source and timing effects varied with soil type, year and tillage. Phosphorus fertilizer also tended to increase Cd concentration in the grain, but the effect of P placement also varied with site, year and tillage. Further information and more carefully scrutiny of the data is required to determine if significant patterns exist that can explain the differences observed. Cadmium concentration in canola seed did not increase with N application. In fact, the level of Cd tended to be lower with N application, with significant reductions occurring in some instances. While P occasionally increased Cd concentration in canola seed, the effect was neither as large nor as consistent as with durum. The differences in response to fertilizer application in durum and canola may provide some clues as to the mechanism of the effect of N and P on Cd concentration in crops.

Differences in weed populations appear to be developing due to both tillage and fertilizer management. High variability in the natural distribution of weeds reduces the statistical significance of the observations. However, volunteer canola populations were much higher under ZT than CT. Further analysis of changes in populations over the four-year course of the study should allow for clarification of the influence of fertilizer management on weed populations.

Conclusions

Yield of canola and durum under conventional tillage management was higher than or did not differ from yield under zero tillage management on a fine sandy loam and a clay loam soil. Fall-banded applications of NH_3 tended to produce higher yields of canola and durum than did fall-banded urea or UAN, particularly under zero till management. The various N sources generally performed similarly when applied as spring band applications. Although in-soil band applications tended to produce higher yields than surface applications, differences were not always large or significant, indicating that surface N applications may be a reasonable management practice under many conditions.

Stand density was not greatly influenced by tillage system. Differences in stand density of canola and durum occurred due to N applications, but the effects varied from year to year and site to site. Application of P tended to increase stand density of durum on both soils and of canola on the clay loam soil.

Application of N fertilizer increased Cd concentration in durum grain, but had no effect or decreased Cd concentration in canola. Phosphorus fertilizer also tended to increase Cd concentration in durum grain, but the effect was not always significant. In canola, P occasionally increased Cd concentration in the grain, but the effects were smaller and less consistent than with durum. The difference in responsiveness of seed Cd to N application in canola as compared to durum is interesting and may provide some clues as to the mechanism leading to N effects of Cd accumulation by plants.

Volunteer cereal population tended to be lower under ZT as compared to CT, but volunteer canola tended to be higher. Difference in weed population due to fertilizer management occurred, but were not consistent. More complete analysis of the data over the four years of the study will be required to clarify the effect of fertilizer management on the various weed species present.

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References

Campbell, C.A., R.P. Zentner, H.H. Janzen, and K.E. Bowren. 1990. Crop rotation studies on the Canadian Prairies, Research Branch, Agriculture Canada Pub. 1841/E. Supply and Services Canada. Ottawa, Ont. 164. pp.

Statistical Analysis Systems Institute, Inc. 1985. SAS Users' Guide: Statistics. Version 5 Edition. SAS Institute Inc. Cary, NC. 956 pp.