IMPORTANCE OF GRANULAR NITROGEN FERTILIZER APPLICATOR SELECTION AND ADJUSTMENT WHEN FERTILIZING FOR MAXIMUM ECONOMIC YIELD OF NO-TILL WINTER WHEAT

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Introduction

Many grain producers today are concerned with the economics and efficiency of their nitrogen fertilizer application methods. With the constant need for applying nitrogen for the production of "stubbled-in" winter wheat several application methods are available to producers.

Spreading the nitrogen on the soil surface with the use of a pneumatic or spinning disc granular applicator is a popular method considered. Deep banding is another option which has had widespread usage. Banding involves placing the fertilizer beneath the soil surface either below or to the side of the seed.

With the production of "stubbled-in" winter wheat, seeding is the only tillage operation (Fowler 1983). Therefore, if the producer plans to band in nitrogen fertilizer, it is recommended that he does so at the same time as his seeding operation to try and minimize stubble knockdown.

The objective of this paper was to examine the economic aspects of nitrogen application as they pertain to maximizing the yields of winter wheat production in Saskatchewan.

MATERIALS AND METHODS

Two different types of granular fertilizer spreaders were tested. A dual spinning disc (Willmar 500) applicator (Fig. 1) and a pneumatic applicator (Valmar 240) (Fig. 2).

The Willmar spreader consisted of a ground driven chain conveyor which transported the fertilizer to the back of the spreader. There the product was thrown horizontally by two p.t.o. driven spinning discs.

The Valmar applicator uses a stream of air to blow the fertilizer vertically down onto the soil surface. The fertilizer rollers are ground driven and the air delivery system for this model was an auxiliary gas engine.

A number of collection trays were placed out in the field to catch fertilizer from each spreader. Once the fertilizer was measured, a distribution pattern was derived. 34-0-0 (Ammonium Nitrate) is the recommended form of nitrogen for spreading on the surface because of the volatilization properties of 46-0-0 (Urea). Ammonia volatilization is the loss to the atmosphere of ammonia gas when ammonium N is present near the soil surface (Harapiak _et al._, 1986). However, for economic reasons and the handling and availability of 34-0-0, 46-0-0 was used for all these tests.

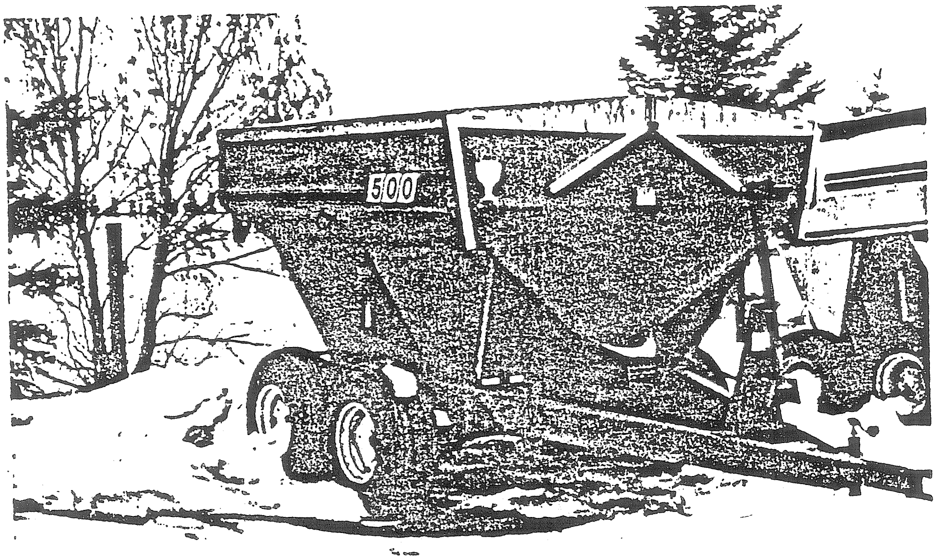


Figure 1. Willmar spinning disc spreader

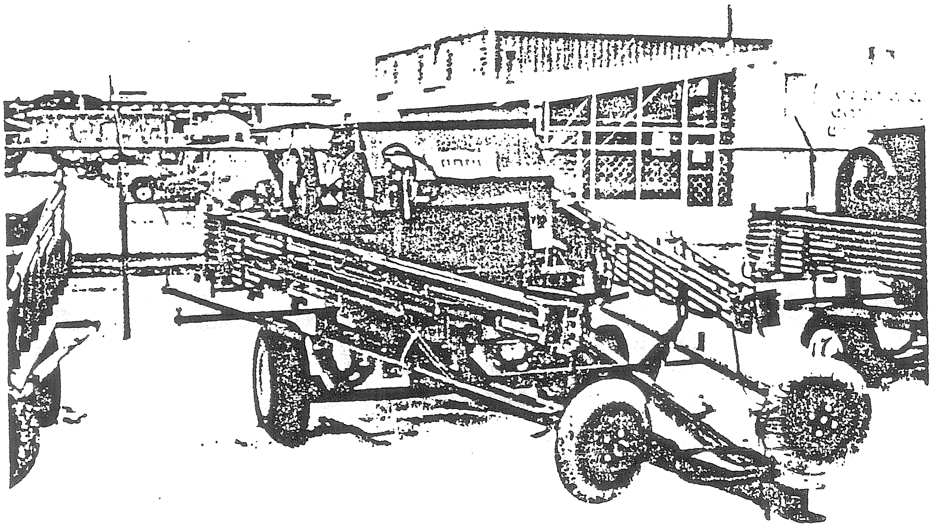


Figure 2. Valmar pneumatic applicator

The banding tests were carried out on three soil types in Saskatchewan. A sandy loam north of Watrous, a clay loam east of Watrous and a heavy clay near Indian Head (See Table 1).

Draft values were measured at all three sites using a load cell located between the tractor and the implement (Collins et al., 1987). The drill used for the majority of the tests was an Edwards HD812 four rank hoe drill with ten openers on eight inch centers (Fig. 3). For one of the trials at the clay-loam site, a Haybuster 1000 double disc drill was used instead of the Edwards.

Five depths (0.4, 0.89, 1.2, 1.6 and 2.0 inches) and three speeds (3.5, 4.5 and 5.5 m.p.h.) were used. The depths listed were seeding depths measured from an average soil surface. An "average" soil surface was used because of the soil "cave in" associated with a V-type packer wheel.

Seven different openers were used for these trials. (1) Acra Plant knife, (2) Versatile knife, (3) Edwards Chisel point, (4) Gen tip, (5) Dutch knife, (6) Thompson knife and (7) Haybuster 1000 double disc. (Figs. 4-9).

Results and Discussion

Fertilizer Spreader Uniformity

The spread pattern for the spinning disc spreader was very non-uniform (Fig. 10). The recommended driving interval for this spreader was to be forty feet, however the amount of fertilizer that was spread twenty feet to either side of the spreader was far less than that directly behind the spreader. Thus, only minimum fertilizer overlapping occurred which would probably lead to strips in the fields caused by a nitrogen deficiency.

The Willmar spreader was set to factory specifications. Fig. 12 shows the factory spinning disc blade configuration. It was possible to alter the spread pattern by changing the positions of the spinner blades, however all tests were performed while the spreaders were adjusted to factory specs.

Reducing the driving interval (i.e. increasing the overlap) was another adjustment that could be made. This was performed, however only a small improvement was made on the uniformity pattern when the driving interval was reduced to twenty-five feet. Also, it must be remembered that by reducing the driving interval, the actual spreading time increases. Therefore, in order for grain producers to spend more time than manufacturers suggest there has to be some economic benefit. After studying these points, a driving interval of forty feet was chosen for these tests (Fig. 13).

One other possible explanation for the poor distribution pattern was that the spinning discs were not turning at the proper speed. However, the spinning discs speed were measured to be 780 R.P.M. which was within the accepted range.

A second Willmar spreader was tested and uniformity pattern was obtained which was very similar to the original test which would negate any evidence there may have been that the original spreader was not working properly.

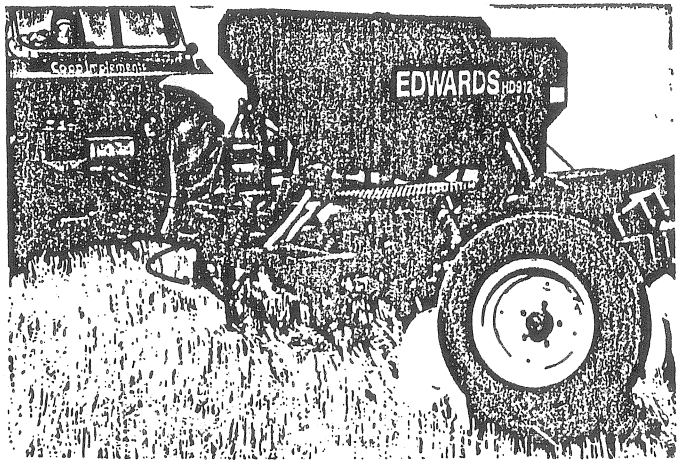


Figure 3. Edwards HD812 hoe drill

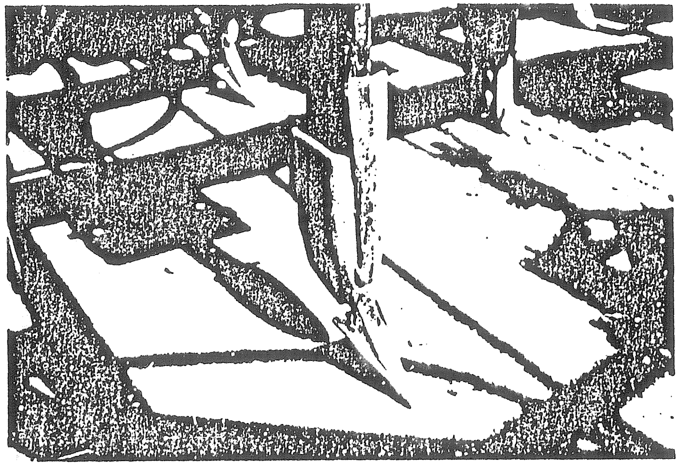


Figure 4. Acra Plant

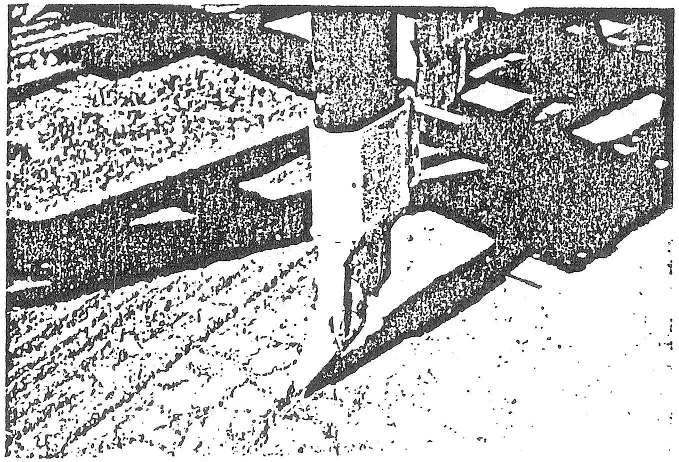


Figure 5. Versatile

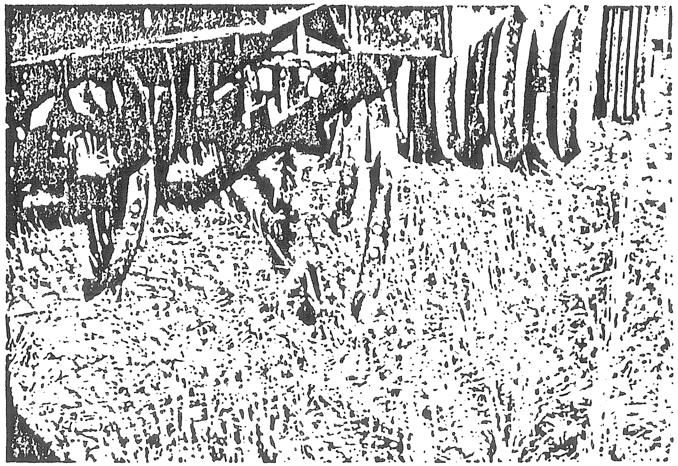


Figure 6. Edwards chisel point

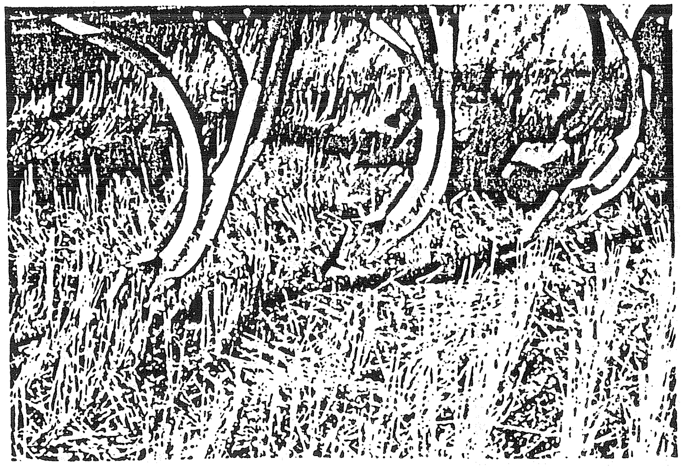


Figure 7. Gen Tip

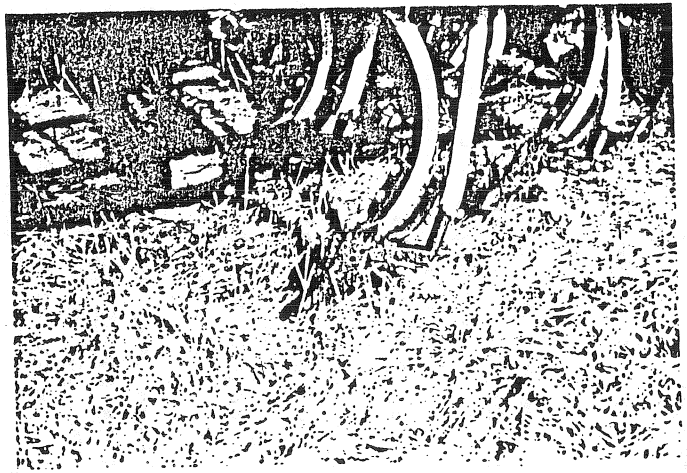


Figure 8. Dutch

Figure 9. Thompson

There was only a small difference in uniformity of spread patterns between trials carried out on summerfallow and those on standing stubble that was approximately eight inches high.

The Valmar (pneumatic applicator) was also tested for its pattern uniformity. Unlike the Willmar, the Valmar applies its fertilizer vertically down with a stream of air. Thus, only one pass was needed since overlapping was not a concern.

The Valmar's spread pattern was extremely uniform (Fig. 11). The reason for the good results was probably due to the method of application. The Valmar forces the fertilizer straight down towards the soil, thus reducing the chance of uneven distribution providing the air system can deliver sufficient air pressure to move the product.

The Valmar was available with several different power sources. The particular model tested had an auxiliary gasoline engine, however both a p.t.o. and hydraulic models were available. It was noticed that at high fertilizer outputs, the factory gasoline engine which drove the fan was having trouble applying a constant amount of product due to overloading.

Nitrogen response curves (Fig. 15) have been developed for different environmental regions in Saskatchewan (Fowler et al. 1987). The variable nitrogen values were taken from the spread patterns for each one foot width and were fit to the nitrogen response curve to determine average expected yield for both application methods. The Valmar's application was taken as 100% of the mean because of its uniform pattern.

Fig. 15 shows a very small average difference in yield response between the Willmar and the Valmar. It is evident from Fig. 10 that the uniformity of the Willmar is very poor and yet Fig. 15 shows that there is essentially no difference in average yield for a field between the two types of spreaders. The reason for the lack of significant difference in average yields for the spreaders was due to the unique spread pattern of the spinning disc spreader. Figure 10 shows that approximately the same amount of fertilizer is applied above the mean rate as is applied below the mean. Thus, in areas where the nitrogen was in excess, the crop was able to make use of it, causing an increase in yield which would compensate for areas which received considerably less fertilizer.

The Willmar was applying up to 123% of the mean application rate directly behind the spreader and only 60% of the mean twenty feet to either side.

Therefore, if these two types of spreaders were placed out in the field under identical circumstances the average yields would be the same. However, "nitrogen stripping" or plant foliage color differences may be evident in fields in which the Willmar spreader was used.

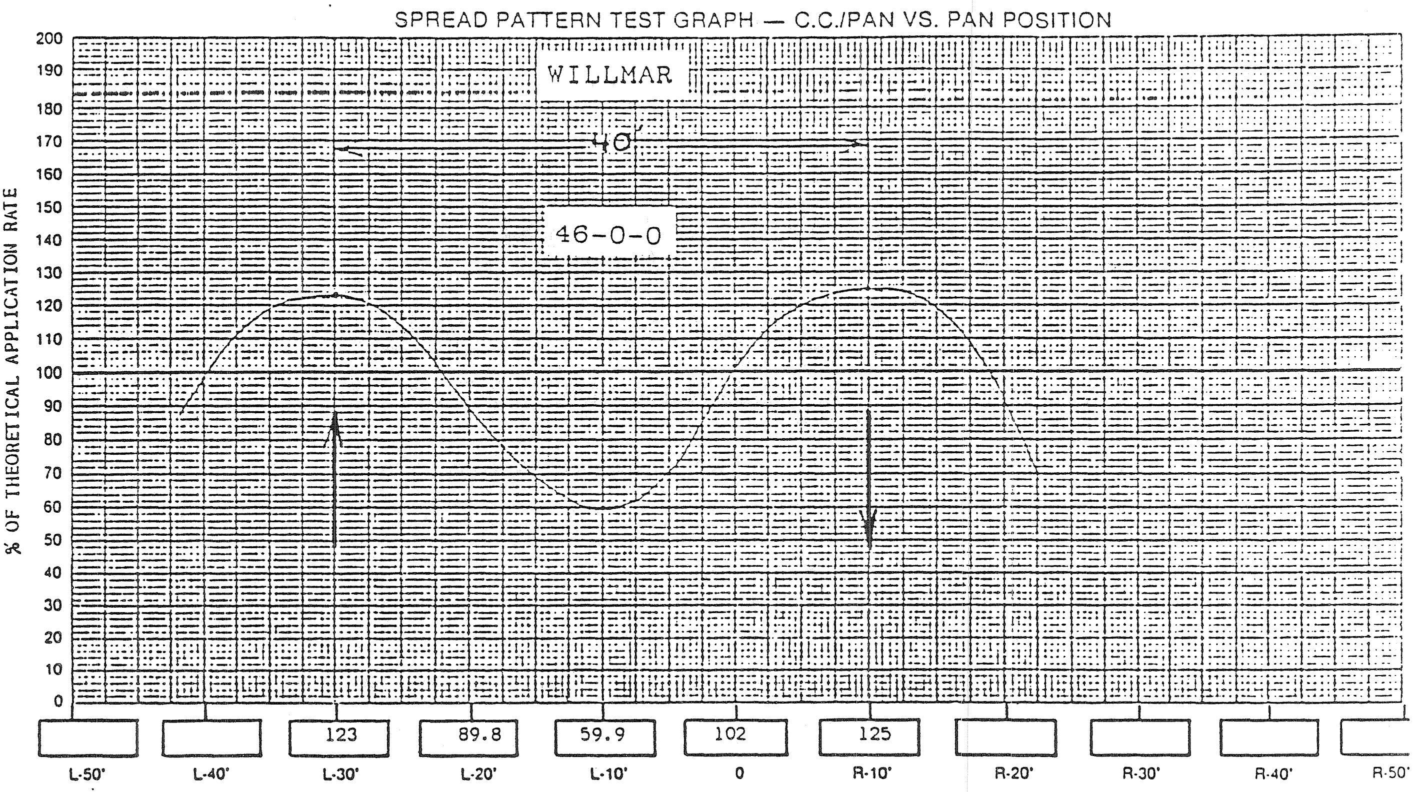


Figure 10. Willmar spread pattern

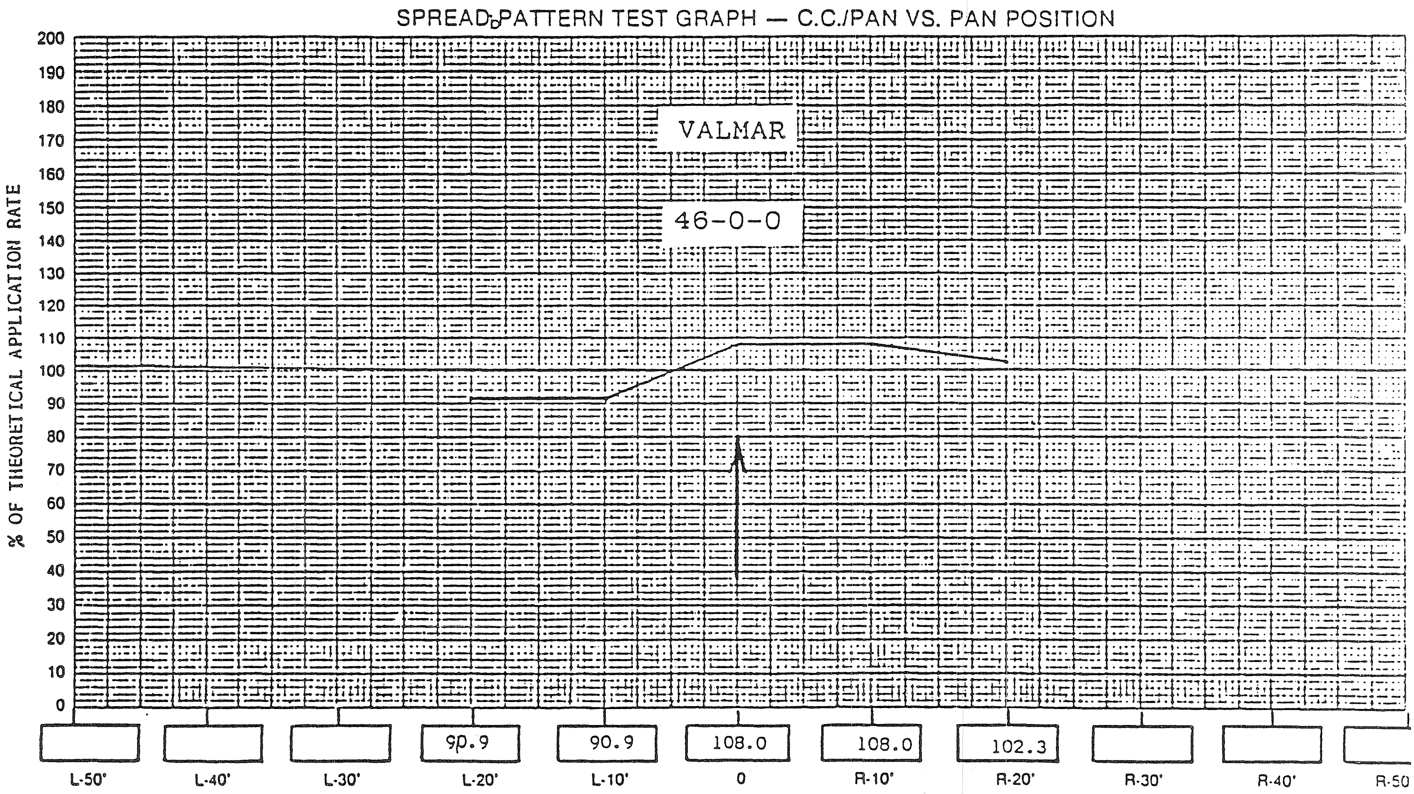
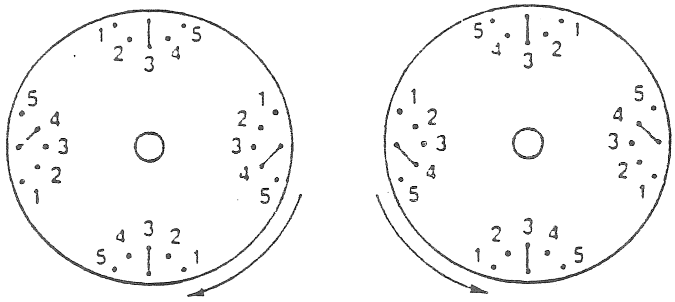
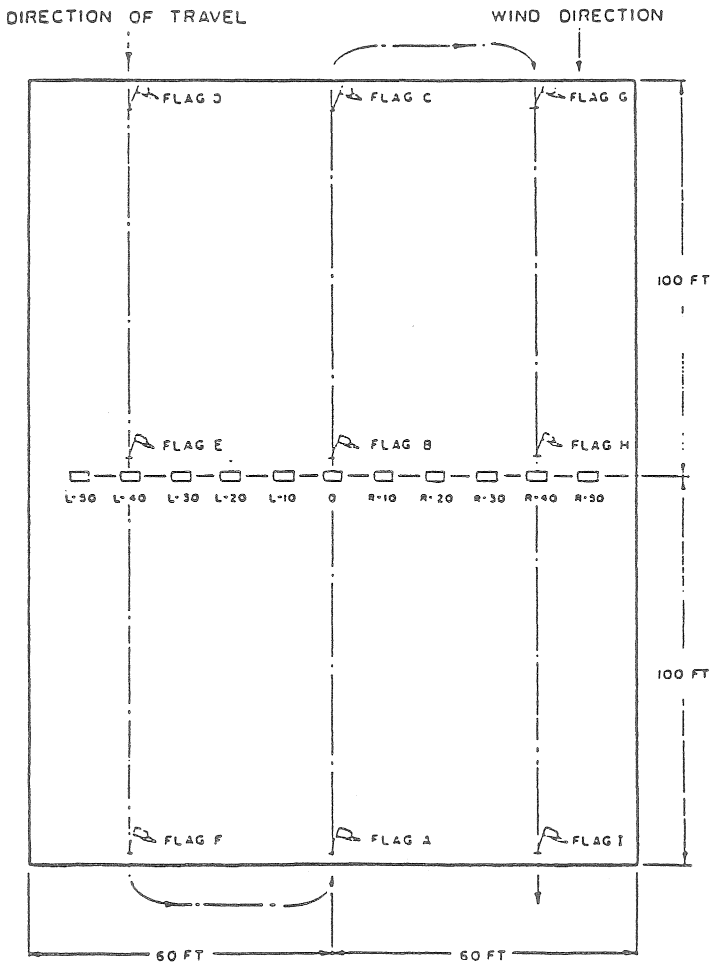


Figure 11. Valmar spread pattern



SPINNER BLADE POSITIONS

Figure 12. Spinner blade configuration



COURSE SET FOR FIELD SIMULATION TEST

Figure 13. Fertilizer spreader test course

FIELD SIMULATION TEST - DUAL SPINNER SPREADERS:

Actual field conditions using the Willmar recommended full overlap method can be simulated by following the procedure shown in the illustration below. This will test and demonstrate the effect of the "switch back" driving method.

The results from Fig. 15 encouraged one to believe that regardless of the fertilizer spreader uniformity pattern, the average grain yield for a field would be unaffected. Thus, an artificial or exaggerated distribution pattern was created for the Willmar spreader (see Fig. 14). This artificial pattern was so non-uniform that there was actually strips in the field (twenty feet on either side of the spreader path) that were not receiving any fertilizer while directly behind the spreader, approximately two hundred percent of the mean was being applied. Once again, the variable nitrogen values were taken off Fig. 14 and were applied to be N response curves for yield (Fig. 16). Now there was a definite reduction in average yield for a field due to the highly non-uniform spread pattern of the Willmar. The same Valmar patterns were plotted in Fig. 15 and 16.

Banding Power Requirements

$$P = \frac{Dr \times S}{375} \qquad (1)$$

where P = Power (Hp)

Dr = Draft Force (lbs_f)

S = Speed (m.p.h.)

375 = Conversion constant

Equation (1) shows a relationship between power, draft and speed. Once a power value was arrived at, the proper tractor size could be calculated by using equation (2) (P.A.M.I. 1984)

$$\text{Tractor Size} = P \times T.E. \times L.F. \qquad (2)$$

(HP)

Where P = Power (Hp)

T.E. = Tractive Efficiency factor of 1.25 representing a tractive efficiency of 80% on hard soils (heavy primary tillage)

L.F. = Tractor load factor (L.F. = 1.25 representing a tractor operating at 80% of maximum p.t.o. output)

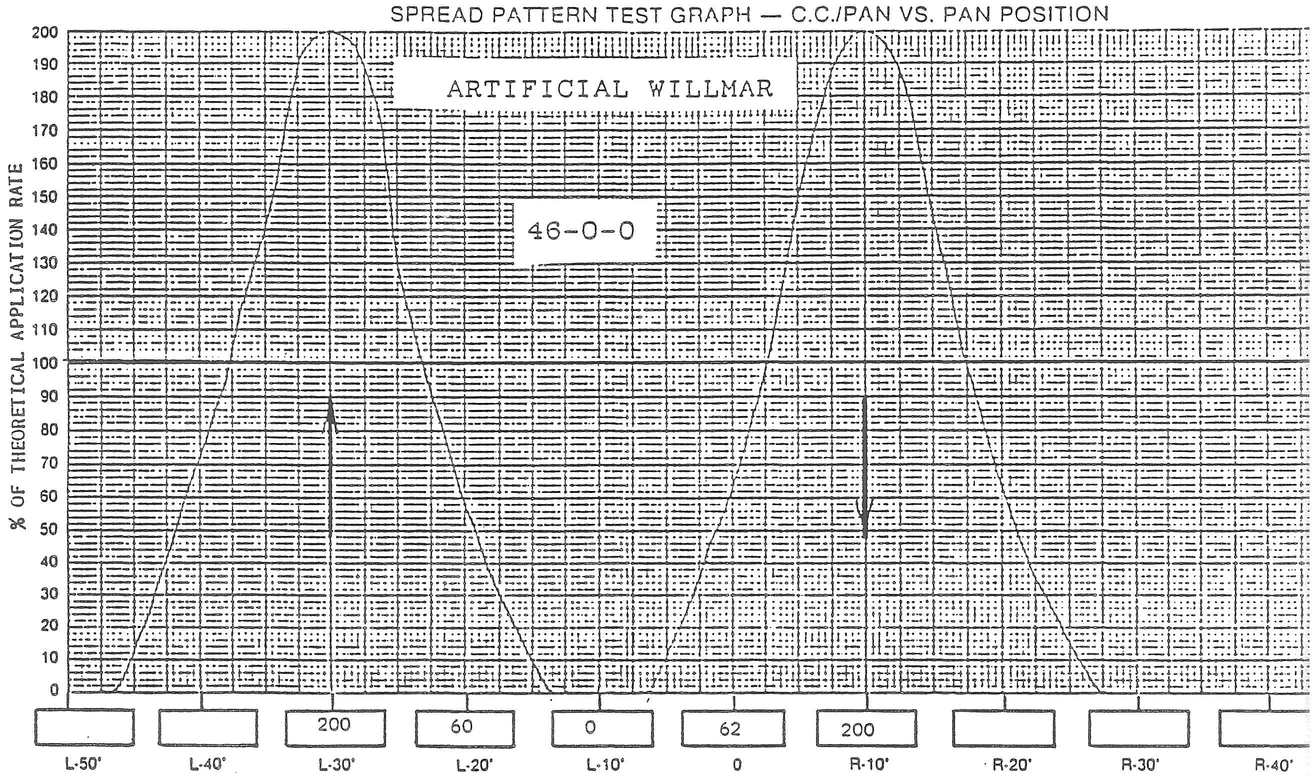


Figure 14. Artificial Willmar spread pattern

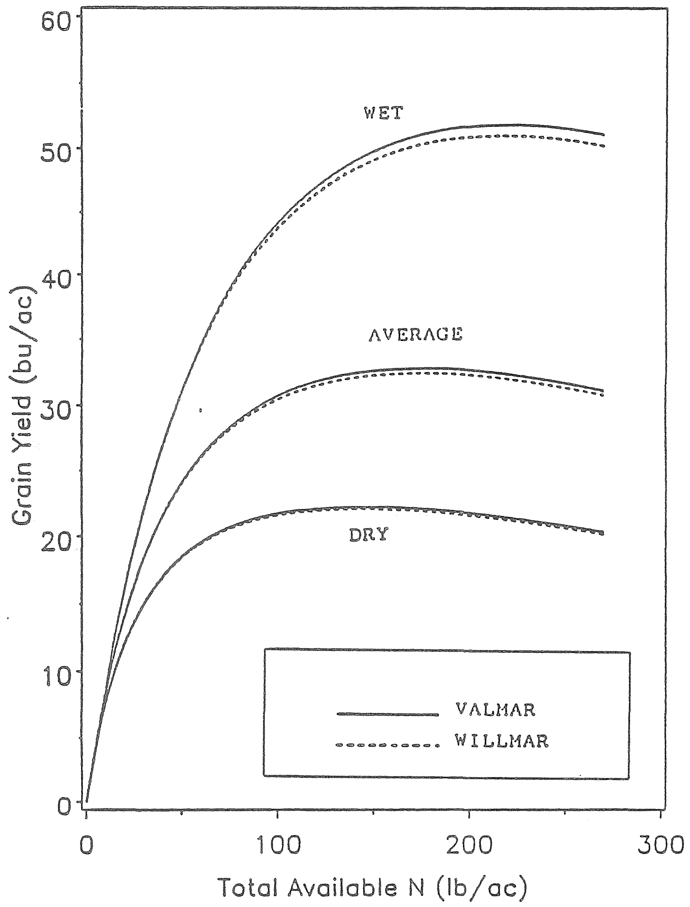


Figure 15. Fertilizer response curve

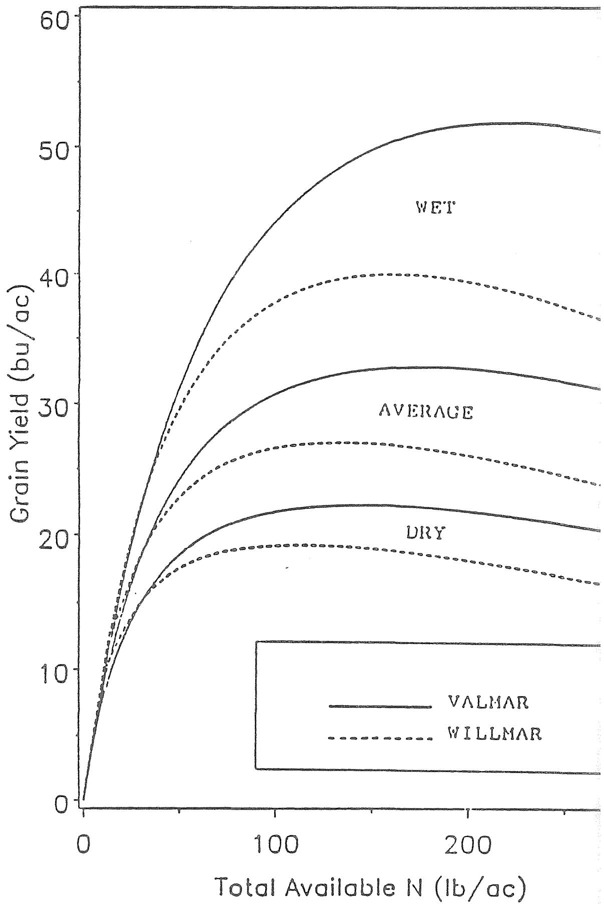


Figure 16. Artifical fertilizer response curve

The position of the seed with respect to the fertilizer could be varied with the Thompson knife. The seed could be placed vertically higher or lower or to the side of the fertilizer. However, for all these tests the fertilizer was constantly kept 1.5 inches below the seed.

Several conventional seeding openers were also tested to compare power requirements of the seeding operation to the power requirements associated with banding and seeding at the same time. A standard cultivating chisel point was also tested to act as a reference for the power values.

The three sites chosen for these tests gave a wide range of soil conditions that exist in Saskatchewan. The openers behaved similar at the Treble Farm (sandy site) (Fig. 17) and the Pool Farm (clay loam site) (Fig. 18). And there were only minor changes at Indian Head (heavy clay site) (Fig. 19).

Table 2 lists the power equations for the various types of openers at the three sites, where P = Power (Hp); S = Speed (m.p.h.); D = Depth (inches).

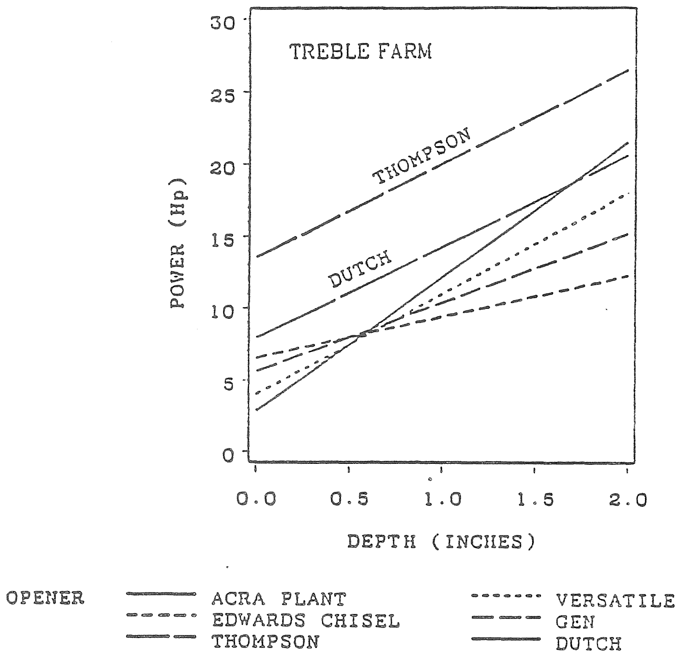


Figure 17. Power versus depth for ten openers at 4.5 m.p.h. at Treble Farm.

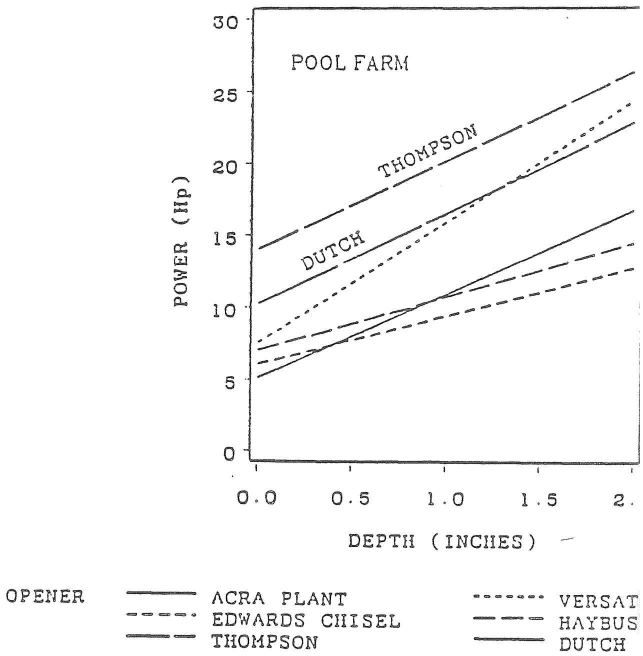


Figure 18. Power versus depth for ten openers at 4.5 m.p.h. at Pool Fa

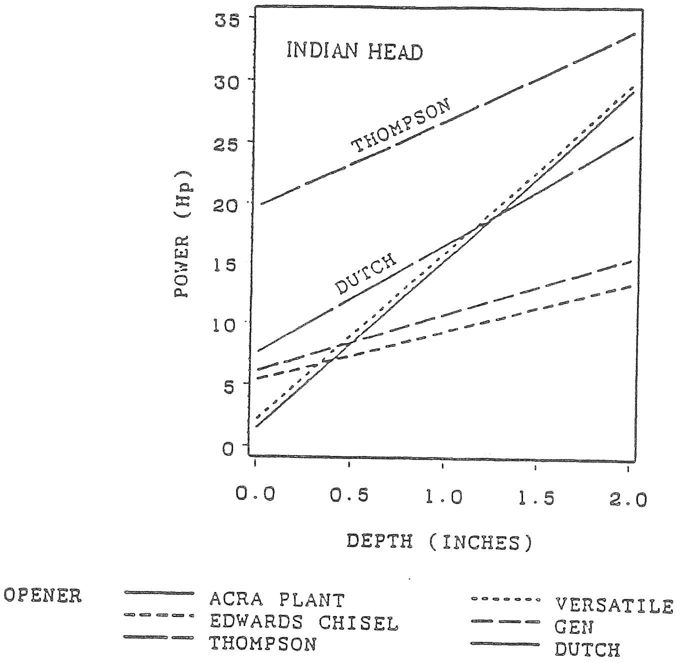


Figure 19. Power versus depth for ten openers at 4.5 m.p.h. at Indian Head

Table 2. Regression Equations for Ten Openers at Three Sites.

Site	Opener	Equation	R^2
Treble	Acra Plant	P=4.00*S+9.33*D-15.17	0.93
"	Dutch	P=4.25*S+6.32*D-11.19	0.96
"	Chisel Point	P=2.68*S+2.84*D-5.51	0.96
"	Gen Tip	P=3.64*S+4.78*D-10.77	0.93
"	Thompson	P=5.83*5+6.45*D-12.66	0.94
"	Versatile	P=3.41*S+6.99*D-11.35	0.93
Pool	Acra Plant	P=3.59*S+5.82*D=11.05	0.89
"	Dutch	P=5.06*S+6.30*D-12.52	0.97
"	Chisel Point	P=2.58*S+3.35*D-5.55	0.92
"	Haybuster	P=3.54*S+3.73*D-8.92	0.95
"	Thompson	P=5.10*S+6.15*D=8.90	0.95
"	Versatile	P=4.93*S+8.41*D-14.67	0.96
Indian Head	Acra Plant	P=4.30*S+13.92*D-17.89	0.94
"	Dutch	P=4.30*S+9.04*D-11.76	0.87
"	Chisel Point	P=2.12*S+3.99*D-4.16	0.83
"	Gen Tip	P=2.54*S+4.67*D-5.31	0.80
"	Thompson	P=8.26*S+7.09*D-17.39	0.93
"	Versatile	P=5.87*S+13.84*D-24.25	0.92

At the Treble Farm, the Thompson knife had a power requirement of 2.13 times that of the Edwards Chisel point at a depth of one inch and a speed of 4.5 m.p.h. For all of the power requirement comparisons, a depth of one inch and a speed of 4.5 m.p.h. were used. The Dutch knife had power requirements that were 1.52 times as high as the Chisel point. The Acra Plant knife opener (a conventional seeding opener) had power requirements that were 1.28 times that of the chisel point. Extensive tests were previously performed on the Acra Plant opener and it was found to have reasonably low power requirements (Collins _et_ _al_. 1987).

One possible reason why the Thompson knife had higher power requirements than the Dutch knife was because it was actually positioned approximately 3/4" deeper in the soil due to its physical shape.

At the Pool Farm, the Thompson, Dutch and Acra Plant openers behaved in much the same fashion. Their power requirements were 2.15, 1.76 and 1.16 times the chisel point respectively. At this site the Haybuster 1000 offset double disc drill was also tested. The double disc had power requirements which were fifteen percent higher than that of the Chisel point.

At Indian Head, the Thompson knife had 2.87 times the power requirements of the Chisel point while the Dutch was 1.77 times that of the Chisel point. The Acra Plant opener required 1.64 times the power than that of the Chisel point. The power requirements were significantly higher at Indian Head than at the other two sites because of the heavy clay and the high moisture content.

The other openers which were included were used as conventional seeding openers. However, some of the knives like the Gen Tip may be used as banding knives as well. The Gen Tip (Fig. 7) had very low draft values. It had power requirements of only ten to twenty percent higher than the Chisel point. The reason for such low draft forces was due to its V-shape. It is able to slice and uplift the soil, thus reducing the shear forces (skin friction).

Economic Analysis

Table 3 gives the economic comparison between the two methods of applying nitrogen; spreading and banding. Two different forms of nitrogen are listed 46-0-0 (urea) and 34-0-0 (ammonium nitrate). Ammonium nitrate was listed for spreading because of the threat of volatilization properties of urea. Urea was used for banding because of its price, availability and ease in handling.

All nitrogen for Table 3 was applied at sixty pounds of actual nitrogen per acre. A forty foot fertilizer spreader was used for the calculations along with a twenty-one foot hoe drill or a twenty-one foot cultivator with an air seeder. From the power curves (Figs. 18-20) proper tractor sizes were chosen on the basis of a one inch seeding depth.

All dollar values shown in Table 3 were based on recommendations from Saskatchewan Agriculture 1987.

The seeding costs per acre with the Thompson and Dutch knives were higher than those knives which could not band at the same time. Seeding costs included labor, implement and tractor costs.

Although the seeding costs for the non-banding or conventional openers are lower, a second operation is required to apply the nitrogen. This second operation usually takes place the following spring in the form of fertilizer spreading. This spreading operation added another dollar per acre to the total cost per acre. Thus, the total cost, comparing both methods of nitrogen application, came out to be virtually equal if labor costs are assumed to be equal. So the extra operation, with the conventional openers, associated with spreading compensated for the higher seeding costs of the banding knives.

As an example, on the clay loam using an air seeder, cultivator and the Thompson banding and seeding knife at 4.5 m.p.h. a 100 HP tractor would be needed. The seeding costs would be $7.25/acre. The fertilizer (46-0-0) would be $13.20/acre for a total cost of $20.45/acre.

If instead the producer chose to seed the winter wheat at 4.5 m.p.h. with a hoe drill and Acra Plant knife openers and then spread his nitrogen the following spring as a separate operation, the cost would be as follows. Using at least a 55 HP tractor the seeding costs would be $4.97/acre. If he were to spread at 7.5 m.p.h. with a 50 HP tractor the spreading costs (spreader, tractor and labor) would be $1.02/acre. The fertilizer (34-0-0) would cost $14.40/acre for a total cost of $20.39/acre.

Table 1. Banding sites

TEST CONDITIONS			
LOCATION	SOIL TEXTURE	MOISTURE CONTENT	BULK DENSITY
WATROUS	SANDY LOAM	16.2%	1.02 g/cm^3
WATROUS	CLAY LOAM	12.1%	1.06 g/cm^3
INDIAN HEAD	HEAVY CLAY	30.2%	1.16 g/cm^3

Table 3. Cost analysis for the two methods of nitrogen application

	OPENER	NITROGEN APPLICATION METHOD	SEEDING TRACTOR SIZE (Hp)	SEEDING COSTS ($/acre)	SPREADING TRACTOR SIZE (Hp)	SPREADING COSTS ($/acre)	FERTILIZER ($/acre)		TOTAL COST ($/acre)
							34-0-0	46-0-0	
SANDY LOAM SITE	THOMPSON	BANDED	95	6.92	-	-	-	13.20	20.12
	DUTCH	BANDED	70	6.57	-	-	-	13.20	19.77
	EDWARDS HOE	SPREAD	65	5.15	50	1.02	14.40	-	20.57
	VERSATILE	SPREAD	55	4.97	50	1.02	14.40	-	20.39
	ACRA PLANT	SPREAD	55	4.97	50	1.02	14.40	-	20.39
	IHC	SPREAD	45	4.85	50	1.02	14.40	-	20.27
	GEN	SPREAD	45	4.85	50	1.02	14.40	-	20.27
CLAY LOAM SITE	THOMPSON	BANDED	100	7.25	-	-	-	13.20	20.45
	DUTCH	BANDED	80	6.69	-	-	-	13.20	19.89
	EDWARDS HOE	SPREAD	70	5.56	50	1.02	14.40	-	20.98
	VERSATILE	SPREAD	80	5.68	50	1.02	14.40	-	21.10
	ACRA PLANT	SPREAD	55	4.97	50	1.02	14.40	-	20.39
	IHC	SPREAD	55	4.97	50	1.02	14.40	-	20.39
	GEN	SPREAD	55	4.97	50	1.02	14.40	-	20.39
	HAYBUSTER	SPREAD	55	4.97	50	1.02	14.40	-	20.39
HEAVY CLAY SITE	THOMPSON	BANDED	125	7.53	-	-	-	13.20	20.73
	DUTCH	BANDED	80	6.69	-	-	-	13.20	19.89
	EDWARDS HOE	SPREAD	90	5.91	50	1.02	14.40	-	21.33
	VERSATILE	SPREAD	75	5.56	50	1.02	14.40	-	20.98
	ACRA PLANT	SPREAD	75	5.56	50	1.02	14.40	-	20.98
	IHC	SPREAD	95	5.91	50	1.02	14.40	-	21.33
	GEN	SPREAD	55	4.97	50	1.02	14.40	-	20.39

NOTE:
- ALL NITROGEN WAS APPLIED AT 60 LBS. N/ACRE
- THE FERTILIZER SPREADER WAS 40 FT. AND TRAVELLED AT 7.5 M.P.H.
- 21 FT. HOE DRILL OR 21 FT. AIR SEEDER WITH CULTIVATOR WERE USED AT 4.5 M.P.H.
- THE SEEDING DEPTH WAS 1 IN.

Given these two examples, the difference in total cost between these two methods of fertilizer application is negligible. By studying Table 3, it is evident that throughout the three sites and the different openers, the differences in total cost per acre between the two different methods of fertilizer application is minimal. These observations indicate that the value placed on labor during seeding and harvest compared to early spring would often be a major factor in determining the relative costs of these two seeding and N fertilizer application systems.

Conclusions

The spread pattern of the spinning disc spreader was very non-uniform. The spread pattern for the pneumatic granular was extremely uniform.

Although the spread pattern of the spinning disc spreader was not uniform, the predicted grain yields associated with these spreaders were not affected. However, if the spread pattern became highly non-uniform, there would be a significant decrease in predicted yields in fields where the spinning disc spreader was used.

Banding knives which can seed and band at the same time have higher seeding input costs than conventional seeding knives. However, when the conventional seeding knives are used, a separate spreading operation is required the following spring. The extra operation associated with spreading results in essentially no difference in total cost between the two methods of fertilizer application if labor costs are assumed to be equal.

Acknowledgements

The authors gratefully acknowledge the financial support from Agriculture Canada through the Canada-Sakatchewan Economic Regional Development Agreement (ERDA).

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