DEEP BANDING OF N-P FERTILIZERS: SOME CONCLUSIONS AND RECOMMENDATIONS[1]

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The credit for creating an interest in the potential benefits of deeper placement of fertilizer in western Canada really belongs to some observant south central Alberta farmers. They suggested some 15 years ago that their crops were producing better yields when fertilized with a newly introduced product, anhydrous ammonia, rather than with the traditional broadcast granular nitrogen.

Some preliminary research by WCFL agronomists indicated that anhydrous was superior to broadcast nitrogen, particularly if the growing season was relatively dry. Early research also indicated that the benefits associated with anhydrous could be obtained by similarly applying other nitrogenous materials into the soil. We refer to this method of applications as pre-plant deep banding.

Over the past 15 years, WCFL has conducted hundreds of research trials with nitrogenous fertilizers that have contributed greatly to a better understanding of the importance of proper fertilizer placement for dryland grain production. More recently, our research has emphasized the evaluation of pre-plant, deep band application of N-P fertilizer combinations.

Although there are still many questions to be answered regarding this method of fertilizer application, we have achieved a significant amount of new information. This pool of information can be used to formulate some practical recommendations to aid the many farmers who would prefer to include deep banding in their fertilizer program to insure maximum returns from their increasingly more expensive fertilizer investment.

From the large number of deep-banding trials conducted by WCFL during the past two years, 27 were of sufficiently similar design to allow the data to be pooled. Of these trials, 23 were grown under dryland conditions and 4 were irrigated. The results of these trials are summarized in Appendix I and II. These trials were located throughout the western half of Saskatchewan and the southern half of Alberta. The test crop was wheat or barley.

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Benefits Due To Deep Banding

The banding benefits (i.e. additional yield increase due to banding in excess of yield response due to comparable broadcast treatment) are summarized in Table I. In the case of dryland trials, the benefit due to banding ranged between 20% to 50%, while under irrigation banding benefits ranged from 0% to 26%. Under dryland conditions, deep banding appeared to be quite beneficial for all fertilizer combinations tested. However, under irrigation, deep banding was only beneficial where deep placement of N+P was combined with an application of starter fertilizer. This data suggests that the benefit attributed to deep band placement is modified by soil moisture conditions. That is, the more favourable the moisture conditions, the less critical fertilizer placement becomes. Nevertheless, maximum yields were achieved only in treatments that included deep banded N+P. The strong interaction of deep banded N+P with starter P on irrigated soils occurred consistently despite fairly high soil P levels at one of the four sites. Since these crops were seeded quite early into soils that were quite cool and wet, soil temperature may be a key factor in determining the benefit of retaining some P for application in the seed-row.

Table I. Banding Benefit for N and N+P Treatments for Dryland and Irrigated Trials.

	Banding Benefit*			
	Dryland		Irrigated	
Fertilizer	No Starter	Starter	No Starter	Starter
N	38%	38%	0%	1%
N+P	50%	20%	1%	26%

* Banding benefit (%) based on weighted average of all fall and spring treatments.

Deep Banding And Moisture Stress

The 23 dryland trials were divided into those that were subjected to some growing season moisture stress (9 trials) and those that experienced more favourable growing season moisture (14 trials). The data is summarized in Table II. The average yields for the unfertilized crops in these situations were 0.94 t/ha and 2.10 t/ha respectively. The results show quite clearly that banding benefits are climatically sensitive. That is, if a crop is subjected to some degree of moisture stress, the benefits of deeper placement are more dramatic. Under favourable moisture conditions, any nitrogen application combined with drill-in or deep-banded phosphate appeared to be almost equally effective. A complete N+P broadcast application appeared to be somewhat less effective compared to the other combinations tested. In the case of moisture stressed sites, deep band placement of N or N+P appeared to be most effective.

Table II. Deep Banding Benefit on Dryland Trials as Related to Growing Season Moisture Conditions

	Favourable Moisture		Moisture Stressed	
Fertilizer Treatment	Yield Increase (t/ha)	Banding Benefit	Yield Increase (t/ha)	Banding Benefit
N Broadcast, Drill-in P	0.72		0.58	
N Deep Banded, Drill-in P	0.83	15%	1.02	76%
N+P Broadcast	0.59		0.62	
N+P Deep Banded	0.76	29%	1.15	85%
Average		22%		80%
Number of Trials	14		9	
Unfertilized Yield	2.10 t/ha		0.94 t/ha	

At the sites experiencing favourable moisture conditions, the traditional approach consisting of broadcast N and drill-in P was slightly less effective than pre-plant deep banding of N+P. Deep banding of N and seed-row application of P resulted in a slightly higher average yield increase than deep banding of N+P (i.e. 0.76 t/ha vs. 0.83 t/ha). It is however unlikely that this slight yield advantage (i.e. approximately 1 bushel/acre) in favour of applying the phosphate in the seed-row is sufficient to offset the costs associated with a 20-30% reduction in seeding rate.

In the case of the sites subject to a higher degree of moisture stress, the response to deep banding of N+P was greater than to the traditional separate application of N and P (0.58 t/ha vs. 1.15 t/ha) by approximately 10.5 bushels of barley/acre. Furthermore, the response to deep banded N+P exceeded that to deep banded N + drill-in P (1.02 t/ha vs. 1.15 t/ha) by approximately 2.5 bushels of barley/acre. Obviously, under these conditions, all of the fertilizer should be pre-plant deep banded for maximum yield increases and for maximum seeding efficiency.

In a practical sense, this means that if a farmer is deep banding nitrogen, he might as well deep band the required phosphate as well. The exceptions would be those soils that are very phosphate deficient and/or those fields that are seeded early into wet, cold soils. In those situations, we would suggest retaining 1/3 of the phosphate for application directly in the seed-row to help get the crop off to a rapid start.

Phosphate Response And Placement

The average phosphate response for the 23 dryland trials is summarized in Table III. The data indicate that a greater response was obtained from drill-in phosphate when the nitrogen was band rather than broadcast applied. On average, the response to deep banded phosphate combined with nitrogen was equal to that obtained when the nitrogen was deep banded and the

Table III. Response to Phosphate as Influenced by Method of Placement in Dryland Trials.

Treatment	Yield 100 kg/ha	Total P2O5 Response	Starter P2O5 Response
Check	17.0		
N Broadcast	21.8		
N Band	23.4		
N Broadcast +	23.5	1.7	1.7
N Band +	26.0	2.6	2.6
N+P Broadcast	22.9	1.1	-
N+P Band	25.9	2.5	-
N+P Broadcast +	25.1	3.3	2.2
N+P Band +	26.6	3.2	0.7

- based on average of 23 dryland trials including fall treatments from 16 trials.

+ indicates application of starter phosphate.

phosphate was applied separately in the seed-row. The response to starter phosphate in addition to a pre-plant application of phosphate was three times as large if the pre-plant phosphate was broadcast rather than deep banded. The results of the phosphate responses obtained in the irrigated trials are summarized in Table IV. It is quite apparent that the most consistent response to phosphate occurred when it was placed directly in the seed-row (i.e. starter fertilizer). The maximum benefit resulted from combining some phosphate with deep banded nitrogen and some phosphate in the seed-row. Application of all

Table IV: Response to Phosphate as Influenced by Method of Placement in Irrigated Trials.

Treatment	Yield 100 kg/ha	Total P2O5 Response	Starter P2O5 Response
Check	28.3		
N Broadcast	46.0		
N Band	45.9		
N Broadcast +	47.0	1.0	1.0
N Band +	47.3	1.4	1.4
N+P Broadcast	46.0	0.0	-
N+P Band	45.7	-0.2	-
N+P Broadcast +	45.6	-0.4	-0.4
N+P Band +	49.7	3.8	4.0

- based on average of 4 irrigated trials including fall treatments from 3 trials.

+ indicates application of starter fertilizer.

the phosphate by either broadcasting or deep banding was ineffective. These plots were seeded relatively early into soils that were cool and moist which undoubtedly explains the need for starter phosphate. The soil test levels for available P were low at three sites (range 0-27 kg/ha) and relatively high at one location (i.e. 99 kg/ha). The response pattern was similar at all four sites.

Soil Test Levels And Phosphate Response

To assess the influence of soil test levels for available phosphate on response due to method of phosphate placement, the trials were subdivided into those that contained low levels of available P in the 0-15 cm depth (0-28 kg/ha for Alberta sites and 0-17 kg/ha for Saskatchewan sites) and those that were located on soils with medium to high levels of available phosphate. The results are summarized in Table V. Although there was some

Table V. Response at Dryland and Irrigated Sites to Phosphate Fertilizer as Influenced by Level of Available Soil Phosphate.

	Low Soil Test P			Medium-High Soil Test P		
Treatment	Yield 100 kg/ha	Total P2O5 Response	Starter P2O5 Response	Yield 100 kg/ha	Total P2O5 Response	Starter P2O5 Response
			DRYLAND			
Check	14.9			20.0		
N B'Cast	18.7			26.2		
N Band	21.0			26.8		
N B'Cast +	21.6	2.9	2.9	26.8	0.6	0.6
N Band +	24.3	3.3	3.3	28.3	1.5	1.5
N+P B'Cast	20.9	2.2	-	25.7	-0.5	-
N+P Band	24.4	3.4	-	28.0	1.2	-
N+P B'Cast +	23.4	4.7	2.5	28.0	1.8	2.3
N+P Band +	25.3	4.3	0.9	29.3	2.5	1.3
Number of Trials		14			9	
			IRRIGATED			
Check	31.6			20.2		
N B'Cast	48.1			40.6		
N Band	47.6			41.8		
N B'Cast +	49.3	1.2	1.2	41.1	0.5	0.5
N Band +	49.4	1.8	1.8	42.0	0.2	0.2
N+P B'Cast	47.4	-0.7	-	42.5	1.9	-
N+P Band	48.0	0.4	-	40.0	-1.8	-
N+P B'Cast +	47.1	-1.0	-0.2	41.8	1.2	-0.7
N+P Band +	51.3	3.7	3.3	45.8	4.0	5.8
Number of Trials		3			1	

+ indicates application of starter P2O5 fertilizer.

tendency for a higher average phosphate response at the trials located on low soil P sites, generally, the soil test did little to help explain the response to applied phosphate.

Response to Pre-Plant Phosphate And Moisture Supply

The average response to pre-plant applied phosphate in the dryland trials as influenced by moisture supply is summarized in Table VI. The data indicate that there was a greater response to phosphate at the sites that were stressed for moisture. Under stress conditions, the response to pre-plant deep banded phosphate was almost three times the response obtained from pre-plant broadcast and incorporated applications. The difference between the two application methods was less striking when the test crop was exposed to a favourble growing season moisture supply.

Table VI: Response to Pre-Plant Applied Phosphate in Dryland Trials as Influenced by Moisture Conditions.

	Yield Increase (100 kg/ha)		
Treatment	Moisture Stressed	Favourable Moisture	Average
Broadcast	1.3	1.0	1.2
Deep Banded	3.7	1.7	2.7
Average	2.5	1.4	2.0

The average response to drill-in or starter phosphate applied directly in the seed-row as affected by moisture supply is summarized in Table VII. It is apparent that the response to starter phosphate is greater under favourable moisture conditions. The exception to this trend was the response to starter phosphate when nitrogen alone was pre-plant deep banded.

Under conditions of favourable moisture supply, the response to drill-in P was equivalent regardless whether the pre-plant applied nitrogen was broadcast or deep banded. However, in situations of moisture stress, the response to drill-in P was definitely larger when combined with deep banded rather than broadcast nitrogen. It is possible that under conditions of moisture stress, positionally less available nitrogen (i.e. stranded in dry surface soil) hindered the ability of the crop to obtain maximum benefit from the phosphate applied in the seed-row.

In situations where both N and P were applied prior to planting, the response to additional starter phosphate applied directly in the seed-row was greater where the pre-plant N+P application was broadcast rather than deep banded. It would therefore appear that the deep band placement of N+P was more effective in meeting the crops phosphate requirements than a broadcast application. The benefit from additional phosphate applied as a starter was least evident under stress conditions where the pre-plant N-P fertilizer was deep banded.

Table VII: Response to Starter Phosphate in Dryland Trials as Influenced by Moisture Conditions.

Treatment	Yield Increase (100 kg/ha) Moisture Stressed	Favourable Moisture	Average
N Broadcast	0.9	2.4	1.6
N Banded	2.4	2.4	2.4
N+P Broadcast	1.4	2.3	1.8
N+P Banded	0.6	1.3	1.0
Average	1.3	2.1	1.7

Banding Benefits As Influenced By Moisture Supply And Soil Phosphate Levels

It is frequently suggested that the benefit in favour of deep band compared to broadcast placement of fertilizer should be of maximum economic importance to the farmer only in situations where low soil nitrogen levels are accompanied by low phosphate levels. The data summarized in Appendix III quite clearly demonstrates that growing season moisture conditions are far more important in determining the extent of the banding benefit than are soil test P levels. Under favourable moisture conditions the average banding benefit amounted to 16% and 20% for the two P soil test categories. Under moisture stressed conditions, the banding benefit amounted to 66% and 124% for the two categories. In both cases, the highest average banding benefits occurred on the soils with the higher soil test P levels.

Phosphate Response As Influenced By Moisture Supply And Soil Phosphate Levels

Based on the data compiled in Appendix III it is apparent that the largest average response to phosphate was obtained when low soil P levels were accompanied by favourable growing season moisture supply. Under those conditions, drill-in phosphate was more effective than phosphate deep banded with nitrogen. Where low soil test P levels were accompanied by moisture stress, drill-in P was less effective than phosphate deep banded with nitrogen.

At the sites that were located on soils testing medium or high in available soil test P, the best phosphate response was obtained from a combination of drill-in and deep banded phosphate. There was a tendency for deep banded phosphate to be superior to drill-in phosphate when the crop was subjected to moisture stress.

Banding Benefits For Late Seeded Crops

Of the 23 dryland trials, two were established in the Pincher Creek area of southwestern Alberta in the spring of 1981. This area received an excessive amount of rainfall in the spring and the plots could not be established until mid-June. At that time the surface soil was quite warm and sub-soil moisture reserves were excellent. Below normal precipitation followed plot establishment resulting in a very heavy reliance of the crop on sub-soil moisture reserves.

The results of these two trials are summarized in Table VIII. The banding benefit averaged 68% for all treatments thus clearly demonstrating the interaction between method of fertilizer placement (i.e. deep banded vs. broadcast) and growing season moisture distribution. In this situation, deep banded fertilizer was located in moist soil and probably encouraged deeper rooting which would have helped the crop tap sub soil moisture reserves. These data clearly indicate why we suggest that deep banding can be a form of drought insurance. Under drought conditions broadcast and incorporated fertilizer was much more subject to being stranded in the dry surface soil. Secondly, broadcast fertilizer placement could encourage a shallower rooting system to the detriment of the crop if the latter part of the growing season was relatively dry.

Under the conditions experienced, the response to starter phosphate was usually negative except where N had been deep banded. The greatest response to phosphate occurred where the N and P were deep banded together prior to planting.

Table VIII: Response of Late Seeded Barley to Fertilizer Placement.

Treatment	Yield (100 kg/ha)	Yield Increase	Banding Benefit	Total P2O5 Response	Starter P2O5 Response
Check	12.4	-			
N B'Cast	22.9	10.5			
N Band	29.2	16.8	60%		
N B'Cast +	22.6	10.2		-0.3	-0.3
N Band +	30.6	18.2	78%	1.4	1.4
N+P B'Cast	23.9	11.5		1.0	-
N+P Band	31.2	18.8	63%	2.0	-
N+P B'Cast +	22.9	10.5		0.0	-1.0
N+P Band +	30.3	17.9	70%	1.1	-0.9

+ indicates application of starter phosphate.

Banding Benefits For Winter Wheat

The results obtained from two winter wheat trials conducted in southwestern Alberta in 1981 are summarized in Table IX. An average banding benefit of 72% for all treatments clearly demonstrates the superior results that can be expected with deep band rather than broadcast placement of fertilizer for winter wheat. Furthermore, placing starter phosphate directly in the seed row consistently reduced yields by 2-3 bushels/acre of wheat. The only positive response to phosphate occurred when phosphate was pre-plant, deep banded in combination with nitrogen. The soil test P levels at both of these sites were high.

Table IX: Response of Winter Wheat to Fertilizer Placement.

Treatment	Yield (100 kg/ha)	Yield Increase	Banding Benefit	Total P2O5 Response	Starter P2O5 Response
Check	38.2				
N B'Cast	45.9	7.7			
N Band	49.2	11.0	43%		
N B'Cast +	43.4	5.2		-2.5	-2.5
N Band +	46.9	8.7	67%	-2.3	-2.3
N+P B'Cast	45.0	6.8		-0.9	-
N+P Band	49.9	11.7	72%	0.7	-
N+P B'Cast +	43.2	5.0		-2.7	-1.8
N+P Band +	48.4	10.2	104%	-0.8	-1.5

+ indicates application of starter phosphate.

Fall Versus Spring Fertilizer Rating

The yield increases from fall application of fertilizer compared to a comparable application in the spring of the year are summarized in Table X. It would appear that there was approximately a 10% loss in fertilizer value resulting from fall rather than spring application. The least effective fall application was broadcast nitrogen without the addition of starter fertilizer at the time of planting.

Table X: Relative Rating of Fall vs. Spring Applied Fertilizer Under Dryland and Irrigated Conditions.

Treatment	Fall Rating: Dryland	Fall Rating: Irrigated	Average
N Broadcast	76%	86%	81%
N Band	96%	89%	92%
N+P Broadcast	100%	78%	89%
N+P Band	94%	90%	92%
Average	92%	86%	89%

Some General Observations and Conclusions

Based on extensive field research conducted to date, WCFL agronomists feel that the following statements can be made relative to deep band placement of fertilizer:

1) Under dry soil conditions (most frequently encountered in the Brown, Dark Brown and also on the degraded soils of the Peace River region), fall broadcast N is 75-100% as effective as N broadcast in the spring of the year. Fall application of N by deep banding is 90-105% as effective as spring banding. If the soil is dry in the spring, the tillage associated with deep banding could dessicate the soil further, making it less effective than fall banding.

2) Where soil moisture is more abundant, fall broadcast N is 50-75% as effective as spring broadcast N. Under these same conditions, fall banded N is 85-95% as effective as spring application.

3) On poorly drained soils (i.e. subject to spring flood or saturated conditions), fall broadcast N can be 25-50% as effective as spring broadcast N. Under these conditions of excess spring surface moisture, fall banded N can be 75-85% as effective as spring banded N.

4) The relative improvement in yield due to deep banding rather than broadcasting is enhanced as the risk of surface applied fertilizer being trapped in dry surface soil increases. In fall, the relative increase due to deep banding also increases as soil conditions become favourable for denitrification of soil and fertilizer N to occur.

5) Because of the importance of growing moisture in determining banding benefit, average rainfall patterns in the prairie region should provide a reliable estimate of how frequently deep band placement is likely to result in significantly larger yield increases than broadcast fertilizer placement. We estimate that in regions that average less than 14" of annual precipitation, deep banding should significantly outyield broadcast applications in at least 9 out of 10 years. In regions that receive between 14" and 16" of annual precipitation, deep banding should significantly outyield broadcast placement in 8 out of 10 years. For those regions that receive between 16" and 18" of annual precipitation, we estimate deep banding should outyield broadcasting in 7 out of 10 years. For the regions that expect between 18" to 20" of annual precipitation, deep banding should outyield broadcast placement applications in 5 or 6 out of 10 years. Short term predictions are complicated greatly by distribution of growing season precipitation as well as total precipitation.

6) The relative performance of deep banding N-P combinations in the fall compared to spring should be approximately equal to that for banding N alone.

7) Under conditions where a good response to phosphate can be expected, the benefits of deep banding as opposed to broadcasting N-P fertilizers should be greater than the benefits of banding N alone.

8) Under conditions of moisture stress, deep banding of N-P fertilizers is usually superior to deep banding N and banding P in the seed-row. This will vary according to soil test levels of P and soil conditions which affect uptake of P (i.e. soil temperature and moisture). The practical implications of this research is that if a farmer located in the Brown, Dark Brown or Thin Black soil zone plans to deep band nitrogen, he would, in most cases be further ahead to also deep band the required phosphate in terms of increased yields. A secondary, but important consideration is that by eliminating handling starter fertilizer at the time of seeding, the rate of seeding can be speeded by 20-30%. To date, starter P (i.e. banded in the seed-row) and P pre-plant deep banded with N appear to be about equally effective in enhancing crop maturity. Frequently a crop treated with starter P appears to grow more rapidly in the early stages but any advantage in favour of placing P directly in the seed-row disappears by harvest.

9) A serious phosphate deficiency further increases the chances of obtaining a significant benefit from deep band placement of N+P fertilizers. However, deep banding benefits are not limited to soils that are deficient in nitrogen and phosphate. Important benefits can be obtained from deep banding nitrogen alone. Secondly, important benefits have been obtained by deep banding N+P fertilizers on soils that contain relatively high levels of available phosphate under conditions of moisture stress. Date of seeding and soil temperature also appear to be important factors in determining the response to applied phosphate.

10) Under favourable moisture conditions applying P in the seed-row may have a slight advantage over deep banding all of the P with the N. We however feel that maximum yields will be achieved using a combination of deep banded N-P fertilizer and P banded in the seed-row in these situations. In cases of low soil test P levels and/or cold, wet soils, consideration should be given to applying a portion of the phosphate directly in the seed-row (perhaps 1/4 to 1/3 of total requirements) to encourage early growth and to maximize yields.

11) Under dryland conditions, the benefit of starter P (i.e. banded in the seed-row) in addition to P deep banded with N will vary between 0-0.3 t/ha (0-5 bushels/acre) depending on soil conditions previously discussed.

12) Because irrigated cereals are frequently seeded quite early into soils that may be quite wet and cold, yields will be maximized by combining a pre-plant deep band application of N-P with starter P applied directly in the seed-row.

13) Preliminary results suggest that the total N and P requirements of winter wheat should be pre-plant deep banded for maximum yields. This may not however be the case under conditions of serious soil phosphate deficiencies.

14) Preliminary data suggest that for rapeseed, the need for some starter phosphate appears to be more important than in the case of cereals. Only a limited amount of phosphate can be applied directly in the seed-row for this crop. Yields will therefore most likely be maximized by combining an application of starter phosphate with a pre-plant deep banding application of N-P fertilizer.

15) Preliminary data indicate that higher yields can be expected on potash deficient soils if the required potash is deep banded with the N-P fertilizer rather than separately. Since both N and K are more mobile than phosphate, diffusion of these nutrients out of the band would increase the chances of the plant roots intercepting the fertilizer band (i.e. larger target). Root proliferation in the band caused by presence of ammonium nitrogen and possibly by potash would help insure adequate P recovery. Placing N and K in a common band with P increases the flexibility of P placement. When placing P alone in a band, it appears to be necessary to apply the P closer to the seed-row to insure adequate plant uptake. Under these conditions, the P would have to be applied at the time of planting to insure the desired proximity to the seed-row can be maintained. By pre-plant deep banding of P with N or N+K, the need for precise placement near the seed-row is dramatically diminished.

16) Placement of starter P in the seed-row can reduce yields. There have been no cases in which P deep banded with N has resulted in a yield reduction.

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Appendix I: Influence of Fertilizer Placement and Time of Application on Yield (WCFL 1979/80 & 1980/81).

	Fall Applied*			Spring Applied*				Spring Applied **		
	Yield and (Increase) 100 kg/ha	Banding Benefit	Starter Benefit	Yield and (Increase) 100 kg/ha	Banding Benefit	Starter Response	Fall Rating	Yield and (Increase) 100 kg/ha	Banding Benefit	Starter Benefit
Check	17.1			17.4				17.0		
Check +	17.7		0.6	18.8		1.4		18.2		1.2
N Broadcast	20.7 (3.6)			22.3 (4.9)			73%	22.5 (5.5)		
N Broadcast +	22.8 (5.7)		2.1	24.5 (7.1)		2.2	80%	24.0 (7.0)		1.5
N Banded	22.6 (5.5)	53%		23.0 (5.6)	14%		98%	24.0 (7.0)	27%	
N Banded +	24.9 (7.8)	37%	2.3	25.7 (8.3)	17%	2.7	94%	26.7 (9.7)	39%	2.7
N+P Broadcast	22.6 (5.5)			22.8 (5.4)			101%	23.1 (6.1)		
N+P Broadcast +	24.6 (7.5)		2.0	24.9 (7.5)		2.1	100%	25.4 (8.4)		2.3
N+P Band	24.5 (7.4)	35%		25.3 (7.9)	46%		94%	26.8 (9.8)	61%	
N+P Band +	26.0 (8.9)	19%	1.5	26.8 (9.4)	25%	1.5	95%	27.1 (10.1)	20%	0.3

Application Rate: N - 84 kg/ha, P205 28 kg/ha

+ Indicates equivalent amount of P placed in the seed row (ie. starter).

* Indicates data from 16 separate dryland trials that included fall and spring treatments.

** Includes data from 23 dryland trials, 16 of which also included fall treatments.

Appendix II: Influence of Fertilizer Placement and Time of Application on Yield Under Irrigation (WCFL, 1980/81).

	Fall Applied			Spring Applied*			
	Yield and (Increase) 100 kg/ha	Banding Benefit	Starter Benefit	Yield and (Increase) 100 kg/ha	Banding Benefit	Starter Benefit	Fall** Rating (%)
Check	28.4			28.3			
Check +	27.4		-1.0	28.8		0.5	
N Broadcast	43.2 (14.8)			48.1 (19.8)			74%
N Broadcast +	46.4 (18.0)		3.2	47.4 (19.1)		-0.7	97%
N Band	43.9 (15.5)	5%		47.4 (19.1)	-4%		81%
N Band +	46.8 (18.4)	2%	2.9	47.6 (19.3)	1%	0.2	97%
N+P Broadcast	43.9 (15.5)			47.6 (19.3)			82%
N+P Broadcast +	42.6 (14.2)		-1.3	47.9 (19.6)		0.3	74%
N+P Band	47.7 (16.3)	5%		46.5 (18.2)	-6%		90%
N+P Band +	48.6 (20.2)	42%	3.9	50.6 (22.3)	14%	4.1	91%

Application rate: N-105 kg/ha, P2O5-30 kg/ha

\+ Indicates equivalent amount of P placed in the seed row (i.e. starter).

* Average data of four trials including the three trials that also included fall treatments.

** Based on data from the three trials with fall and spring treatments.

Appendix III: Banding Benefits and Phosphate Responses Under Dryland Conditions is Influenced by Soil Test Levels and Growing Season Moisture Supply.

	Moisture Stressed					Favourable Moisture				
Treatment	Yield (100 kg/ha)	Yield Increase	Banding Benefit	Total P Response	Starter P Response	Yield (100 kg/ha)	Yield Increase	Banding Benefit	Total P Response	Starter P Response
LOW SOIL TEST P LEVELS										
Check	8.6					21.2*				
N Broadcast	13.8	5.2				24.0*	2.8			
N Band	16.5	7.9	52%			24.9*	3.7	32%		
N Broadcast +	15.1	6.5		1.3	1.3	28.8*	7.6		4.8	4.8
N Band +	19.9	11.3	74%	2.7	2.7	28.9*	7.7	1%	4.0	4.0
N+P Broadcast	15.4	6.8		1.6	-	26.6*	5.4		2.6	-
N+P Band	21.1	12.5	84%	3.9	-	28.2*	7.0	30%	3.3	-
N+P Broadcast +	16.9	8.3		3.1	1.5	29.8*	8.6		5.8	3.2
N+P Band +	21.2	12.6	52%	4.0	0.1	30.0*	8.8	2%	5.1	1.8
	Average		66%	2.8	1.4	Average		16%	4.3	3.4
	Site Years of Data		10			Site Years of Data		13*		
MEDIUM-HIGH SOIL TEST P LEVELS										
Check	10.4	-				22.4				
N Broadcast	13.0	2.6				29.3	6.9			
N Band	16.1	5.7	119%			29.3	6.9	0%		
N Broadcast +	13.2	2.8		0.2	0.2	29.2	6.8		-0.1	-0.1
N Band +	16.5	6.1	118%	0.4	0.4	30.9	8.5	25%	1.6	1.6
N+P Broadcast	13.3	2.9		0.3	-	28.6	6.2		-0.7	-
N+P Band	17.2	6.8	134%	1.1	-	30.4	8.0	29%	1.1	-
N+P Broadcast +	14.6	4.2		1.6	1.3	29.6	7.2		0.3	1.0
N+P Band +	19.8	9.4	124%	3.7	2.6	31.5	9.1	26%	2.2	1.1
	Average		124%	1.2	1.1	Average		20%	0.7	0.9
	Site Years of Data		3			Site Years of Data		13		

* Excludes 2 site years of data (i.e. fall and spring application) from one trial located in an area subject to spring flooding that exhibited a very high banding benefit for fall applied treatments.