FERTILIZER PLACEMENT FOR CEREAL GRAINS

H. Ukrainetz
Research Branch, Canada Agriculture
Experimental Farm, Scott, Saskatchewan

Introduction:

The use of fertilizers in the production of cereal grain crops has increased markedly during the past decade in Saskatchewan and western Canada. A major portion of this increase has occurred within the last five years. During this period there has also been an increase in the number of fertilizer formulations placed on the market, and a substantial shift upward in fertilizer analyses.

Inquiries received and communication with farmers also indicate a definite trend towards the use of rates at or near the high end of recommended ranges.

Although the use of fertilizers on soils where nutrient deficiencies exist is a profitable practice, the cost of fertilizers and their application are significant factors to be reckoned with in the business of grain farming. The usual method of fertilizing cereal grain crops is to place the fertilizer with the seed by means of a fertilizer attachment or adaptation of the grain drill. This method has proven to be both safe and effective when moderate rates of fertilizer are used. With high rates of fertilizers, there is evidence of definite detrimental effects of fertilizers placed in contact with the seed. There has arisen a need for a thorough evaluation of fertilizer placement methods in order to arrive at the most efficient methods that a farmer can use to avoid damage to germination, reduce costs, and obtain maximum returns.

Review of Literature on Fertilizer Placement

Research in the United States

Olsen and co-workers in Nebraska (15) stated that 15 pounds should be the maximum rate of nitrogen in fertilizers applied with the seed of small grains in the drier areas of the State. Several reports (2,15) have shown that the low soil moisture and the length of time that seed and fertilizer are in contact in dry soil are major factors which influence the amount of damage to germination from fertilizer salts.

There are other reports of research in the United States showing the effects of N placement at various rates, but it would appear to be of greater significance at this time to turn to some of the results reported from phosphate placement experiments.

In a review of phosphate fertilizer investigations in 15 western States up to 1949, Peterson, et al (16) concluded that the most effective placements of phosphate are drilling with or near the seed for small grains. However, studies in Colorado indicated that irrigated wheat and barley absorbed more fertilizer phosphorus from rototilling the phosphate 4 inches deep than from rototilling 2 inches deep, and that rototiller placement was slightly more effective than band placement. Haddock, et al (9) in an experiment with NH_4NO_3 and C.S.P. in which only 2 percent of applied P was utilized, found no significant differences in P uptake from fertilizers applied either broadcast or banded at seeding. On the other hand Vavra and Bray (28) found the application of soluble phosphates in the row at planting much more efficient than broadcasting, and Gingrich (7) reported increased top growth, P percentage in tops and total yield of P in winter wheat to be higher from applying phosphate fertilizer in a zone approximately 2 inches below the soil surface.

From field experiments in Indiana, Barber (1) concluded that it is as profitable to use broadcast applications of high rates of phosphate to build up soil phosphate levels, along with small amounts in the row, as to place smaller amounts in the row only. In these experiments top wheat yields were obtained from either broadcast or row P, where adequate rates were used.

Nitrogen and potassium are generally considered to be the harmful fertilizer constituents when used at high rates with the seed, but work in Michigan (5, 8) has shown that the phosphate content of fertilizers is as important as N and K in producing seedling injury of wheat and oats. Several reports from the United States have indicated that banding of mixed fertilizers either to the side or below and to the side of the seed was superior to banding with the seed (10, 11). However, in these experiments relatively high rates of fertilizer were used.

Robertson, et al (22) concluded from a survey of the effects of fertilizer placement, that a conventional drill placing fertilizer in contact with the seed is not satisfactory for high rates and grades of fertilizer because of the damage to

germination. They pointed out that most consistent yield increases are obtained when fertilizer is banded 1 inch to the side and 1-2 inches below the seed.

Research in England and other European Countries

Workers at the Rothamstead Experimental Station (31) showed that ammonium sulphate could be safely drilled with the seed of wheat and barley up to rates of 67 lb. N per acre, and $CaNO_3$ up to 33 lb. N per acre, and this placement gave higher yields than broadcasting. Urea and $CaNO_3$ were more detrimental to germination than ammonium sulphate when applied with the seed. It was emphasized that gains from combine drilling over broadcasting are restricted to fertilizers containing most or all of their N as ammonium (6). Recently laboratory experiments by Widdowson, et al (30), showed that urea killed many plants of barley when placed with the seed in the row, but that little or no damage resulted when it was placed 1/2 - 1 inch to the side of the seed.

Cooke (3) reviewed fertilizer placement research in 1954 and concluded that PK fertilizers for cereals were approximately twice as effective when drilled with the seed as compared to broadcasting. In recent experiments at Rothamstead (4) combine drilling of PK and NPK fertilizers were found to increase yields of barley more than broadcasting when used at moderate rates which did not damage germination and early growth.

In Holland, Prummel (17) reported that band placement of phosphate 2 cm. from the seed was 2.5 times more effective than broadcasting.

Research in Other Parts of Canada

Field experiments at the Soil Research Institute, Ottawa (26) showed that the drilled placement of fertilizer produced larger yields than broadcasting with increasing amounts of N and P_2O_5. Sherrell, et al (23) concluded from the results of greenhouse experiments that placement of NP fertilizers with the seed, or 1 inch below the seed, was superior to placement to the side of the seed. Phosphorus absorption was greater during the early stages of growth when placed below the seed than when placed with the seed. Placement with the seed was as good as or better than other methods at rates of fertilizers which did not exceed the requirements of the crop. Work done at

the Ontario Agricultural College, Guelph, Ontario, showed that the effectiveness of the broadcast method of N placement increased with increasing rate of N above 20 lb. per acre, and that spring top dressing was generally better than fall top dressing (25). In other experiments (24) with wheat, comparing banding and mixing of 100 lb. P_2O_5 per acre, it was reported that for acid soils, mixed fertilizer was utilized much less than when banded just below the seed, and for neutral and no free lime soils, mixing resulted in slightly lower uptake of P. However, for soils with free lime, mixing was more effective than banding.

Experiments conducted at the Experimental Farm, Beaverlodge, Alberta (13) showed that ammonium nitrate, ammonium phosphate, and treblesuperphosphate banded with the seed at relatively high rates delayed and or reduced germination of wheat, oats and barley. The order of tolerance was oats > barley > wheat, and N was more injurious than P. More recent results (14) indicated that 15 or 30 lb. N per acre in the seed row with 15 lb. P_2O_5 had little or no influence on emergence of these crops.

Robertson, at the University of Alberta (21) carried out placement experiments with grain crops during the period 1956-1959, using N up to 80 lb. per acre, and P_2O_5 up to 40 lb. per acre, and concluded that:

1) Nitrogen alone broadcast on the surface produced highest yields, followed by banding near the seed and with seed.
2) Phosphorus is more efficiently used by cereals when placed with the seed than when banded near seed.
3) N and P fertilizers are most efficiently used when the N and P are placed together.
4) When using N and P separately, it appears that the best application is to drill the 11-48-0 at recommended rates and broadcast the N on the surface.

From a field experiment with Chinook wheat at Nobleford, Alberta, Smith (27) reported that placement of 50 lb. 11-48-0 per acre 3.5 inches below the seed was superior to placement with the seed.

Research in Saskatchewan

In a summary of nitrogen placement experiments conducted during the period 1954-1958, Rennie (18) stated that:

1) N applied with the seed at rates less than 20 lb. N/acre can be expected to be much more effective than comparable broadcast applications.
2) Rates of N applied with the seed greater than 20 lb./acre may cause yield reductions.
3) The critical amount of N that can be safely applied with the seed can be expected to vary from year to year with moisture conditions.

Results obtained in 1955 and 1956 are shown in tables 1 and 2. In 1955, a similar experiment to that reported in table 1 conducted on Regina heavy clay showed benefits from broadcast N only when applied without P at rates above 25 lb./acre. The lack of response to broadcast N on the Melfort soil in 1956 may have been due to the low soil moisture content and the failure of the nitrogen to move into the root zone.

Mitchell (12) reviewed tracer phosphorus studies in Saskatchewan up to 1956, and concluded that best results from phosphate fertilizers applied to wheat or other small grains may be expected when fertilizer is placed in the drill row with the seed at optimum seeding depths. In a greenhouse study of phosphorus placement for wheat (19), placement of resin P and ammonium phosphate with the seed resulted in a highly significant difference in "A" values and banding produced higher forage yields of wheat. Mean "A" values for mixed and banded treatments were 107.5 and 67.8 respectively. It was suggested that either lower positional availability or fixation of the mixed phosphates reduced their effectiveness. Results of field experiments in 1964 reported by Rennie and Hutcheon (20) showed a marked superiority of with-seed placement of phosphate for wheat over broadcast applications. Although some yield increases were obtained where 11-48-0 was broadcast and incorporated before seeding, an application of 40 lb. 11-48-0 with the seed in general resulted in significantly higher yield increases than 80 lb. 11-48-0 broadcast. Results are shown in table 3.

Warder (29) at Swift Current investigated phosphate placement effects with wheat in 1964 and found a marked superiority of with-seed placement over broadcasting and disking prior to seeding. Both grain and straw yields were substantially higher when 11-48-0 was placed with the seed on Sceptre heavy clay at two locations, as shown in table 4.

In order to study the effectiveness of slight separation of nitrogen fertilizers from the seed, as compared to placement with seed at several rates, experiments were carried out on several soil types during the period 1960-1963 by the Experimental Farm, Scott, Sask. Ammonium nitrate 33.5-0-0 and treblesuperphosphate 0-43-0 were used as the source of N and P. Results obtained with wheat on fallow on Asquith fine sandy loam at Conquest, and with barley on stubble on Scott loam at Scott are shown in tables 5 and 6. Yields of wheat were not increased on Asquith fine sandy loam when N was applied alone, but yields were higher with increasing rates of N when seed and fertilizer were placed separately in adjacent bands. With the addition of 40 lb. P_2O_5 per acre, yields and yield increases were substantially higher for separate placement of N and P at N rates of 20-160 lb. per acre. Lowest yields for the 20 and 40 rates of N with P were obtained when the N only was placed with the seed. The relative effects are also shown in the grain:straw ratios and the plant population data. It should be noted that the differences varied from year to year depending upon moisture conditions. Results with barley on stubble on Scott loam are somewhat different than with wheat on fallow, as shown in table 6. Barley is more tolerant to fertilizer salts than wheat, and although germination and emergence were delayed when 40 and 80 lb per acre of N was placed with the seed, severe damage occurred only with the 160 lb. rate of N, applied either alone or with the seed.

Similar results were obtained on several other soil types.

In these experiments, as the rate of N increased, and at high rates of N + P, bushel weights tended to decrease, particularly in dry years, quite markedly when fertilizer was placed with the seed and only slightly when seed and fertilizer were separated. There were no significant differences in protein content between the two methods of fertilizer application, but protein percentages were increased by high rates of N or N + P.

A large proportion of the total P taken up by plants was apparently taken up during the first few weeks of growth. However, there was some indication that as rate of applied P increased, the uptake continued at later stages of growth.

Yields of wheat grown at 59°F were determined, and showed highest yields with the seed placement of phosphate (table 10). Increases in yield were rather small, but this was expected as the soil contained 8.48 ppm P initially.

In other experiments on Scott loam, it was found that residual available P can be increased substantially by repeated phosphate fertilizer applications, but additional applications of phosphate produced significant increases in yield of wheat even on plots which had very high levels of "residual" available phosphate.

Discussion:

Several arguments in favor of and against band placement of phosphate with the seed of cereal grains have been proposed. Some of these are:

For: 1) Less fixation of fertilizer phosphate occurs, on certain soils particularly.

2) Band placement results in greater availability of fertilizer phosphate during early stages of growth.

3) Better uptake of fertilizer phosphate occurs in dry soil.

Against: 1) Root systems that are influenced and modified to take up fertilizers placed shallowly or in bands near seed may be inadequate during conditions of drought. The crop may suffer because a shallow rooting system had been induced.

2) If roots absorb nutrients and water at the same time, the highly developed root system in the fertilizer zone may absorb so much water from that part of the soil that salt concentration will be increased detrimentally.

Summary:

The work on fertilizer placement for cereal grains up to the present time indicates that with-seed placement is superior to broadcast placement of phosphate and

moderate rates of N. However, with higher rates and higher analyses, the injurious effects may overcome the beneficial ones. Band applications close to the seed but not in contact appears to offer the best solution to the problem of applying higher rates and analyses, at least until future research in placement and fertilizer composition may indicate otherwise.

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Table 1 Effect of nitrogen placement on yields of grain on Whitewood loam - 1955[1]

Nitrogen Placement	Rate of N-lb/acre (NH_4NO_3) 0	25	50	100
		No Phospate		
With seed	16.9	26.6	32.3	40.8
Top dressed	16.9	27.6	33.3	45.1
		15 lb. P_2O_5 with seed		
With seed	16.5	29.6	35.2	33.8
Top dressed	16.5	25.3	39.5	44.2
		30 lb. P_2O_5 with seed		
With seed	19.3	24.1	33.2	32.3
Top dressed	19.3	25.2	30.4	37.2
L.S.D. (P = .05)		5.0		

[1]Yields in bushels per acre

From: 1955 Tracer Fertilizer Research Report,
Department of Soil Science,
University of Saskatchewan.
(D.A. Rennie and M. Nyborg)

Table 2 Effect of nitrogen placement on yields of grain on two soil types, 1956

Fertilizer treatment lb/acre P_2O_5	N	Grain Yields - bu/acre Sceptre Clay	Melfort SiCL
0	0	22.4	36.4
20	0	26.5	41.8
20	20 with seed	36.8	47.3
20	20 broadcast	35.9	47.6
20	40 with seed	41.6	50.3
20	40 broadcast	48.5	44.6
20	80 with seed	41.9	46.0
20	80 broadcast	50.0	44.6
L.S.D. (P = .05)		5.8	4.8

Note: N Top dressed after seeding and raked in

From: 1956 Tracer Fertilizer Research Report,
Department of Soil Science,
University of Saskatchewan.

Table 3 — Comparative effectiveness of broadcast and with seed placement of phosphate for wheat - 1964

Fertilizer Treatment		Yield bu/A	% Protein	Milligrams P/gram Total P	Fert. P	Soil P	A Value (lb./A.P.)	T Uptake (Fert.)
Check		37.7	18.4					
With Seed								
11-48-0 @	8.74#P	43.9	18.4	4.35	0.72	3.62	44.9	21.9
	17.48#P	47.3	18.2	4.38	1.23	3.14	44.6	20.3
23-23-0 @	8.74#P	43.1	18.6	--	--	--	--	--
Broadcast								
11-48-0 @	17.48#P	40.5	18.3	4.42	0.71	3.81	94.3	9.7
	34.96#P	40.5	18.2	4.44	1.25	3.34	93.4	9.1
L.S.D. (P = .05)		2.1	N.S.	N.S.	.13	.22	10.1	2.1

From: 1963-64 Tracer Fertilizer Research Report,
Department of Soil Science,
University of Saskatchewan.
(D.A. Rennie and W.L. Hutcheon)

Table 4 — Effect of fertilizer placement on yields of wheat on Sceptre heavy clay - 1964

Fertilizer Treatment	Grain-Bu/ac Location 1 B'cast	Location 1 Seed	Location 2 B'cast	Location 2 Seed	Straw-cwt/ac Location 1 B'cast	Location 1 Seed	Location 2 B'cast	Location 2 Seed
Check	24.9	28.5	25.6	28.8	14.9	17.2	17.0	19.4
11-48-0 20#	24.0	31.2	26.1	34.0	15.4	19.9	18.0	23.6
40#	25.7	32.1	28.1	35.1	16.4	21.6	18.7	23.9
60#	25.0	31.1	28.0	36.2	17.6	22.4	18.7	23.1
80#	27.0	33.3	26.8	36.6	17.4	22.6	18.0	25.4
100#	27.0	34.4	28.1	38.9	17.6	24.5	18.9	24.8
L.S.D. (P = .05)	1.25	2.61	2.11	2.64	1.60	1.50	1.71	2.61
S.E.M. %	1.55	2.61	2.46	2.40	3.06	2.23	3.33	3.55

Table 5 Effect of fertilizer placement on yields and plant population of wheat on fallow - Asquith fine sandy loam

Fertilizer treatment lb/acre N	P_2O_5	Grain-bu/A. (4-yr. Ave.) With	Grain-bu/A. (4-yr. Ave.) Separate	Straw-lb/A. (3-yr. Ave.) With	Straw-lb/A. (3-yr. Ave.) Separate	Grain/Straw (3-yr. Ave.) With	Grain/Straw (3-yr. Ave.) Separate	Plants/12'row (2-yr. Ave.) With	Plants/12'row (2-yr. Ave.) Separate
10	0	23.3	24.1	2126	2281	.71	.73	124	118
20	0	23.8	24.8	2122	2252	.73	.74	112	119
40	0	23.4	24.1	2089	2183	.71	.72	113	112
80	0	21.8	24.4	2003	2235	.70	.71	107	116
160	0	17.2	22.8	1595	2242	.60	.66	95	104
10	40	24.5	26.2	2257	2314	.64	.75	80	120
20	40	25.0	28.5	2158	2476	.74	.66	81	125
20	40*	21.0		1739		.69		78	
40	40	24.2	28.1	2119	2522	.68	.68	96	122
40	40*	23.3		1913		.70		91	
80	40	22.2	29.0	1857	2528	.60	.68	86	129
160	40	19.2	26.4	1669	2290	.50	.63	74	106
0	40	21.5	25.7	1818	2226	.74	.76	68	124
Check		24.8		2101		.77		122	

*N only placed with seed

Table 6 Effect of fertilizer placement on yields and plant population of barley on stubble - Scott loam

Fertilizer treatment lb/acre N	P_2O_5	Grain-bu/A (2-yr. Ave.) With	Grain-bu/A (2-yr. Ave.) Separate	Straw-lb/A (2-yr. Ave.) With	Straw-lb/A (2-yr. Ave.) Separate	Grain/Straw (2-yr. Ave.) With	Grain/Straw (2-yr. Ave.) Separate	Plants/12' row (2-yr. Ave.) With	Plants/12' row (2-yr. Ave.) Separate
10	0	28.8	29.0	1381	1600	1.00	.92	68	66
20	0	26.3	28.5	1662	1656	.83	.88	72	69
40	0	28.8	27.2	1740	1722	.87	.83	66	64
80	0	32.3	32.2	1840	1864	.91	.87	67	68
160	0	28.4	31.6	1846	1920	.80	.85	63	62
10	40	32.4	30.2	1840	1841	.86	.81	66	65
20	40	33.0	28.7	1973	1878	.84	.78	70	78
20	40*	33.0		2006		.82		66	
40	40	34.3	30.5	2140	2045	.81	.76	68	68
40	40*	31.0		2092		.76		70	
80	40	37.8	35.6	2159	2409	.88	.76	62	71
160	40	34.0	38.2	2097	2330	.83	.82	56	66
0	40	27.6	31.0	1610	1648	.85	.92	62	66
Check		25.8		1413		.94		71	

*N only placed with seed.

Table 7 Effect of fertilizer placement for wheat on fallow on Scott loam - 4 year average

Treatment		Fert. with Seed			Fert. Separate		
		Grain bu/A	Straw lb/A	G/S	Grain bu/A	Straw lb/A	G/S
5	0	15.7	1530	.70	14.0	1467	.64
5	20	17.9	1774	.70	18.5	1869	.66
5	40	18.4	1810	.69	21.0	2001	.70
5	80	19.0	1827	.70	22.0	2103	.70
10	0	15.1	1505	.66	13.5	1463	.62
10	20	18.6	1819	.70	18.1	1812	.66
10	40	18.0	1820	.70	20.3	1987	.71
10	80	19.0	1792	.74	19.0	2042	.70
20	0	14.8	1538	.66	14.2	1522	.65
20	20	19.1	1887	.70	17.8	1779	.68
20	40	19.2	1904	.70	17.6	2001	.69
20	80	20.2	1924	.75	21.4	2000	.72
0	20	17.9	1750	.70	18.4	1818	.68
0	40	18.2	1759	.68	20.2	1956	.69
0	80	17.8	1734	.71	21.2	2030	.71
Check		14.7	1492	.67	14.8	1598	.65
Mean		17.7	1742	.70	18.2	1840	.68

Note: 33.5-0-0 and 0-43-0 used as sources of N and P.

Table 8 Effect of fertilizer placement on phosphorus content of wheat grown on Scott loam at two constant soil temperatures - 1964

Fertilizer treatment		% total P in plant tissue 79°F 28 days	79°F 38 days	59°F 28 days	59°F 38 days
Check		.300	.272	.246	.206
Check - NK only		.298	.298	.244	.243
K + 11-48-0 (20)	on surface	.292	.280	.358	.272
	top 4"	.301	.285	.294	.214
	all soil	.314	.327	.258	.226
	with seed	.317	.264	.339	.232
	3/4" to side	.318	.236	.338	.243
K + 11-48-0 (40)	on surface	.342	.270	.310	.320
	top 4"	.349	.268	.298	.268
	all soil	.332	.284	.272	.256
	with seed	.389	.275	.451	.326
	3/4" to side	.394	.278	.416	.326
K+ 11-48-0(160)	on surface	.492	.364	.535	.451
	top 4"	.485	.380	.534	.428
	all soil	.420	.378	.450	.382
	with seed	.544		.650	.507
	3/4" to side	.557	.433	.628	.454
Means:	on surface	.375	.305	.401	.348
	top 4"	.378	.311	.375	.303
	all soil	.355	.330	.327	.288
	with seed	.417		.480	.355
	3/4" to side	.423	.316	.461	.341
L.S.D. (P = .05)		.047	.034	.084	.071

Table 9 Effect of fertilizer placement on phosphorus content of barley grown on Scott loam at two constant soil temperatures - 1964

Fertilizer Treatment		% total P in plant tissue					
		79°F			59°F		
		28 days	38 days	56 days	28 days	38 days	56 days
Check		.210	.234	.208	.170	.150	.122
Check - NK only		.198	.211	.226	.172	.168	.116
K + 11-48-0 (20)	on surface	.248	.221	.205	.228	.204	.156
	top 4"	.251	.248	.190	.222	.189	.134
	all soil	.230	.208	.196	.202	.176	.139
	with seed	.283	.232	.178	.266	.224	.141
	3/4" to side	.260	.196	.232	.211	.198	.134
K + 11-48-0 (40)	on surface	.312	.239	.187	.266	.273	.200
	top 4"	.268	.215	.184	.238	.207	.156
	all soil	.232	.208	.192	.208	.190	.147
	with seed	.343	.261	.189	.316	.261	.174
	3/4" to side	.314	.245	.200	.316	.238	.174
K + 11-48-0(160)	on surface	.421	.226	.264	.407	.422	.366
	top 4"	.398	.351	.272	.430	.398	.350
	all soil	.371	.314	.206	.350	.332	.221
	with seed			.294	.452	.335	.288
	3/4" to side	.427	.393	.277	.504	.387	.250
Means:	on surface	.327	.229	.219	.300	.300	.241
	top 4"	.306	.271	.215	.297	.265	.213
	all soil	.278	.243	.198	.253	.233	.169
	with seed				.345	.273	.201
	3/4" to side	.334	.278	.236	.344	.274	.186
L.S.D. (P = .05)		.058			.080	.070	.055

Table 10 Effect of fertilizer placement on yields of wheat at constant soil temperature of 59°F - Scott loam, 1964

Fertilizer Treatment		Yield in grams per pot Grain	Straw
Check - NK only		6.44	9.06
K + 11-48-0 (20)	on surface	6.24	8.24
	top 4"	7.20	9.24
	all soil	7.62	10.44
	with seed	9.12	11.92
	3/4" to side	7.60	11.44
K + 11-48-0 (40)	on surface	7.44	10.46
	top 4"	6.60	8.70
	all soil	7.46	9.68
	with seed	8.92	12.32
	3/4" to side	7.24	9.96
K + 11-48-0 (160)	on surface	7.32	11.08
	top 4"	6.72	9.58
	all soil	7.38	9.48
	with seed		
	3/4" to side	8.52	11.76

Note: N and K (NH_4NO_3 and KCl) mixed with all soil, at 36# N/acre and 80# K 20/acre.

$NaHCO_3$ - extr. P at beginning of experiment - 8.48 ppm. P.