Relative Efficiencies of Urea and Ammonium Nitrate for Cereal and Forage Crops

H. Ukrainetz

Introduction

Growth and yields of crops are influenced by a number of factors, frequently interrelated. Under field conditions, the main factors directly influencing crop production are the availability of moisture and nutrients. However, for maximum yields of a crop, a certain minimum plant population is required. Crop response to fertilizer and fertilizer efficiency depend on the amount of nutrients applied in relation to soil available nutrient status, method of fertilizer placement, availability to plants of the form of nutrient applied on its transformation products, and also the effect of the fertilizer on germination and crop stands. If the fertilizer depresses germination and plant population below a critical level, yields will also be depressed, even though a response to the fertilizer nutrients is obtained.

Field experiments carried out at the Experimental Farm, Scott, Saskatchewan, have shown that maximum yields of wheat and barley can be obtained from seed rates of 40 to 80 lb/acre and 60 to 80 lb/acre, respectively. Therefore, some decrease from the normal plant population can be tolerated with no loss in yield, especially if the response to added nutrients is strong. If nutrient deficiency is severe and response to added fertilizer large, effects of decreased plant population resulting from fertilizer damage can be largely masked. However, large decreases in population below the critical level will result in decreased yield. Certain crops, such as rapeseed, are much less sensitive to variations in plant population than wheat and barley and are able to compensate for large reductions in plant density by increased production of individual plants.

In the case of perennial forage crops, such as brome grass, particularly when in solid stands, the effect of the fertilizer on plant populations is seldom a significant factor. Efficiency of the fertilizer is related to rate of nutrients applied in relation to soil available nutrient status, availability of the form of the nutrients in the fertilizer to the crop, soil moisture status as it influences crop growth and fertilizer solution and movement into the root zone, and fertilizer placement in relation to possible losses of fertilizer nutrients by runoff and volatilization of some forms on certain soils.

Experimental Methods

Urea and ammonium nitrate were compared as sources of nitrogen for wheat and barley grown on stubble land on four different soil types in western Saskatchewan during the period 1967-72. Nitrogen was applied with the seed at rates of 0, 20, 30, 40, 60 and 80 lb N/acre in combination with phosphate in ratios of 1:1 and 2:1 ($N:P_2O_5$). Nitrogen was also broadcast and incorporated before seeding at rates of 40 and 80 lb/acre to compare with seed placement. In 1972, additional treatments were included to compare ammonium nitrate and urea when broadcast and incorporated before seeding at rates up to 160 lb N/acre on several soil types.

Urea and ammonium nitrate were applied by broadcasting at several rates in fall and spring on established stands of bromegrass on three soil types in west-central and northwestern Saskatchewan. The experiments were conducted during the period 1959-1968. Data on hay and seed yields were obtained, but results on hay yields and quality are discussed here only.

Effects of fertilizer treatments on average grain and straw yield patterns were almost identical; and therefore, only grain yield results will be discussed here.

Wheat - On a sceptre heavy clay soil (ScHvC), there was very little damage to germination of wheat from seed-placed ammonium nitrate or urea with phosphate at rates up to 80 lb N/acre. Three-year average yield results are shown in Fig. 1. Yields were slightly higher with

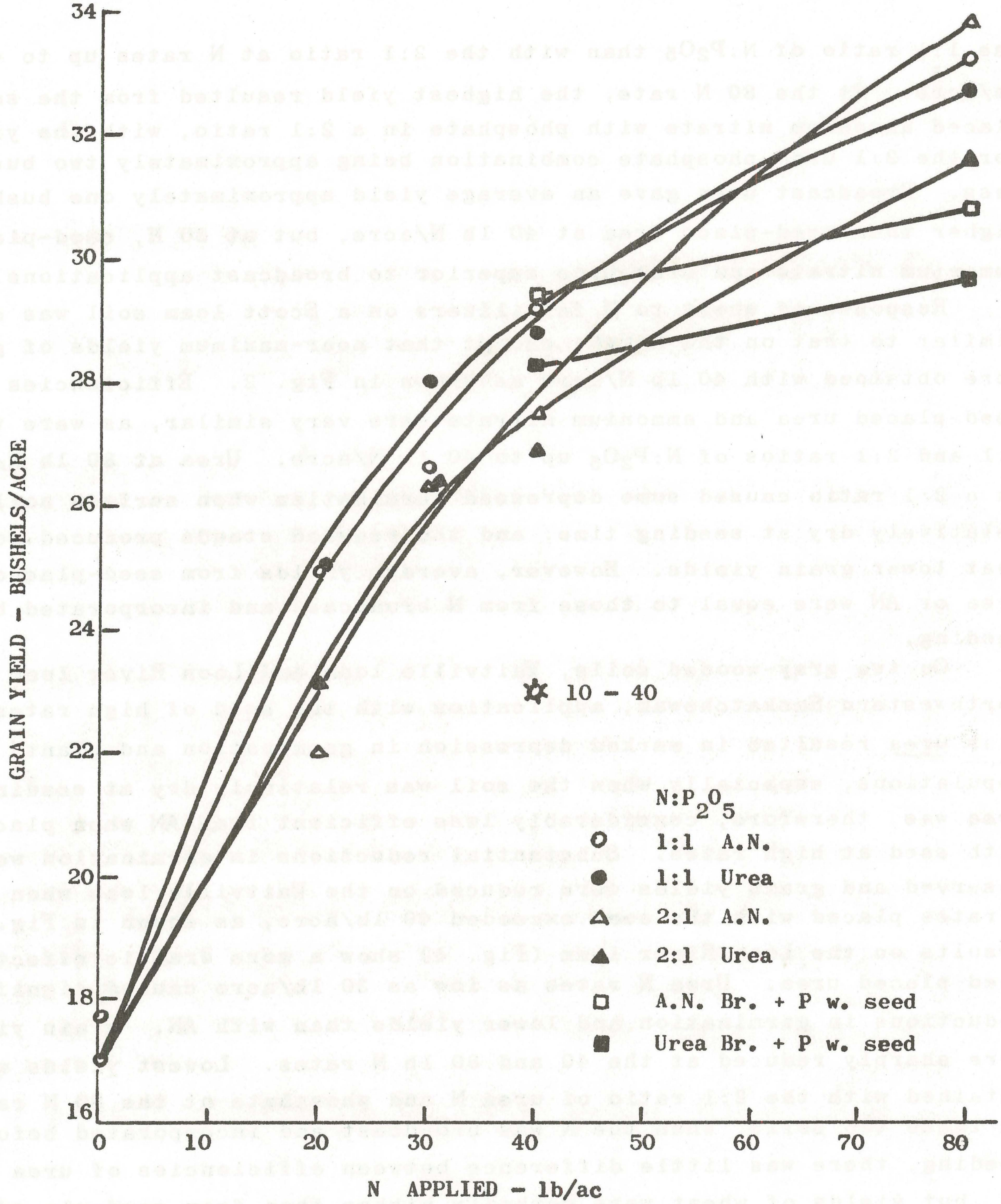

FIGURE 1. The effects of urea and ammonium nitrate applied with the seed and broadcast (incorporated) on yields of wheat on stubble on Sceptre heavy clay. 3-year average (1969,70,72)

the 1:1 ratio of $N:P_2O_5$ than with the 2:1 ratio at N rates up to 40 lb/acre. At the 80 N rate, the highest yield resulted from the seed-placed ammonium nitrate with phosphate in a 2:1 ratio, with the yield for the 2:1 urea-phosphate combination being approximately two bushels less. Broadcast urea gave an average yield approximately one bushel higher than seed-place urea at 40 lb N/acre, but at 80 N, seed-placed ammonium nitrate and urea were superior to broadcast applications.

Response of wheat to N fertilizers on a Scott loam soil was quite similar to that on the ScHvC, except that near-maximum yields of grain were obtained with 40 lb N/acre as shown in Fig. 2. Efficiencies of seed-placed urea and ammonium nitrate were very similar, as were the 1:1 and 2:1 ratios of $N:P_2O_5$ up to 40 lb N/acre. Urea at 80 lb N/acre in a 2:1 ratio caused some depressed germination when surface soil was relatively dry at seeding time, and the reduced stands produced somewhat lower grain yields. However, average yields from seed-placed N as urea or AN were equal to those from N broadcast and incorporated before seeding.

On two grey-wooded soils, Waitville loam and Loon River loam in northwestern Saskatchewan, application with the seed of high rates of N as urea resulted in marked depression in germination and plant populations, especially when the soil was relatively dry at seeding. Urea was, therefore, considerably less efficient than AN when placed with seed at high rates. Substantial reductions in germination were observed and grain yields were reduced on the Waitville loam when urea N rates placed with the seed exceeded 40 lb/acre, as shown in Fig. 3. Results on the Loon River loam (Fig. 4) show a more drastic effect of seed-placed urea. Urea N rates as low as 30 lb/acre caused significant reductions in germination and lower yields than with AN. Grain yields were sharply reduced at the 40 and 80 lb N rates. Lowest yields were obtained with the 2:1 ratio of urea N and phosphate at the 80 N rate. On these two soils, when the N was broadcast and incorporated before seeding, there was little difference between efficiencies of urea and AN, but yields of wheat were markedly higher than from seed-placed urea and equal to or slightly higher than for seed-placed AN.

Barley - Barley appears to be somewhat more sensitive to seed-placed urea N than wheat on some soils. Barley was not included in the

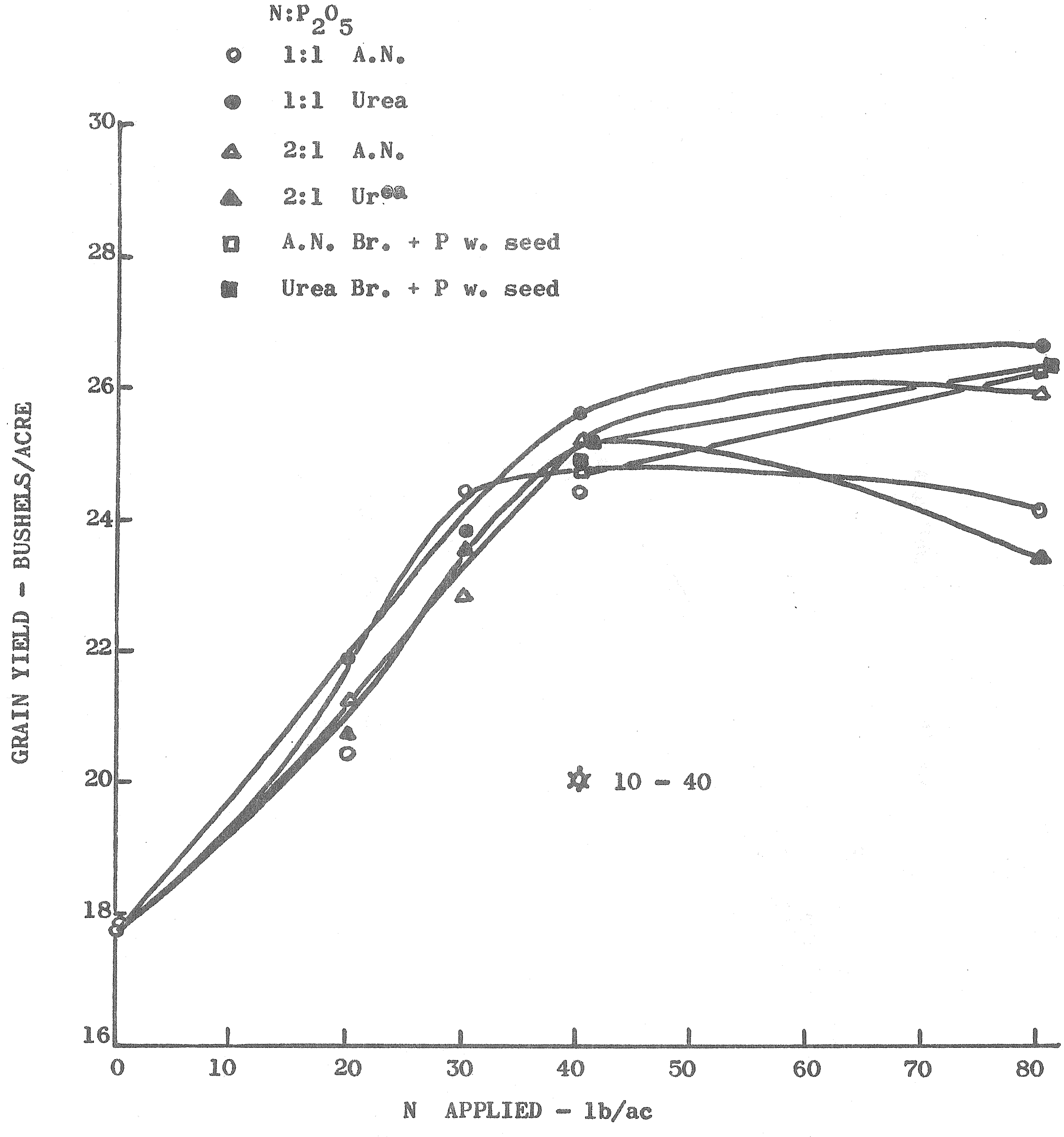

FIGURE 2. The effects of urea and ammonium nitrate applied with the seed and broadcast (incorporated) on yields of wheat on stubble on Scott loam. 4-year average (1969-72)

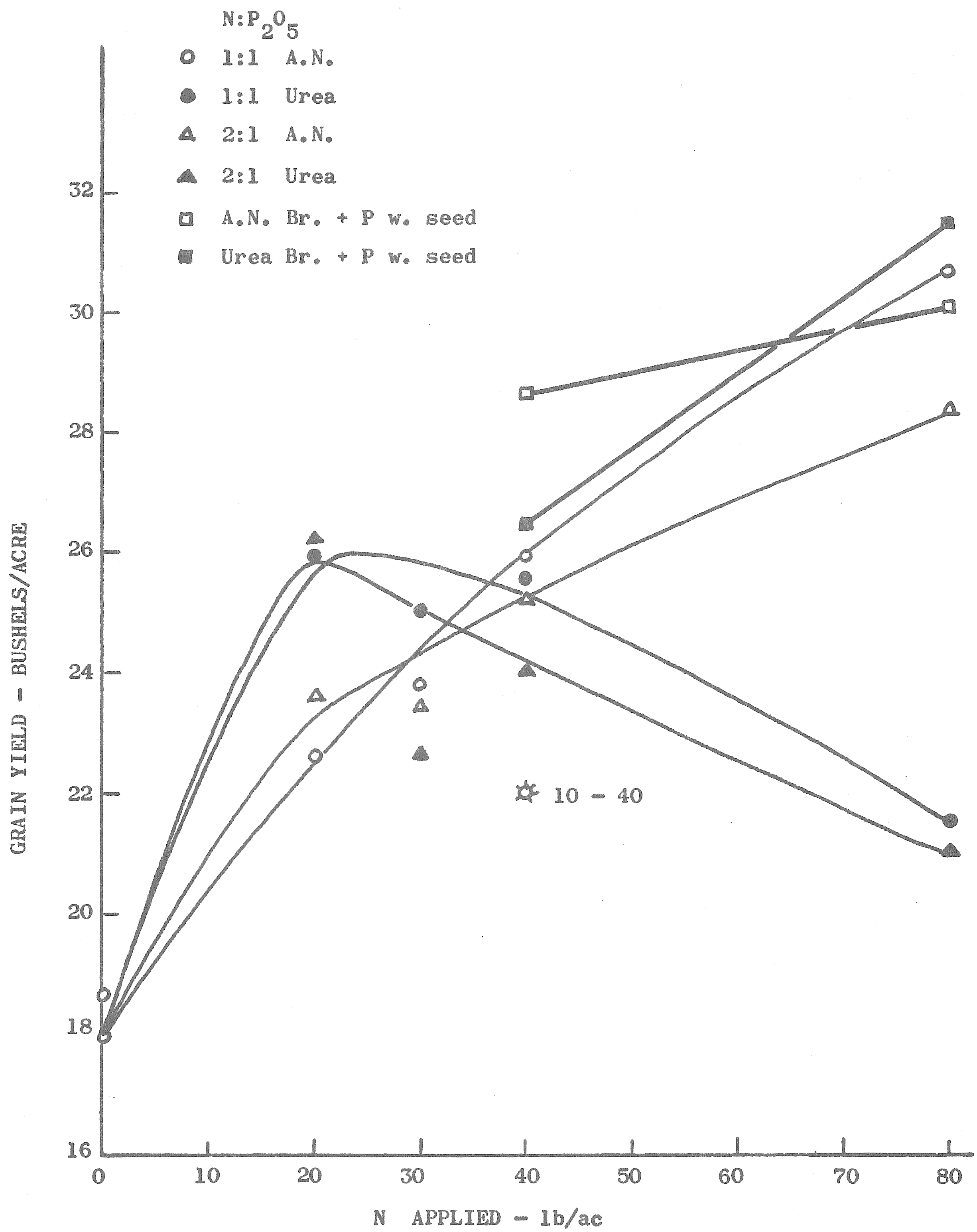

FIGURE 3. The effects of urea and ammonium nitrate applied with the seed and broadcast (incorporated) on yields of wheat on stubble on Waitville loam. 4-year average (1969-72)

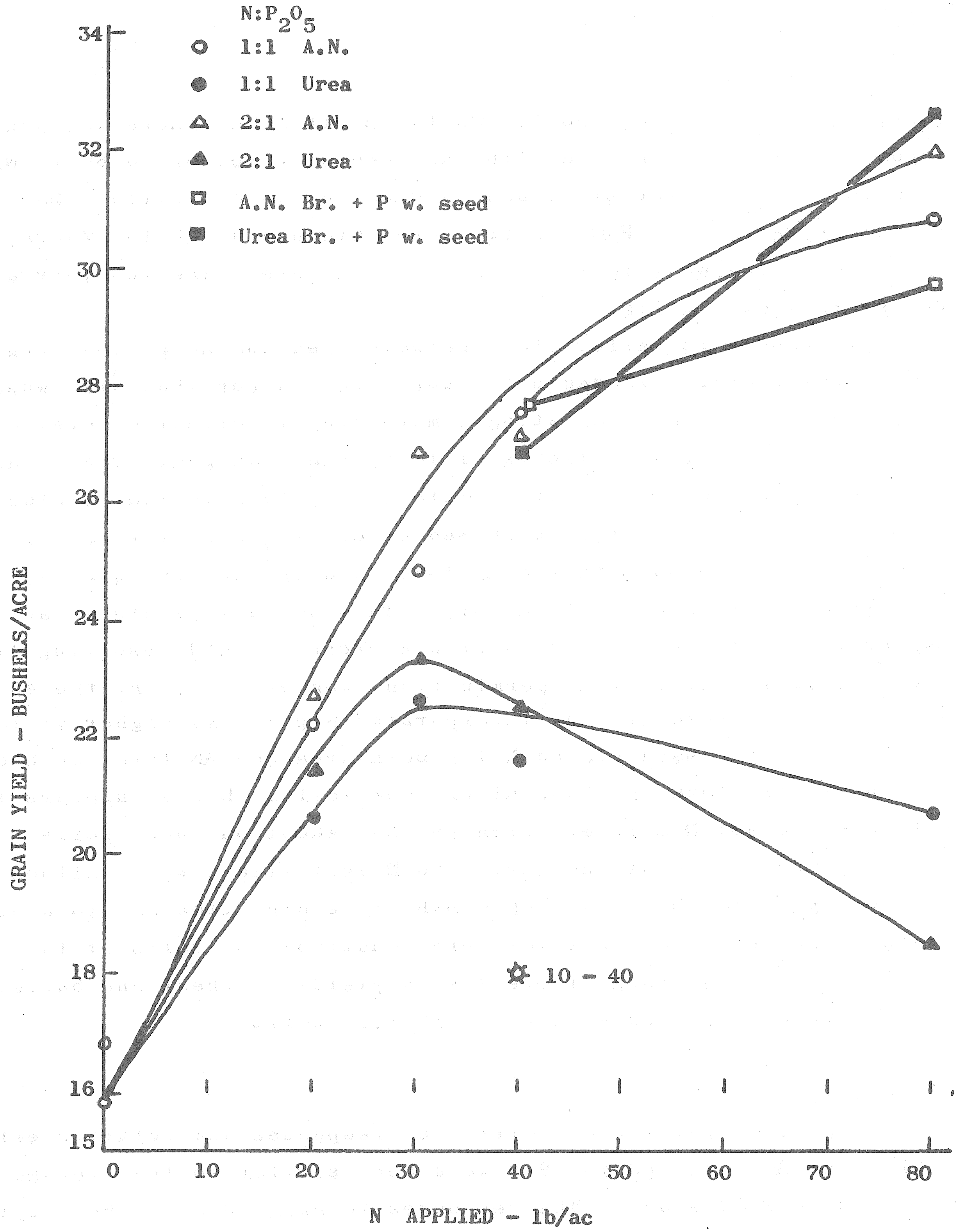

FIGURE 4. The effects of urea and ammonium nitrate applied with the seed and broadcast (incorporated) on the yields of wheat on stubble on Loon River loam. 3-year average (1969-71)

experiments on the ScHvC soil. On the Scott loam, there was a strong response to N with P placed with the seed at rates up to 80 lb N/acre as AN in 1:1 and 2:1 ratios, and as urea in the 1:1 ratio. Maximum yields for the 2:1 ($N:P_2O_5$) ratio were obtained at 40 lb N/acre, and the yield decreased slightly with the 80 N rate. The two-year average yields are shown in Fig. 5.

Differences in barley yield between urea and AN placed with the seed on the two grey-wooded soils were even larger than with wheat at the lower rates of N, indicating a more drastic effect of urea on germination of barley. Effects of fertilizers on grain yields are shown in Figures 6 and 7. It is interesting to note that yields for the AN seed-placed treatments showed a leveling off at rates of N above 30 lb/acre even with the AN form, and the decline was especially evident on the Loon River loam soil. This would indicate a lack of response to N at the high rates or a depressed yield resulting from some detrimental effects on germination even with AN. At the 40 and 80 lb N rates, broadcast and incorporated N produced higher yields of barley grain than seed-placed N for both urea and AN forms on Scott loam, Waitville loam and Loon River loam soils. Barley appears to utilize broadcast N more efficiently than wheat on these soils.

Responses of wheat and barley to N fertilizers were influenced by available soil NO_3-N to 24-inch depth at seeding time and to available moisture. Under favourable moisture conditions on soils of low to medium available N, large increases in yields of wheat and barley were obtained from N applied with P on all four soils.

1972 Results

The general pattern of fertilizer responses and relative effects of urea and AN obtained in 1972 were very similar to the average results discussed above. The responses to applied N on the Sceptre heavy clay, Scott loam and Waitville loam soils were somewhat greater than the average, and the depressing effect of seed-placed urea on germination and yield was more pronounced than indicated on the average

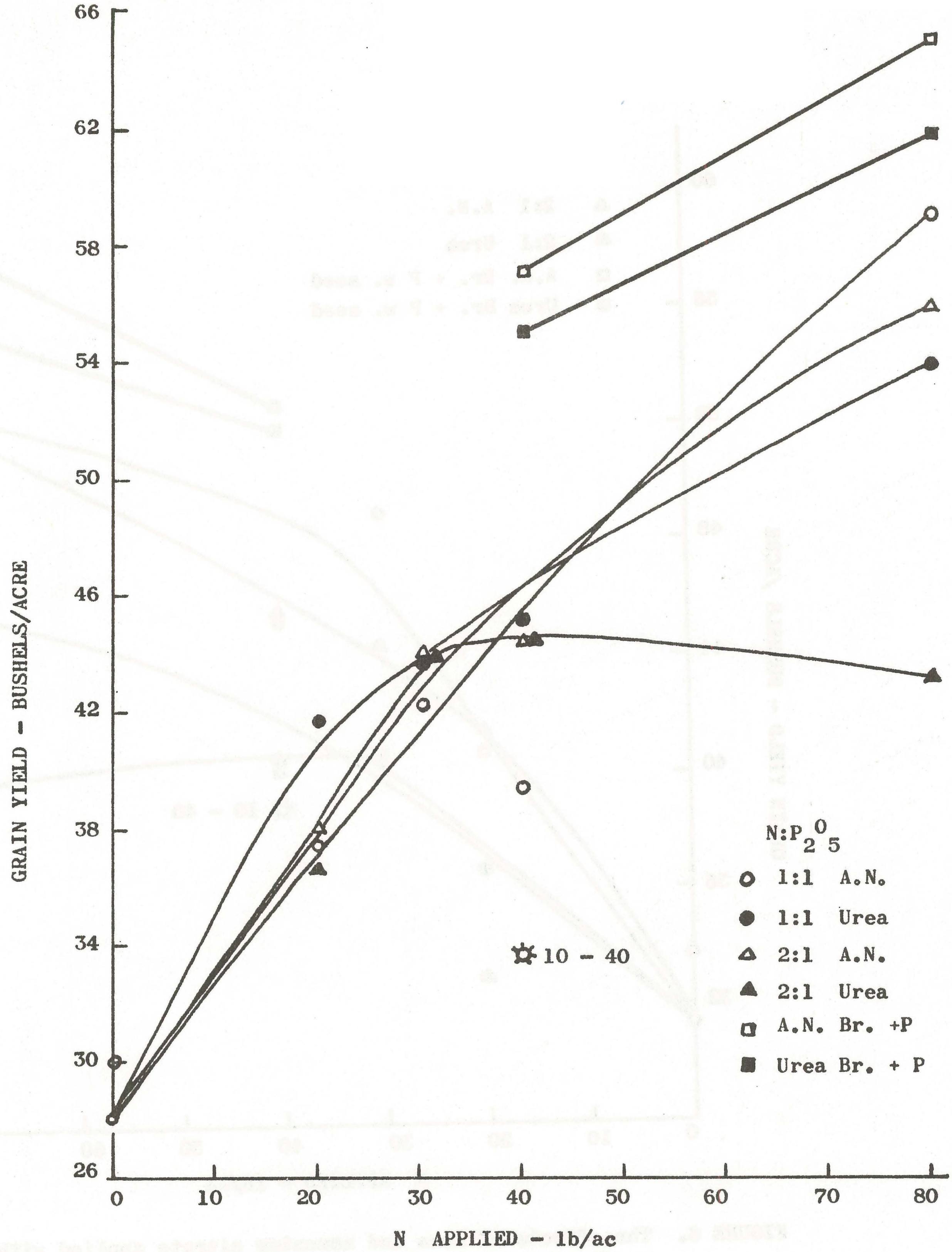

FIGURE 5. The effects of urea and ammonium nitrate applied with the seed and broadcast (incorporated) on yields of barley on stubble on Scott loam. 2-year average (1970-71)

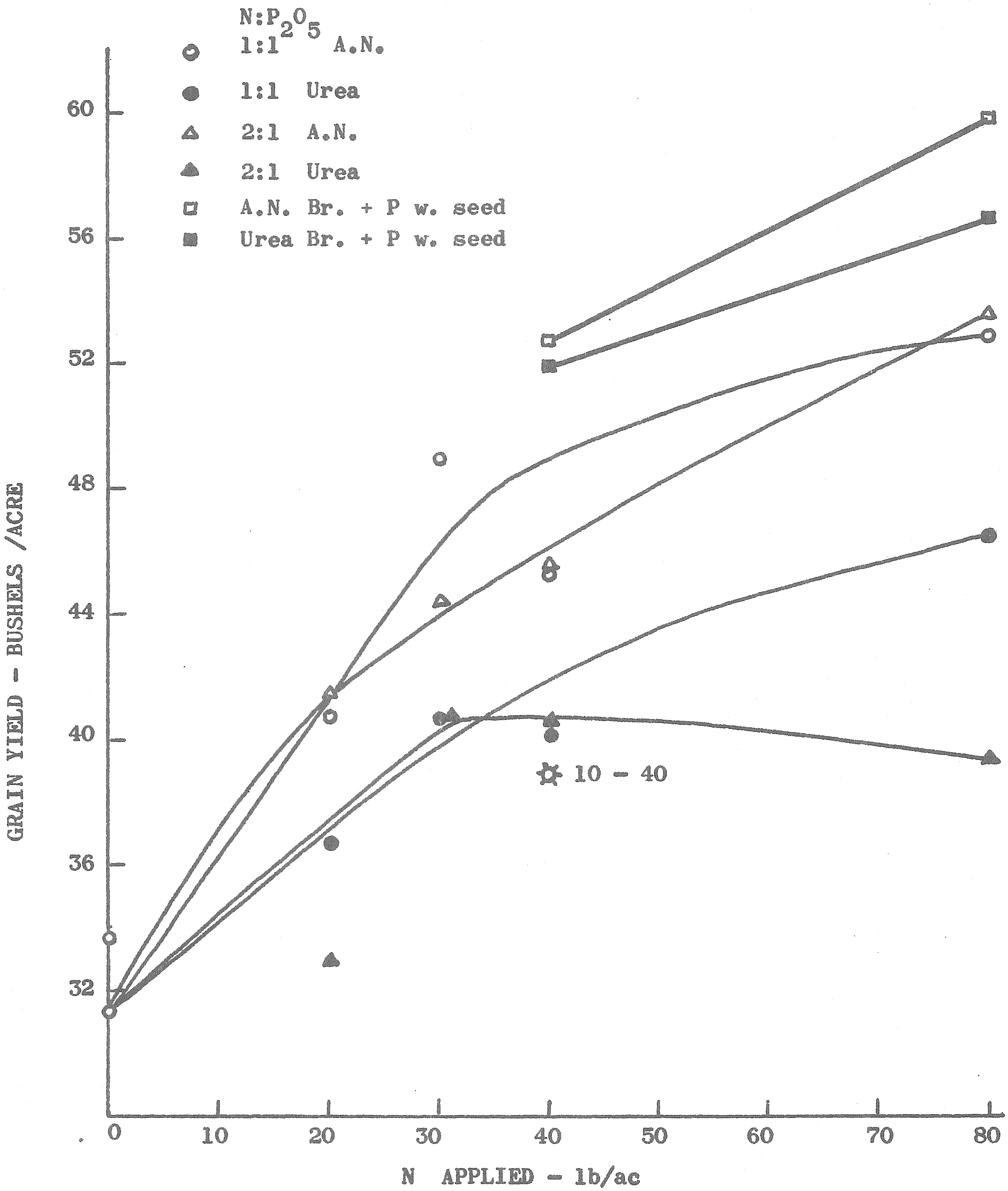

FIGURE 6. The effects of urea and ammonium nitrate applied with the seed and brodcast (incorporated) on yields of barley on stubble on Waitville loam. 3-year average (1969-71)

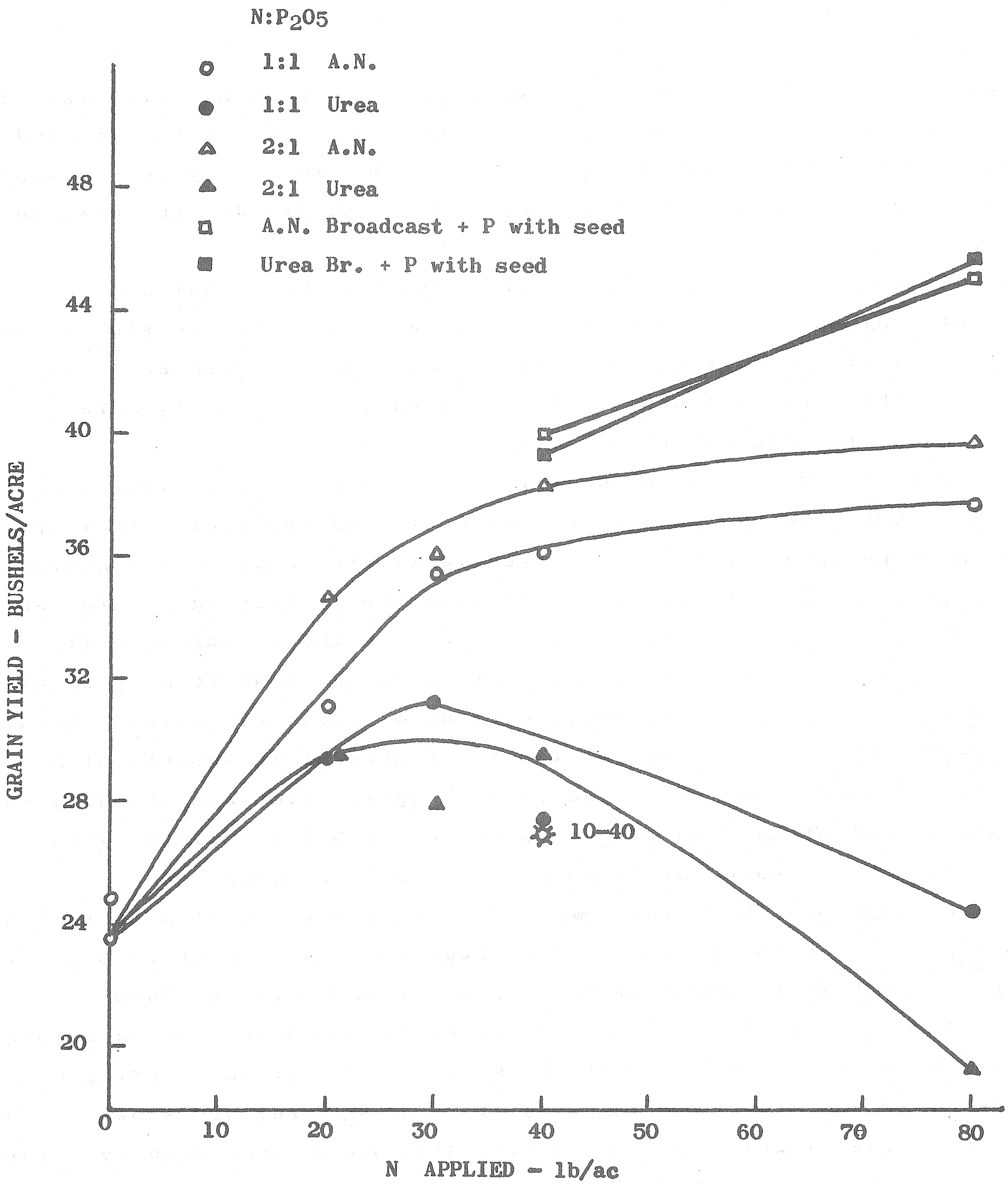

FIGURE 7. The effects of urea and ammonium nitrate applied with the seed and broadcast (incorporated) on yields of barley on stubble on Loon River loam. 4-year average (1969-72)

yield graphs on the grey-wooded Waitville and Loon River loams. In 1972, a high level of available N in the Loon River loam resulted in higher than average yields of barley but smaller responses to applied N. Effects of the fertilizer treatments on grain yields are shown in Table 1.

In 1972, when urea and AN were compared, broadcast and incorporated at rates of 40 to 160 lb N/acre for wheat and barley on stubble on several soil types, there were essentially no differences in efficiencies of these two N sources. Urea tended to be slightly more efficient than AN at the highest rates of N.

Part of the yield response from the fertilizer applications can be attributed to the phosphate component, and the yields from applied ammonium phosphate only (10-40 treatment) are shown on the average data graphs. The increased yields from the increasing N rates show than N was the primary limiting nutrient on these stubble soils.

Application of N fertilizers at rates up to 40 lb N/acre seldom significantly increased protein content of wheat or barley. Usually protein content decreased for the first several increments of N as yields increased sharply. The 80 lb N application occasionally raised protein content by 1 to 2%, and when 160 lb N was applied, wheat protein was increased by as much as 4% in some cases.

Bromegrass - Urea and ammonium nitrate were applied in fall and spring on established stands of bromegrass on a dark-brown Scott loam, a grey-black Whitewood loam and a grey-brown Dorintosh loam.

The results of fertilizer experiments conducted during a three-year period (1966-68) on Scott loam, in which fall and spring application of AN and urea were compared at 80 lb N/acre, are shown in Table 2. Urea was slightly less effective than AN as indicated by lower average total dry matter yields and protein contents of the hay.

On the Whitewood loam, results of experiments carried out during 1959-65 (Table 3) showed that average dry matter yields as a direct response to applied urea were 22% lower than with AN at 40 lb N/acre, 11% less at 80 lb N/acre, but equal to AN at 160 lb N/acre. However,

Table 1

Effects of rate and placement of NP fertilizers containing urea and AN on yields of wheat and barley grain

Fertilizer treatment lb/ac			Grain - bushel/acre			
N	P_2O_5		Kindersley ScHvC wheat	Scott SttL wheat	Glaslyn WvL wheat	Loon Lake LnL barley
20	20	ANP	20.2	12.7	18.4	36.0
30	30		23.4	15.2	20.1	40.9
40	40		27.1	12.6	26.0	42.7
60	60		31.5	15.9	31.8	40.2
80	80		28.5	13.8	40.5	39.5
20	20	UAP	22.1	12.0	21.6	36.5
30	30		25.7	13.2	24.5	37.7
40	40		26.4	14.7	23.9	25.3
60	60		30.7	16.6	13.4	29.8
80	80		29.3	13.9	9.2	22.8
20	10	ANP	17.2	13.8	16.8	41.9
30	15		24.4	13.0	20.8	37.6
40	20		25.3	15.2	27.3	41.1
60	30		31.2	12.8	31.5	41.6
80	40		33.3	13.7	32.8	39.3
20	10	UAP	21.1	8.6	21.7	33.8
30	15		23.8	12.5	19.5	31.2
40	20		25.1	15.5	20.5	31.4
60	30		25.9	13.5	7.4	21.6
80	40		30.2	14.6	5.9	15.7
40 BR	40	AN	24.6	13.4	26.9	40.1
80 BR	40		30.6	13.7	30.4	39.7
40 BR	40	Urea	24.5	12.5	21.3	36.6
80 BR	40		27.6	12.6	30.1	44.6

Table 1 (Cont'd)

Fertilizer treatment lb/ac		Grain - bushel/acre			
N	P_2O_5	Kindersley ScHvC wheat	Scott SttL wheat	Glaslyn WvL wheat	Loon Lake LnL barley
Check (rotovated)		13.1	8.2	10.9	33.2
Check		12.5	6.7	10.7	24.0
L.S.D. 5%		4.5	4.6	6.2	10.4
1%		6.0	6.1	8.2	13.7
Soil analysis					
NO_3-N lb/ac	0-24"	8	57	52	74
P	0- 6"	6	30	14	19
K	0- 6"	400+	400+	340	250
S	0-24"			16	18

ANP - ammonium nitrate + ammonium phosphate
UAP - urea + ammonium phosphate

All P placed with seed. N placed with seed except BR which indicates broadcasting and incorporation before seeding.

Table 2

Effects of urea and ammonium nitrate fertilizers on hay yields and protein content, and seed yields of bromegrass on Scott loam.[1]

N Applied lb/ac		Dry Matter (lb/ac) (6)	% Protein (5)	Seed (lb/ac) (6)
80	F1 AN	1610	12.9	104
	F2	2112	11.5	120
	F3	1988	11.4	114
	S1	1890	12.2	87
	S2	1760	13.0	71
	S3	1856	13.4	68
80	F1 Urea	1716	11.6	108
	F2	1855	11.8	102
	F3	1733	12.0	88
	S1	1397	11.8	60
	S2	1673	12.1	72
	S3	1809	12.9	66
Check		723	9.2	44

[1] Data from experiments carried out during 1966-68. Numbers in brackets refer to number of trials averaged.

F1-3 Three fall applications at 10 to 14 day intervals beginning during the first week in September.

S1-3 Three spring applications at 10 to 14 day intervals beginning during the second week in April.

Table 3

Effects of urea and AN on bromegrass production on whitewood loam, 1959-65.

N Applied (lb/ac)	D.M. yield (lb/ac) Direct (10)	D.M. yield (lb/ac) Residual (4)	% Protein (4)	(lb/ac) Protein (4)	Seed (lb/ac) Direct (6)	Seed (lb/ac) Residual (3)
40 AN	2379	1301	9.22	205	267	130
80	2963	1480	10.32	269	295	131
160	3338	2320	13.30	430	332	193
40 Urea	1950	1234	8.84	157	188	124
80	2670	1240	9.60	230	264	132
160	3318	1689	11.11	351	288	301
Check	1051	1120	9.07	86	154	121

Numbers in brackets indicate number of trials averaged. Averages of fall and spring applications for each rate.

the dry matter yields from residual N, hay protein contents and hay protein yields as direct effects showed increasing differences between urea and AN as rate of N increased. Results on Dorintosh loam were somewhat less consistent as shown in Table 4. The data obtained during 1962-63 show equal direct effects of urea and AN on dry matter yields at the 40 lb N rate, but yields from urea were lower at the 80 and 160 lb N rates. The two forms of N appeared to be similar in efficiency from the standpoint of residual effect on dry matter yields and direct effect on hay protein content.

Urea was also slightly less efficient than AN for seed production.

Discussion

Observations in the field as well as plant population and yield

Table 4

Effects of urea and AN on bromegrass production on Dorintosh loam, 1962-63.

N Applied (lb/ac)		D.M. yield (lb/ac) Direct (3)	D.M. yield (lb/ac) Residual (1)	% Protein (2)	Seed (lb/ac) Direct (2)	Seed (lb/ac) Residual (1)
40 AN	Fall	2376	1228	9.59	382	124
	Spring	2160	2662	10.92	215	116
80	Fall	2427	2048	11.32	586	232
	Spring	3297	2774	12.52	316	430
160	Fall	4307	4454	11.78	599	464
	Spring	3083	3569	14.68	438	513
40 Urea	Fall	2393	2182	8.76	369	199
	Spring	2136	1492	10.64	270	132
80	Fall	2729	2640	11.90	560	182
	Spring	2255	2299	11.66	305	306
160	Fall	3141	4091	13.25	512	397
	Spring	3350	4222	14.60	346	364
Check		780	1250	9.47	86	74

Numbers in brackets indicate number of trials averaged.

data show that the differences obtained between seed-place urea and AN were closely related to effects on germination and seedling emergence. The soil factors which appeared to have the greatest influence on extent of damage resulting from seed-placed N fertilizer were soil (seed-bed) moisture content during the germination and emergence period and cation exchange capacity (C.E.C.). The C.E.C. for the 0 to 6" depths of the four soils investigated are shown on the following page:

Soil	C.E.C. (me/100 g)
Sceptre heavy clay	41
Scott loam	18
Waitville loam	14
Loon River loam	11

In soils of high C.E.C., ammonia released on hydrolysis of urea would be quickly and relatively completely absorbed on the soil exchange sites. At low C.E.C., high concentration of unabsorbed ammonia could be detrimental to germinating seedlings. At high soil moisture content, urea would dissolve readily, be diluted and probably move away from the seed prior to hydrolysis. Also the NH_4 concentration in the solution adjacent to the seed would be lower, thus reducing the harmful effects. High soil moisture content adjacent to the seed could also result in less concentrated AN solution, and thus reduce harmful salt effects on germination from this N source. The most severe depressions in germination and yields of wheat and barley were observed on low C.E.C. soils that had low moisture content at seeding time.

The influence of soil pH, though apparently not a significant factor in itself, may be important if considered in relation to C.E.C. The Loon River loam, on which seed-placed urea at high rates most severely depressed yields, had the highest pH and lowest C.E.C. (7.0 and 11, respectively). At this pH, the probable high concentrations of ammonia and the further increase in pH on liberation of ammonia on hydrolysis of urea could have been significant factors responsible for the marked detrimental effects of seed-placed urea in this soil. The influence of soil C.E.C. on germination of wheat at several levels of seed-placed urea N is shown in Table 5.

It has been shown that less germination damage and higher yields of wheat and barley were obtained on some soils with seed-placed urea N in a 1:1 ratio with phosphate as compared to the 2:1 ratio, in spite of the higher total salt concentration. These results may

Table 5

Effect of urea placed with the seed on germination of wheat in relation to soil type.[1]

lb/ac		Emergence at 10 days - % of check			
N	P_2O_5	Sceptre heavy clay	Scott loam	Waitville loam	Loon River loam
20	0	90	72	20	20
40	0	64	37	5	0
80	0	10	5	0	0
40	40	89	82	92	100
Soil C.E.C.		41	18	14	11

[1] Seed placed into soil adjusted to 50% available moisture.

have been partly related to the nutritional effect of the increased level of phosphate. However, in growth chamber experiments, the added P resulted in a marked improvement in germination of wheat when compared to urea applied alone, as shown in Table 5.

The frequently observed lower efficiency of urea as compared to AN when broadcast on the soil surface on established bromegrass is probably related to a slower availability of the urea N to the crop resulting from slow hydrolysis of the urea placed on a dry soil surface. There is also a possibility of some loss of N as NH_3 to the atmosphere when urea hydrolysis occurs at the surface of a soil that may be at a relatively high temperature.

Implications for Fertilizer Recommendations and Further Research

On certain soils having high C.E.C. and abundant moisture at seeding depth, wheat and barley can tolerate and utilize efficiently relatively large amounts of urea or AN fertilizer placed with the seed. On soils of low C.E.C. and low available moisture in the seedbed, relatively low rates (20 to 30 lb N/acre) of seed-placed urea can be detrimental. On these latter soils, broadcasting and incorporation of the N before seeding produces substantially better results. A knowledge of soil conditions and certain soil characteristics such as pH and C.E.C. can be useful in determining the form of N fertilizer to use and the method of fertilizer placement for a given rate of N required. Further research is required on other soil types to obtain information on effects of soil pH and C.E.C. on efficiency of urea fertilizer.