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ASSESSMENTS OF THE RELATIVE VALUES OF COMPOUND NITROGEN-PHOSPHORUS FERTILIZERS FOR WHEAT PRODUCTION

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A general procedure is developed for calculating optimal rates of application of compound fertilizers, containing several nutrients in fixed composition. The calculations are based on response surface models that have been obtained with single nutrient fertilizers. The relative values of alternative compounds can be assessed from the increases in profit that result from their use at optimal rates and this is preferable to simply comparing fertilizer compositions with that of an ideal mix of single nutrient fertilizers.

The relative values of a range of standard nitrogen-phosphorus fertilizers are assessed for wheat production in southern New South Wales. The results indicate the need for a compound with a low nitrogen/phosphorus ratio of about 0.5. For the range of fertilizers considered it is concluded that it will generally be preferable to use superphosphate, supplementing with nitrogen fertilizer where N deficiency is suspected.

The assumptions required for the calculation of optimal fertilizer rates are discussed.

The rates at which fertilizers should be applied to crops are commonly calculated from response or production functions that have been estimated from the data of fertilizer experiments. When more than one soil nutrient is deficient, the experiment treatments usually consist of different rates of application of single nutrient fertilizers, each supplying one of the deficient nutrients. A response function is then estimated from the data, as by a regression procedure, and optimal simultaneous rates of application of the single nutrient fertilizers calculated. These rates correspond to those that should be used by a farmer applying the several fertilizers from separate fertilizer boxes on his combine fertilizer seed-drill or as an optimal mix of the separate fertilizers. In practice, however, farmers do not apply several fertilizers nor attempt to prepare ideal mixes but rather apply a compound fertilizer containing the several nutrients in some fixed ratio supposedly approximating to that of an ideal mix. Consequently there is a need to estimate optimal application rates of compound fertilizers as distinct from optimal mixtures of individual fertilizers, and to assess their relative economic value to farmers. This does not seem to have been done in Australia possibly because at first sight it seems that special experiments would be required with ranges of alternative compound fertilizers. Such experiments require much work, and because compounds offered by fertilizer manufacturers and their prices change periodically, the experimental data might soon cease to be of current interest. Estimates can be obtained however from the data of standard fertilizer experiments with combinations of various rates of application of single nutrient fertilizers and this paper demonstrates this for a range of fertilizers available to wheat farmers in southern New South Wales.

Experimental Data

1. *Fertilizer experiments*

The calculations to be described are based on a series of yield-fertilizer response surfaces estimated from the data of 46 fertilizer experiments with wheat carried out in a region of southern New South Wales in the three years, 1968 to 1970. The treatments were factorial combinations of the nutrient rates 0, 22, 56, 112kg N and 0, 11, 28, 56kg P per hectare, with three replicates i.e. 4 x 4 x 3 giving 48 plots

TABLE 1

Coefficients for Response Surfaces

No.	District	b_0	b_1	b_2	b_3	b_4	b_5	C.V.	R^2
1	Tarago	454·	47·9	452·	3·90	−5·62	−42·4	·16	·88
2	Tarago	515·	−29·7	170·	−·421	3·95	−14·9	·29	·43
3	Tarago	777·	7·18	397·	−1·74	·030	−22·1	·07	·96
4	Tarago	134·	14·1	195·	13·2	·044	−15·4	·14	·95
5	Lake Bathurst	1332·	−33·9	146·	−5·42	2·40	−13·3	·11	·56
6	Goulburn	598·	12·3	228·	−2·22	−1·15	−12·7	·10	·91
7	Goulburn	128·	77·1	299·	10·6	−6·57	−31·8	·18	·89
8	Goulburn	918·	68·3	467·	−5·46	−7·63	−34·5	·19	·75
9	Goulburn	740·	−3·48	76·4	−·107	−·743	−6·80	·11	·57
10	Canberra	2393·	−28·1	195·	6·03	−4·02	−19·2	·09	·72
11	Canberra	2060·	19·9	125·	4·20	−4·39	−18·2	·08	·49
12	Canberra	866·	78·5	127·	−1·78	−3·70	−14·3	·19	·37
13	Boorowa	1608·	−46·00	244·	3·46	1·95	−17·9	·12	·74
14	Wallendbeen	3269·	−·356	218·	−7·57	−1·38	−21·7	·04	·75
15	Wallendbeen	3170·	−5·87	383·	−4·51	−·645	−33·1	·07	·74
16	Wallendbeen	2264·	11·6	194·	−·434	−1·35	−17·4	·08	·53
17	Cootamundra	1652·	−1·50	166·	4·78	4·71	−9·25	·09	·81
18	Stockinbingal	2041·	40·0	219·	2·70	−4·15	−22·5	·06	·76
19	Quandialla	1178·	15·5	140·	2·41	−2·70	−8·50	·09	·79
20	Quandialla	2061·	8·84	256·	−3·76	−5·89	−13·8	·10	·67
21	Quandialla	1524·	42·4	158·	6·93	−·222	−16·2	·06	·90
22	Quandialla	1345·	121·	267·	−1·76	−8·09	−21·7	·13	·62
23	Wyalong	475·	1·72	56·3	−·439	·985	−·935	·08	·86
24	Ariah Park	2389·	16·8	125·	−1·32	−2·32	−5·86	·04	·81
25	Ardlethan	1785·	5·92	138·	−5·86	−·234	−6·47	·06	·72
26	Ardlethan	2698·	14·3	60·9	2·58	−1·80	−5·52	·05	·43
27	Ardlethan	1794·	64·1	232·	−1·11	−4·98	−15·4	·04	·92
28	Ardlethan	1722·	−4·14	115·	1·79	−·540	−5·20	·07	·78
29	Kamarah	1989·	·210	116·	−2·12	−·772	−9·30	·06	·56
30	Kamarah	2248·	51·4	118·	−4·82	−4·49	−6·96	·03	·80
31	Barellan	1203·	17·2	180·	2·91	−1·44	−7·43	·09	·87
32	Barellan	951·	23·0	309·	7·73	−1·56	−22·2	·06	·97
33	Barellan	588·	−2·08	203·	9·84	−·639	−12·9	·18	·84
34	Barellan	1179·	47·9	144·	11·5	−3·31	−3·01	·10	·89
35	Barellan	1685·	37·2	123·	9·53	−6·43	−2·77	·13	·74
36	Barellan	1302·	5·96	278·	6·82	−·839	−7·17	·11	·90
37	Barellan	1279·	79·2	333·	3·40	−5·15	−26·2	·07	·92
38	Barellan	1480·	56·8	427·	−4·96	−5·54	−38·0	·07	·90
39	Barellan	1721·	−34·4	364·	6·17	1·31	−27·2	·09	·87
40	Barellan	2315·	11·1	329·	−1·56	−1·98	−24·3	·07	·83
41	Barellan	2619·	21·6	285·	6·21	−4·18	−22·0	·07	·83
42	Coolamon	2326·	−5·41	305·	·946	−1·74	−28·2	·09	·69
43	Tootool	2491·	−2·22	172·	−1·62	−1·36	−14·1	·04	·79
44	Tootool	1794·	40·6	294·	7·03	−5·34	−19·1	·08	·89
45	Boree Creek	1209·	−23·7	167·	−5·77	2·37	−12·9	·11	·62
46	Boree Creek	2230·	15·8	64·6	−·667	−2·56	−·371	·05	·70

per experiment. The fertilizers used were ammonium nitrate and double superphosphate (17 per cent P), the wheat variety was Heron and the fertilizers were applied at seeding following local farming methods. The experiments were located in wheat fields distributed throughout a region extending from Tarago-Goulburn in the east to Narrandera-Barellan in the west, and from West Wyalong in the north to The Rock in the south.

2. *Response surfaces*

The data from the field experiments are represented in Table 1 by the coefficients of the response surface model,

$$(1) \qquad Y = b_0 + b_1 N^{\frac{1}{2}} + b_2 P^{\frac{1}{2}} + b_3 (NP)^{\frac{1}{2}} + b_4 N + b_5 P$$

where Y is yield expressed as kg grain per ha, N, P are application rates of nitrogen and phosphorus, as kg N and kg P per ha, and the coefficients are those estimated by the standard least-squares regression procedure. Experience has shown that this model gives a good representation of yield as a function of fertilizer application rates, e.g. (1, 4, 8). The square root scale is preferable to the natural scale for this quadratic model because it gives a more realistic response form with low curvature in the vicinity of maximum yield. The experimental error associated with these estimates of response surfaces can be gauged from the coefficients of variation for the regressions, Table 1, where C.V. = (residual mean square)$^{\frac{1}{2}}$/mean. Values of R^2, the square of the multiple correlation coefficient, are also given. R^2, being the fraction of the sums of squares of deviates attributable to the regression, should not be used to assess goodness-of-fit or the reliability of a regression. For example, where there is no response to fertilizers, the R^2 value for a fitted regression will not differ significantly from zero irrespective of the appropriatenesss of the model or the level of experimental error.

TABLE 2

Single Nutrient and Compound Fertilizers, Compositions and Costs

Fertilizer	Composition N	Composition P	$\frac{N}{P}$	Cost (+ handling) \$/kg fertilizer	Equivalent Cost of 1 + 2
1. Ammonium nitrate	0·34	0·0	∞	0·071	—
2. Superphosphate	0·0	0·096	0·0	0·031	—
3. Compound A	0·12	0·22	0·54	0·104	0·096
4. Compound B	0·15	0·13	1·18	0·082	0·072
5. Compound C	0·18	0·079	2·29	0·082	0·063
6. Compound D	0·20	0·047	4·26	0·069	0·057

3. *The fertilizers*

The fertilizers to be compared are listed in Table 2. These were selected to represent the range of nitrogen-phosphorus compound fertilizers currently available to farmers in the region, with nitrogen/phosphorus ratios ranging from low (compound A) to high (compound D). In addition the single nutrient fertilizers ammonium nitrate and superphosphate are included to give the extremes of this range as well as for the calculation of optimal simultaneous rates for comparison with the compounds.

Costs of fertilizer application vary with freight charges, handling, etc., as well as the manufacturer's price, and for this study these extra costs have been set arbitrarily at \$0.01 per kg fertilizer (\$10 per ton). The costs in Table 2 have thus been obtained by adding \$0.01 to the manufacturer's price. The costs of the compounds can be compared with those of the single nutrient fertilizers, on a composition basis and for this purpose equivalent costs of the nutrients in a mixture of ammonium nitrate and superphosphate, are also given in Table 2. In all cases the compounds cost more than the equivalent of single fertilizers, allowing for the same freight and handling costs. However, unless the farmer has two fertilizer boxes on his seed-drill, or access to blended fertilizers at these prices, this comparison may not be fair, the convenience of a compound justifying some extra cost.

Fertilizer Rates and Assessments

1. *Calculation formulae*

Given the functional relationship (1), defining crop yield, Y, as a function of rate of application of the nutrients N and P in fertilizers, a corresponding function relating profit from the crop to money invested in fertilizer can be derived,

$$(2) \qquad \begin{aligned} \text{Profit} &= VY - C_nN - C_pP - Q \\ &= V(b_0 + b_1N^{\frac{1}{2}} + b_2P^{\frac{1}{2}} + b_3(NP)^{\frac{1}{2}} + b_4N + b_5P) \\ &\quad - C_nN - C_pP - Q \end{aligned}$$

where V is unit value of the yield Y, C_n and C_p are unit costs of the nutrients N and P, and Q is a term representing all costs not affected by rate of fertilizer application. Profit with nil fertilizer is ($V\ b_0 - Q$) so that profit from the yield response to the nutrient applications, N and P, is

$$(3) \qquad \begin{aligned} \Pi = {} & V(b_1N^{\frac{1}{2}} + b_2P^{\frac{1}{2}} + b_3(NP)^{\frac{1}{2}} + b_4N + b_5P) \\ & - C_nN - C_pP \end{aligned}$$

Typically this profit function is of a diminishing form such that increments in investments in the nutrients N or P give corresponding increments in profit, and these latter decrease as N or P increase. In terms of the calculus the rates of return $\frac{\partial \Pi}{\partial (C_nN)}$ and $\frac{\partial \Pi}{\partial (C_pP)}$ decrease as N and P increase, and equal zero at the point of maximum profit. The *optimal* rates of application of N and P are thus simply defined as those rates that satisfy the equations,

$$\frac{\partial \Pi}{\partial (C_nN)} = \frac{\partial \Pi}{\partial (C_pP)} = R$$

where R is a minimal rate of return on the last differential investment in fertilizer. An appropriate value for R should be chosen from a consideration of the rates of return on alternative investments that are available to the farmer. For the profit function (3) these equations may be written,

$$2\left[b_4 - \frac{C_n}{V}(R + 1)\right]N^{\frac{1}{2}} + b_3P^{\frac{1}{2}} = -b_1$$

(4)
$$b_3N^{\frac{1}{2}} + 2\left[b_5 - \frac{C_p}{V}(R + 1)\right]P^{\frac{1}{2}} = -b_2$$

It can be shown that this derivation of optimal rates is equivalent to the corresponding derivations based on the formulation of isoquants and isoclines, e.g. [7].

Calculations of fertilizer rates by (4) are only valid if the response to each fertilizer is of the diminishing form and if extrapolation errors are avoided. Problems arising from non-diminishing forms have been described elsewhere [6] and a computer program with appropriate checks has been written to cover such problems in the calculation of optimal rates [5].

The calculation of the optimal application rate of a compound fertilizer is similarly the solution of the equation,

$$\frac{d\Pi}{d(C_wW)} = R$$

where W is rate of application of the compound and C_w is cost of a unit of the compound. The yield function for response to W can be derived directly from a yield function for individual nutrient rates by substitution of N = nW, P = pW where n, p are the proportions by weight of the respective N and P constituents in the compound. Thus the function,

$$Y = b_0 + b_1(nW)^{\frac{1}{2}} + b_2(pW)^{\frac{1}{2}} + b_3(nW)^{\frac{1}{2}}(pW)^{\frac{1}{2}} + b_4(nW) + b_5pW$$

is derived from the response equation (1) and gathering terms,

(5) $$Y = b_0 + (b_1n^{\frac{1}{2}} + b_2p^{\frac{1}{2}})W^{\frac{1}{2}} + (b_3n^{\frac{1}{2}}p^{\frac{1}{2}} + b_4n + b_5p)W$$

or $Y = b_0 + B_1W^{\frac{1}{2}} + B_2W$

where B_1 and B_2 are bracketed expressions in (5). Profit from the fertilizer is

(6) $$\Pi = V(B_1W^{\frac{1}{2}} + B_2W)$$

and the solution of the equation $\frac{\partial\Pi}{\partial(C_w\ W)} = R$ is

(7) $$W = \left[\frac{B_1}{2(R^* - B_2)}\right]^2$$

where $R^* = \frac{C_w}{V}(R + 1)$. These equations are similar to (3) and (4) given above.

This calculation procedure can easily be extended to other yield functions containing more than two nutrients.

2. *Assumptions*

There are many examples of the type of calculation described above for optimal fertilizer rates, e.g. [3]. The calculations usually require assumptions about other factors that can affect the rates (e.g. [2]), these being treated as negligible or irrelevant to a particular situation. Important assumptions required for the present data are as follows.

(1) It is assumed that values of the crop and costs of the fertilizers, V and C_i, to the average farmer are known and that they will remain relatively constant so that the conclusions remain valid. This seems reasonable for wheat grown under Australian conditions. It may be noted that equations (3) and (7) involve the ratio V/C_i so that inflationary variations tend to cancel.

(2) A value for the marginal rate of return, R, has to be assumed. The optimal rates and the optimal ratio N/P for a compound or fertilizer mix varies curvilinearly with R as can be shown by calculating $\frac{\partial N}{\partial R}$, $\frac{\partial P}{\partial R}$ or $\frac{\partial (N/P)}{\partial R}$ from equations (3). For the present data, the ratio N/P decreases with increase of R because of the generally much greater effects of P than N on yields. The effect is illustrated in Fig. 1 by a 3-dimensional representation of the response surface for site 1. This diagram has been drawn by a Calcomp plotter attached to the CDC3600 computer. The graphs show the range of N, P values for positive values of R in the N, P plane and the projection of these values on to the response surface gives the corresponding yield response curve. The curvilinear form of the graph in the N, P plane results in a 3-dimensional curved form of projection on the response surface and this contrasts with the curves for the compound and single nutrient fertilizers.

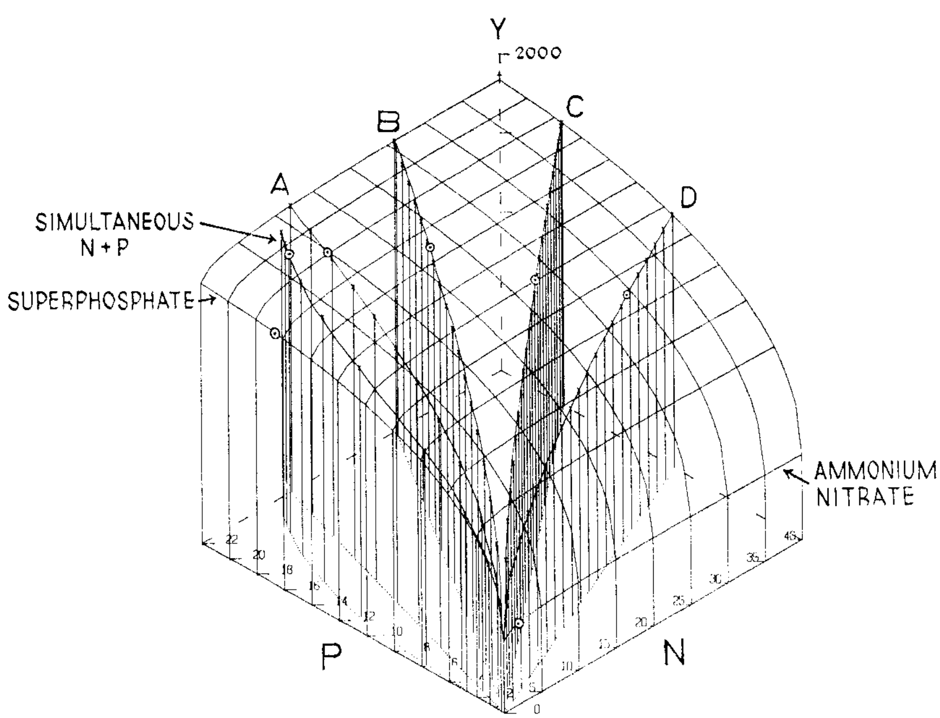

FIGURE 1—Response surface for site 1 as drawn by the Calcomp plotter. The vertical intersecting surfaces represent response to optimal fertilizer rates for positive values of R. Points for R = 0·2 indicated by point in circle.

Too much should not be made of this effect of R on the optimal N/P ratio since for the range of R values that are likely to be important, i.e. in the vicinity of $R = 0{\cdot}2$, the effects are always small. For the region represented by the data, appropriate values of R will range from about 0·1 to 0·5, with about 0·2 appropriate to most farmers. On this basis the assessments and calculations described below are all based on the assumed value, $R = 0{\cdot}2$.

(3) The calculations can in theory be extended to cover the residual effects of fertilizers on subsequent crops, but there seems to be no reliable quantitative data on such effects for both N and P, at least for wheat in the region of the present data. Checks by the author on old experiment sites suggest that such effects, though often very obvious in the colour of subsequent crops, have but small effects on yields. Attempts to measure yield differences due to residual effects have as a consequence been unsuccessful. On this basis it seems reasonable to regard residual effects as negligible for calculation purposes.

(4) For the general application of the results it must be assumed that yield responses will be substantially the same for varieties of wheat other than the variety Heron used for the experiments. Effects of form of fertilizer or of genetic variety on yield response to N and P are not known for the region represented by the data and experiments to determine these effects would require an enormous amount of work over several years. In the meantime it seems reasonable to assume that such effects are likely to be small relative to variations due to site features such as soil nutrient status and seasonal weather conditions.

(5) The effects of fertilizers on yields within a region obviously vary widely between sites and between years because of largely unpredictable effects from variations in soils, weather, farming methods, etc. By treating these variations as random effects, characteristic of the region, the consequent uncertainty on the effects of fertilizers can be described in probabilistic terms and best estimates made of optimal fertilizer rates for the region considered as a whole and on a long term basis. Thus response surfaces calculated from the data of experiments at particular sites can be regarded as samples from a large population of possible response surfaces typical of the region. An adequate sampling would entail experiments at many sites over many years and the present data must be considered accordingly as simply a first sampling from which first estimates can be made of optimal rates for the region as a whole.

3. *Simultaneous fertilizer requirements*

Optimal simultaneous rates of application of the single nutrient fertilizers, ammonium nitrate and superphosphate, indicate ideal application rates of the nutrients N and P and ideally a compound fertilizer would supply the nutrients at the same rates and at the same cost. Accordingly optimal simultaneous rates have been calculated for comparison with the compound fertilizers. The calculations, based on equations (4), were carried out by the computer subroutine FERTS 2 [5], using the coefficients given in Table 1, and putting $V = 0{\cdot}038$ as the unit value of wheat ($ per kg), $C_n = 0{\cdot}209$ and $C_p = 0{\cdot}323$ as unit costs of the nutrients N and P (calculated from values in Table

2) and R = 0·2 as an appropriate marginal rate of return for the region. Optimal rates and corresponding profits from these applications (equation 3) are listed in Table 3.

TABLE 3

Optimal Rates of Application of N and P Simultaneously and of Individual Fertilizers, Calculated for Marginal Return, R = 0 2.

	Optimal Mix of N as NH_4NO_3 + P as Superphosphate				Optimal Rates of Single Fertilizers: Superphosphate		Compound A		Compound B	
	N	P	N/P	Profit	Fert.	Profit	Fert.	Profit	Fert.	Profit
Site	kg/ha	kg/ha		$/ha	kg/ha	$/ha	kg/ha	$/ha	kg/ha	$/ha
1	7	19	0·4	41·78	193	38·15	82	41·00	118	39·08
2	0	11	0·0	11·64	119	11·64	32	8·08	39	6·43
3	0	38	0·0	48·67	392	48·67	125	42·67	164	37·80
4	45	31	1·5	26·18	151	15·07	113	21·95	193	22·99
5	0	10	0·0	9·19	100	9·19	17	4·84	17	3·36
6	0	25	0·0	23·24	259	23·24	72	19·42	85	16·50
7	21	17	1·2	32·33	132	21·11	80	30·09	124	30·92
8	2	27	0·1	49·33	285	48·24	92	46·16	119	41·94
9	0	5	0·0	3·59	53	3·59	13	2·60	13	2·00
10	0	11	0·0	12·96	114	12·96	34	9·74	37	7·42
11	2	5	0·4	6·40	51	5·55	21	6·17	22	5·52
12	13	6	2·2	12·20	69	6·64	36	10·69	53	11·29
13	0	19	0·0	21·30	196	21·30	72	19·42	85	16·50
14	0	12	0·0	14·86	121	14·86	29	11·06	35	9·22
15	0	20	0·0	33·45	204	33·45	61	27·63	80	24·14
16	0	12	0·0	13·95	129	13·81	42	12·61	53	11·12
17	35	25	1·4	18·78	191	14·72	95	16·35	152	16·23
18	5	12	0·4	17·02	117	14·63	49	16·56	68	15·70
19	2	15	0·1	11·62	146	10·88	49	10·46	56	8·90
20	8	26	0·3	31·60	297	27·83	97	30·34	120	28·11
21	25	13	1·9	16·77	93	9·51	59	14·21	96	15·06
22	15	17	0·9	31·31	182	22·30	80	30·17	109	30·03
23	0	6	0·0	3·12	67	3·12	15	2·34	16	1·83
24	0	15	0·0	10·43	159	10·28	41	8·68	44	7·18
25	0	17	0·0	11·97	179	11·97	34	8·18	37	6·55
26	1	4	0·3	3·00	39	2·49	15	2·81	18	2·51
27	7	20	0·4	24·47	214	21·37	77	23·57	98	21·88
28	0	14	0·0	9·07	146	9·07	39	7·07	41	5·48
29	0	9	0·0	7·12	92	7·12	22	5·35	25	4·32
30	3	10	0·3	9·59	124	8·51	36	9·06	42	8·31
31	4	28	0·1	20·71	272	19·19	96	18·85	113	16·17
32	15	27	0·6	34·77	237	29·41	116	33·66	170	32·24
33	11	26	0·4	21·57	200	18·10	105	20·54	146	18·77
34	~60	> 56	–	> 35·70	310	16·84	289	33·22	350	30·57
35	13	37	0·4	19·71	234	12·50	128	17·84	128	13·33
36	~20	> 56	–	> 50·70	> 583	> 45·86	296	49·63	362	42·62
37	17	23	0·7	38·42	218	30·29	101	37·27	145	36·52
38	2	19	0·1	38·28	205	37·28	70	36·59	95	33·94
39	0	24	0·0	35·11	246	35·11	95	31·50	136	28·01
40	0	23	0·0	31·24	237	31·22	75	27·58	97	24·27
41	6	22	0·3	27·85	204	25·29	86	26·72	114	24·28
42	0	16	0·0	24·08	164	24·08	55	21·04	72	18·39
43	0	12	0·0	12·29	129	12·29	34	9·56	39	7·84
44	11	28	0·4	34·13	248	28·81	112	32·98	149	30·40
45	0	13	0·0	12·34	136	12·34	27	7·47	29	5·66
46	1	9	0·1	4·56	97	4·35	22	3·68	22	2·96
Average				> 21·92		> 19·22		19·57		17·91

At many sites the optimal rate for N is nil so that the simultaneous rates become simply that for superphosphate, applied alone. For sites

34 and 36 the estimates are extrapolated beyond the range of the treatment levels of the experiments, due to large responses to P. For these sites optimal N rate has been calculated by substituting P = 56, and the value thus obtained is less than the true optimum because of positive interaction effects. Profits calculated for these values of N and P at these two sites are thus less than the potential optimal return and the regional average profit for optimal applications at all sites ($21·95 in Table 3) is thus also slightly underestimated.

The N/P ratio for these optimal rates range from zero to 2·2, suggesting that all of the compounds except D (N/P = 4·3) will be appropriate for wheat production on at least some sites in the region. The compounds should not be assessed, however, simply by comparisons of composition as will now be shown.

4. *Compound fertilizer requirements*

Optimal rates of the compound fertilizers can be calculated by equation (7) and corresponding profits from their application at these rates by equation (6). The potential value of the fertilizers can then be assessed by comparisons of these profits thus allowing for differences of costs, composition and responses to the nutrients. The need for this method of comparison is illustrated by the calculated values in Table 4 for site 12. For this site, optimal rates of ammonium nitrate and superphosphate give an N/P ratio of 2·14. Compound C is closest in composition to this ideal mix with N/P = 2·29, yet profit from its optimal rate is less than for optimal applications of compound B (N/P = 1·18) or D (N/P = 4·26). Clearly fertilizers should not be compared simply on the basis of their composition but rather on basis of potential returns from their use at optimal rates.

TABLE 4

Optimal Rates of Application, R = 0·2, for Simultaneous Applications of Ammonium Nitrate and Superphosphate, and of Compounds A, B, C and D, and Profits from Yield Response to These Applications.

Fertilizer	Rate (kg/ha)	N/P	Profit ($/ha)
Ammonium nitrate + Superphosphate	38·1 + 63·0	2·14	12·20
Compound A	36·4	0·54	10·69
Compound B	52·8	1·18	11·29
Compound C	55·9	2·29	10·70
Compound D	69·3	4·26	10·85

Optimal rates and corresponding profits for the fertilizers superphosphate, compound A and compound B are listed in Table 3 together with rates and profits for simultaneous applications of ammonium nitrate and superphosphate. Comparisons of the profits show that in general the only fertilizers warranting recommendation are superphosphate and compound A. Average profits for these in the region, estimated from the averages in Table 3 are respectively $19·22 and $19·57 so that on a regional basis there is little to choose between these fertilizers.

The profits for superphosphate and compound A may be compared with those for the simultaneous application of ammonium nitrate and superphosphate. The latter profits are always higher both because the N, P rates are optimal and because equivalent amounts of single nutrient fertilizers are cheaper. The average gain of $2·70 and $2·35 over the average profits for superphosphate and compound A would seem ample to offset the inconvenience of handling two separate fertilizers.

Conclusions

This paper demonstrates how data obtained from fertilizer experiments with single nutrient fertilizers can be used to assess the potential values of a range of compound fertilizers each containing the corresponding nutrients in some fixed ratio. To allow for differences in costs and compositions of the fertilizers, optimal rates of application of each are calculated and then comparisons made of the net values of the yield responses to these applications. Thus any range of compound fertilizers can be assessed, given suitable data from a series of fertilizer experiments.

The study has shown that there is a general need for a compound containing phosphorus and a small amount of nitrogen approximating in composition to compound A ($N/P = \cdot 54$). There are, however, clear advantages in the use of the traditional superphosphate, supplemented with some nitrogen fertilizer for nitrogen deficient sites. Thus average profit from optimal use of superphosphate and ammonium nitrate is indicated as being about $21·92 per hectare whereas that for optimal use of the best of the compounds is about $19·57. This compound gives in fact an average profit not much greater than that for superphosphate used alone ($19·22).

These conclusions are based on the optimal applications of the respective fertilizers, allowing for their individual costs and their effects on wheat production. In practice of course it is difficult to estimate optimal requirements but nevertheless this is, or should be, the goal when choosing fertilizer rates and the comparison is accordingly based on the ideal rate for each fertilizer. The conclusions are valid then to the extent that fertilizer practice aims at optimal rates throughout the region.

The conclusions are based on the 46 response surfaces listed in Table 1 and their validity for the region as a whole is limited by the representativeness of these surfaces of the responses to be obtained in the region. The response surfaces, regarded as a sample of the soils, weather conditions, farming methods, etc., of the region, indicate a wide diversity of response and fertilizer requirements so that there is an obvious need for a larger and more comprehensive sampling, both with respect to location and time. More extensive data may indicate bases for stratification such as type of soil, location, land-use history, etc. Attempted stratifications of the present data on the basis of location within districts, and of Great Soil Group [9] did not, however, indicate any worthwhile groupings of the data. Land use and fertilizer histories seem to be the main source of variations, apart from the more or less unpredictable effects of seasonal weather. Some improvement is possible on the basis of soil tests for phosphorus requirements and current work is in progress investigating this possibility. There seems no prospect, however, of estimating nitrogen requirements by soil tests with any worthwhile precision, so that the most important need seems to be correlations of land-use histories with fertilizer needs. Such work would logically cover both nitrogen and phosphorus requirements.

Finally it is stressed that this study was not intended to provide a comprehensive survey of important fertilizers for the region, but rather to present the sample of response surfaces (Table 1) and to demonstrate how this sample could be used to compare fertilizers, allowing for local costs, value of wheat and appropriate marginal rates of return on the investment. The conclusions might well be altered by different fertilizer prices, particularly by a decrease in price of N fertilizer or of compound fertilizers.

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