Economic, Agronomic and Environmental Impacts of Varied Soil Testing Philosophies

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Years of intensive soil fertility research at agricultural experiment stations with associated soil test calibration efforts have established the reliability of soil testing as a means for predicting nutrient needs of crops to be grown. Well accepted though the practice of soil testing is, real philosophical differences have developed on test interpretation with increasing numbers of concerns doing testing for farmers. This has resulted in radically different fertilizer recommendations going forth to farmers with attendant erosion in credibility of soil testing. It was the purpose of the investigation reported here to determine how well the economic, agronomic and environmental interests of agriculture were being served by soil testing as being practiced in Nebraska and to acquire further assurance of the adequacy of University recommendations for satisfying those interests.

Three different concepts are commonly in use by the various organizations doing soil testing, viz. 'cation saturation ratio', 'nutrient maintenance', and 'sufficiency level'. The first of these projects an ideal soil as one having the following distribution of exchangeable bases: 65% calcium, 10% magnesium, and 5% potassium, or Ca/Mg ratio of 6.5, Ca/K of 13, and Mg/K of 2. Outside these ratios one or the other of Mg or K would be considered deficient. The 'nutrient maintenance' concept implies that, irrespective of soil test level, an amount of nutrient should be added to replace that expected to be removed by the crop to be grown. The 'sufficiency level' approach, finally, is based on soil test calibrations that reveal no yield response to an applied nutrient when the soil tests above a certain level.

Soil Sampling and Crop Management

Reported here are results on four major soils of Nebraska comparing corn yields from treatments recommended by the five laboratories doing most of the soil testing in the state, one of which being the University's. In the first year of the study a representative soil sample was collected from the entire experimental area of each site, which was then thoroughly mixed, split into five subsamples, and sent to the various laboratories, A-D being commercial labs, E the University's. In subsequent years, each laboratory received a sample from each site composited from all replicated plots to which fertilizer had been applied according to that lab's recommendations. All samples were sent 'blind' under farmers names such that no laboratory, including the University's, would recognize the sample as representing other than a farmer's production field. By the end of the 1981 crop season yield results had been acquired from 32 field comparisons which are summarized here. This should have given sufficient time interval for all labs' objectives in soil testing to be realized.

All nutrients recommended by the various laboratories were broadcast and incorporated before planting a high yielding corn hybrid adapted to

1/ This paper is a contraction of one prepared by Olson, Frank, Grabouski and Rehm published in the Oct. 1982 issue of Crops and Soils.

the specific locality. Cultural practices included planting in 76-cm rows at an average 60,000 seeds/ha for the irrigated sites, 45,000 non-irrigated, with irrigation, cultivation and pest control practices applied as needed for each site. Fertilizer costs expressed in the accompanying figure were average retail costs for the nutrients during the spring peak consumption period for the years involved.

Following the 1980 harvest soil samples were taken of the surface 15 cm and by 30 cm increments throughout the 180-cm profile of all plots at each location. Determinations were made of soil nutrients in these samples by the University's laboratory for registering any changes in soil properties that may have transpired with the different labs' fertilizer programs.

Soils Characterized

Soils employed for the investigation are Sharpsburg silty clay loam on the Mead Field Station, Hastings silt loam on the South Central Station, Moody silt loam on the Northeast Station, and Cozad silt loam on the North Platte Station (Table 1). The Sharpsburg, Hastings and Moody upland soils

Table 1. Characteristics of soils and yield objective at the four experimental sites.

Soil property, management practices or objective	Mead Field Station	North Platte Station	South Central Station	Northeast Station
Soil type	Sharpsburg sicl	Cozad sil	Hastings sil	Moody sil
Moisture regime	Irrigated	Irrigated	Irrigated	Non-irrigated
Parent soil material	Loess	Loess/alluvium	Loess	Loess
Yield objective	170 bu/a	170 bu/a	190 bu/a	90 bu/a
Time period	1973-80	1974-80	1974-79	1974-80
	Chemical Properties of Surface Soil1/			
pH	6.6	7.0	6.8	6.0
C.E.C., meq/100g	22.9	14.5	22.3	26.3
Ca saturation, %	62.4	78.3	69.1	56.8
Mg saturation, %	15.6	14.4	11.0	17.7
K saturation, %	3.7	7.6	5.0	2.9
Ca/Mg ratio	4	5.4	6.3	3.2
Mg/K	4.2	1.9	2.2	6.2
Ca/K	16.9	10.3	13.8	19.6

1/ Values for check plots at 1980 harvest time.

developed on loess are three of the most extensive soils in Nebraska embracing in aggregate in the order of 25 percent of the cropped land in the state. The Cozad occupies a large area of central Platte Valley benchland. All are regarded as productive soils with irrigation enhancing production potential at all but the Moody soil site.

A wide range in Ca/Mg ratios from 3.2 to 6.3 will be noted among the four soils, likewise of Ca/K from 10.3 to 19.6, and Mg/K of 1.9 to 6.2. Of further significance is the very high profile levels of exchangeable K^+, generally well in excess of 200 ppm. The large subsoil reserves of available P in most of the soils should presumably have a significant influence on soil P delivery potentials and the recommendations given for P fertilization. The profile pH values for Sharpsburg and Hastings (only surface soil data shown here) are virtually ideal for maximizing overall nutrient availability while the high pH from excess lime in the deep subsoil of Moody and throughout the Cozad soil could possibly impose limitations for certain elements.

Treatment Costs and Yield Effects

Yield goals were reasonably met at all locations throughout the 8-9 year investigation period despite the climatic, pest and other problems inherent in agricultural production (Table 2). There were no significant yield differences from treatments recommended by the various labs except for the South Central Station where yields for lab C were less than those for the other labs. But there were large differences in the kinds and amounts of nutrients advocated with great disparity in average costs for the fertilizer treatments made. Thus, from the purely economic standpoint there can be no question of the superiority of the more conservative fertilizer recommendations of lab E based on the sufficiency approach.

When soil test calibration work of the country's Agricultural Experiment Stations have shown that yield response to applied K is quite unlikely at soil test levels above 100 ppm exchangeable K (other than with cold subsoils in the far north), the rationale for some of the high K recommendations is subject to question with these soils of very high K level throughout the entire rooting profile. Clearly overlooked, too, by most of the commercial labs in their substantial S recommendations are the 10-30 ppm SO_4-S in irrigation water of the irrigated locations, more than enough with nominal irrigation to supply all possible crop S requirements. Also discounted has been the substantial gypsum presence in the calcareous subsoils of Cozad and Moody soils. Of further concern is the common recommendation of some fertilizer micronutrients that have yet to be proved deficient in the cropping of any Nebraska soil.

Soil Residual Effects

Large differences in status of some soil nutrient elements have developed from the varied fertilizer treatments, little or none with others (Table 3). Note that the profile soil NO_3-N level had reached a point with all labs where a substantial reduction in fertilizer N rate should have been possible in 1981. Lab E did indeed reduce its recommendation to 50 kg N/ha for the Cozad soil in contrast with the average 219 kg of labs A, B and D, and no N was recommended for the Moody soil by lab E while the other four labs averaged 77 kg N to be applied. Since there were no yield differences among the 1981 plots and in consideration of ground water nitrate depollution projects already in operation in the state it is quite

Table 2. Soil test recommendations, fertilizer costs and yield response for the soil-test comparison study.

Fertilizer recommendations, ave. annual costs & yields	Lab A	B	C	D	E	Check
			MEAD FIELD STATION, 1973-81			
Ave. ann. recommendation, kg/ha						--
N	240	229	257	208	203	
P	41	37	32	36	15	
K	70	52	59	15	--	
Mg	4	1	--	--	--	
S	6	24	76	8	--	
Zn	3	2	6	2	2	
Mn	2	.3	.4	--	--	
Fe	--	--	--	2	--	
Cu	1	.3	1	.1	--	
B	.1	--	.6	--	--	
Ave. ann. fert. cost, $/ha	161	142	193	129	89	--
Ave. annual yield, kg/ha	9907	9530	9468	9593	9719	4264
			NORTH PLATTE STATION, 1974-81			
Ave. ann. recommendation, kg/ha						--
N	214	225	237	211	178	
P	34	26	16	28	--	
K	7	22	--	--	--	
Mg	3	12	.4	--	--	
S	13	19	69	--	--	
Zn	2	2	7	--	.7	
Fe	.5	.1	--	--	--	
Mn	1	.4	--	--	--	
Cu	.3	.2	1.5	--	--	
B	.6	--	.5	--	--	
Ave. ann. fert. cost, $/ha	126	140	148	104	59	--
Ave. annual yield, kg/ha	10596	10784	10408	10471	10471	6458
			SOUTH CENTRAL STATION, 1974-79, 1981			
Ave. ann. recommendation, kg/ha						--
N	205	193	214	190	171	
P	38	23	19	22	3	
K	39	24	--	--	--	
Mg	3	11	.5	--	--	
S	24	31	48	4	--	
Zn	3	2	6	.7	1	
Mn	1	--	3	--	--	
Cu	.2	.2	1	--	--	
B	.5	.5	.7	--	--	
Ave. ann. fert. cost, $/ha	137	118	133	86	65	--
Ave. annual yield, kg/ha	11537	11474	11161	11788	11725	7775
			NORTHEAST STATION, 1974-81			
Ave. ann. recommendation, kg/ha						
N	75	95	78	124	70	
P	19	12	9	19	2	
K	27	12	7	6	--	
S	10	8	32	2	--	
Zn	2	2	5	1	.3	
Mn	--	--	1	--	--	
Fe	--	--	--	1	--	
Cu	--	.2	.1	--	--	
B	--	--	.4	.1	--	
Ave. ann. fert. cost, $/ha	62	61	68	74	26	--
Ave. annual yield, kg/ha	5392	5330	5455	5330	5455	--

Table 2. Soil test recommendations, fertilizer costs and yield response for the soil test comparison study.

Fertilizer recommendations, ave. annual costs & yields	Lab A	Lab B	Lab C	Lab D	Lab E	Check
			MEAD FIELD STATION, 1973-81			
Ave. ann. recommendation, kg/ha						--
N	240	229	257	208	203	
P	41	37	32	36	15	
K	70	52	59	15	--	
Mg	4	1	--	--	--	
S	6	24	76	8	--	
Zn	3	2	6	2	2	
Mn	2	.3	.4	--	--	
Fe	--	--	--	2	--	
Cu	1	.3	1	.1	--	
B	.1	--	.6	--	--	
Ave. ann. fert. cost, $/ha	161	142	193	129	89	--
Ave. annual yield, kg/ha	9907	9530	9468	9593	9719	4264
			NORTH PLATTE STATION, 1974-81			
Ave. ann. recommendation, kg/ha						--
N	214	225	237	211	178	
P	34	26	16	28	--	
K	7	22	--	--	--	
Mg	3	12	.4	--	--	
S	13	19	69	--	--	
Zn	2	2	7	--	.7	
Fe	.5	.1	--	--	--	
Mn	1	.4	--	--	--	
Cu	.3	.2	1.5	--	--	
B	.6	--	.5	--	--	
Ave. ann. fert. cost, $/ha	126	140	148	104	59	--
Ave. annual yield, kg/ha	10596	10784	10408	10471	10471	6458
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N	205	193	214	190	171	
P	38	23	19	22	3	
K	39	24	--	--	--	
Mg	3	11	.5	--	--	
S	24	31	48	4	--	
Zn	3	2	6	.7	1	
Mn	1	--	3	--	--	
Cu	.2	.2	1	--	--	
B	.5	.5	.7	--	--	
Ave. ann. fert. cost, $/ha	137	118	133	86	65	--
Ave. annual yield, kg/ha	11537	11474	11161	11788	11725	7775
			NORTHEAST STATION, 1974-81			
Ave. ann. recommendation, kg/ha						
N	75	95	78	124	70	
P	19	12	9	19	2	
K	27	12	7	6	--	
S	10	8	32	2	--	
Zn	2	2	5	1	.3	
Mn	--	--	1	--	--	
Fe	--	--	--	1	--	
Cu	--	.2	.1	--	--	
B	--	--	.4	.1	--	
Ave. ann. fert. cost, $/ha	62	61	68	74	26	--
Ave. annual yield, kg/ha	5392	5330	5455	5330	5455	--

Table 3. Average soil test values for the four locations at the end of the 1980 crop season

Nutrient	Lab A	B	C	D	E	Control
Profile NO_3-N, kg/ha	197	181	209	223	190	65
B & K #1P, ppm	43	31	27	45	26	18
Exch. K^+, ppm	419	383	387	389	377	377
Ext. SO_4-S, ppm	14.1	14.4	14.2	13.0	14.0	14.7
DTPA Ext. Mn^{+2}	21.5	20.5	21	21	19.5	19
DTPA Ext. Cu^{+2}	1.1	1.0	1.3	1.0	.9	.8
DTPA Ext. Fe^{+2}	30	28	26	28	24	22
HCl Ext. Zn^{+2}	9.5	8.8	16.1	6.5	7.1	5.3
Ext. B	.9	.8	.8	.8	.7	.6

apparent that profile NO_3-N accumulations must be taken into account not only for economic reasons but the environmental as well.

Only lab A with its most liberal K recommendations has measurably changed the average soil exchangeable K status of the experimental sites. These loess and alluvial soils of very high exchangeable and reserve feldspar mineral K have not changed perceptibly in K level from the control even without supplemental K fertilizer despite the high yields obtained.

As with N and K, differences in extractable soil S, Mn, and Fe have been slight and are not discussed here. Very substantial changes have occurred as an average, however, with extractable P and Zn, modest with Cu, and at least on one soil with soluble B. These changes are not surprising in view of the average 47 kg/ha of Zn applied to plots of lab C in the experimental period for example, and the 214 kg of P by lab D. The soil P and Zn levels have become quite excessive with certain of the labs' programs with potential for accentuating eutrophication of surface waters by the former and the possibility of inducing Fe problems by the two in tandem. The growing Cu concentrations, too, give portent of the possible induction of Cu toxicity problems as have been created in southern France and Florida from excessive use of Bordeaux mixture as fungicide. Likewise, the growing level of B in especially the Hastings soil will have to be a matter of concern.

Otherwise, these residual nutrient measurements give no indication of the 'sufficiency level' approach as practiced by lab E causing a depletion of soil nutrients with potential lowering of future soil productivity. There appears to be no cause for concern on this issue so long as continuous surveillance maintains soil test values above the sufficiency level. This does not mean to say that a farmer should not take advantage of a period of favorable fertilizer prices for assuring that sufficiency in subsequent years even though the level is reasonably adequate at the moment.

Conclusions

The introduction of inorganic fertilizers in quantity into the agricultural enterprise since WW II has done more than any other factor toward doubling and trebling average crop yields of the country during the period. Fertilizer is conservatively estimated to be responsible for 40 percent of our grain crop yields today and can be regarded as the input that has made possible the massive agricultural exports of the U.S. in recent times. This investigation was not intended to downgrade this all-important fertilizer requisite and rather was aimed only at enhanced fertilizer use efficiency to the benefit of farmer and country.

The study clearly shows that 'cation balance' is an irrelevant consideration for estimating nutrient needs of corn to be grown on the soils involved since neither K nor Mg responses were obtained notwithstanding the wide ranges of Ca/K, Ca/Mg, and Mg/K involved. The 'maintenance' concept in recommendations does not apply with soils having more than enough of the nutrients measured for optimum yields. Combination of the two concepts results in excessive cost to the farmer and can have unacceptable ramifications with some nutrients. This leaves the 'nutrient sufficiency' concept as having the greatest promise for providing most economic yields, requiring only regular surveillance in keeping the soil above the sufficiency level. It is indeed the most conservative of the three approaches and in the long run will assist the conservation of energy, natural resources and an acceptable environment. In realizing these objectives it becomes necessary to make nutrient measurements of not only surface soils but deeper horizons as well, particularly for such mobile nutrients as N. Soil testing must remain as the most viable means available for prescribing fertilizer nutrient needs of crops, and a major commercial input will always exist for getting the job done. Hopefully, the objectives cited can be shared by industry and the university community for the benefit of farmer and country.