REVISED IOWA P AND K RECOMMENDATIONS: NEW SOIL-TEST K INTERPRETATIONS AND SUPPORT FOR A NEW SOIL P TEST

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Recent History of Iowa Phosphorus and Potassium Recommendations

The Iowa soil-test interpretations and fertilizer recommendations for phosphorus (P) and potassium (K) were last updated in 1996 and 1999. The 1996 update involved the most important changes compared with previous recommendations. New soil-test P and K interpretation classes (very low, low, optimum, high, and very high) were developed to classify soil-test values into two sets corresponding to Iowa soils with either low or high subsoil P and K levels. This classification recognized research results suggesting that less topsoil P or K was needed when subsoil nutrient levels were comparatively higher. The probability of yield response to fertilization in the optimum class was considered small, and only maintenance fertilization based on nutrient removal was recommended for this class. No fertilization was recommended for soils testing in the high or very high classes, except for starter fertilization for corn under specific conditions.

The 1999 update added interpretations for the Mehlich-3 (M3) P and K soil tests to existing interpretations for the Bray-1 and Olsen P tests and the ammonium-acetate K test. This update added needed support for a test that measures P and K at the same time and that was being used by many laboratories. All other interpretations and fertilizer recommendations remained the same. The actual impact of this update on soil-test interpretations was minor because interpretation classes for the M3 and ammonium-acetate K test are similar, and interpretations for the M3 and the Bray-1 P tests also are similar. However, two important issues for P testing were emphasized. One was that interpretations for all P tests, including the M3 test, should be based on a colorimetric determination of extracted P. The other was that the M3 and Olsen P tests are better than the Bray-1 test in predicting crop response to P fertilization in many Iowa high-pH (calcareous) soils.

The Iowa fertilizer recommendations have not specified a tillage system or a fertilizer application method. Research conducted during the 1950s to the late 1970s showed no major difference between band and broadcast placement methods for the chisel-plow/disk tillage system, and there was little or no local research for no-till or ridge-till systems. However, the current recommendations only specify that starter fertilization for corn could be advantageous within the high category under conditions of limited soil drainage, cool soil conditions, or with crop residues on the soil surface.

Research and soil testing developments since the middle 1990s justify adding interpretations for a new soil P test, making changes to soil-test K interpretations, and making K fertilizer

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placement recommendations for crops managed with no-till and ridge-till systems. These changes are discussed in this article. Other minor changes are not discussed in this article because they are easily understood from the revised extension publication Pm-1688 "A General Guide for Crop Nutrient and Limestone Recommendations in Iowa". These other changes include adjustments to nutrient concentrations in harvested products and default yield values used to estimate maintenance fertilization and a reorganization of fertilizer recommendations for hay and pasture into fewer tables.

New Soil-Test P and K Interpretations

The Mehlich 3 - ICP Soil Phosphorus Test.

The M3 extractant was developed in the middle 1980s for routine testing of P, K, and other nutrients, and the determination of extracted P was based on a colorimetric method. The most commonly used colorimetric determination method is based on the Murphy and Riley method, in which the intensity of a blue color increases with increasing extracted P. Research comparing this original version of the M3 test and other P tests in Iowa and other regions showed that soil P measured with the M3 test was similar to or only slightly higher (1 to 2 ppm) than P measured with the Bray-1 test in acidic or neutral soils. However, the M3 test often measures more P than the Bray-1 test in high-pH, $CaCO_3$-affected soils. Iowa field calibrations showed that the M3 test is more effective than the Bray-1 test and often as effective as the Olsen test in predicting crop response to P across Iowa soils ranging from approximately pH 5.2 to 8.2. Amounts of K extracted with the M3 or ammonium-acetate K tests are similar.

Adoption of ICP instruments by routine soil testing laboratories has expanded rapidly since the late 1980s. In fact, the ICP method is displacing the colorimetric P determination used with the M3 test because its cost has decreased and several elements can be measured at once. Because molecules injected into a very hot plasma undergo instantaneous vaporization, dissociation and ionization, the ICP method measures other P forms in addition to orthophosphate P. Thus, the P measured with ICP is usually higher than P measured with the colorimetric methods. Although research has suggested that the additional P measured with the ICP method is derived mainly from organic P compounds, no consistent relationships have been found between the additional P measured with ICP and manure application or soil organic matter. Most soil-test interpretations in the USA do not specify the M3 version used, which is creating great confusion because by 2002 approximately 65% of soil testing labs enrolled in the North American Proficiency Testing Program for the M3 test were using the M3-ICP version. Research has shown no significant differences in measurements of M3-extracted K with various determination methods that included the ICP method.

Field calibration research with corn and soybean conducted in Iowa during recent years provide the basis for the first Iowa interpretations for the M3-ICP test. The average soil P measured by the M3-ICP test, the original M3 colorimetric test (M3-COL), and the Bray-1 test across all fields was 31, 19, and 17 ppm, respectively. Fig. 1 shows relationships between P measured by the three tests. The correlation between the M3-ICP and M3-COL tests was high (R^2 = 0.84) and did not change when high-pH sites (7.4 to 8.1) affected by $CaCO_3$ were excluded from the analyses. However, the relationship between the M3-COL and Bray-1 tests across all sites (R^2 =

0.89) was improved significantly ($R^2 = 0.97$) by excluding a site with pH 8.1. Previous Iowa research also showed that the M3 P test is better than the Bray-1 P test for many high-pH soils.

Figure 2 shows the relationships between the corn yield response to P fertilizer and soil-test P measured with the Bray-1, M3-COL, and M3-ICP tests for samples collected from a 6-inch depth. Relationships for soybean are not shown. When Bray-1 data for a one high-pH (calcareous) field is excluded, the figures suggest no major differences in the capacity of the tests to estimate plant-available P. The research sites included chisel-plow/disk, no-till, and ridge-till management, but the tillage system had no consistent effect on the relationship between yield response and soil-test P. A shallower soil sampling depth for the no-till system increased soil-test P (as expected), but did not improve the prediction of yield response. In ridge-till fields, collecting samples only from the ridges (as opposed to both ridges and valleys) increased soil-test P and only slightly improved the prediction of yield response.

Several mathematical models (not shown) were fitted to data in Fig. 2 to calculate critical soil-test ranges. In addition, additional economic and practical aspects were considered to establish interpretation categories for the M3-ICP test. The existing soil-test P interpretation categories for the Bray-1, Olsen, and M3-COL (which were not changed) and the new interpretations for the M3-ICP tests are shown in Table 1. This table is a simplified version of more detailed tables included in the revised publication Pm-1688.

New Interpretations for Soil-Test Potassium.

A need to update Iowa soil-test K interpretations was first suggested during the late 1990s by an increasing frequency of K deficiency symptoms in corn. These symptoms occurred mainly when spring rainfall was below normal, but were observed in other conditions even in some soils that tested Optimum according to current interpretations. Also, field experiments designed to evaluate K placement methods often showed larger than expected yield response in soils testing Optimum, and smaller responses in soils testing High. In previous years deficiency symptoms and large yield responses were seldom observed for the Optimum category.

Recent field calibration trials have confirmed that current soil-test K interpretations sometimes would recommend too little or no K fertilizer for soils with a high probability of yield response. Figure 3 shows the relationship between relative corn yield response and ammonium-acetate soil-test K (results for the M3-K test were similar and are not shown). The white data points represent data for Iowa soil series where crop responses would deviate little from expected responses according to existing interpretations. The black points identify data for soil series in which the response to K fertilizer was larger than current interpretations would predict. Although all soils represented by black points have low subsoil K, the white points include soil series with either low or high subsoil K. Thus, the current sets of interpretation categories (two) based on subsoil K concentration can explain only partially the response differences.

Several reasons could explain increased soil-test K requirements for many soils and large response variation across soils with similar soil-test K values. Ongoing research is addressing these issues and no firm conclusions are possible at this time. However, a very likely reason relates to a 1989 change from interpretations based on analyses of field-moist samples to dried samples. Ongoing research suggests that the average K extraction ratio between field-moist and dried samples used to adjust previous field calibrations was not appropriate for many conditions. As an example, data in Fig. 4 show the difference in extracted K for samples dried at different temperatures relative to a field-moist ammonium-acetate K test. Differences in amounts of K extracted from air-dried or moist samples and the effect of drying samples at 104 or 122 F (40 or 50 °C) varied markedly across soils with contrasting soil series and soil moisture content. These results confirm old research in showing that a uniform drying temperature across labs is critical to achieve comparable results. However, interpretations are complicated because research also suggests that the sample drying effects vary with the initial field moisture, the soil, and history of K fertilization. Preliminary data suggest that soil properties such as texture, clay mineralogy, or cation exchange capacity do not completely explain sample drying effects on extracted soil K or differences in crop response. Moisture relations partly associated with internal soil drainage and landscape position seem important.

The available yield response data suggest two contrasting groups of soil series for which soil-test K interpretations should be different. However, because of the wide data spread below soil-test K values of about 170 ppm and a need to study crop responses for other conditions, the new interpretations were made to apply across all Iowa soil series. Data in Table 2 show, as an example, the current and new soil-test K interpretations and K fertilizer recommendations for corn and soybean grown in soils with low subsoil K. Yield data from numerous field trials established this year that have not been analyzed and new trials should provide information useful to develop specific interpretations for different Iowa soil series or regions in future updates.

Potassium Fertilizer Placement Methods Updates

With reduced tillage, broadcast fertilizers are not incorporated (such as in no-till) or are incorporated in a way that may not optimize early nutrient uptake (such as in ridge-till). Continued broadcast or planter-band fertilization and nutrient recycling with crop residues result in large P and K accumulation near the soil surface. Increased residue cover with conservation tillage improves water availability and root efficiency in shallow soil layers during dry periods but may result in cooler and wetter soils in early spring, which may reduce early crop growth and nutrient uptake. These considerations and increased adoption of no-till management since the late 1980s prompted extensive placement research in Iowa.

Ten long-term studies assessed P and K placement methods for the corn-soybean rotation under chisel-plow/disk or no-till management from 1994 to 2001. Treatments were various rates of granulated fertilizers broadcast, deep banded, and banded with the planter. Approximately 80 additional short-term trials were established on farmers' fields managed with no-till and ridge-till systems. The planter-band treatment was not evaluated in these short-term trials. At fields managed with no-till or chisel-plow/disk tillage, the deep bands were applied at a 5-7 inch depth and at a spacing that coincided with the corn row spacing (usually 30 inches), and planter-applied bands were placed 2 inches beside and below the seeds. At the ridge-till fields, the deep bands were applied through a slit opened either through the center or the shoulder of the ridges and the fertilizer was placed approximately 3 inches below the planned seed depth. Summary results of these studies were published in this series and other publications and only a brief overview is provided here.

The results of the research have shown only small and inconsistent differences between P placement methods for any crop or tillage system. These results confirmed results of Iowa research conducted decades ago. It is noteworthy, however, that no field tested less than 6 ppm in soil-test P (Bray-1) and that only rates of 28 lb P_2O_5/acre or higher were evaluated. Thus, results and recommendations do not exclude the possibility of differences between placement methods (mainly favoring the planter-band placement) when lower fertilizer rates are applied to soils testing very low in P. Results of the K placement studies showed very small and inconsistent K placement differences for crops managed with chisel-plow/disk tillage. However, the results for no-till and ridge-till corn indicated that deep-band K applications often are more efficient than either broadcast or planter-band K (Figs 6 and 7). The differences were more consistent and larger for ridge-till corn than for no-till corn. Responses of soybean to K placement (not shown) were smaller and less consistent than for corn.

Based on these results, the new P fertilizer recommendations do not include specific guidelines for placement methods for this nutrient, except for suggesting starter fertilization under a few specific conditions as was done previously. In contrast to recommendations for P, deep-band K fertilization is recommended for no-till and ridge-till management. However, it is stated that the no-till corn yield increase from deep K banding often is not large and may not offset increased application costs. Large variation in the no-till corn response to deep-band K seemed more related to soil moisture in late spring and early summer than to soil-test K stratification, and responses tended to be larger when rainfall was deficient.

Summary

Recent field calibration research with corn and soybeans provided the basis for an update of Iowa P and K recommendations. Results for the Olsen P, Bray-1, and M3 colorimetric P tests confirmed earlier soil-test P interpretations and no change was made. Increasing use of an ICP method to measure P extracted by the M3 test and unpredictable differences with the standard colorimetric method lead to field-based specific soil-test P interpretations for the M3-ICP test.

Results of ongoing field calibrations for the ammonium acetate and M3 K tests based on dried soil samples showed large variation across soils and conditions, and suggested an urgency to increase the soil-test K levels considered optimum for crop production. Although the change was made uniformly across all Iowa soils, continued research will likely provide information for establishing different soil-test K interpretations for different Iowa soil series or regions in the near future.

Table 1. Soil-test P interpretation categories for four soil test methods and P fertilizer recommendations for corn and soybean.

Soil test	Soil-test category †				
	Very low	Low	Optimum	High	Very high
	ppm P				
Olsen	0-5	6-10	11-14	15-20	21+
Bray-1 or M3 colorimetric	0-8	9-15	16-20	21-30	31+
M3-ICP	0-15	16-25	26-35	36-45	46+
Crop	**Phosphorus fertilizer recommendation**				
	lb P_2O_5/acre				
Corn	100	75	55 ‡	0	0
Soybean	80	60	40 ‡	0	0

† Interpretations shown for the Olsen, Bray-1, and M3 colorimetric tests were not changed. Categories are shown only for soil series with low subsoil P.
‡ The fertilizer amounts recommended for the Optimum category assume corn and soybean yields of 150 and 55 bu/acre.

Table 2. Current and updated Iowa soil-test K interpretation categories for the ammonium acetate and Mehlich-3 K tests and K fertilizer recommendations for corn and soybean.†

Soil-test category	Current recommendations			New recommendations		
		K fertilizer rate			K fertilizer rate	
	Soil-test K	Corn	Soybean	Soil-test K	Corn	Soybean
	--- ppm ---	---- lb K_2O/acre ----		--- ppm ---	----lb K_2O/acre ----	
Very Low	0-60	120	90	0-90	130	120
Low	61-90	90	75	91-130	90	90
Optimum ‡	91-130	40	65	131-170	45	75
High	131-170	0	0	171-200	0	0
Very High	171+	0	0	201+	0	0

† Categories are shown only for soil series with low subsoil K.
‡ The fertilizer amounts recommended for the Optimum category assume corn and soybean yields of 150 and 55 bu/acre.

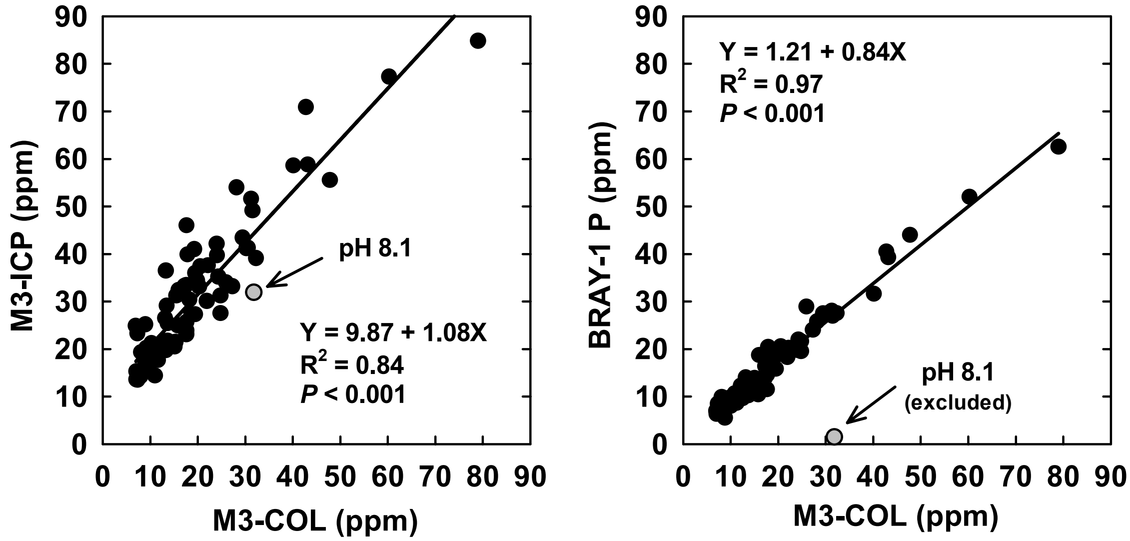

Fig. 1. Relationship between soil-test P measured with the Bray-1 test and the Mehlich-3 extractant with a colorimetric (M3-COL) or inductively-coupled plasma (M3-ICP) determination method.

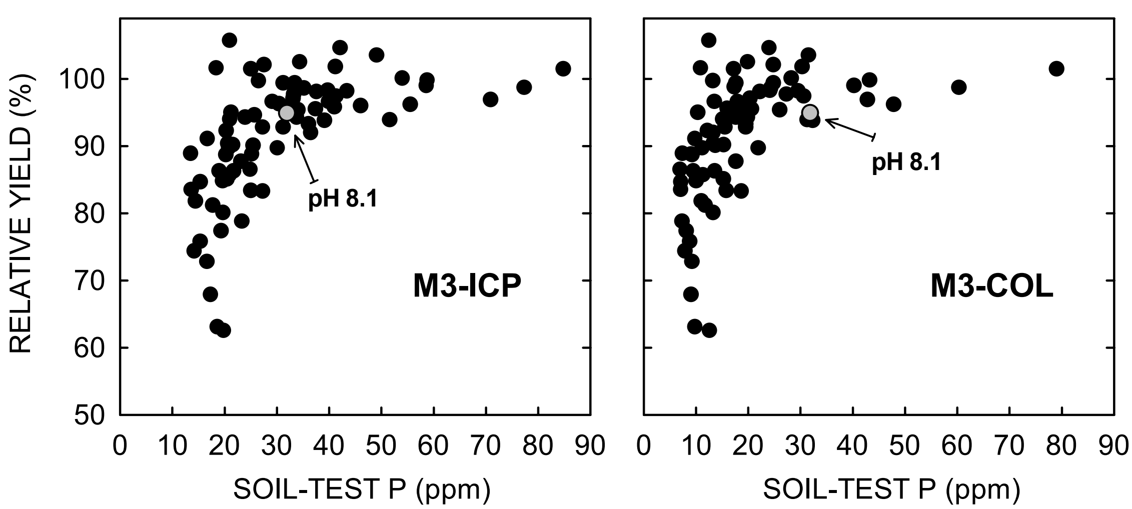

Fig. 2. Relationship between the corn yield response to P fertilizer and soil-test P measured with the Mehlich-3 extractant with a colorimetric (M3-COL) or a inductively-coupled plasma (M3-ICP) determination method.

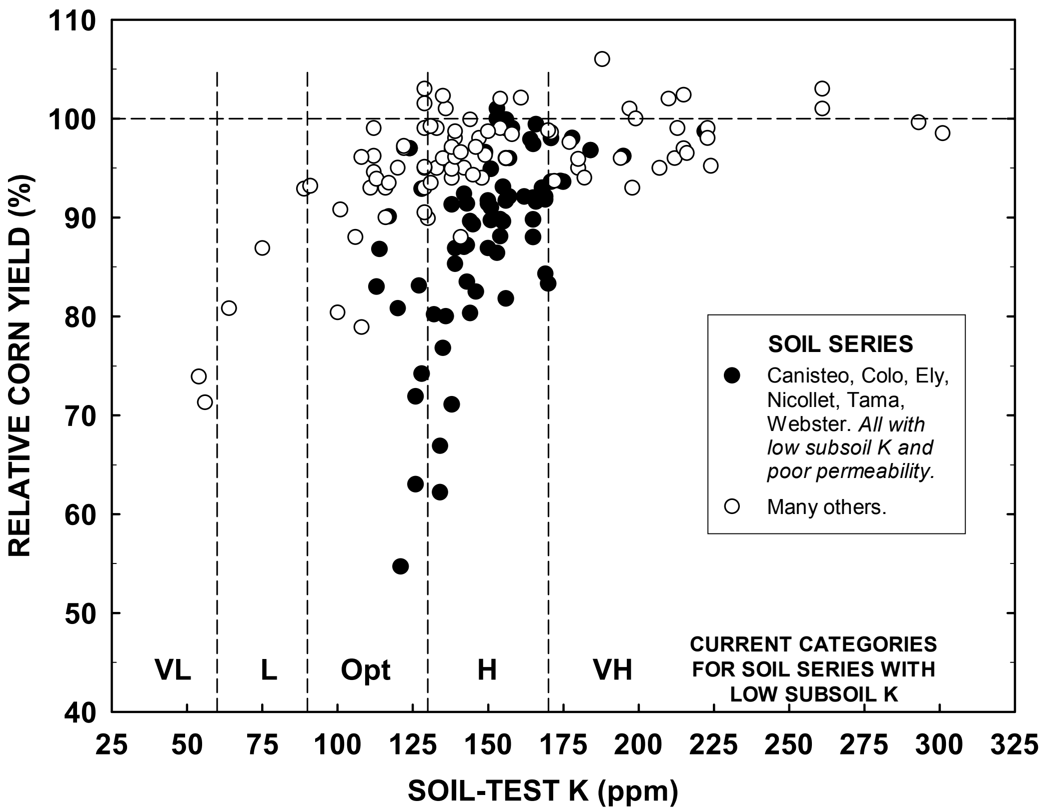

Fig. 3. Relationship between corn yield response to K fertilizer and amonium-acetate soil K test. The interpretation classes shown are those used until 2002 (the relationships and classes for the Mehlich-3 K test were similar).

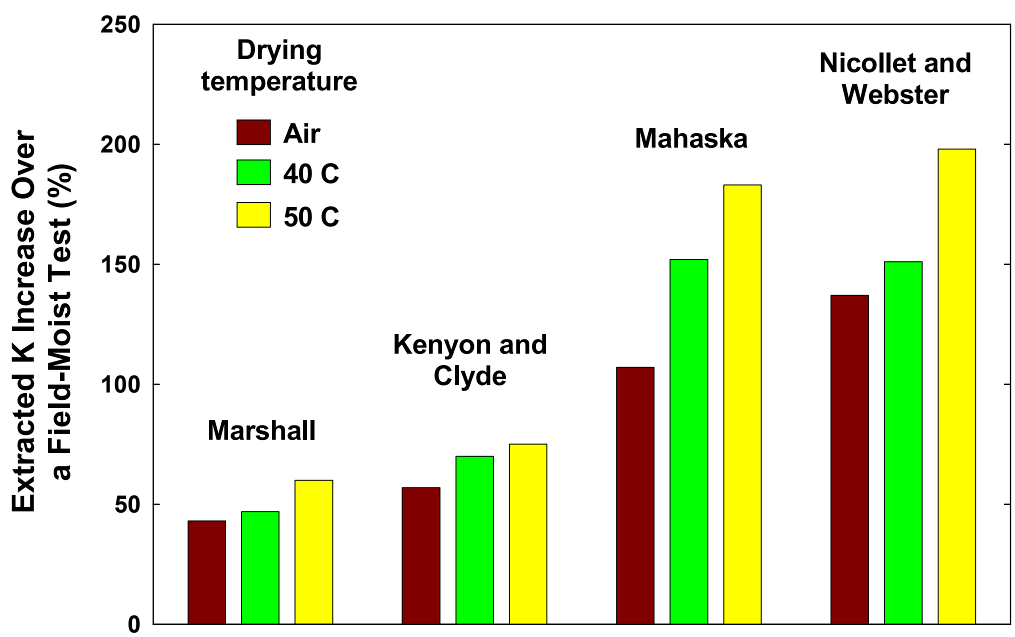

Fig. 4. Example of the effect of the sample drying temperature on soil K extracted with the ammonium-acetate test compared with a field-moist K test for sites with contrasting soil series.

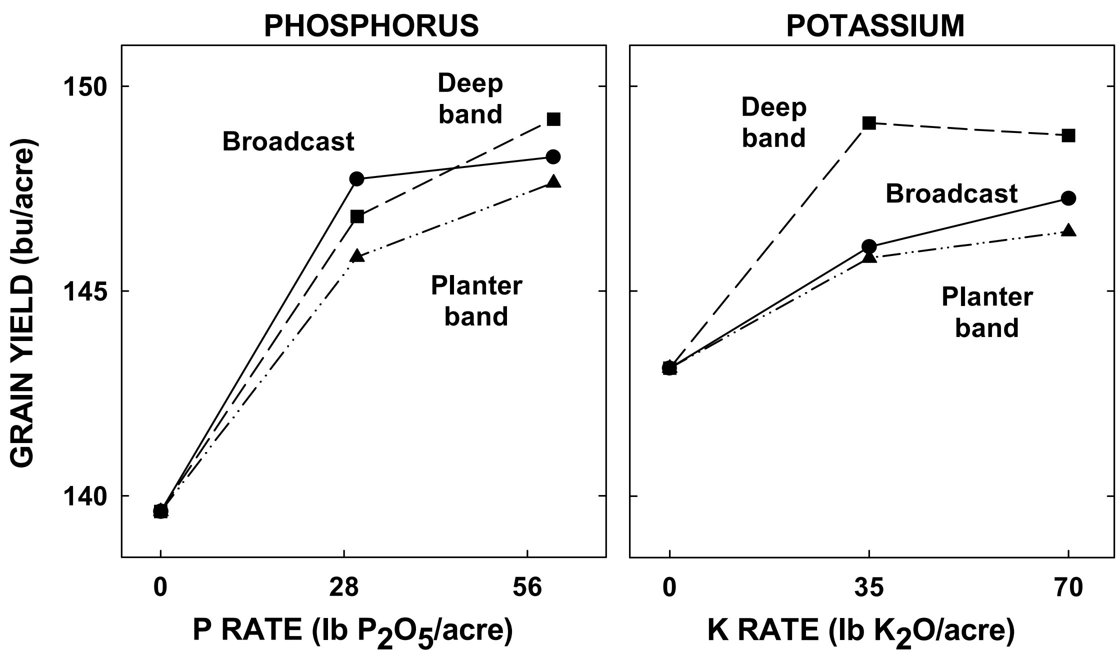

Fig. 5. Yield response of no-till corn to P and K fertilizer placement methods (means across five fields and four years).

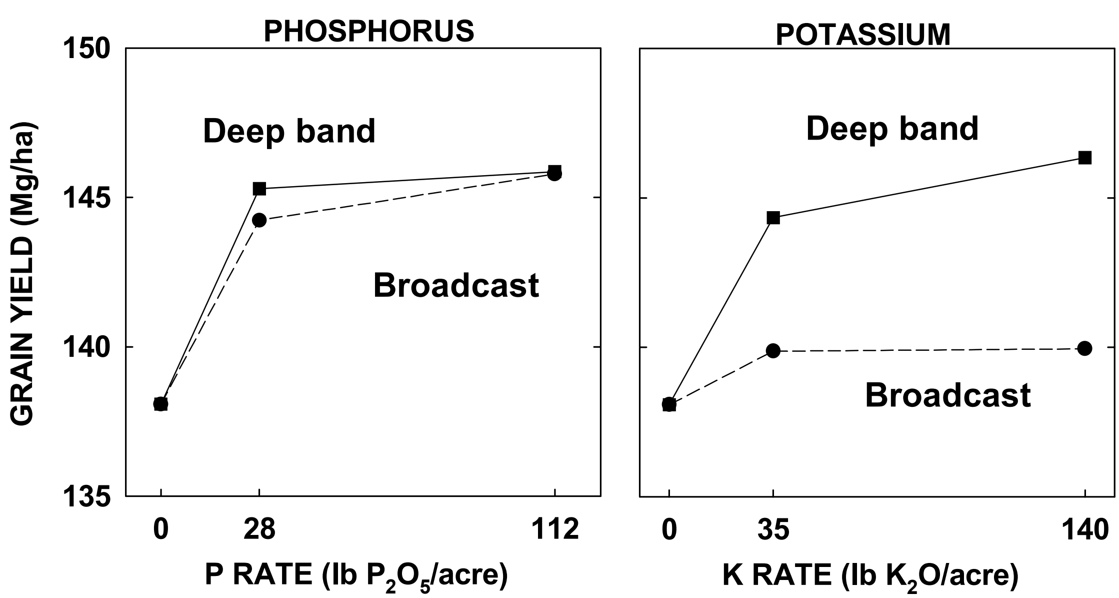

Fig. 6. Yield response of ridge-till corn to broadcast and deep-band P and K fertilizer placement methods (means across15 trials for each nutrient).