Phosphorus Interactions with Other Nutrients

An interaction occurs when the level of one production factor influences the response to another factor. A positive interaction occurs when the influence of the combined practices exceeds the sum of the influences of the individual practices. Such positive interactions have served as the science-based justification for development of a "balanced" plant nutrition program. Positive interactions with P and other nutrients are well documented. In addition, P interactions have been identified with other practices such as crop varieties or date of crop planting.

Phosphorus (P) fertilization practices help to insure an adequate supply of P during peak growth demand periods of a crop. Phosphorus is affected by or affects the availability or utilization of many other nutrients. It improves the effectiveness of other production practices. The effects of P on other nutrients or practices or the effects of other nutrients or practices on P are interactions significant to profitable crop production.

Positive interactions of P with other essential nutrients have been documented in research studies on many crops. Certain crop production practices along with environmental conditions can serve as indicators when P interactions might occur:

- Higher crop yields place greater demand on soil nutrient reserves and applied fertilizer P. The objective is to supply nutrient needs during peak crop uptake periods.
- Liming an acid soil alters nutrient availability to growing plants. It improves P availability to most crops. Liming can reduce availability of micronutrients such as iron (Fe), zinc (Zn), manganese (Mn), or boron (B) and increase the availability of the micronutrient molybdenum (Mo).
- The shift to reduced tillage practices can alter the method of fertilizer application and often results in P accumulation in the surface zone of the soil. Lower temperature and higher moisture and organic matter content in the surface soil can reduce availability and utilization of P by certain crops.
- Solid seeded crops such as soybeans, small grains, or cotton result in more plants per unit area and smaller individual plant root systems. Soil with a high level of fertility is beneficial for optimum plant growth.
- The agronomic adaptation of genetically engineered crops provides greater tolerance to specific herbicides and/or insect protection. Site-specific nutrient requirements are being evaluated. Changes in land topography and the crop rooting zone can result from land leveling, deeper tillage, minimum tillage, and/or loss of topsoil through erosion.

Nutrient Interactions with Phosphorus

Nitrogen (N). Phosphorus and N are both involved in vital plant functions such as photosynthesis, protein formation, and symbiotic N fixation. The primary benefit from band placement of N and P fertilizers is greater P

TABLE 1. Nitrogen/P interaction affects corn yield (Illinois).

N, lb/A	P_2O_5, lb/A	Yield, bu/A	Increase, bu/A
0	0	41	—
200	0	50	9
0	160	58	17
200	160	123	82

uptake because of increased P solubility and proximity to seedling roots. Also, ammoniacal-N fertilizers can improve P availability to plants and thereby improve crop growth. Examples of positive N/P interactions are shown in **Tables 1** and **2**.

Kansas research (**Table 3**) illustrates the beneficial influence of balanced NP fertilization on no-till grain sorghum. Grain yield was increased by more than 13 bu/A, and the period from emergence to mid-bloom was shortened by seven days with proper use of N and P.

Potassium (K). Phosphorus and K are both essential for photosynthesis, enzyme/energy driven reactions, seed formation and quality, stress tolerance, crop maturity, etc. Research has documented cases of P/K interactions, (**Tables 4**, **5** and **6**). They illustrate the agronomic and economic benefits of eliminating P and K as limiting factors in crop production.

Balanced fertility is essential for high corn grain yields. Phosphorus and K each boosted grain yields in a study. Together, they increased grain yield by 64 bu/A, or 38 to 41 bu/A more than when each was applied alone (**Table 7**).

Sulfur (S). Research in California illustrates the effects of a positive P/S interaction on increased forage production and the resulting improved sheep performance due to improved yields and nutritive value of the forage. Phosphorus alone did not increase lamb gain significantly, but the P/S interaction greatly increased production.

Magnesium (Mg). Phosphorus and Mg are essential for photosynthesis and seed formation. Crop uptake of both nutrients tends to decline under cold and wet soil conditions which sets the stage for nutrient interactions.

Micronutrients. Phosphorus interactions with micronutrients have been reported on a wide variety of crops. Interactions with P have been reported for B, copper (Cu), Fe, Mn, Mo, and Zn. Soils with high soil P levels (naturally or through buildup) should be

TABLE 2. Nitrogen/P interactions affect dryland wheat yields and profits (Colorado).

N, lb/A	P_2O_5, lb/A	Yield, bu/A	Prod. costs $/A	Prod. costs $/bu	Net return, $/A
0	0	32	98	3.06	-10
30	0	42	104	2.48	12
30	30	45	112	2.48	12
60	0	38	110	2.89	-6
60	60	58	125	2.16	35

Low soil test P; N 20¢/lb; P_2O_5 25¢/lb; wheat $2.75/bu.

TABLE 3. Nitrogen and P for improved no-till grain sorghum yield and maturity.

Starter, lb/A N	Starter, lb/A P_2O_5	Grain sorghum yield, bu/A	Days to bloom
0	30	88	67
90	0	87	66
90	30	101	59

TABLE 4. Positive P/K interactions can make a difference with soybeans (Virginia).

P_2O_5, lb/A	K_2O, lb/A	Yield, bu/A	Yield increase, bu/A
0	0	24	—
30	0	26	2
0	120	37	13
30	120	45	21

TABLE 5. Phosphorus and K work together for higher wheat yields (average of two varieties).

	K_2O rate, lb/A		
P_2O_5, lb/A	0	40	80
	Yield, bu/A		
0	52	64	64
30	78	84	87
60	77	88	91

With Tilt fungicide; low P and K soil test; N, 75 lb/A.

TABLE 6. Positive P/K interaction increases Coastal bermudagrass yields (Texas).

P_2O_5, lb/A	K_2O, lb/A	Yield, lb/A	Response, lb/A
0	0	5,375	—
0	300	5,294	-81
100	0	6,510	1,135
100	300	9,146	3,771

monitored for a possible micronutrient interaction.

- **Boron.** Phosphorus/B interactions caused a reduced B absorption by corn seedlings grown in an acid soil high in P. However, strawberries gave no significant interaction between P and B.
- **Copper.** Phosphorus/Cu interaction was found when high levels of P accentuated an acute Cu deficiency in citrus seedlings. However, Cu and Zn solubilities can be increased by high levels of P fertilization. This interaction is believed to occur at the site of absorption...possibly with Cu precipitation at the root surface. In other studies, applied P reduced the effect of toxic levels of Cu. Excess Cu can decrease P and Fe absorption.
- **Iron.** Phosphorus/Fe interaction showed up in bush beans grown in either an excess or deficient level of soil P. In either case, Fe absorption was reduced. Both corn and rice, grown on soils containing excess Cu, exhibit severe Fe chlorosis. Heavy P fertilization is often recommended under such circumstances.
- **Manganese.** Phosphorus/Mn interactions can develop when soil Mn availability increases with higher soil P levels. On some soils this is believed partially due to increased soil acidity from high rates of P.
- **Molybdenum.** The P/Mo interaction depends upon whether the soil is alkaline or acidic in nature. For acidic soils, P increases Mo uptake while reducing Mo uptake on alkaline soils. The increase with acidic soils is believed to be the result of enhanced absorption and translocation due to the $H_2PO_4^-$ ion.
- **Zinc.** Nutrient accumulation studies in corn have found P and Zn uptake, translocation, and deposition patterns to be quite similar. Research indicates the tendency of P to depress Zn nutrition is physiological in nature and not due to inactivation in the soil. In high yield environments, negative interactions among micronutrients can develop. Results on corn in Kansas given in **Table 8** illustrate how a negative response can be turned into a positive interaction with proper fertilization.

TABLE 7. Positive PK interaction increases corn grain yields.

	Grain yield	Response
	bu/A	
N (-PK)	113	—
NK (-P)	136	23
NP (-K)	139	26
NPK	177	64

TABLE 8. Turn negative responses on corn into postitive interactions (Kansas).

P_2O_5, lb/A	Zn, lb/A	Yield, bu/A
0	0	131
80	0	119
0	20	109
80	20	175

Agronomic Significance

Crop response to applied P can be improved by making adjustments for time, rate, and method of application. It varies with soil physical and chemical properties, high yield crop management practices, and crop stress conditions such as drought or nutrient deficiencies. Nutrient interactions have been noted for cereals, vegetables, tree, specialty, and row crops.

Early diagnosis of deficiencies of P and/or other nutrients can help minimize losses in crop yield, quality, and farm profitability. In-field inspection, along with soil and plant analyses, helps to provide needed facts for immediate correction and next-season planning. BC