

PHOSPHORUS FOR POTATOES: FERTILIZATION STRATEGIES IN WEST TEXAS

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PHOSPHORUS AND POTATOES

Phosphorus is an essential macronutrient for potatoes and plays a critical role in plant growth and development. Adequate phosphorus is vital for developing stronger roots, promoting tuber initiation and supporting nutrient uptake. Phosphorus contributes to stress tolerance and under sufficient supply, potatoes develop stronger root systems that enable them to extract water from soil layers and enhance water use efficiency. Stronger roots reduce susceptibility to environmental stresses including heat, drought and maintain consistent yields. This is important in semi-arid conditions of West Texas where the cultivated soils often have low phosphorus availability. Phosphorus deficiency results in slow plant growth, weak root systems, delayed tuber formation, uneven tuber set, reduction in tuber size, and overall poor performance of the crop.

Monoammonium phosphate (MAP) and Diammonium phosphate (DAP) are common commercial fertilizer sources of phosphorus. Phosphorus fertilization and cycle involves biological and chemical processes that regulate phosphorus transformation, availability and fate. Phosphorus is immobile compared to nitrogen which can freely move with water in the soil. Once applied, phosphorus availability can be affected due to its reactions with other soil minerals. Plants absorb phosphorus in the form of orthophosphate ions (H_2PO_4^- and $\text{H}_2\text{PO}_4^{2-}$). However, during the transformation in soil solutions, availability of these forms is influenced by soil pH, mineral composition and other soil properties. Phosphorus may precipitate with calcium and magnesium forming insoluble compounds in alkaline soils including those in West Texas. Phosphorus can also be adsorbed by iron and aluminum that influence its availability to potatoes in acidic soils. As the phosphorus pool is replenished by mineralization of organic matter or manure, phosphorus can also be tied up (or immobilized) in crop residues and in soil microbial biomass (Figure 1). These complex interactions and processes highlight the challenges in maintaining sufficient phosphorus availability to potatoes.

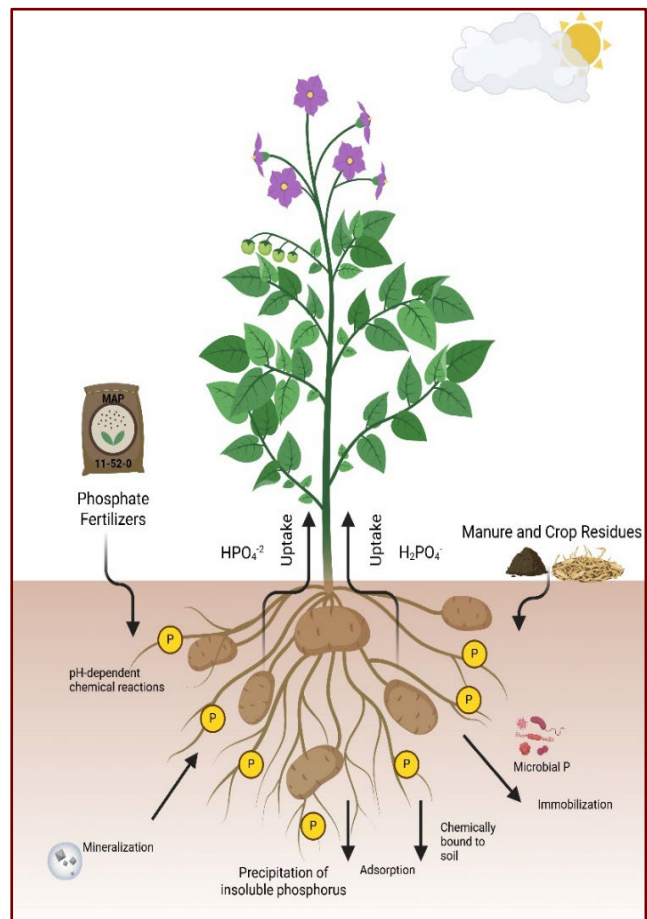


Figure 1. Phosphorus dynamics and movement from fertilizer to a potato plant (Adapted: BioRender).

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Field Trial in West Texas: To evaluate the phosphorus management for potatoes in West Texas, a field research trial was conducted (Photo 1). The soil at the experimental site is a clay loam with pH 7.7 and calcium carbonate (limestone) parent material. Preplant soil analysis indicated 2% organic matter, 4.8 ppm nitrate, 12 ppm phosphorus and 478 ppm potassium. Yukon Gold, which is a popular potato variety known for its thin, smooth, golden skin and yellow flesh was used in this assessment. The experiment was arranged in a randomized complete block design with four replications and potatoes were planted in mid-February 2025, maintaining a plant-to-plant distance of 30 cm. Experimental treatments included phosphorus fertilizer application rates and a control receiving no phosphorus fertilizer. Monoammonium phosphate (MAP) (11-52-0) was applied at rates of 35, 55 and 75 lb P₂O₅ acre⁻¹ (67, 106 and 144 lb MAP acre⁻¹, respectively). Urea (46-0-0) was added to maintain equal fertilizer N rates across treatments. All the phosphorus fertilizer was applied prior to planting in a 8×4 ft plot having two rows of potatoes on 24-inch spacing. Total N fertilizer added was 300 lb N acre⁻¹, with 43 lb acre⁻¹ applied at planting, and the remainder split among four equal applications in April and May. A sprinkler irrigation system was installed, and the experiment was irrigated frequently to avoid water stress. Herbicides pendimethalin (Prowl H₂O) and s-metolachlor (Dual Magnum) were applied at 32 and 16 oz ac⁻¹, respectively, at planting to control annual weeds. Perennial weeds (nightshade) were manually removed to avoid competition between crops and weeds for applied phosphorus treatments. Pesticide Zeta-cypermethrin (Mustang Maxx) was applied at 3 oz ac⁻¹ to control insects and pests.



Photo 1. Potatoes growing in clay loam soil in West Texas (left) and potato plant with tubers at harvest (right) (photo Tajamul Hussain).

What We Measured: Potatoes were manually harvested in mid-June. Three plants were removed, and vines and tubers were separated. Tubers were washed to remove soil and were cut into smaller pieces. All samples were oven dried at 150 °F until a constant weight was achieved. Remaining plants in all plots were harvested to determine potato yields. Soil was sampled (12-in depth) from 6 spots in each plot to obtain a composite soil sample to determine post-harvest soil P. Dried plant and soil samples were ground to pass through a 1-mm sieve and were analyzed for nutrient content. Measured responses were analyzed using mixed models considering phosphorus application rate as fixed effect, and block as random. Significant differences were identified at $\alpha = 0.05$.

What We found: Conducting the research trial under local conditions ensures that the results are applicable to West Texas potato growers. Unlike controlled-environment research, this trial accounted for local soil variability, climatic conditions, and typical management practices. During

the potato growing seasons, mean maximum and minimum air temperatures ranged between 25-104 and 12-78 °F, respectively. Whereas the experiment received 9.2 inches of total rainfall. Statistical evaluation indicated that fertilizer application rate affected tuber yield, vine dry matter, vines, tuber and total plant phosphorus uptake and tuber and total nitrogen uptake. However, phosphorus concentration in vines and tubers and soil residual phosphorus concentration along with vines and tubers and soil residual nitrate concentration were not significantly influenced. Key findings are presented in the following section.

Tuber Yield: Potato tuber yield in all phosphorus fertilized plots was significantly ($p = 0.0007$) higher compared to the unfertilized control (Figure 2). Tuber yield at 35 lb P_2O_5 $acre^{-1}$ was 90% higher compared to unfertilized control. Interestingly, no significant differences were observed among phosphorus fertilizer application treatments of 35, 55 and 75 lb P_2O_5 $acre^{-1}$. Increasing phosphorus application to 55 lb P_2O_5 $acre^{-1}$ only increased the tuber yield by 3% compared to 35 lb P_2O_5 $acre^{-1}$ whereas yield was slightly decreased with increasing phosphorus fertilization up to 75 lb P_2O_5 $acre^{-1}$. This indicates that a moderate phosphorus application at 35 lb P_2O_5 $acre^{-1}$ was sufficient to meet the crop requirements in this season. Regression analysis indicated that tuber yield plateau was achieved at 53 lb P_2O_5 $acre^{-1}$.

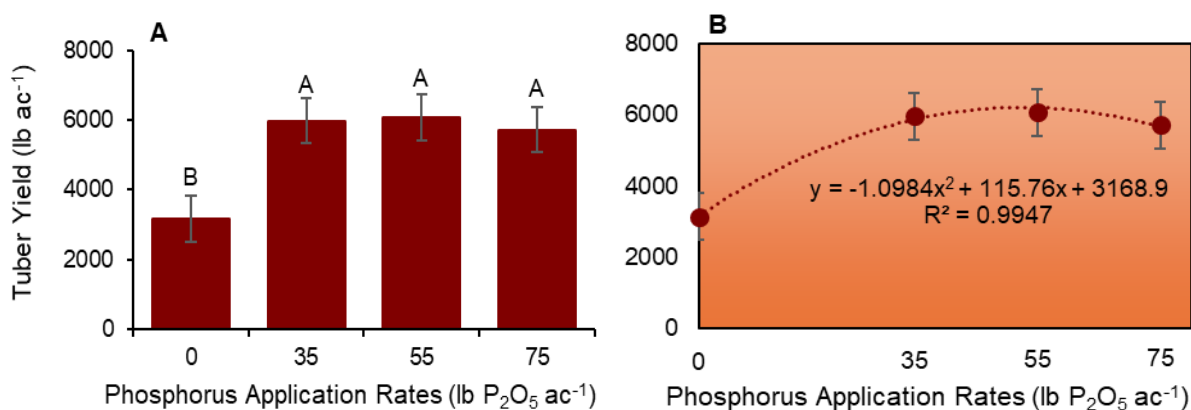


Figure 2. Effect of phosphorus application rates on tuber yield (A) and regression relationship between phosphorus application rates and tuber yield (B) of Yukon Gold potatoes.

Vine Dry Matter: Vine dry matter is a critical indicator of above-ground plant growth and overall plant development. We found that phosphorus application significantly ($p < 0.0001$) increased vine biomass (Figure 3). Vine biomass at 35, 55 and 75 lb P_2O_5 $acre^{-1}$ was 56, 91 and 89 % higher compared to unfertilized control. Similar to tuber yield, no significant differences were observed among phosphorus fertilizer rates of 35, 55 and 75 lb P_2O_5 $acre^{-1}$. However, a considerable increase in vine biomass suggests increased vegetative growth relative to tuber development. While robust vines contribute to greater photosynthetic capacity that supports tuber development, the efficient

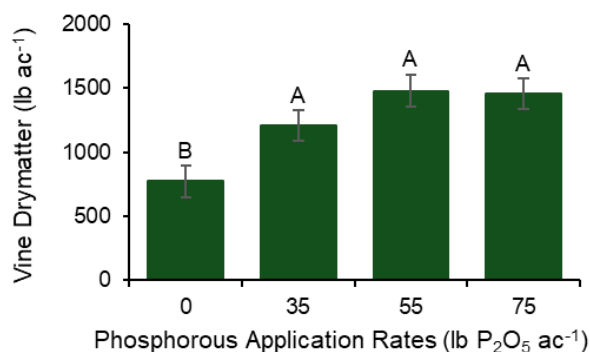


Figure 3. Effect of phosphorus application rates on vine dry matter of Yukon Gold potatoes.

translocation of photosynthates from vines to tubers remains a critical factor. Surplus phosphorus along with sufficient nitrogen supply may prolong vine growth and delay assimilate partitioning leading to decreased proportional gains in tuber yields.

Phosphorus Uptake: Phosphorus uptake increased significantly in both tuber ($p = 0.0236$) and total plant biomass ($p = 0.0097$) under phosphorus fertilization relative to unfertilized plots (Figure 4). This demonstrates that phosphorus fertilization enhances plant ability to fulfill its nutritional requirements. In this assessment, application of 35 lb P_2O_5 acre⁻¹ provided sufficient phosphorus for maximum uptake. Additional increases in P fertilizer application did not result in additional yield. It is critical to apply the optimal amount of fertilizers as over or under fertilization may result in economic or environmental losses. Excessive fertilizer that plant cannot absorb or remain in the potato vines may accumulate in soil. Our findings also support that cost-effective fertilization can enable growers to reduce input costs.

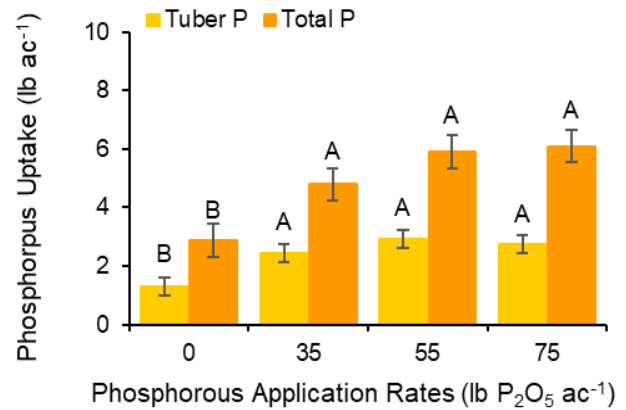


Figure 4. Effect of phosphorus fertilizer application rates on tuber and total phosphorus uptake in Yukon Gold potatoes.

Phosphorus -Nitrogen Synergy: Nitrogen is a key element in plant growth, and N deficiency can cause severe yield losses. In this study, potatoes received sufficient nitrogen in all phosphorus treatments, we also measured nitrogen uptake to better understand the overall nutrient dynamics and crop performance. Results showed that nitrogen uptake improved in all phosphorus fertilized treatments compared to control (Figure 5). This response aligns with well-known synergistic interaction between nitrogen and phosphorus where phosphorus promotes root development which in turn promotes plant's ability to absorb nitrogen efficiently. Nitrogen fertilization in potato production is the most expensive input, therefore this interaction is important for growers as the results indicated when phosphorus nutrition was optimal, nitrogen uptake in potatoes also increased. These findings suggest phosphorus management not only directly improved potato growth and tuber yield but also supported efficient nitrogen use.

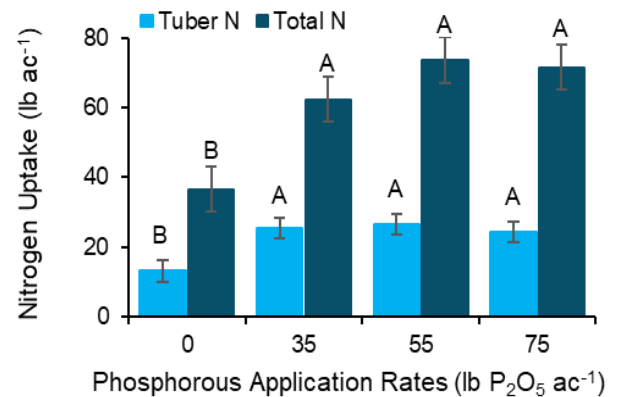


Figure 5. Tuber and total plant nitrogen uptake under different phosphorus fertilizer application rates.

PRACTICAL RECOMMENDATIONS

Based on the findings from our trial, the following recommendations are suggested for potato growers in West Texas:

- **Phosphorus Fertilization:** Sufficient phosphorus should be validated with a soil test, and fertilizer applied before planting when growing potatoes in West Texas. Growers should band

all the required phosphorus below the seed potatoes at planting. Although we obtained yield plateau at 53 lb P₂O₅ acre⁻¹, we recommend soil testing prior to planting to determine phosphorus availability and quantify the phosphorus rate needed. In this way, soil testing is useful to prevent over application. Growers can take soil samples in the top six to eight inches. If phosphorus deficiency symptoms are observed, whole leaf analysis can be performed to better understand crop nutrient availability and phosphorus uptake during the crop growing season.

- **Balanced Fertilization:** Balanced fertilization including nitrogen and potassium helps promote plant growth. As we observed in this study, sufficient and balanced phosphorus and nitrogen supply ensure enhanced nutrient uptake and efficiency.
- **Irrigation:** Potatoes are sensitive to water stress. Limited water supply negatively affects potato plant growth and nutrient availability. In this season maximum temperature reached 104 °F whereas it is well known that if temperatures are over 90 °F, potato tuber numbers and size are affected. Often high temperatures and dry conditions in West Texas can reduce potato performance. Hilling helps moderate soil temperature and reduces soil moisture loss, thereby protecting plants from extreme temperatures and desiccation. It is also recommended to avoid heavy clay soil for potato production. Depending on prevailing climatic conditions and soil, we suggest adequate irrigation for improved nutrient availability and crop yields.
- **Insect, Pest, Disease and Weed Control:** Potatoes are generally exposed to various insects, pests and diseases during crop growth. Insect pests and disease can be controlled using pesticides and fungicides. Most annual weeds can be controlled by application of recommended herbicides. Manual or mechanical options can be used to control perennial weeds to avoid competition for nutrients between weed and potato plants. To control insects, pests, diseases and weeds, growers should use chemicals that comply with current Environmental Protection Agency label registration. Growers should follow label instructions regarding application rate, timing and the safety measures. Make sure to follow any restrictions on the current label of chemical that you may plan to use.

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