

Asian Journal of
Agricultural
Research



Review Article

Role of Phosphates Fertilizers in Sustain Horticulture Production: Growth and Productivity of Vegetable Crops

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Abstract

Phosphorus is one of the major nutrients that play a vital role in the whole plant stages. It is a limiting factor in the growth and productivity of different crops. Phosphorus is used in both synthetic and organic fertilizer forms. Vegetable plants absorb phosphorus as H_2PO_4 . Phosphorus deficiency produces small and dark green leaves, reduces growth and delays fruit ripening, while, excessive phosphorus fertilizing reduced total soluble solids in fruits and affects fruit quality particularly delaying rind coloring. Under arid and semi-arid regions conditions different vegetable crops like potatoes, tomatoes, cucumber, pepper and eggplants, suffering from phosphorus deficiency after a short time of application, which, inhibits the vegetative stage, reduce the productivity of various crops and delays fruit ripening. Therefore, preferable to use phosphorus as a part of fertigation processing which allows accurate timing and uniform distribution of fertilizers to provide adequate nutrient requirements for the crop and increase the efficiency of nutrient use. In addition using phosphate-solubilizing microorganisms such as mycorrhiza fungi increase phosphorus availability for various plants like tomatoes and potatoes, which required relatively high phosphorus.

Key words: Vegetable crops, phosphorus, potatoes, tomatoes, flowering, tuber, fruit

Citation: Abobatta, W.F. and M.A. Abd Alla, 2023. Role of phosphates fertilizers in sustain horticulture production: Growth and productivity of vegetable crops. Asian J. Agric. Res., 17: XX-XX.

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Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

It is well documented that vegetable crops respond well to continuous application of major nutrients, meanwhile, due to excessive use of fertilizers¹. In the last decades, there are trends to use adequate nutrient doses to sustain economic production and protect the environment from pollution^{2,3}.

Yan *et al.*⁴ reported that improving nutrient management in vegetable crops provide two perspectives:

- Sustain natural resource management
- Reducing hazards to the environment

Phosphorus (P) is one of 17 nutritive necessary members of all plants required to complete their life circle and without any surrogate for its functions⁵. The essential macronutrients, N, P and K, are nominated as such since they are most often deficient and not because of their concentration in plants. Although N and K just about always have the highest mineral nutrient concentrations, the secondary macronutrients (S, Mg and especially, Ca) are mostly higher or equal concentrations in plants as P. Phosphorus is involved in every growth stage in every living cell.

Phosphorus plays an important role in whole plant level (Fig. 1), P promotes morphological growth, seed germination, plant height, leaf area, branch number, leaf number, shoot and root fresh matter, development of roots, flower and seed formation, early yield, crop yield and quality, availability of P increases the ages, right from germination till maturity^{4,6}.

Various vegetable crops such as potato (*Solanum tuberosum* L.), tomato (*Solanum lycopersicum* L.), cucumber (*Cucumis sativus* L.) pepper (*Capsicum annuum*) etc., have high demand for different nutrients particularly P during whole growth stages⁷.

Potato is arguably the crop species with the greatest susceptibility to P deficiency⁸. Therefore, deficiency of P in potato cultivation causes a negative impact on the developing

root system and crop productivity, so, adequate applied P improves root growth and increases production⁹.

Phosphorus element plays an essential role in tomato plant growth both at the vegetative and generative phases, therefore, tomato plants required balanced P fertilization to induce growth¹⁰.

In this work, an overview of the role of phosphorus on vegetable crops particularly potato and tomato crops. Also, discuss the importance of P as a specific factor in the growth and production of vegetable crops and the impact of phosphorus deficiency on vegetable crops. In addition to exploring the role of phosphate-solubilizing microorganisms like arbuscular mycorrhiza and phosphate-solubilizing bacteria fungi in increasing P availability for plants for a long time.

Phosphorus and horticulture crops: In agronomy and horticulture, P is vital in nutrient management for achieving maximum crop yields an adequate supply of P is required for optimum growth and reproduction¹¹.

The P is classified as a major nutrient, meaning that it is frequently deficient for crop production and is required by crops in relatively large amounts. The total P concentration in vegetative crops generally varies from 0.1-0.5%¹². Uptake and transport of phosphorus enter the plant through root hairs, root tips and the outermost layers of root cells¹⁰. Microorganisms like arbuscular mycorrhizal fungi and soluble-phosphorus bacteria that grow in the rhizosphere of many crops facilitate uptake of P¹³. In addition, P may be stored in the root or transported to the upper portions of the plant¹⁴.

Phosphorus in the plant: Through different chemical reactions, it is mixed into organic compounds, including nucleic acids (DNA and RNA), phosphoproteins, phospholipids, sugar phosphates, enzymes and energy-rich phosphate compounds for example, Adenosine Triphosphate (ATP)¹⁵.

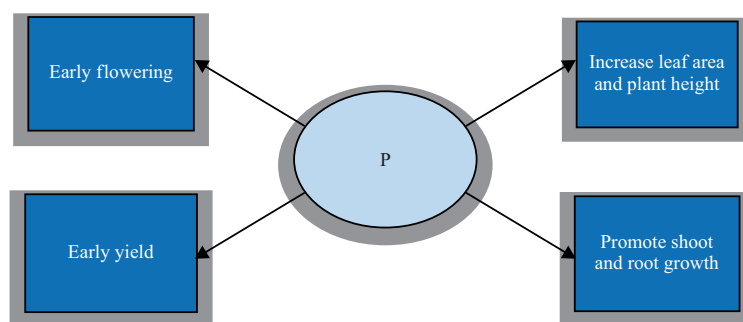


Fig. 1: Schematic for the impact of adequate phosphorus for the plant

It is in these organic forms as well as the mineral phosphate ion that P is mobile throughout the plant, where it is available for furthermore reactions. Plant energy reactions phosphorus has a necessary role in virtually every plant process that includes energy transport. High-power P is held as a part of the chemical structures of adenosine diphosphate (ADP) and Adenosine Triphosphate (ATP). The ADP and ATP are the sources of energy that push the multitude of chemical reactions during the plant. When ADP and ATP transfer the high-energy phosphate to other molecules (dubbed phosphorylation), the phase is set for many vital processes to occur¹⁶⁻¹⁸. The P is a necessary component of the substances that are structure bulks of genes and chromosomes. Therefore, it is the main part of the process of carrying the genetic code from one generation to another. Providing the “planner” for all sides of plant growth and development. Adequate phosphorous is essential to the development of new cells and the transfer of the genetic code from one cell to six. In the case of the plant, p is necessary for many physiological tasks that are included with energy transferences¹⁹.

Effect of P nutrition on vegetable crops

Effects of vegetative growth: The P be a necessary nutrient for potato plants (*Solanum tuberosum* L.) has high phosphorus demand that is required to achieve the desired growth and yield. Potato production systems have a relatively high phosphorus requirement and inefficiently use soil P. Fertilizer phosphorus (P) is a crucial part of potato production systems. Phosphorus promotes rapid canopy development. The P is especially important in uplifting early crop growth. An increase in P concentrations at the beginning of the growing season resulted in rising in shoot length, leaf area and shoot and root weight, linearly²⁰. Thus, under P deficiency (Fig. 2), decreased plant height, total leaf area per plant, shoot dry matter, relative growth rate, leaf number, whole plant relative leaf expansion rate⁸. Low P provided did not influence chlorophyll fluorescence rate, net photosynthetic rate per unit leaf area and leaf dark respiration rate (Balemi and Negisho)¹⁵.

Adding phosphorous (P) fertilizer to tomatoes led to increased growth with plant phosphorus uptake raised, but obvious P regain lowering with increasing in fertilizer phosphorous rate²¹. The P element functions a vital role at both of vegetative plant growth phase and the generative phase, therefore, adjusting its concentration in the nutrient solution is necessary to stimulate vegetative growth¹⁰. Increasing phosphorous fertilizer levels led to a significant increase in morphological growth, plant high, leaf area,



Fig. 2: Phosphorus deficiency of potato

no of the branch, leaf number, shoot and root fresh matter. The rising phosphorus concentration caused a linear increase in seedling growth²²⁻²⁴. The relative growth rate increased pointedly as the phosphorous concentration increased in the plant before it leveled off, resulting in a wide plateau²⁵.

Phosphorus insufficiency reduces plant growth, which is due to either a lack of photosynthesis or increased investment in energy²⁶. The P deficiency reduces the fresh and dry weights of shoots and impairs the morphological features of the roots (Fig. 3).

Growth suppression was linked with reduced photopigment content, net photosynthesis rate, stomatal conductance, transpiration rate and water use effectiveness and increased intercellular CO₂ concentration^{27,28}. Under P deficiency, the total leaf area per plant decreased and this decrease may be due to a decrease in the number of leaves and the small size of the individual leaf. The decrease in the number of leaves in P-deficient plants can be attributed to the decreased leaf initiation and activity of the shoot meristems. In addition, decreased individual leaf size can be due to a decreased rate of cell division or reduced epidermal cell expansion^{11,29,30}. P deficiency leads to a total decrease in shoot biomass. However, the decrease in leaf expansion was not associated with a decrease in the dry weight of the leaves. The dry weight of the leaves was found to be higher due to excess starch or cellulose and hemicelluloses. In general, plant growth characteristics were found to be more sensitive to phosphorous availability than photosynthesis³¹. Anthocyanins usually accumulate on a dark green background, due to the high concentration of chlorophyll caused by decreased cell division and expansion in plants with P deficiency³².

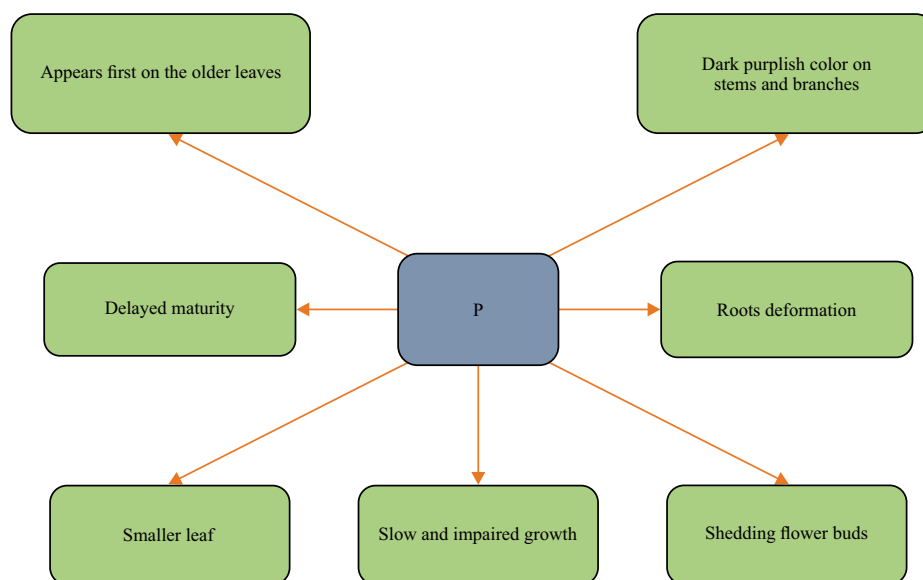


Fig. 3: Schematic for some symptoms of phosphorous deficiency

Effects of flower and yield: Adding phosphorous fertilizer to soils with medium to high levels increases the number of tubers per plant and the total yield of tubers. An increase in the number of tubers increased the yield of smaller tubers and a decrease in the yield of larger tubers. Consequently, the marketable yield was not affected by P fertilizer application. Sufficient P is important for attaining high yields in processing potatoes^{8,33}. Phosphorus promotes tuber set, starch synthesis, tuber yield, solids content, nutritional quality³⁴. The P plays a vital role in improving procreative growth of plants, inclusive of flower and seed formation and seed germination, while phosphorous of seed is the only phosphorous available to plants at the time of germination and helps support early seedling growth¹¹. There are a positive impact of P on flowering and increased fruit number per plant. The increased concentration of phosphorous prevented the flowers from falling and increased the number of flowers from the starting of the generative period to the end, which improved the yield of cherry tomatoes at the end of the vegetative stage^{10,22,35}.

Phosphorus is closely related to yield especially for vegetable crops. P Improved yield contributing characters: Numeral of fruits cluster, the numeral of fruits per plant, early yield, fruit yield, maximum harvest duration harvest index and productivity^{24,36,37}. The addition of fertilizer P should be improved by taking into account the needs of the P crop in conjunction with the actual yield production to ensure that the processed tomatoes are produced in an environmentally sustainable manner²¹. The P adversely affects the yield and

quality of crops. It is estimated that phosphorous deficiency reduces crop yields in 30-40% of the world's arable lands²⁶.

Effects of tuber and fruit quality: The markets of potatoes have specific size preferences, so the effects of P on the number of tubers and the size of the tubers deserve more attention. The yield response to the fertilizer P has received the most interest, but there are also reports that phosphorous can affect the tuber's number, the tubers' size, distribution of the tubers and the increase of the tubers' set^{8,38-40}. The excessed availability of P in the soil enabled the production of tubers with higher dry content, lower sugar content and a higher proportion of starch and protein synthesis. Subsequently, increased starch phosphorylation promoted considerable changes in amylose content as well as thermal and adhesive properties^{8,41,42}. The number and the size of the tubers often have an inverse relationship⁴³, but increases in the number of tubers with P fertilization have been associated with both increases and decreases in tuber size³⁸. The P shows a tendency to increase starch synthesis when applied at rising rates up to a maximum, but unlike N, it speeds up rather than delays ripening. Typically, potato plants deficient in phosphorous produce tubers of less specific gravity compared to those with adequate nutrition of phosphorous⁴⁴.

The increase in phosphorous fertilizer levels increased the fruit properties: Length, diameter, average fruit weight, lycopene, ascorbic acid, pH, total soluble solids (TSS), crude fiber and crude protein content in tomato fruits, except for the moisture content and ether extract^{10,22,45}.

Low P stress in the seedling phase or flowering phase affects the quality of tomato fruits. The major dyes and major organic acids associated with the acidity of the fruit were accumulated differentially as the fruits ripened, while the total content of the soluble sugars contributing to the sweetness of the fruit decreased significantly. These changes are largely attributed to altering enzyme activities in the related metabolic pathways. The low phosphorous pressure had differential effects on the activation of the am-aminobutyric acid shunt which was likely responsible for the preferential accumulation of different organic acids in the tomato fruits⁴⁶.

Effects on the root system: Phosphorous uptake is relatively harder for plants with a superficial and ineffective rooting system, such as potatoes. The low efficiency of phosphorous use in potatoes was primarily associated with a relatively low root to shoot ratio and particularly a low proportion of root hairs^{8,47}. Phosphorous has a necessary role in root growth and evolution, promotes root cell division, stimulating root formation and resistance to some diseases^{8,48,49}.

Effects on P/N ratio: The different ratio of nutrients P/N affects the yield of tomato fruits. Expected that an increase of element N will increase the vegetative growth and delay the flowering growth of the plant, while the increase of element P equates to increased nitrogen absorption the plant development, the numeral of flowers and fruit yield of tomato could be improved⁵⁰.

CONCLUSION

Phosphorus is vital nutrients for vegetable crops to achieve maximum crop yields. In addition, P is a specific factor in the growth and productivity of the different crops. Vegetable plants absorb phosphorus as H_2PO_4 , from both synthetic and organic forms.

Phosphorus deficiency causes adverse effects of some characteristics of vegetable crops like minimizing vegetative growth, flowering, yield, tuber and fruit quality, roots and P/N ratio. Furthermore, phosphate deficiency appears first on the older leaves, produces small and dark green leaves, dark purplish color on stems and branches, delayed maturity, roots deformation, smaller leaf, slow and impaired growth, shedding flower buds. Due to climate change conditions, phosphatic fertilizers convert to unavailable form after, which inhibits the growth and productivity of vegetable crops. Hence, using soluble-phosphorus microorganisms improve the efficiency of phosphatic and increases phosphorus availability for plants for a long time.

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