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# Implications of P and Se Interactions on Maize Growth

**Reham S.M. Elshinawy, Omar H.M. El-Hussieny, Ihab M. Farid*,** and **Mohamed A. Bassouny ***

*Soils and Water Department, Faculty of Agriculture, Benha University, Egypt*

SELENIUM (Se) is an important nutrient for human health; thus its content should be appraised in edible plant parts to satisfy his needs. Its interaction with P in plants is not well identified. Accordingly, a pot experiment of a complete randomized design was conducted to highlight this effect using a soil enriched with Se at a rate of 10 mg Se $kg^{-1}$. Calcium superphosphate was then added at three different rates i.e. 6.7, 13.4 and 20.1 mg P $kg^{-1}$ and all pots were planted with maize seeds (*Zea mays* L f16) and incubated under the greenhouse conditions for 60 days; thereafter soils and plant samples were collected. Generally, maize fresh and dry weights increased significantly owing to application of P at a rate of 13.4 mg P $kg^{-1}$, while decreased with increasing the rate of applied-P. Likewise, AB-DTPA-Se increased significantly in soil; yet such increases were significant only with the application of the highest rate of P. In plants, Se uptake decreased significantly with increasing the rate of applied P. In this concern, there were negative correlations between AB-DTPA extractable Se and maize fresh and dry weights. In conclusion, P inputs at a rate of 13.4 mg P $kg^{-1}$ raised significantly P uptake while diminished the uptake of Se. This probably indicates that P inputs suppress the influx of Se to plant roots. At higher P rates, both Se and P uptake decreased considerably. This might indicate that Se underwent co-precipitated with P in soil.

**Keywords:** *Zea mays* L; AB-DTPA-Se; calcium superphosphate; Se uptake; p uptake**.**

## 1. Introduction

Selenium (Se) was discovered in 1817 via the chemist J.J. Berzelius in Gripsholm, Sweden, who named this new element selenium after "selene" the Greek goddess of the moon (Wisniak, 2000). This nutrient is important for man and animal nutrition (Birringer *et al*. 2002). It is needed for normal functions of the thyroid gland hormones, named triiodothyronine (T3) and thyroxine (T4) and for antioxidant protection (Gorini *et al*. 2022). Moreover, Se is associated with an immune system function and can reduce cancer risks (Rayman, 2000). Recent estimates indicate that 15–20% of the children and adults around the world are suffering from Se deficient (Thavarajah *et al*. 2017). For poultry and livestock, Se can be added directly as a feed additive (Birringer *et al.* 2002), while for human, concentration of this nutrient should be appraised in edible plant parts to satisfy human needs. This may take place via supplying plants with biofortification or Se fertilizers (Longchamp *et al.* 2013; El-Ramady *et al.* 2021 a and b; El-Nahrawy 2022; El-Ramady *et al.* 2023). In this concern, Se is found mainly in soil in inorganic oxidized forms, i.e. selenate (Se(+VI) and selenite (Se(+IV) (Longchamp *et al.* 2013). The ability of plants to absorb and metabolize Se depends on its concentration and the dominant chemical species in soil (Dhillon and Dhillon 2003). Many factors affect its mobility and availability in soils such as redox conditions, pH, EC, $CaCO_3$, organic matter (OM) and clay contents (Eich-Greatorex *et al.* 2007).

On the other hand, P is the second major essential nutrient for plants that is needed for development of roots, cell division, fruit formation and flowering seed (Brady 1984). However, its availability is low in soils because of its high fixation **(**Abbas et al. 2021) as insoluble phosphates of iron, aluminum, and

*Corresponding author e-mail: rehamsaad529@yahoo.com
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calcium (especially in calcareous soil) (Hellal *et al.* 2019). Accordingly, P deficiency has become an important factor restricting plant growth, thus chemical phosphatic fertilizers are widely used to attain optimum yields ( Hellal *et al.* 2019). Excessive uses of P fertilizers may lead to severe environmental problems as heavy metal pollution and eutrophication (Atafar *et al.* 2010; Le *et al.* 2010; Li *et al.* 2014).

Interactions between P and Se in plants are somehow confusing. Although, available Se increases in soil with increasing the application rate of P fertilizers (Liu *et al.* 2004; Mora *et al.* 2008; Nakamaru and Sekine 2008); yet these fertilizers strongly diminish Se distribution within different plant parts (liu *et al*. 2018). A point to note is that P and Se are not within the same periodic group (Li *et al.* 2008). Overall, three scenarios might explain reductions of Se in plants that received P fertilizers (1) the dilution effect owing to increasing plant growth with P inputs, (2) competition on active phosphate transporters with P (Li *et al*. 2008), P with relative superiority for P (Zhou *et al.* 2020) and/ or Se co-precipitation during rapid fixation of phosphate minerals (Ros *et al.* 2016).

The aim of the current study is a trial to find out a reasonable explanation for the interactions between P and Se in soil and plants. In this concern, maize was taken as an indicator plant because it is one of the important grain crops in Egypt that can be used as food and fodder (Farid et al., 2014 a and b). If the uptake of Se increased by plants while its content decreased within plant tissues, then the first scenario becomes acceptable (hypothesis 1). If Se uptake decreased, while P uptake increased, then the competition on the uptake carriers between Se and P seems more sensible (hypothesis 2). Finally, if the uptake of both elements decreased at the highest application rates of P, then the third scenario is more workable (hypothesis 3). We believe that the results of this study may improve our understanding on P and Se interactions in soil and plants and this may help to maintain acceptable concentration of Se in plants for human health.

## 2. Materials and Methods

### *2.1. Materials of Study*

A surface soil sample (0-30 cm) was collected from the experimental farm of the Agricultural Research and Experimental Center, Faculty of Agriculture, Benha University, Egypt (31$^o$ 13′ 24.4″ E. and 30$^o$; 21′ 22.2″ N) This soil is classified as *Typic torriorthent*. Soil sample was air dried, crashed and sieved via a 2 mm sieve than analyzed for its chemical and physical characteristics as outlined by Sparks *et al.* (1996) and Klute (1986).

**Table 1. Chemical and physical characteristics of the investigated soil.**

| Parameter | Value | Parameter | Value |
|---|---|---|---|
| pH* | 7.28 | Sand% | 35.9 |
| EC** (dS $m^{-1}$) | 1.33 | Silt% | 17.3 |
| Organic matter (g $kg^{-1}$) | 10.07 | Clay% | 46.8 |
| Calcium carbonate(g $kg^{-1}$) | 38.5 | Textural class | clay |
| Available P (mg $kg^{-1}$) | 12.026 | Field capacity % | 61.45 |
| Available Se (mg $kg^{-1}$) | 0.31 | Wilting point % | 30.73 |

Soil pH* was determined in 1:2.5 soil:water suspension, while the EC** was determined in soil paste extract.

This sample was then spiked with Se at a rate of 10 mg Se $kg^{-1}$ using Selenium (IV) oxide (ACROS chemicals, purity>99%). *Zea mays* L(F16) was obtained from Techno Seeds Company, Alexandria.

### *2.2. Experimental Work*

Plastic pots of 18 cm height ×22 cm diameter were used in this investigation. Each pot was packed uniformly with four kilograms of the Se spiked soil and received one of the following P rates i.e. 100, 200 and 300 mg $kg^{-1}$ in the form of calcium superphosphate (67 g P $kg^{-1}$) corresponding to 6.7, 13.4 and 20 mg P $kg^{-1}$. This fertilizer contained 27 mg Se $kg^{-1}$ as impurities. All pots were then planted with 6 seeds of maize (*Zea mays L*). Potassium and nitrogen fertilizers were added to all pots at constant rates of 50 and 310 mg $kg^{-1}$, respectively in the form of $K_2SO_4$ (400 g K $kg^{-1}$) and Urea (460 g N $kg^{-1}$) respectively. The whole amount of potassium was applied just before planting, while the amount of nitrogen was divided in three equal doses; the first one was added just before planting, the second was added 10 days later, and the third was applied 25 days after planting. After seedling emergence, plants were thinned to three seedlings per pot and then incubated under the greenhouse conditions for 60 days. During this period, soil moisture was maintained gravimetrically at the field capacity.

Afterwards, whole plants were removed gently from soil and washed with tap water then distilled water several times and left to dry in air. Maize fresh weights were recorded and the plant material was oven dried at 70° C for 48 h to determine their dry weights. Also, soil samples were collected from the rhizosphere on each pot

*2.3. Plant and soil analyses*

All reagent used were of analytical grade. Portions of the dried plant samples, equivalent to 0.5 g was digested with a mixture of concentrated sulfuric and perchloric acids on the sandy hot plate at 250 °C until the digest turned colorless according to Cottenie et al. (1982). Total phosphorus and Se were determined in this digest using spectrophotometer (spectronic20D) and atomic absorption (UNICAM 929 AA spectrometer), respectively.

- Available P and Se were extracted from soil using (AB DTPA) as described Soltanpour and Schwab (1977) then determined by spectrophotometer and Atomic absorption, respectively.

*2.4. Data analyses*

The obtained data was subjected to one way ANOVA and Dunken's test. All figures were plotted with Sigma Plot 10.

## 3. Results and Discussion

*3.1. Effect of increasing P-inputs on plant growth parameters*

Plant fresh and dry weights increased significantly owing to application of P at a rate of 13.4 mg P $kg^{-1}$; yet these biomasses decreased considerably when plants were amended with a higher P rate (Fig .1). This result seems logic because P is a determining nutrient in plant growth and productivity, for example it is a structural element of nucleic acids, sugars and lipids (Malhotra *et al.* 2018). In contrast, excess P produces shallow root system and also decreases primary root growth (Shukla *et al.* 2017). Moreover, excess P immobilizes micronutrient in soil (Abd El-Aziz *et al.* 2020). These factors may, in turn; affects negatively plant growth as found herein for plants amended with P at a rate of 20 mg P $kg^{-1}$. Results also indicate that neither of the number of branches per plant or their heights was affected significantly by P additions

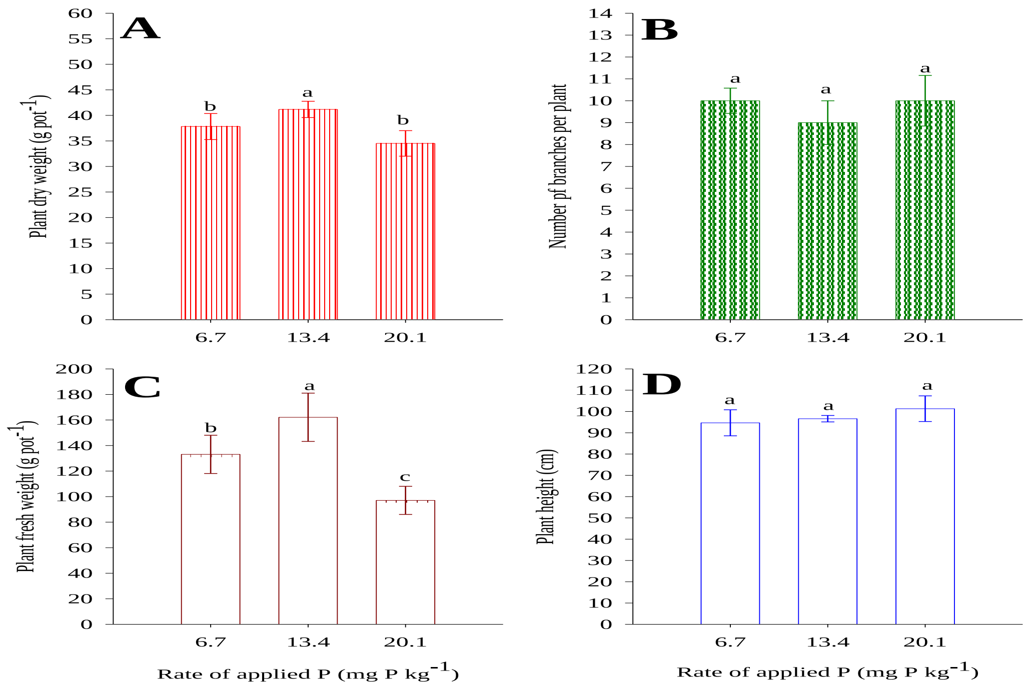


**Fig. 1. Plant growth parameters as affected by the increasing rate of applied P fertilizers. Similar letters indicate no significant variations among treatments.**

*3.2. Effect of increasing P-inputs on the availability of P and Se in soil and their contents within plant tissues*

AB-DTPA extractable P increased significantly in the investigated soil with application of P at a rate of 13.4 mg P $kg^{-1}$ (Fig 2). This consequently raised its content within plants. On the other hand, increasing the rate of applied P from 13.4 to 20 mg P $kg^{-1}$, diminished the AB-DTPA extractable P-content in soil and also reduced their contents within plant tissues.

Likewise, Se available content increased significantly in soil with application of P only at its highest rate Probably, P competed and substituted Se on soil particles; hence raised its mobility in soil (Mora *et al*. 2008; Lee *et al*. 2011). Nevertheless, the uptake of Se decreased significantly with application of P. This result agrees with the findings of Lee *et al*. (2011), Zhang *et al*. (2017), Liu *et al*. (2018), while contradict those of El-Ghanam (2004), Liu *et al*. (2004) and Abou-Zaid (2019).

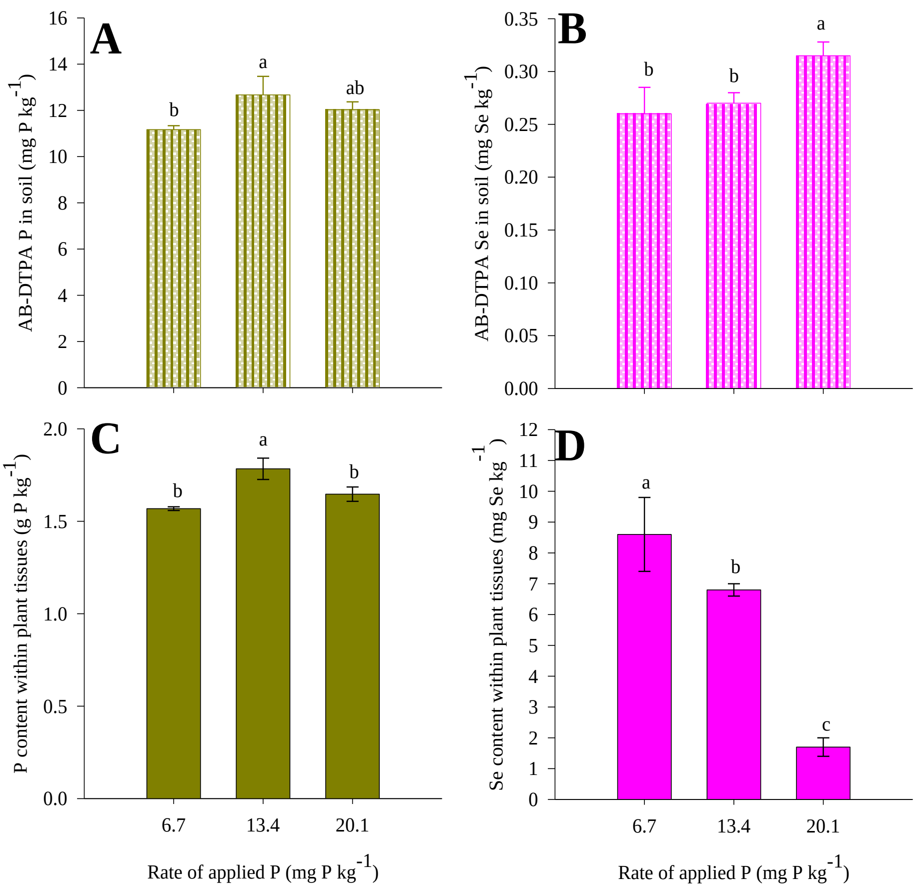


**Fig. 2. AB-DTPA extractable P and Se and their content within plants as affected by the increasing dose of applied P fertilizers. Similar letters indicate no significant variations among treatments.**

Regarding the uptake of these two nutrients by plants, P uptake increased significantly with application of superphosphate at a rate of 13.4 mg P $kg^{-1}$; while decreased with application of 20.1 mg P $kg^{-1}$ (Fig 3). In case of Se, its uptake decreased considerably with increasing the rate of applied P. This result did not support the first hypothesis (the dilution effect of Se with P applications), while support the second and third ones. Maybe the second one becomes valid with application of at a rate of 13.4 mg P $kg^{-1}$ (P uptake increased while Se uptake decreased). The third becomes valid with application of at a rate of 20 mg P $kg^{-1}$ as the uptake of both P and Se decreased significantly at higher P rates.

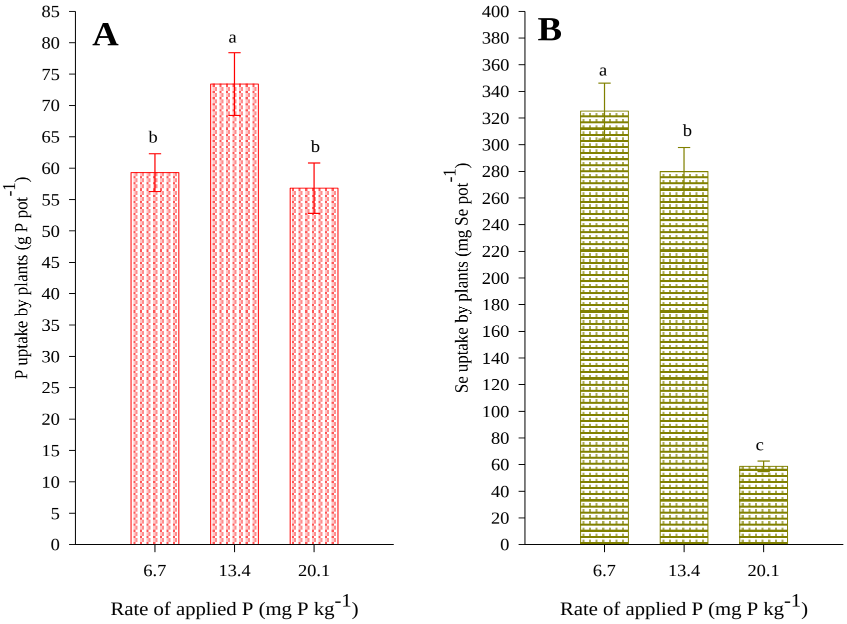


**Fig. 3. P and Se uptake by plants as affected by the increasing rate of applied P fertilizers. Similar letters indicate no significant variations among treatments**

### *3.3. Effect of increasing P-inputs on soil EC and pH*

Soil EC increased significantly with the application of P fertilizer, especially with increasing the rate of P-application (Fig 4). On the other hand, such a fertilizer recorded no significant impacts on soil pH. Probably P fertilizers decrease soil pH (Boukhalfa-Deraoui *et al.* 2015); yet because of the high buffering capacity of soil, mainly due to the presence of organic matter and clay content in soil (Xu *et al*. 2012), such variations were not detectable.

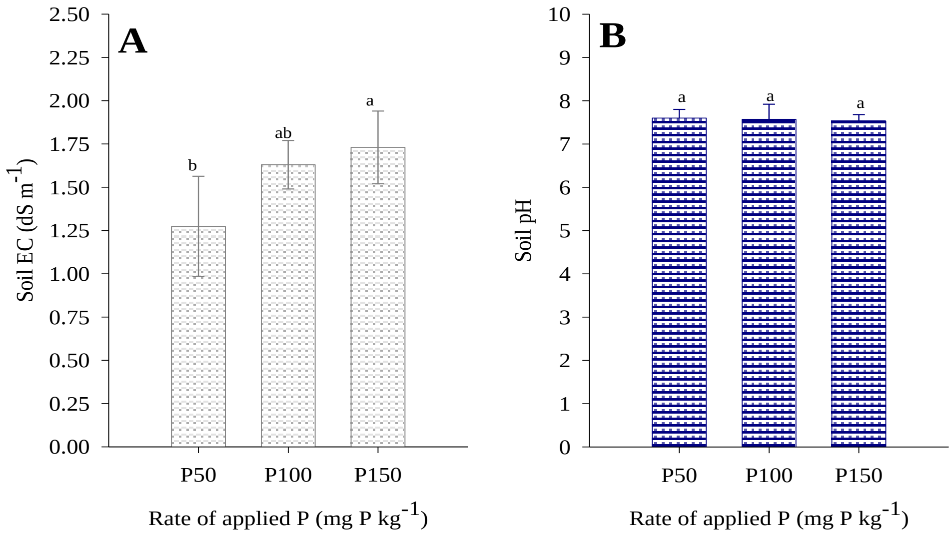


**Fig. 4. Soil EC and pH as affected by the increasing dose of applied P fertilizers. Similar letters indicate no significant variations among treatments**

### ***3.4. Correlation between P and Se in soil and plant***

A negative correlation exist between AB-DTPA Se and Se uptake by plants (Table 2). This result did not agree the finding of Song *et al.* (2018) who recorded that Se content in plant was positively correlated with its available content in soil. Probably, P inputs antagonize Se uptake and therefore this relation was the consequence of such an antagonize effect. Results also reveal that both fresh and dry weights were correlated significantly with AB-DTPA Se in soil. .This finding support those of Hawrylak-Nowak (2008) who reported that the dry mass of maize plants was negatively correlated with increasing dose of applied Se. Finally, P content in plants were correlated significantly and positively with the corresponding ABDTPA extractable P content in soil, while recorded no significant correlations with either AB-DTPA Se or its uptake by plants

**Table 2. Correlation coefficients among AB-DTPA extractable P and Se , their contents in plant and plant growth parameters.**

| | AB-DTPA Se | AB-DTPA P | Soil EC | Se content in plant | P content in plant | Fresh weight | Dry weight | Plant height |
|---|---|---|---|---|---|---|---|---|
| AB-DTPA P | 0.326 | | | | | | | |
| Soil EC | 0.639 | 0.459 | | | | | | |
| Se content in plant | -0.707* | -0.296 | -0.548 | | | | | |
| P content in plant | -0.039 | 0.823** | 0.431 | -0.094 | | | | |
| Fresh weight | -0.808** | 0.207 | -0.294 | 0.582 | 0.514 | | | |
| Dry weight | -0.779* | 0.302 | -0.297 | 0.542 | 0.552 | 0.978** | | |
| Plant height | 0.248 | 0.021 | 0.266 | -0.442 | 0.097 | -0.150 | -0.146 | |
| Number of branches per plant | 0.061 | -0.115 | -0.619 | -0.102 | -0.275 | -0.252 | -0.232 | -0.194 |

*Significant at $P < 0.05$ **Significant at $P < 0.01$

## 4. Conclusion

Application of P fertilizers suppresses the influx of Se to plant roots. Accordingly, Se uptake and content within different plant parts decreased considerably. At higher rate of applied p both Se and P uptake decreased considerably. This might indicate that Se underwent co-precipitated with P in soil.

### Conflicts of interest

There are no conflicts to declare.

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