Improved Efficiency of P Fertilization with Bio and Organic additives on Growth, Seed Quality and Soybean Yield

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ABSTRACT

Two field experiments were conducted at Experimental Farm of Tag El-Ezz, Agricultural Research Station, Dakahlia Governorate, Egypt, during two successive summer seasons of 2019 and 2020 to study the improving efficiency of different P mineral sources with bio, and organic additives as combined treatments on growth performance, quantitative and qualitative productivity of soybean plants (Glycine max L., cv. Giza 111). A split-plot design with three replicates was used, representing three sources of P fertilizers (control, Ordinary superphosphate OSP, and Mono ammonium phosphate MAP) as the main plots, six bio and organic treatments (control, arbuscular mycorrhizal fungi AM, vermicompost V, potassium humate KH, AM+V, and AM+KH) as the subplots. The results were collected briefly as follows: MAP gave the highest values of vegetative growth, yield, its components, and seed quality compared to (OSP) or control. AM+KH had the best-mentioned adjectives compared to other bio and organic additives, where the plants fertilized with AM+V came in the second-order followed by KH then V, and lately AM alone. The combination of MAP and AM+KH was the superior treatment effect on all studied traits compared to the other treatments, the highest P use efficiencies values and (benefit: cost) ratio were achieved from this reaction. The available N, P, K and pH value of soil after the harvest of soybean were improved significantly due to the integration of inorganic fertilizers with bio and organic fertilizers.

Keywords: Mono ammonium phosphate, Mycorrhiza, vermicompost, potassium humate and soybean.

INTRODUCTION

Soybean (Glycine max L.) is among the most important protein and oil crops, where it contains about 40% of protein and 18-22% of cholesterol-free oil as well all some vitamins (Mahrous et al., 2016, Morokhovets, 2016 and Ghaly et al., 2020). In the year 2019, according to the Ministry of Agriculture and Land Reclamation (MALR), the total production of soybeans reached 25000 Mg in Egypt from an area of 9000 hectares.

The phosphorus (P) element is an essential nutrient for all plants, especially legumes e.g., soybean, where its uptake by soybean plants is essential for proper The majority of oil supplies in Egypt is imported; thus, the Egyptian government strategy aims to duplicate the areas for soybeans cultivation. The phosphorus (P) element is an essential nutrient for all plants, especially legumes e.g., soybean, where its uptake by soybean plants is essential for proper nodule formation (Ghaly et al., 2020). In addition, phosphorus plays an essential role in several vital functions such as photosynthesis, transformation of sugar to starch, protein synthesis, nucleic acid production, nitrogen fixation, and oil formation. It is also, part of all biochemical cycles in the plant (Mehrvarz and Chaichi, 2008). And despite that, its availability for plants is limited due to different chemical reactions, especially in arid and semi-arid soils. Plants absorb phosphorus from soil solution as phosphate anion. It is the least moving element in the plant and soil, unlike other macronutrients. precipitated form i.e. orthophosphate is absorbed by Fe\(^{3+}\), Ca\(^{2+}\), and Mg\(^{2+}\) in the soil through legend exchange. A large quantity of P applied as a fertilizer becomes immobile through a precipitation reaction with highly reactive Fe\(^{3+}\), Ca\(^{2+}\) and Mg\(^{2+}\) in the acidic and calcareous, alkaline , or neutral soils (Awasthi et al., 2011). Therefore, the efficiency of P fertilization throughout the world is around 10-25%. Phosphorus availability in soil depends on soil pH were, recorded the highest availability within the range of 6 to 7 of soil pH (Gulmezoglu and Dughan, 2017) Phosphorus availability depends also on other factors like soil physicochemical properties, dominant climate and soil organic matter content and phosphorus fertilizers (Ghoname et al., 2012). Phosphorus fertilizers are the main input of inorganic phosphorus in agricultural soils. The most commonly used phosphatic fertilizers are ordinary superphosphate (OSP), diammonium phosphate (DAP), mono ammonium phosphate (MAP) and NPK. OSP is manufactured from reactions between rock phosphate and sulfuric acid, while MAP is the product of reactions between phosphoric acid and ammonia (Green, 2015). Potassium humate (KH) is a humic acid potassium salt, completely water-soluble (Taha et al.,2016).Fulvic (FA) and humic (HA) acids are the major parts of humic materials, where they lead to an increase in soil fertility as well as nutrients availability by increasing the activity of soil organisms and reducing soil pH value, therefore enhancement of plant growth (Taha, 2018 and Samie et al., 2018). Hemida et al,(2017) illustrated that KH improved N,
P, K, Ca, and vitamin C of snap bean plants compared to untreated plants.

Vermicompost is nutrient-rich organic fertilizer, where the vermicomposting can be defined as a process through which earthworms converts organic residues into compost which can be very beneficial for plant growth (Blouin et al., 2019). The microbiologically active organic decomposition due to interactions during the breakdown of organic matter (O.M) between micro-organisms and earthworms positively affects soil properties e.g., porosity available water capacity, bulk density, porosity and hydraulic conductivity (Demir, 2019) Moghadam1 and coworkers (Moghadam1 et al., 2014) found that vermicompost increased the growth performance and seeds development of soybean relative to the control treatment.

Mycorrhiza inoculant plays an essential role in improving osmotic regulation and photosynthetic rate, enhancing nutrients uptake and water use efficiency as well as improving the growth of plants grown on soil containing low phosphorous levels (Khatab, 2016). Rahmawat et al., (2014) revealed that soybean plants inoculated with mycorrhiza fungi have chlorophyll a, b and total chlorophyll contents in leaves more compared to non-mycorrhiza-inoculated plants. The presence of mycorrhizae in the cultivation of plants can increase the inorganic P uptake by plants because the hyphae of mycorrhizal fungi that live in the root zone also emit phosphatase enzymes that are capable of transforming organic P into inorganic P thereby increasing P availability for plants. (Sasongko et al., 2019).

The integrated supply of nutrients via the bio, organic and mineral sources could be an effective practice to optimize crop productivity. (El-Sheshawy et al., 2019).

Table 1. Average physical and chemical properties of the experimental soil (combined seasons).

<table>
<thead>
<tr>
<th>Sand</th>
<th>Silt</th>
<th>Clay</th>
<th>FC</th>
<th>SP</th>
<th>WP</th>
</tr>
</thead>
<tbody>
<tr>
<td>15.73</td>
<td>38.39</td>
<td>45.88</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Textural class is Clayey</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ca²⁺</td>
<td>Mg²⁺</td>
<td>Na⁺</td>
<td>K⁺</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3.18</td>
<td>6.7</td>
<td>5.62</td>
<td>2.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Soluble anions, meq L⁻¹</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CO₃²⁻</td>
<td>HCO₃⁻</td>
<td>Cl⁻</td>
<td>SO₄²⁻</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5.43</td>
<td>10.74</td>
<td>1.83</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>N (\text{Available element, mg kg} \text{⁻¹})</td>
<td>P</td>
<td>K</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>50.39</td>
<td>7.350</td>
<td>215.5</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

1. Description of the search experience and treatments.

The experimental design was a split-plot design aiming at evaluating the impact of different phosphorus fertilizers as main plots [control, ordinary superphosphate (OSP) and mono ammonium phosphate (MAP)], bio and organic treatments (control, arbuscular mycorrhizal fungi (AM), vermicompost (V), potassium humate (KH), (AM+V) and (AM+KH) as the sub-plots on the performance of soybean plants. Each treatment was replicated three times. The sub-plot size was 10.5 m² (3.5 m × 3.0 m). Seeds of soybean (Glycine max L. Giza 111) were obtained from ARC, Giza, Egypt. The Seeds were sown manually (3-4 seeds hill⁻¹) at a rate of 30 kg fed⁻¹ using one side of the ridge in hills 15 cm apart on the 5th of May in both seasons. Nitrogen in a form of urea (46% N) was applied at a rate of 55 kg N fed⁻¹ in two equal doses after 21 and 42 days from sowing before the first and second irrigations, respectively. While potassium sulfate, (48 % K₂O) was added with the second irrigation at a rate of 50 kg fed⁻¹. Other recommended agriculture practices for soybean as well as irrigation process (flooding system) were done according to the recommendations of MALR. At period of 20 days from sowing, plants were thinned to obtain one soybean plant hill⁻¹.

The experimental treatments were as follows: The first factor (main plots): P₀: Control (without addition). P₁: Ordinary superphosphate (OSP). P₂: Mono ammonium phosphate (MAP).

Fe: Potassium humate (KH) as a single treatment.
F2: AM+V together.
F3: AM+KH together.

Potassium humate was added at a rate of 2 kg fed\(^{-1}\) before and after 21 days from sowing, while plots received vermicompost at a rate of 500 kg fed\(^{-1}\) during soil preparation. Regarding mycorrhiza treatments, soybean seeds were inoculated with mycorrhiza before sowing at a rate of 1.0 kg fed\(^{-1}\) (using sugar solution for 10 minutes until all soybean seeds were thoroughly coated). Calcium superphosphate (15.5 % P\(_2\)O\(_5\)) was added once during soil preparation at a rate of 150 kg fed\(^{-1}\) (equivalent to 23.25 kg P\(_2\)O\(_5\) fed\(^{-1}\)), while mono ammonium phosphate (62.0 % P\(_2\)O\(_5\) and 11.0 % N) was added at a rate of 37.50 kg fed\(^{-1}\) (equivalent to 23.25 kg P\(_2\)O\(_5\) fed\(^{-1}\)) in three equal doses; the first one was at sowing while the 2\(^{nd}\) and 3\(^{rd}\) one were added at 21 and 42 days from sowing. All these fertilizers were provided by MALR, Egypt. Data of both vermicompost and potassium humate analyses are shown in Table 2.

### Table 2. Some characteristics of vermicompost and potassium humate.

<table>
<thead>
<tr>
<th>Vermicompost characteristics</th>
<th>Organic matter</th>
<th>% Total carbon</th>
<th>Total N</th>
<th>C/N</th>
<th>mg kg(^{-1}) Fe</th>
<th>Mn</th>
<th>Total P</th>
<th>% Saturation</th>
<th>pH (1:10)</th>
<th>EC (1:10), dSm(^{-1})</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moisture</td>
<td>FA</td>
<td>HA</td>
<td>Solubility</td>
<td>N</td>
<td>P(_2)O(_5)</td>
<td>K(_2)O</td>
<td>pH</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5.87</td>
<td>3.10</td>
<td>60.5</td>
<td>100</td>
<td>0.48</td>
<td>1.12</td>
<td>11</td>
<td>8.50</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

2. Measurement traits.

**A- Vegetative growth and chemical traits.**

At the period of 65 days after sowing of soybean seeds, a random sample of five plants was taken from each subplot to determine the following criteria:

- **Vegetative growth criteria:** shoot fresh and dry weights as well as roots fresh weight.
- **Photosynthetic pigments:** chlorophyll a, b, total and carotenoids were determined using a method described by (Sumanta et al., 2014).
- **Chemical constituents of leaves:** the samples of soybean leaves were digested with a mixture of H\(_2\)SO\(_4\) and HClO\(_4\) to determine total N, total P and K percentages according to the methods described by (Kalra, 1997).

**B- Yield and seeds quality.**

The following traits were done at a period of 120 days from sowing soybean (harvesting stage).

- **Yield measurements:** Pods, seeds and stover weights (g/plant), the weight of 100 seeds, seed and stover yield (kg/seed) were measured. In addition, plant height was measured as an indicator of treatments effect at harvest stage.
- **Chemical constituents of seeds:** digestion of soybean seeds was done as formerly mentioned in leaves for N, P and K and their determinations were done as formerly mentioned in leaves. While, digestion of seed samples for Mg, Zn and Fe determination was done by a mixture of nitric acid, H\(_2\)O\(_2\) and hydrofluoric acid (Gotteni et al., 1982), where they were determined according to (Chapman and Pratt, 1961) using apparatus of Atomic Absorption Spectrophotometer.
- **P- uptake** was determined according to the following formula:

\[
P-\text{uptake} = \frac{\text{Nutrient concentrations yield/100}}{\text{P-}\text{P}_{2}\text{O}_{5} \text{ applied (23.25 kg fed}^{-1})} \times 100
\]

- **Bio constituents of seeds:** Total lipid and protein content of seeds were determined according to (AOAC, 2016).
- **Fatty acid analysis:** Saturated and unsaturated fatty acids were determined in the oil by using methyl esters boron trifluoride method (AOAC, 2000).
- **Phytic acid analysis:** Phytic acid was determined based on precipitation of phytate according to the procedure of (Wheeler and Ferrel, 1971), using Iron (III) nitrate calibration curve.

**C- Phosphorus -use efficiencies.**

It was calculated as the following formula according to (Naem et al., 2017).

\[
\text{Agronomic use efficiency AUE (kg yield/ P2O5 applied)} = \frac{\text{Seed yield of treated (kg fed}^{-1}) - \text{Seed yield of control (kg fed}^{-1})}{\text{P2O5 applied (23.25 kg fed}^{-1})}
\]

\[
P-\text{recovery efficiency PRE(%) = } \frac{\text{Total P uptake of treated (kg fed}^{-1}) - \text{Total P uptake of control (kg fed}^{-1})}{\text{P2O5 applied (23.25 kg fed}^{-1})} \times 100
\]

- **Partial Factor Productivity (PP) (Kg/kg) = Seed yield (Kg fed}^{-1}) / P2O5 applied (23.25 Kg fed}^{-1}).**

**D-Soil estimates:**

After harvest of soybean, soil samples were randomly taken to determine the following residuals (available N and K) and P forms in soil:

- Available N and K were determined according to (Reeuwijk, 2002). Available P form was determined according to (Olsen and Sommers, 1982). Total P form was determined as described by (Hesse, 1971). Other Inorganic P forms i.e.,Ca-P, Al-P and Fe-P were determined according to (Murphy and Riley, 1962). All P forms were determined using spectrophotometer apparatus.
- Also, soil pH and electrical conductivity values (EC) were determined using a Gallen Kamp pH-meter and electrical conductivity meter (EC meter Model TDiscan 3), respectively (Richards, 1954).

**3. Economic profitability.**

It was done through an account of the total cost, gross return, net return and B: C ratio was calculated as below.

\[
\text{Benefit Cost Ratio (BCR) = Gross return/Total Cost of cultivation}
\]

**4. Statistical Analysis.**

Results from convergent experiments of the 2 years were combined for analysis. Data of the present study were statistically analyzed using CoSTATE Computer Software. The significant differences among the mean of various treatments were established by the Least Significant Differences method (LSD) and Duncan’s Multiple Comparisons Test according to (Gomez and Gomez, 1984).

**RESULTS AND DISCUSSION**

**1. Performance at period of 65 days.**

Data of Table 3 show the impact of different P fertilizers, bio and organic additives and their interactions on...
growth criteria i.e. shoot fresh and dry weights, roots fresh weight (g plant⁻¹), the photosynthetic pigment in fresh weight of leaves i.e. chlorophyll a, chlorophyll b, total chlorophyll a + b and carotenoids contents (mg g⁻¹ F.W) and chemical constituents of leaves i.e., N, P and K percentages of soybean plants at a period of 65 days from sowing.

Table 3. Impact of P fertilizers, bio with organic additives and their interactions on performance of soybean plants during a period of 65 days from sowing (combined data over both seasons).

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Shoot fresh weight</th>
<th>Shoot dry weight</th>
<th>Roots fresh weight</th>
<th>Chl. a</th>
<th>Chl. B</th>
<th>Total chl+a+b</th>
<th>Carotenoids</th>
<th>N (%)</th>
<th>P (%)</th>
<th>K (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>P0</td>
<td>38.87b</td>
<td>10.92c</td>
<td>6.58c</td>
<td>0.438b</td>
<td>0.235b</td>
<td>0.673b</td>
<td>0.148c</td>
<td>4.20c</td>
<td>0.320c</td>
<td>2.42b</td>
</tr>
<tr>
<td>P1</td>
<td>42.61a</td>
<td>11.90b</td>
<td>6.88b</td>
<td>0.454a</td>
<td>0.251a</td>
<td>0.705a</td>
<td>0.157b</td>
<td>4.31b</td>
<td>0.342b</td>
<td>2.56a</td>
</tr>
<tr>
<td>P2</td>
<td>44.46a</td>
<td>12.30a</td>
<td>6.96a</td>
<td>0.460a</td>
<td>0.263a</td>
<td>0.723a</td>
<td>0.162a</td>
<td>4.37a</td>
<td>0.356a</td>
<td>2.62a</td>
</tr>
</tbody>
</table>

Bio and organic additives

| F1         | 27.51f             | 8.72e            | 5.61c             | 0.391f | 0.190f | 0.581e        | 0.118f      | 3.95e | 0.265d| 1.88f |
| F2         | 34.63e             | 10.50d           | 6.14d             | 0.412e | 0.211ae | 0.623d        | 0.136e      | 4.05d | 0.338b| 2.33e |
| F3         | 39.15d             | 11.63c           | 6.70c             | 0.455d | 0.236d | 0.691c        | 0.152d      | 4.16d | 0.316c| 2.48d |
| F4         | 43.42c             | 11.87c           | 6.80c             | 0.468c | 0.255c | 0.723c        | 0.160c      | 4.27c | 0.328bc| 2.70c |
| F5         | 51.21b             | 13.32b           | 7.74b             | 0.483b | 0.288b | 0.771a        | 0.180b      | 4.58b | 0.389a| 2.82b |
| F6         | 55.97a             | 14.19a           | 7.86a             | 0.496a | 0.318a | 0.814a        | 0.187a      | 4.75a | 0.399a| 2.99a |

Interaction

| F1         | 25.00j             | 8.22k            | 4.91i             | 0.380j | 0.185j | 0.565j        | 0.112m      | 3.90j | 0.252i| 1.76m |
| F2         | 33.47l             | 10.24j           | 6.07g             | 0.402h | 0.196h | 0.598kld      | 0.130j      | 4.02hj| 0.290gh| 2.07k |
| F3         | 37.50g             | 11.12g           | 6.50f             | 0.432f | 0.225fh | 0.657ghi       | 0.146gh     | 4.10gj| 0.306gh| 2.38g |
| F4         | 43.89ef            | 11.26ef          | 6.68ef            | 0.475e | 0.237eh | 0.694gh        | 0.149g      | 4.14gh| 0.290gh| 2.66gh|
| F5         | 46.67d             | 12.27de          | 7.61c             | 0.477bc | 0.278cd | 0.755bced      | 0.172d      | 4.46ced| 0.382ab| 2.79-f |
| F6         | 51.25c             | 12.40d           | 7.73c             | 0.480bc | 0.290c | 0.77bced       | 0.178c      | 4.59bced| 0.388ab| 2.93abc|

The soybean plants fertilized with MAP have the highest values of fresh and dry weights, chlorophyll and carotenoids contents, N, P and K percentages followed by the plants fertilized with OSP; however, plants untreated with P fertilizers possessed the lowest values of all aforementioned traits. The superiority of MAP compared to OSP is due to that MAP fertilizer contains 11.0 % nitrogen as well as other essential plant nutrients. This finding is in agreement with (Ragab et al., 2015) who illustrated that MAP fertilizer gave the best growth parameters compared to the other phosphorus fertilizers.

Soybean plants fertilized with AM+ KH have the highest values of all aforementioned traits compared to other bio and organic additives. The plants fertilized with AM+V came in the second-order followed by those fertilized with KH alone then V alone and lately AM alone, while the plants untreated with bio and organic applications recorded the lowest values of the all aforementioned traits.

This primitive influence of studied bio and organic fertilizers may be due to that these additives supply soybean plants with nutrients and improve soil properties and fertility. AM+ KH as combined treatment is superior more than all other studied bio and organic fertilizers and this may be to the benefit of the combination of both KH and AM, where KH contains high contents from N (0.48 %), K₂O (11%), HA (60.5%), FA (3.1%), P₂O₅ (11.2%) as well as mycorrhiza plays an important role in facilitating phosphorus element availability, which it increases the uptake of poorly soluble P sources. Generally, the beneficial influences of mycorrhiza on soybean plant growth have been related to the raising in the absorption of immobile nutrients, especially phosphorus (P). This effect due to the large surface area of fungal hyphae, which are much longer and finer than plant root hairs, and partly because some such fungi can mobilize soil minerals unavailable to the plants' roots. Which improve the plant's mineral absorption capabilities. While AM+V is superior treatment compared to all studied bio and organic fertilizers in sole applications due to the aforementioned role of AM in addition with the role of V that is rich in nutrients status. These results are in harmony.

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with these obtained by Rahmawati et al. (2014); Hemida et al. (2017) and Bloun et al. (2019).

Concerning interaction effect, the combination of AM+ KH as organic fertilizer and MAP was the superior treatment for all aforementioned parameters, while the lowest values were realized with soybean plants untreated with investigated fertilizers (P0×F1).

2. Performance at period of 120 days (harvest stage).

Data in Table 4 demonstrated yield and its components i.e. pods, seeds, and stover weights (g plant⁻¹), the weight of 100 seed (g plant⁻¹), seed and stover yield (Kg fed⁻¹) and plant height (em). In addition seed yield quality traits i.e. N, K, Mg (%), Zn, Fe (mg kg⁻¹), protein and oil contents (% of soybean plants are shown in (Table 5). Regarding P fertilization treatments, results illustrated pronounced differences among all P sources, where the sequence of treatments from top to less was MAP > OSP > control. The features mentioned above were significantly affected as a result of studied bio and organic additives, where the sequence of treatments from top to less was AM + KH > AM+V > KH > V > AM > control.

Concerning the interaction effect, the combination of AM+KH as organic fertilizer and MAP (P0×F0) was the superior treatment as for all studied parameters, while the lowest values were realized with soybean plants untreated with investigated fertilizers (P0×F1).

The reason for the difference between the studied treatments were explained above. From another explanations, it may be attributed to the content of MAP from N element that improves root activity and biological processes in the root zone which reflects on soil pH value that declines as activity increases. This increases the viability of the nutrients in the soil, with the exception of molybdenum. On the other hand, it is known that the presence of N and P in the root zone stimulates Mg uptake by plants, so it can be said that the combination of MAP and AM+KH provided more N and P into the root zone of soybean plants compared to other combined treatments, thus led to increasing Mg uptake which reflected on Mg content in the seeds. Generally, the Mg element is involved as a Co-enzyme with enzymes responsible for synthesis of oils and fats in oil-producing plants such as soybean plants.

Data enclosed in Table (6) clearly reveal that P%, P uptake in seed and stover yield, total P uptake, agronomic P use efficiency (AUE), P recovery efficiency (PRE) and partial factor productivity (PPF) of soybean plant under P fertilizers, bio and organic additives and their interactions.

From this previous data, it is shown that MAP showed significantly enhancement in the studied parameters compared to OSP which became the second-order and lately control treatment, these might come back to one or more the following, MAP fertilizer high content (61% as P2O5, 27%P), the highest water solubility (365g/L, at 20 °C) and/or pH value (4.0 to 4.5). The pH of the solution surrounding is moderately acidic, making MAP an especially desirable fertilizer in alkaline soil. In addition, the nitrogen in the ammonium form (NH4⁺) in MAP, which resists leaching and a slower release form of nitrogen (Youssef et al., 2017). As well as improves root activity and biological processes in the root zone which reflects on soil pH value that declines as activity increases.

Table 4. Impact of P fertilizers, bio with organic additives and their interactions on yield and its components of soybean plants and (plant height) at harvest stage (combined data over both seasons).

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Pods weight (g plant⁻¹)</th>
<th>Seeds weight (g plant⁻¹)</th>
<th>Stover weight (g)</th>
<th>Weight of 100 seed (g)</th>
<th>Seeds yield (g seed⁻¹)</th>
<th>Stover yield (Kg fed⁻¹)</th>
<th>Plant height (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>P0</td>
<td>4.240c</td>
<td>22.66a</td>
<td>47.16c</td>
<td>18.42c</td>
<td>1510.74c</td>
<td>2421.82cc</td>
<td>79.05a</td>
</tr>
<tr>
<td>P1</td>
<td>46.45b</td>
<td>33.35a</td>
<td>50.06b</td>
<td>18.77b</td>
<td>1556.35b</td>
<td>2481.57b</td>
<td>80.68a</td>
</tr>
<tr>
<td>P2</td>
<td>48.15a</td>
<td>23.91a</td>
<td>51.24a</td>
<td>18.98a</td>
<td>1593.75a</td>
<td>2527.08a</td>
<td>81.75a</td>
</tr>
</tbody>
</table>

F: Control (without addition); P: Ordinary superphosphate (OSP); F: Mono ammonium phosphate (MAP); P: Control (without addition); F: Mycorrhiza (AM) as a single treatments; F: Vermicompost (V) as a single treatment; F: Potassium humate (KH) as a single treatments; F: AM+V together and F6: AM+KH together.
Treatments | N (%) | K (%) | Mg (%) | Zn (mg kg⁻¹) | Fe (mg kg⁻¹) | Protein (%) | Oil (%) | Bio and organic additives
---|---|---|---|---|---|---|---|---
P₀ | 5.24c | 1.81b | 0.70c | 14.40b | 35.85b | 32.76c | 21.50b | 20.91c
P₁ | 5.32b | 1.84a | 0.78b | 14.82a | 36.50a | 33.27b | 21.66ab
P₂ | 5.37a | 1.80b | 0.82a | 15.05a | 36.78a | 33.5a | 21.88a
F₁ | 4.94f | 1.63f | 0.45 | 13.10d | 33.60d | 30.85f | 20.93f | 20.95f
F₂ | 5.08e | 1.71e | 0.58 | 13.70c | 35.17c | 31.77e | 21.11e | 21.15e
F₃ | 5.30d | 1.81 | 0.74 | 14.43b | 36.13b | 33.14d | 21.34d | 21.38d
F₄ | 5.38c | 1.90c | 0.79 | 14.83b | 36.80b | 33.63c | 21.58c | 21.62c
F₅ | 5.55b | 1.97b | 0.97 | 16.00a | 38.07a | 34.71b | 22.35b | 22.40b
F₆ | 5.61a | 2.01a | 1.03 | 16.47a | 38.50a | 35.04a | 22.66a | 22.70a

Table 5. Impact of P fertilizers, bio with organic additives and their interactions on seed quality parameters of soybean plants(combined data over both seasons).

<table>
<thead>
<tr>
<th>Treatments</th>
<th>P (%)</th>
<th>P uptake (Kg fed⁻¹)</th>
<th>AUE</th>
<th>PRE</th>
<th>PFP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Seed</td>
<td>Stover</td>
<td>Seed</td>
<td>Stover</td>
<td>Total</td>
<td>Kg Kg⁻¹</td>
</tr>
<tr>
<td>P₀</td>
<td>0.302b</td>
<td>0.218c</td>
<td>4.60b</td>
<td>5.33c</td>
<td>9.94c</td>
</tr>
<tr>
<td>P₁</td>
<td>0.322a</td>
<td>0.258abc</td>
<td>5.05a</td>
<td>6.09a</td>
<td>11.14a</td>
</tr>
<tr>
<td>P₂</td>
<td>0.328a</td>
<td>0.246a</td>
<td>5.27a</td>
<td>6.27a</td>
<td>11.54a</td>
</tr>
</tbody>
</table>

Table 6. Impact of P fertilizers, bio with organic additives and their interactions on P %, P uptake in seed and stover, total P uptake, P use efficiencies and partial factor productivity of soybean plants(combined data over both seasons).

Concerning bio-organic fertilization of soybean with AM+KH has the highest values for all the parameters mentioned above in qualities compared to other bio and organic additives because the hyphae of mycorrhizal fungi that live in the root zone emit phosphatase enzymes that were able to convert organic P into inorganic P Subsequently.
increasing P availability for plants. Plants fertilized with AM+V came in the second-order followed by those fertilized with KH only then V only and lastly AM only, while the plants untreated with bio and organic additives recorded the lowest values of all the aforementioned traits. As regards %P, fertilizing with (AM) gave a higher value than adding (KH), (VC) and control, respectively. This is because, mycorrhizal fungi could increase the production of hormones such as auxin and cytokinin, which can increase cell wall elasticity also prevent and slow down the aging process of roots therefore, it increase the phosphorous in the plant this reported by (Sasongko et al.,2019).

The highest interaction effect was produced from MAP fertilization and (AM+KH). The mean values were 0.365 P%, 0.295 P%, 7.00, 8.12 Kg P fed¹, P-uptake, 15. 12 Kg P fed¹ total uptake for seed and stover, respectively. while the lowest values were realized with soybean plants untreated with investigated fertilizers (P0 ×F1).Highest agronomical P-use efficiencies PUE 23.19 Kg fed¹, PFP 82.54, % P- recovery(36.09 %) were achieved with MAP and (AM+KH) because of the total P uptake from organic and inorganic was highest 15.12 Kg fed¹ than other treatments. Soybean plants treated with humic substances as soil application gave the highest phosphorus uptake due to the increase in total dry matter plant¹ and nutrient content in plant parts including seeds. that were studied by (Savita et al., 2018).

Fatty and phytic acids content
1- Fatty acids content
The studied fatty acids composition studies are important for accessing the quality and stability of soybean oil. Treated plants with different sources of P fertilizers showed variation in the fatty acid composition of their seeds (Table7).

<table>
<thead>
<tr>
<th>Treatments</th>
<th>(P2×F1)</th>
<th>(P2×F3)</th>
<th>(P2×F6)</th>
</tr>
</thead>
<tbody>
<tr>
<td>% Lauric acid</td>
<td>C12:0</td>
<td>5.41</td>
<td>2.35</td>
</tr>
<tr>
<td>%Myristic acid</td>
<td>C14:0</td>
<td>0.13</td>
<td>0.12</td>
</tr>
<tr>
<td>%Palmitic acid</td>
<td>C16:0</td>
<td>11.00</td>
<td>11.14</td>
</tr>
<tr>
<td>%Palmitoleic acid</td>
<td>C16:1:0</td>
<td>0.12</td>
<td>0.13</td>
</tr>
<tr>
<td>%Heptadecanoic acid</td>
<td>C17:0</td>
<td>0.11</td>
<td>0.11</td>
</tr>
<tr>
<td>% Stearic acid</td>
<td>C18:0</td>
<td>3.83</td>
<td>3.95</td>
</tr>
<tr>
<td>%Oleic acid</td>
<td>C18:1</td>
<td>24.92</td>
<td>24.97</td>
</tr>
<tr>
<td>%Vaccinic acid</td>
<td>C18:1</td>
<td>1.31</td>
<td>1.34</td>
</tr>
<tr>
<td>%Linoleic acid</td>
<td>C18:2</td>
<td>47.44</td>
<td>49.53</td>
</tr>
<tr>
<td>%Linolenic acid</td>
<td>C18:3</td>
<td>4.95</td>
<td>5.21</td>
</tr>
<tr>
<td>% Arachidic acid</td>
<td>C20:0</td>
<td>0.30</td>
<td>0.30</td>
</tr>
<tr>
<td>%Gondoic acid</td>
<td>C20:1</td>
<td>0.21</td>
<td>0.21</td>
</tr>
<tr>
<td>%Behenic acid</td>
<td>C22:0</td>
<td>0.29</td>
<td>0.30</td>
</tr>
</tbody>
</table>

Phytic acid concentration appears to be a function of plant P status during soybean seed development. (Alamu et al., 2019) demonstrated the positive relationship between nutrient P and phytic acid accumulation in rice. Phytic acid is present in soybean and most soybean products at a level of 1‒1.5 g/100 g dry matter. The present results showed that the application of bio and organic fertilizers to MAP fertilizer did not significantly increase the phytic acid content in seeds during different treatments.

Fig. 1. Impact the interactions between P fertilizers, bio with organic additives on Phytic acid content of soybean seeds(combined data over both seasons).
Pc: Control (without addition); P1: Ordinary superphosphate (OSP); P2: Mono ammonium phosphate (MAP); P3: Control (without addition); F1: Mycorrhiza (AM) as a single treatments; F2: Vermicompost (V) as a single treatment; F3: Potassium humate (KH) as a single treatments; F4: AM+V together and F5: AM+KH together.

Phytic acid concentration appears to be a function of plant P status during soybean seed development. (Alamu et al., 2019) demonstrated the positive relationship between nutrient P and phytic acid accumulation in rice. Phytic acid is present in soybean and most soybean products at a level of 1‒1.5 g/100 g dry matter. The present results showed that the application of bio and organic fertilizers to MAP fertilizer did not significantly increase the phytic acid content in seeds during different treatments.

Soil Properties.
Available nutrients as average i.e. N, P and K(mg kg⁻¹), total P and inorganic P forms i.e.Ca-P, Al-P and Fe-P (mg kg⁻¹) as average, pH and EC (dsm⁻¹) values as average in the soil at harvest stage of soybean plants as affected by bio and organic additives, different P fertilizers are shown in Figs from 2 to 7.

a- Available N.
Available N in soil (Fig 2) after harvesting soybean plants increased over that before sowing due to all studied bio and organic additives which caused an increase in available N in soil (mg kg⁻¹), where available N of soil fertilized with AM+V was more than other additives. The
soil fertilized with V alone came in the second-order followed by that fertilized with AM+KH together then KH alone and AM alone, while the available N of untreated soil slightly differed compared to pre-planting. Although MAP fertilizer contains 11% nitrogen, soils treated with OSP contain more available N than soil treated with MAP. This is may be due to that plants treated with MAP have grown better than plants treated with OSP, thus raising the uptake of N from soil under MAP more than OSP.

Fig. 2. Impact of P fertilizers, bio with organic additives on soil available N (mg kg\(^{-1}\)) after soybean harvest (combined data over both seasons).

IS: Initial soil before sowing; P\(_2\): Control (without addition); P\(_3\): Ordinary superphosphate (OSP); P\(_4\): Mono ammonium phosphate (MAP); P\(_5\): Control (without addition); P\(_6\): Mycorrhiza (AM) as a single treatments; P\(_7\): Vermicompost (V) as a single treatment; P\(_8\): Potassium humate (KH) as a single treatments; P\(_9\): AM+V together and P\(_{10}\): AM+KH together.

b- Available P.

Available P in soil (Fig 3) after harvesting soybean plants increased over that before sowing due to all treatments, except P\(_3\), P\(_4\), P\(_5\), P\(_6\), P\(_7\), P\(_8\), P\(_9\), and P\(_{10}\) treatment due to the plants of this treatment did not receive any P source. All studied bio and organic additives caused an increase in available P in soil (mg kg\(^{-1}\)), where available P of soil fertilized with AM+V was more than other additives.

Fig. 3. Impact P fertilizers, bio with organic additives on soil available P (mg kg\(^{-1}\)) after soybean harvest (combined data over both seasons).

IS: Initial soil before sowing; P\(_2\): Control (without addition); P\(_3\): Ordinary superphosphate (OSP); P\(_4\): Mono ammonium phosphate (MAP); P\(_5\): Control (without addition); P\(_6\): Mycorrhiza (AM) as a single treatments; P\(_7\): Vermicompost (V) as a single treatment; P\(_8\): Potassium humate (KH) as a single treatments; P\(_9\): AM+V together and P\(_{10}\): AM+KH together.

The soil fertilized with AM+KH came in the second order followed by that fertilized with AM then V and KH alone. Although the amount of phosphorus added from both types of P fertilizers is constant, however soils treated with OSP contain more available P than soil treated with MAP. This is may be due to that plants treated with MAP have grown better than plants treated with OSP, thus raising the uptake of P from soil under MAP more than OSP. Also, most of the phosphorus of OSP was fixed due to its addition before sowing, while the fixation under MAP was less due to two-thirds (2/3) of MAP amount were added after sowing. These results are in harmony with the obtained findings of (El-Ghamry et al., 2012) who reported that the best time for applying P fertilizer was after sowing of cowpea plants, where fixation of P decrease and phosphorus fertilizer use efficiency enhance

c- Available K.

Available K in soil (Fig 4) after harvesting soybean plants increased over that before sowing due to all studied bio and organic treatments which caused an increase available K in soil (mg kg\(^{-1}\)), where available K of soil fertilized with AM+KH was more than other additives.

Fig. 4. Impact of P fertilizers, bio with organic additives on soil available K (mg kg\(^{-1}\)) after soybean harvest (combined data over both seasons).

IS: Initial soil before sowing; P\(_2\): Control (without addition); P\(_3\): Ordinary superphosphate (OSP); P\(_4\): Mono ammonium phosphate (MAP); P\(_5\): Control (without addition); P\(_6\): Mycorrhiza (AM) as a single treatments; P\(_7\): Vermicompost (V) as a single treatment; P\(_8\): Potassium humate (KH) as a single treatments; P\(_9\): AM+V together and P\(_{10}\): AM+KH together.

d- Total P and its other forms (fractionations).

It is known that most of the phosphorus of soil is in a fixed form unavailable to plants. Total P, inorganic P forms i.e. Ca-P, Al-P, and Fe-P (Fig 5) in the soil after harvest took a reverse trend of the values of available phosphorous In other words, the treatment that caused an increase of available phosphorus in the soil at that same time caused a decrease in the values of total P, inorganic P forms i.e. Ca-P, Al-P, and Fe-P as a result of the conversion of fixed P to available form. Also, it is also worth noting that amount of fixed P with OSP was more than with MAP (due to the above-mentioned reasons) and this definitely reflected on all aforementioned P forms. Also, the ammonium form lower the pH in the root zone which increases the dissolution of Ca-P precipitated compound and thus enhances phosphorus availability and uptake which consequently increase the efficiency (Chien et al., 2011). Mycorrhiza treatments were superior in solubilizing the phosphorus present in fixed form, therefore making P more available to soybean plants.
Fig. 5. Impact of P fertilizers, bio with organic additives on Total P and its other forms in soil (mg kg\(^{-1}\)) after soybean harvest (combined data over both seasons).

IS: Initial soil before sowing; P\(_0\): Control (without addition); P\(_1\): Ordinary superphosphate (OSP); P\(_2\): Mono ammonium phosphate (MAP); P\(_3\): Control (without addition); P\(_4\): Mycorrhiza (AM) as a single treatments; P\(_5\): Vermicompost (V) as a single treatment; P\(_6\): Potassium humate (KH) as a single treatments; P\(_7\): AM+V together and P\(_8\): AM+KH together.

The addition of organic matter produces organic compounds in the soil that can increase P availability through the formation of organophosphate complexes that are easily assimilated by plants, the replacement of H\(_2\)O anions in the adsorption site, and the covering of Fe, Al oxide by humus that forms a protective layer, reduces P adsorption, and increases the amount of organic P mineralized into inorganic P (Tisdale et al., 1993).

e- pH value.

The studied bio and organic additives (F\(_2\), F\(_3\), F\(_4\), F\(_5\) and F\(_6\)) caused decreasing soil pH value, while control treatment caused an increase in soil pH value (Fig 6). The lowest value of soil pH was realized with AM+KH treatment followed by AM+V treatment, KH treatment, AM treatment, V treatment, control (without bio and organic addition), respectively. On the other hand, MAP fertilizer caused a decrease in soil pH value more than OSP and this may be attributed to the ability of MAP in improving plant growth and increasing activity of microorganisms that produce organic acids that decline the soil pH value.

Fig. 6. Impact of P fertilizers, bio with organic additives on soil pH value after soybean harvest (combined data over both seasons).

IS: Initial soil before sowing; P\(_0\): Control (without addition); P\(_1\): Ordinary superphosphate (OSP); P\(_2\): Mono ammonium phosphate (MAP); P\(_3\): Control (without addition); P\(_4\): Mycorrhiza (AM) as a single treatments; P\(_5\): Vermicompost (V) as a single treatment; P\(_6\): Potassium humate (KH) as a single treatments; P\(_7\): AM+V together and P\(_8\): AM+KH together.

f- EC value.

The studied bio and organic additives, except KH treatment alone, caused a decrease in soil EC value (Fig 7). Control treatment (without addition) caused an increase in soil EC value; it may be due to the fertilization process.

Fig. 7. Impact of P fertilizers, bio with organic additives on soil EC value (dSm\(^{-1}\)) after soybean harvest (combined data over both seasons).

IS: Initial soil before sowing; P\(_0\): Control (without addition); P\(_1\): Ordinary superphosphate (OSP) and P\(_2\): Mono ammonium phosphate (MAP); P\(_3\): Control (without addition); P\(_4\): Mycorrhiza (AM) as a single treatments; P\(_5\): Vermicompost (V) as a single treatment; P\(_6\): Potassium humate (KH) as a single treatments; P\(_7\): AM+V together and P\(_8\): AM+KH together.

Although KH treatment alone caused a relative increase in soil EC value compared to control treatment, it has a positive effect on plant performance due to its high content from humic acid. Generally, the lowest value of soil EC was realized with AM+KH treatment. On the other hand, soil addition of both MAP and OSP causes raising soil
EC (dSm⁻¹) compared to no adding P fertilizer, but OSP fertilizer caused increase soil EC value more than MAP.

**Economic Feasibility.**

The highest net return of L.E. 29830 fed⁻¹ was obtained from the application of KH+AM and MAP as combined treatment followed by application of KH+AM and OSP (L.E 26875 fed⁻¹) as combined treatment, while the lowest net return of L.E. 16152 fed⁻¹ was obtained from the application of vermicompost alone without P fertilizers (Table 8) and this may be attributed to the high cost of vermicompost (perpetuation, transport and labor).

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Total cost, L.E.</th>
<th>Gross return, L.E.</th>
<th>Net return, L.E.</th>
<th>B: C Ratio</th>
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</thead>
<tbody>
<tr>
<td>F₁</td>
<td>9124</td>
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<td>16811</td>
<td>1.84</td>
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<tr>
<td>F₂</td>
<td>9184</td>
<td>27498</td>
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<tr>
<td>F₃</td>
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<td>27776</td>
<td>16152</td>
<td>1.39</td>
</tr>
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<td>F₁₅</td>
<td>9824</td>
<td>39654</td>
<td>29830</td>
<td>3.04</td>
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</table>

| F₁ Control (without addition); F₇: Ordinary superphosphate (OSP); F₅: Mono ammonium phosphate (MAP); F₂ Control (without addition); F₄: Mycorrhiza (AM) as a single treatments; F₆: Vemicompont (V) as a single treatment; F₇: Potassium humate (KH) as a single treatments; F₈: AM+V together; F₉:AM+KH together; B: C=benefit : cost. Also, the gross return to total cost ratio (benefit: cost) was ranged from 1.39 to 3.04 profits fed⁻¹. Therefore, the application of mycorrhiza + potassium humate + MAP was economically feasible and recommended for soybean production in the Nile Delta region, Egypt. **CONCLUSION**

Obtained results of the current research illustrate that treating soybean cv. Giza 111’ with mycorrhiza + potassium humate as combined treatment under P fertilization with mono ammonium phosphate was economically feasible and recommended to obtain the best growth parameters, yield, and seed quality in the Nile Delta region and other areas with similar agro-climate conditions.

**REFERENCES**


