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# IMPROVING GROWTH AND PRODUCTIVITY OF INDUSTRIAL POTATOES THROUGH BIOFERTILIZATION, PHOSPHATE FERTILIZATION, AND SPRAYING WITH BRASSINOLIDE

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## ABSTRACT

**The experiment was carried out in southwest Baghdad during fall season 2021 and spring season 2022 that aimed to study the effect of biological inoculation, phosphate fertilization and spraying with Brasinolide on the growth and production of industrial potato of the Arsenal cultivar , the experiment carried out as a three-factors experiment (4 × 3 × 3) in (RCBD), bio-fertilizers distributed into main plot and interaction between phosphorus levels and Brassinolide growth regulator within sub plot using three replicates Bio-fertilizers included *Aspergillus niger* fungus alone and *Bacillus Megaterium* bacteria alone and the combination between them. Phosphorus treatments included three levels (0.100, 200) kg $p_2o_5$ $ha^{-1}$ and Brassinolide spraying of three levels of (0, 0.1, 0.2) mg $L^{-1}$. The results showed the triple combination bio-fertilizer together with the addition of phosphorus at 100 kg $p_2o_5$ $ha^{-1}$ and spraying with Brassinolide, 0.1 mg $L^{-1}$ produced significant highest plant's height (78.78 and 102.830) cm $plant^{-1}$ and in the number of main stems (3.333 and 2.250) stem $plant^{-1}$ for both seasons respectively. The highest number of leaves was when the two fertilized were added together with phosphorus fertilization at the level of 200 kg $p_2o_5$ $ha^{-1}$ with spraying at a concentration of 0.1 mg $L^{-1}$ of Brassinolide (105.333 and 194.111) leaf $plant^{-1}$ for the two seasons respectively The same combination was characterized by an average tuber weight of 105.185 g $tuber^{-1}$ in the fall season and this was reflected in the superiority of productivity (35.254 and 36.923) ton $ha^{-1}$ for the two seasons respectively, The same combination with a concentration 0.2 mg $L^{-1}$ from Brassinolide also gave the lowest value of SOD enzyme in the leaves for both seasons (121.667 and 126.000) units of $g^{-1}$ wet weight.**

**Key words; *Aspergillus niger, Bacillus megaterium*, SOD enzyme, *Solanum tuberosum* L, sustainable agriculture.**
***Part of Ph.D. dissertation of the 1st author**



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## INTRODUCTION

Potato (*Solanum tuberosum* L.) is one of the important vegetable crops in the world and consumed in large quantities in industrial way, as it's rich in carbohydrates, proteins and vitamins (Hassan,2021). Therefore the researchers in a large number of countries have been interested in improving potato cultivation techniques respectively to obtain high production and improve the quality of tubers (Morais et al., 2018) Including the use of biofertilizers that improve soil properties and structure and increase the availability of nutrients by increasing the solubility of major insoluble elements respectively to get the plant's need from nutrients and reach to the optimal use of chemical fertilizers (Sharma et al., 2023). Therefore, the use of bio-fertilizers is the best way to sustainability. by what encouraging biological organisms provide for plant growth in terms of hormones, dissolving unprepared minerals, facilitating the

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absorption of nutrients, reducing stresses, preserving soil properties and fertility and stimulating resistance against pathogens (Joshi et al., 2021). It works on the production of siderophores and (IAA) with high ability to dissolve insoluble mineral phosphate (Li et al., 2021)، and improve plant properties by increasing nutrient absorption، increasing yield and plant tolerance to stresses (Dey et al., 2019). The most important biological organisms that dissolved unavailable phosphate is *Bacillus Megaterium* bacteria that characterized by the ability to increase the availability of phosphorus for the plant as it releases organic acids to dissolve mineral phosphates, decompose organic compounds and produce growth regulators (Wyeiszkiewiez et al., 2017)، among the organic acids that released by Bacillus bacteria are citric, gluconic and proponic acid (Zhong et al., 2017), Where (Al Rubaye et al., 2019) found the mentioned bacteria with mineral fertilizers work to increases plant height, dry weight, number of tubers, and total yield of potatoes plants, and it has the ability to break down organic pesticides and use them as a carbon source for their growth (Mousa et al., 2019). Phosphorus is considered as one of the main plant nutrients that directly or indirectly effects biological operations due to its involvement in energy metabolism, biosynthesis of nucleic acids and cell membranes. Also it's deficiency can reduce crop production, and the activity of biological organisms plays an important role in the availability of phosphorus retained in the soil for plant absorption. The development of roots depends on the availability of phosphorus and the spread of roots depends on the levels of phosphorus in the soil (Hailu et al., 2017). It has been proven that phosphorus fertilization increases tuber size and total yield by (Kelling et al., 2020), it found that the use of external growth regulators is one of the methods to increase plant growth and reduce the time required for growth, in addition to natural internal hormones some of them have been applied to potato plants (Mendel et al., 2020). Brassinolide is one of the important hormones in plant growth and development. It controls cell division, elongation, and differentiation of different cell types throughout the plant's life cycle. It also plays a role in reducing various environmental stresses and stimulating plant resistance to stress and toxic pesticides. also It is non-toxic and environmentally friendly that making it useful for maintaining environmental sustainability (Hussain et al., 2020), It participates in many important physiological and biochemical processes in plants, such as vascular differentiation, elongation, fertility, seed germination and root growth (Rehman et al., 2022). Therefore, the study was aimed to increasing industrial potatoes productivity and improving their vegetative growth through biological and phosphate fertilization and spraying with Brassinolide.

## MATERIALS AND METHODS

This study was carried out south-west of Baghdadon the Eastern Radwaniyah region for the fall season 2021 and spring 2022 season using industrial potato crop cultivar Arsenal. Was carried out as a three-factors the experiment in the arrangement of split plot within a randomized complete block design RCBD The biological factor was within the main plots and the interaction between the composting levels of phosphorus and the Brassinolide within the sub plots, 36 transactions (4 × 3 × 3) with three replicates and 108 experimental units The A order was cultivated in the fall season and in the spring season the imported Elite order was cultivated. The agricultural operations were carried out on the designated field for the study, including plowing, leveling, and smoothing. The land was divided into experimental units with a length of 1.75m and a width of 2m, which equals an area of 3.5m$^2$. Each unit includes two rows for cultivation, spaced 1m apart, with a distance of 0.25m between each plant. This results in an average of 7 plants per row, or 14 plants per experimental unit and an average of 40,000 plants per hectare The biological factor included two types of fertilizers: *Aspergillus niger* and *Bacillus megaterium*, symbolizing the treatment without Bio-fertilizer ($A_0$), *Aspergillus niger* ($A_1$), *Bacillus megaterium* ($A_2$), and a combination of them ($A_3$) Microbiological isolates and mixed with peatmoss with a

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biodiversity of 810, which were added at a rate of 20 g of biomaterial for each plant with soil, adding 800 g of organic matter for each experimental unit and a fixed quantity of poultry residues for all treatment. The second factor is fertilization with phosphorus and includes three levels (0, 100, 200) kg $P_2O_5$ $ha^{-1}$ and symbolized by $P_0$, $P_1$, and $P_2$ respectively, the amount of phosphate fertilizer added on a single batch after five days from planting, The third factor included three levels of growth regulator Brassinoslide (0, 0.1, 0.2) mg $L^{-1}$ and symbolized by $BL_0$, $BL_1$, and $BL_2$ respectively, sprayed with three, first sprinkles after the germination of 15 days the second and third sprinkle at a rate of 15 days. Nitrogen and potassium fertilizer were added in the two batches the first batch was 50% nitrogen after the germination on 10 days with the addition of 25% of recommended potassium fertilizer and after 20 days from the first batch the remaining nitrogen fertilizer was added with 50% of potassium fertilizer, The remaining potassium fertilizer was added after 15 days from the second batch of nitrogen fertilizer and all experimental units were added equally (250 nitrogen and 300 potassium) kg $ha^{-1}$ as recommended. The Genstat program was used for statistical analysis and the averages for all the study indicators were compared by significant differences (L.S.D) at 5%

## RESULTS AND DISCUSSION

### Effect of study factors on vegetative traits

The results of Table 1 shows significant effects of bio-fertilization, phosphate and spraying with Brassinolide on plant height, number of main stems and number of leaves. The bio-fertilization treatment $A_3$ shows the highest plant height, number of main stems and number of leaves for both seasons and its about 75.807 and 95.060 cm $plant^{-1}$, 2.907 and 1.991 stem $plant^{-1}$, 93.679 and 160.086 leaf $plant^{-1}$ for the fall and spring season respectively, compared to treatment $A_0$ which had the lowest plant height reaching to 66.924 and 83.260 cm $plant^{-1}$ and 2.352 and 1.667 stem $plant^{-1}$, 71.185 and 108.749 leaf $plant^{-1}$ for both fall and spring seasons respectively, and the phosphate fertilizer treatment $P_2$ was characterized by producing the highest plant height and number of leaves, reaching to 73.539 and 93.930 cm $plant^{-1}$, 92.435 and 165.108 leaf $plant^{-1}$. compared to the $P_0$ treatment which produced the lowest 70.461 and 85.130 cm $plant^{-1}$, 79.412 and 113.177 leaf $plant^{-1}$ for the spring season and the $P_2$ treatment was characterized by producing the highest number of stems for the spring season that reached to 1.931 stem $plant^{-1}$ compared to the $P_0$ treatment which had the lowest value of 1.667 stem $plant^{-1}$ also $BL_1$ was characterized by producing the highest plant height and the number of leaves for both seasons (73.025 and 92.100 cm $plant^{-1)}$, 89.236 and 145.264 leaf $plant^{-1}$ compared to the $BL_0$ treatment which produce the lowest of 70.901 and 87.480 cm $plant^{-1}$ and there was no significant effects of Brassinolide on the number of stems. Table 2 shows the significant effects of the bilateral interaction between the treatments in vegetative growth indicators, where the $A_3P_2$ treatment excelled and had the highest value in plant height and number of leaves for both seasons that reached to 76.750 and 101.310 cm $plant^{-1}$, 99.907 and 184.851 leaf $plant^{-1}$ compared to the $A_0P_0$ treatment which produce the lowest value of 64.917 and 76.220 cm $plant^{-1}$, 64.926 and 92.259 leaf $plant^{-1}$ for both seasons respectively, and the $A_3P_1$ treatment was characterized by producing the highest number of stems about 3.028 and 2.089 stem $plant^{-1}$ compared to the $A_0P_0$ treatment that had the lowest of 2.222 and 1.500 stem $plant^{-1}$ for both seasons. Table 2 shows the significant effect of the interaction treatment $A_3BL_1$ where it produced the highest plant height, number of stems and number of leaves, reaching to 77.344 and 89.450 cm $plant^{-1}$ and 3.167 and 2.000 stem $plant^{-1}$, 100. 000 and 171.000 leaf $plant^{-1}$ respectively compared to the $A_0BL_0$ treatment which produced the lowest of 66.111 and 80.290 cm $plant^{-1}$ , 2.194 and 1.556 stem $plant^{-1}$ and 69.574 and 104.111 leaf $plant^{-1}$ for the fall and spring seasons respectively,

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**Table 1. Effect of bio-fertilization and phosphate and spray with Brassinolide in In the content of the leaves of the enzyme superoxide Dismutase for industrial potatoes**

| T | Plant height cm | | No. of main stem steam.plant$^{-1}$ | | No. of leaves leaf.plant$^{-1}$ | | No. of tubers tuber.plant$^{-1}$ | | Weight of the tuber g.tuber$^{-1}$ | | Total yield ton.ha$^{-1}$ | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2021 fall | 2022 spring | 2021 fall | 2022 spring | 2021 fall | 2022 spring | 2021 fall | 2022 spring | 2021 fall | 2022 spring | 2021 fall | 2022 spring |
| $A_0$ | 66.924 | 83.260 | 2.352 | 1.667 | 71.185 | 108.749 | 7.664 | 8.461 | 91.938 | 76.319 | 28.045 | 25.721 |
| $A_1$ | 73.669 | 91.140 | 2.907 | 1.898 | 87.938 | 144.483 | 8.310 | 9.571 | 96.510 | 87.372 | 31.869 | 33.285 |
| $A_2$ | 72.237 | 90.790 | 2.796 | 1.778 | 87.561 | 140.629 | 8.279 | 9.505 | 94.757 | 84.254 | 31.134 | 31.680 |
| $A_3$ | 75.807 | 95.060 | 2.907 | 1.991 | 93.679 | 160.086 | 8.380 | 9.896 | 98.966 | 85.553 | 33.001 | 33.797 |
| L.S.D $_{0.05}$ | 4.139 | 6.924 | 0.386 | 0.224 | 3.645 | 10.335 | 0.677 | 0.664 | 3.652 | 6.196 | 1.792 | 1.622 |
| $P_0$ | 70.461 | 85.130 | 2.632 | 1.667 | 79.412 | 113.177 | 8.187 | 9.061 | 89.747 | 81.691 | 29.286 | 29.478 |
| $P_1$ | 72.477 | 91.130 | 2.847 | 1.903 | 83.426 | 137.176 | 8.094 | 9.477 | 97.828 | 83.101 | 31.520 | 31.419 |
| $P_3$ | 73.539 | 93.930 | 2.743 | 1.931 | 92.435 | 165.108 | 8.193 | 9.537 | 99.055 | 85.331 | 32.230 | 32.465 |
| L.S.D $_{0.05}$ | 1.695 | 2.721 | N.S | 0.164 | 3.451 | 5.209 | N.S | N.S | 4.132 | 3.346 | 1.066 | 0.946 |
| $BL_0$ | 70.901 | 87.480 | 2.597 | 1.806 | 82.116 | 128.148 | 8.194 | 9.290 | 92.771 | 82.453 | 30.195 | 30.540 |
| $BL_1$ | 73.025 | 92.100 | 2.854 | 1.812 | 89.236 | 145.264 | 8.200 | 9.368 | 97.335 | 85.099 | 31.737 | 31.816 |
| $BL_2$ | 72.551 | 90.630 | 2.771 | 1.882 | 83.921 | 142.049 | 8.080 | 9.417 | 96.523 | 82.571 | 31.105 | 31.005 |
| L.S.D $_{0.05}$ | 1.695 | 2.721 | N.S | N.S | 3.451 | 5.209 | N.S | N.S | 4.132 | N.S | 1.066 | 0.946 |

and the $P_2BL_1$ interaction treatment was characterized by producing the highest values in plant height and number of leaves that reached to 74.360 and 95.000 cm plant$^{-1}$, 95.375 and 170.666 leaf plant$^{-1}$ for both seasons, while the $P_2BL_1$ and $P_2BL_2$ treatment had the highest number of stems that reached to 3.021 and 1.979 stem plant$^{-1}$ for two seasons compared to the $A_0BL_0$ treatment, which had a little value in plant height and number of stems, reached to 68.221 and 83.330 cm plant$^{-1}$, and 2.542 and 1.601 4 stem plant$^{-1}$ for both fall and spring seasons ,and $P_0BL_2$ and $P_0BL_0$ treatment in the number of leaves about 75.430 and 101.916 leaf plant$^{-1}$ respectively. Table 3 shows the significant effect of the triple interaction between the study treatments, where the $A_3P_1BL_1$ treatment was characterized by producing the highest value in plant height and for both seasons reached to 78.789 and 102.830 cm plant$^{-1}$, while the $A_3P_2BL_1$ treatment produce the highest number of leaves for both seasons reached to 105.339 and 194.111 leaf plant$^{-1}$ while $A_3P_1BL_1$ treatment give the highest value in number of stems about 3.333 stem plant$^{-1}$ for the fall season and the $A_3P_1BL_1$, $A_1P_1BL_1$ and $A_1P_2BL_0$ treatments produce the highest value for the spring season reached to 2.250 stem plant$^{-1}$ respectively, compared to the little value of $A_0P_0BL_0$ treatment in plant height and number of stems and leaves for both seasons was 63.333 and 72.330 cm plant$^{-1}$, 2.000 and 1.333 stem plant$^{-1}$, 61.555 and 83.222 leaf plant$^{-1}$.

**Effect of study factors on yield traits:**

Table 1 shows a significant effects of treatments on the traits of yield, where the treatment $A_3$ was characterized by producing the highest value in the average number of tubers and the total yield for both seasons reached to 8.380 and 9.896 tuber plant$^{-1}$ and 33.001 and 33.797 ton ha$^{-1}$ and also the same treatment characterized by producing the highest average weight tuber its about 98.966 g tuber$^{-1}$ for the fall season and for the spring season, the treatment $A_1$ had the highest value of 87.372.

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**Table 2. Effect of Bilateral interaction for Bio- fertilization and phosphate and Spray with Brassinolide in growth traits and productivity traits For industrial potatoes**

| T | | Plant height cm | | No. of main stem steam.plant$^{-1}$ | | No. of leaves leaf.plant$^{-1}$ | | No. of tubers tuber.plant$^{-1}$ | | Weight of the tuber g.tuber$^{-1}$ | | Total yield ton.ha$^{-1}$ | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 2021 fall | 2022 spring | 2021 fall | 2022 spring | 2021 fall | 2022 spring | 2021 fall | 2022 spring | 2021 fall | 2022 spring | 2021 fall | 2022 spring |
| | $P_0$ | 64.917 | 76.220 | 2.222 | 1.500 | 64.926 | 92.259 | 7.712 | 8.120 | 85.160 | 73.763 | 26.230 | 23.924 |
| $A_0$ | $P_1$ | 66.461 | 84.820 | 2.417 | 1.694 | 66.555 | 102.925 | 7.538 | 8.627 | 93.854 | 75.617 | 28.162 | 25.947 |
| | $P_2$ | 69.394 | 88.740 | 2.417 | 1.806 | 82.074 | 131.062 | 7.743 | 8.635 | 96.801 | 79.577 | 29.743 | 27.292 |
| | $P_0$ | 72.472 | 86.790 | 2.972 | 1.611 | 85.352 | 115.339 | 8.390 | 9.335 | 91.041 | 85.497 | 30.276 | 31.717 |
| $A_1$ | $P_1$ | 73.961 | 92.780 | 3.000 | 2.028 | 82.648 | 143.741 | 8.188 | 9.632 | 99.916 | 87.727 | 32.539 | 33.586 |
| | $P_2$ | 74.572 | 93.870 | 2.750 | 2.056 | 95.815 | 174.370 | 8.350 | 9.746 | 98.574 | 88.892 | 32.792 | 34.551 |
| | $P_0$ | 70.343 | 89.130 | 2.444 | 1.667 | 78.352 | 113.777 | 8.325 | 9.200 | 89.631 | 84.247 | 29.758 | 30.406 |
| $A_2$ | $P_1$ | 72.926 | 91.430 | 2.944 | 1.806 | 92.388 | 137.963 | 8.314 | 9.705 | 96.148 | 83.239 | 31.646 | 32.096 |
| | $P_2$ | 73.441 | 91.830 | 3.000 | 1.861 | 91.944 | 170.148 | 8.197 | 9.611 | 98.492 | 85.275 | 31.999 | 32.537 |
| | $P_0$ | 74.111 | 88.390 | 2.889 | 1.889 | 89.018 | 131.333 | 8.321 | 9.587 | 93.155 | 83.257 | 30.880 | 31.867 |
| $A_3$ | $P_1$ | 76.561 | 95.490 | 3.028 | 2.083 | 92.111 | 164.074 | 8.335 | 9.946 | 101.392 | 85.822 | 33.734 | 34.046 |
| | $P_2$ | 76.750 | 101.310 | 2.806 | 2.000 | 99.907 | 184.851 | 8.482 | 10.155 | 102.351 | 87.580 | 34.387 | 35.478 |
| L.S.D $_{0.05}$ | | 3.391 | 5.443 | 0.517 | 0.329 | 6.901 | 10.418 | 0.859 | 0.977 | 8.264 | 6.692 | 2.133 | 1.892 |
| | $BL_0$ | 66.111 | 80.290 | 2.194 | 1.556 | 69.574 | 104.111 | 7.521 | 8.325 | 91.049 | 76.325 | 27.263 | 25.257 |
| $A_0$ | $BL_1$ | 66.778 | 85.000 | 2.361 | 1.583 | 72.444 | 112.888 | 7.824 | 8.398 | 92.216 | 77.691 | 28.745 | 26.095 |
| | $BL_2$ | 67.883 | 84.490 | 2.500 | 1.861 | 71.537 | 109.247 | 7.648 | 8.659 | 92.551 | 74.941 | 28.126 | 25.811 |
| | $BL_0$ | 72.156 | 89.050 | 2.861 | 1.889 | 83.518 | 133.481 | 8.571 | 9.587 | 92.182 | 85.437 | 31.276 | 32.686 |
| $A_1$ | $BL_1$ | 75.378 | 93.250 | 3.028 | 1.972 | 93.092 | 149.981 | 8.222 | 9.381 | 98.637 | 90.732 | 32.349 | 33.867 |
| | $BL_2$ | 73.472 | 91.130 | 2.833 | 1.833 | 87.204 | 149.987 | 8.135 | 9.745 | 98.711 | 85.947 | 31.981 | 33.301 |
| | $BL_0$ | 71.033 | 90.010 | 2.500 | 1.778 | 86.111 | 127.926 | 8.070 | 9.524 | 93.823 | 83.005 | 30.144 | 31.147 |
| $A_2$ | $BL_1$ | 72.598 | 91.680 | 2.861 | 1.694 | 91.407 | 147.185 | 8.476 | 9.649 | 96.219 | 85.014 | 32.088 | 32.540 |
| | $BL_2$ | 73.078 | 90.700 | 3.028 | 1.861 | 85.166 | 146.777 | 8.289 | 9.342 | 94.229 | 84.742 | 31.171 | 31.352 |
| | $BL_0$ | 74.306 | 90.560 | 2.833 | 2.000 | 89.259 | 147.074 | 8.613 | 9.722 | 94.032 | 85.045 | 32.094 | 33.070 |
| $A_3$ | $BL_1$ | 77.344 | 98.450 | 3.167 | 2.000 | 100.000 | 171.000 | 8.277 | 10.044 | 102.266 | 86.958 | 33.767 | 34.764 |
| | $BL_2$ | 75.772 | 96.190 | 2.722 | 1.972 | 91.778 | 162.185 | 8.249 | 9.922 | 100.6 | 84.655 | 33.14 | 33.557 |
| L.S.D $_{0.05}$ | | 3.391 | 5.443 | 0.517 | 0.329 | 6.901 | 10.418 | 0.859 | 0.977 | 8.264 | 6.692 | 2.133 | 1.892 |
| | $BL_0$ | 68.271 | 83.330 | 2.542 | 1.646 | 77.347 | 101.916 | 8.111 | 8.988 | 86.267 | 80.623 | 27.786 | 28.852 |
| $P_0$ | $BL_1$ | 71.212 | 86.530 | 2.646 | 1.604 | 85.458 | 120.236 | 8.138 | 9.043 | 92.621 | 83.171 | 30.031 | 30.027 |
| | $BL_2$ | 71.900 | 85.540 | 2.708 | 1.750 | 75.430 | 117.379 | 8.313 | 9.151 | 90.352 | 81.278 | 30.041 | 29.556 |
| | $BL_0$ | 71.388 | 86.410 | 2.646 | 1.833 | 79.402 | 125.611 | 8.113 | 9.548 | 95.594 | 81.689 | 31.007 | 31.145 |
| $P_1$ | $BL_1$ | 73.502 | 94.760 | 2.896 | 1.958 | 86.874 | 144.888 | 8.247 | 9.409 | 99.024 | 85.663 | 32.325 | 32.165 |
| | $BL_2$ | 72.542 | 92.220 | 3.000 | 1.917 | 84.000 | 141.027 | 7.921 | 9.475 | 98.866 | 81.951 | 31.229 | 30.947 |
| | $BL_0$ | 73.046 | 92.690 | 2.604 | 1.938 | 89.597 | 156.916 | 8.357 | 9.333 | 96.453 | 85.048 | 31.791 | 31.624 |
| $P_3$ | $BL_1$ | 74.360 | 95.000 | 3.021 | 1.875 | 95.375 | 170.666 | 8.214 | 9.652 | 100.360 | 86.461 | 32.856 | 33.257 |
| | $BL_2$ | 73.213 | 94.120 | 2.604 | 1.979 | 92.333 | 167.740 | 8.008 | 9.625 | 100.351 | 84.484 | 32.044 | 32.512 |
| L.S.D $_{0.05}$ | | 2.937 | 4.714 | 0.448 | 0.285 | 5.977 | 9.022 | N.S | N.S | 7.157 | 5.795 | 1.8471 | 1.638 |

g.tuber$^{-1}$ compared to the treatment $A_0$ which produced the lowest value for all yield indicators For both seasons and reaching to 7.664, 8.461 tuber plant$^{-1}$, 28.045, 25.721 ton ha$^{-1}$, 91.938 and 76.319 g tuber$^{-1}$,The Table 1 also shows the superiority of the treatment $P_2$ in weight tuber average and total yield for both seasons that reached to 99.055, 85.331 g tuber$^{-1}$, 32.230 and 32.465 ton ha$^{-1}$ compared to the $P_0$ treatment which produce the lowest value of 89.747, 81.691g tuber$^{-1}$, 29.986 and 29.478 ton ha$^{-1}$ for the fall and spring seasons

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respectively and there was no significant difference for phosphorus fertilization in number of tubers, The spraying in Brassinolide treatment affected the average tuber weight and total yield. The $BL_1$ treatment produced the highest 97.335 g tuber$^{-1}$ in the fall season. The $A_3P_2$ bilateral interaction treatment excelled the average number of tubers for both seasons respectively, in the tuber weight for the fall season and the total yield for both seasons that reached to 8.482 and 10.155 tuber plant$^{-1}$, 102.351 g tuber$^{-1}$ and 34.387 and 35.478 ton ha$^{-1}$ respectively. The $A_1P_2$ treatment excelled in the average tuber weight for the spring season to 88.892 g tuber$^{-1}$ while the $A_0P_0$ treatment had a lowest average tuber weight and total yield for both seasons (85.160 and 83.763 g Tuber$^{-1}$, 26.230 and 23.924 ton ha$^{-1)}$ $A_0P_0$ treatment produced lowest number of tubers for the spring season and the $A_0P_1$ treatment for the fall season that reaching to 8.120 tuber plant$^{-1}$ and 7.538 tuber plant$^{-1}$, as shown in Table 2 The $A_3BL_1$ binary interaction treatment excelled in total yield value for both seasons of 33.767 and 34.764 ton ha$^{-1}$ and the highest number of tubers in the spring season and the average weight of the tuber in the fall season reached to 10.044 tuber plant$^{-1}$ and 102.266 g tuber$^{-1}$ respectively. While the $A_3BL_0$ treatment produced the highest average number of tubers for the fall season and the $A_1BL_1$ treatment had the highest average weight of tuber in the spring season that reaching to 8.613 tuber plant$^{-1}$ and 90.732 g tuber$^{-1}$, and the $A_0BL_0$ treatment recorded the lowest average number of tubers and the total yield for both seasons and in the average weight of the tuber for the fall season that reached to 27.263 and 25.257 ton ha$^{-1}$, 7.521 and 8.325 tuber plant$^{-1}$ for both seasons respectively and 91.049 g tuber$^{-1}$ for the fall season, while the $A_0BL_2$ treatment recorded the little value in the average tuber weight for the spring season of 74.941 g tuber$^{-1}$ and bilateral interaction treatment $P_2BL_1$ recorded the highest average tuber weight and total yield for both seasons at 100.360 and 86.461 g tuber$^{-1}$, 32.856 and 33.257 ton ha$^{-1}$ respectively compared to the $P_0BL_0$ treatment which produce lowest value for both seasons of 86.267, 80.623 g tuber$^{-1}$, 27.786 and 28.852 ton ha$^{-1}$ and there was no significant difference for spraying with Brassinolide and bio-fertilization and phosphate in the average number of tubers. Table 3 indicates the effect of triple interaction between the treatments, where the $A_3P_2BL_1$ treatment produced the highest total yield for both seasons and the average weight of the tuber for the fall season that reached to 35.254 and 36.923 ton ha$^{-1}$ and 105.185 g tuber$^{-1}$, while the $A_1P_1BL_1$ treatment recorded the highest tubers weight in the spring season and reached to 93.313 g tuber$^{-1}$ compared to the $A_0P_0BL_0$ treatment that produced lowest total yield and the $A_0P_0BL_2$ treatment to the average weight tuber that about 24.738 and 23.196 ton ha$^{-1}$, 84.434 and 73.377 g Tuber$^{-1}$ for both seasons respectively, the $A_3P_2BL_0$ and $A_3P_2BL_2$ treatment also recorded the highest number of tubers of 8.833 and 10.381 tuber plant$^{-1}$ compared to the $A_0P_1BL_2$ and $A_0P_0BL_0$ treatment which had a lowest value ( 7.278 and 7.905 tuber plant$^{-1}$) for both seasons respectively.

**Leaves content of superoxide dismutase (unit.g$^{-1}$ wet weight):** The results of Table 4 shows a significant decreases in the content of the leaves from superoxide dismutase enzyme (SOD) as a result of bio-fertilization with both fertilizers, phosphate fertilization, and spraying with Brassinolide for both fall and spring seasons, where the treatment $A_3$, $P_2$, and $BL_2$ producing the lowest significant value of the leaves content from SOD enzyme for both seasons and amounted to 141.333, 146.074 and 182.583, 188.389 and 195.889, 201.694 unit.g$^{-1}$ wet weight for both seasons respectively, compared to the $A_0$, $P_0$, and $BL_0$ treatments that produced the highest value was 259.667, 267.407 and 224.333, 229.889 and 208.472, 214.972 unit.g$^{-1}$ wet weight for both seasons respectively.

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**Table 3. Effect of triple interaction for Bio- fertilization and phosphate and Spray with Brassinolide in growth traits and productivity traits For industrial potatoes**

| T | | Plant height cm | | No. of main stem steam.plant$^{-1}$ | | No. of leaves leaf.plant$^{-1}$ | | No. of tubers tuber.plant$^{-1}$ | | Weight of the tuber g.tuber$^{-1}$ | | Total yield ton.ha$^{-1}$ | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 2021 fall | 2022 spring | 2021 fall | 2022 spring | 2021 fall | 2022 spring | 2021 fall | 2022 spring | 2021 fall | 2022 spring | 2021 fall | 2022 spring |
| | $BL_0$ | 63.333 | 72.330 | 2.000 | 1.333 | 61.555 | 83.222 | 7.286 | 7.905 | 84.918 | 73.504 | 24.738 | 23.196 |
| $P_0$ | $BL_1$ | 63.667 | 78.500 | 2.250 | 1.417 | 67.167 | 98.777 | 7.881 | 8.170 | 86.128 | 74.408 | 27.062 | 24.415 |
| | $BL_2$ | 67.750 | 77.830 | 2.417 | 1.750 | 66.055 | 94.777 | 7.968 | 8.286 | 84.434 | 73.377 | 26.889 | 24.160 |
| | $BL_0$ | 66.333 | 80.750 | 2.250 | 1.417 | 66.667 | 98.666 | 7.562 | 8.643 | 92.350 | 73.598 | 27.909 | 25.137 |
| $A_0$ $P_1$ | $BL_1$ | 66.583 | 87.080 | 2.250 | 1.750 | 67.332 | 106.222 | 7.775 | 8.452 | 94.030 | 78.339 | 28.992 | 26.493 |
| | $BL_2$ | 66.467 | 86.630 | 2.750 | 1.917 | 65.666 | 103.889 | 7.278 | 8.786 | 95.183 | 74.913 | 27.583 | 26.211 |
| | $BL_0$ | 68.667 | 87.800 | 2.333 | 1.917 | 80.500 | 130.444 | 7.714 | 8.429 | 95.878 | 81.872 | 29.143 | 27.438 |
| $P_3$ | $BL_1$ | 70.083 | 89.420 | 2.583 | 1.583 | 82.833 | 133.666 | 7.817 | 8.571 | 96.490 | 80.327 | 30.181 | 27.377 |
| | $BL_2$ | 69.433 | 89.000 | 2.333 | 1.917 | 82.889 | 129.074 | 7.698 | 8.905 | 98.035 | 76.533 | 29.905 | 27.061 |
| | $BL_0$ | 68.500 | 85.250 | 2.917 | 1.583 | 80.833 | 105.555 | 8.706 | 9.405 | 84.891 | 83.121 | 28.952 | 31.185 |
| $P_0$ | $BL_1$ | 75.167 | 89.120 | 2.917 | 1.667 | 93.167 | 122.277 | 7.913 | 9.095 | 95.827 | 89.620 | 30.353 | 32.269 |
| | $BL_2$ | 73.750 | 86.000 | 3.083 | 1.583 | 82.055 | 118.183 | 8.552 | 9.505 | 92.405 | 83.750 | 31.524 | 31.697 |
| | $BL_0$ | 72.633 | 89.450 | 3.000 | 1.833 | 78.443 | 127.000 | 8.310 | 9.881 | 98.118 | 84.821 | 32.556 | 33.429 |
| $A_1$ $P_1$ | $BL_1$ | 75.417 | 95.630 | 2.917 | 2.250 | 87.444 | 149.444 | 8.373 | 9.167 | 100.421 | 93.313 | 33.269 | 34.210 |
| | $BL_2$ | 73.833 | 93.250 | 3.083 | 2.000 | 82.055 | 154.778 | 7.881 | 9.848 | 101.209 | 85.047 | 31.794 | 33.120 |
| | $BL_0$ | 75.333 | 92.450 | 2.667 | 2.250 | 91.278 | 167.888 | 8.698 | 9.476 | 93.537 | 88.370 | 32.321 | 33.446 |
| $P_3$ | $BL_1$ | 75.550 | 95.020 | 3.250 | 2.000 | 98.667 | 178.222 | 8.381 | 9.881 | 99.664 | 89.263 | 33.427 | 35.122 |
| | $BL_2$ | 72.833 | 94.130 | 2.333 | 1.917 | 97.500 | 177.000 | 7.971 | 9.881 | 102.521 | 89.044 | 32.627 | 35.086 |
| | $BL_0$ | 67.917 | 90.250 | 2.167 | 1.667 | 77.889 | 98.889 | 7.968 | 9.190 | 88.956 | 82.650 | 28.383 | 29.581 |
| $P_0$ | $BL_1$ | 70.930 | 88.130 | 2.333 | 1.583 | 84.333 | 121.444 | 8.635 | 9.167 | 90.322 | 85.184 | 30.883 | 31.088 |
| | $BL_2$ | 72.183 | 89.000 | 2.833 | 1.750 | 72.833 | 120.999 | 8.373 | 9.242 | 89.616 | 84.906 | 30.009 | 30.549 |
| | $BL_0$ | 72.083 | 89.680 | 2.583 | 2.000 | 90.500 | 128.666 | 8.060 | 9.714 | 94.287 | 83.161 | 30.297 | 32.116 |
| $A_2$ $P_1$ | $BL_1$ | 73.227 | 93.500 | 3.083 | 1.583 | 95.221 | 143.444 | 8.548 | 9.947 | 98.237 | 83.589 | 32.817 | 32.924 |
| | $BL_2$ | 73.467 | 91.100 | 3.167 | 1.833 | 91.444 | 141.777 | 8.333 | 9.452 | 95.921 | 82.967 | 31.824 | 31.248 |
| | $BL_0$ | 73.100 | 90.080 | 2.750 | 1.667 | 89.944 | 156.222 | 8.183 | 9.667 | 98.227 | 83.205 | 31.754 | 31.745 |
| $P_3$ | $BL_1$ | 73.639 | 93.400 | 3.167 | 1.917 | 94.667 | 176.666 | 8.246 | 9.833 | 100.099 | 86.268 | 32.563 | 33.608 |
| | $BL_2$ | 73.583 | 92.000 | 3.083 | 2.000 | 91.220 | 177.555 | 8.162 | 9.333 | 97.151 | 86.352 | 31.680 | 32.259 |
| | $BL_0$ | 73.333 | 85.500 | 3.083 | 2.000 | 89.111 | 119.999 | 8.482 | 9.452 | 86.304 | 83.215 | 29.072 | 31.446 |
| $P_0$ | $BL_1$ | 75.083 | 90.350 | 3.083 | 1.750 | 97.167 | 138.444 | 8.125 | 9.738 | 98.208 | 83.475 | 31.825 | 32.337 |
| | $BL_2$ | 73.917 | 89.330 | 2.500 | 1.917 | 80.778 | 135.555 | 8.357 | 9.571 | 94.954 | 83.081 | 31.743 | 31.819 |
| | $BL_0$ | 74.500 | 85.750 | 2.750 | 2.083 | 82.000 | 148.111 | 8.522 | 9.952 | 97.622 | 85.176 | 33.267 | 33.899 |
| $A_3$ $P_1$ | $BL_1$ | 78.783 | 102.830 | 3.333 | 2.250 | 97.500 | 180.444 | 8.294 | 10.071 | 103.406 | 87.413 | 34.222 | 35.032 |
| | $BL_2$ | 76.400 | 97.900 | 3.000 | 1.917 | 96.833 | 163.666 | 8.190 | 9.813 | 103.149 | 84.877 | 33.714 | 33.208 |
| | $BL_0$ | 75.083 | 100.420 | 2.667 | 1.917 | 96.666 | 173.111 | 8.833 | 9.762 | 98.171 | 86.744 | 33.944 | 33.867 |
| $P_3$ | $BL_1$ | 78.167 | 102.170 | 3.083 | 2.000 | 105.333 | 194.111 | 8.413 | 10.322 | 105.185 | 89.988 | 35.254 | 36.923 |
| | $BL_2$ | 77.000 | 101.330 | 2.667 | 2.083 | 97.722 | 187.333 | 8.200 | 10.381 | 103.697 | 86.007 | 33.963 | 35.644 |
| L.S.D $_{0.05}$ | | 5.873 | 9.427 | 0.895 | 0.569 | 11.953 | 18.044 | 1.488 | 1.692 | 14.313 | 11.59 | 3.694 | 3.276 |

The interaction between bio-fertilization, phosphate fertilization, and spraying with Brassinolide growth regulator Table 4 achieved significant effects in reducing the leaves content from SOD enzyme where the $A_3P_2$, $A_3BL_2$, and $P_2BL_2$ treatments produce lowest value of 126.222, 130.556 and 135.444, 139.889 and 75.7501, 181.833 unit.g$^{-1}$ wet weight for both seasons respectively, compared to the treatments $A_0P_0$, $A_0BL_0$, and $P_0BL_0$ which produce the highest value of SOD enzyme in leaves and amounted to 265.667, 284.339 and 265.667, 275.667 and 227.750, 233.833 unit.g$^{-1}$ wet weight for both fall and spring seasons respectively. The triple interaction between study factors achieved

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significant effects and the lowest value was for the $A_3P_2BL_2$ treatment which produced 121.667 and 126.000 unit.g$^{-1}$ wet weight and the $A_0P_0BL_0$ treatment produced the highest value of 287.333 and 293.667 unit.g$^{-1}$ wet weight for both seasons respectively. Tables 1, 2 and 3 show the positive effect of bio-fertilizers in combination with $A_3$ in vegetative growth indicators for potato plants. This effect on plant height, number of main stems, number of leaves, and yield indicators may be returned to the positive effect of *Aspergillus niger* This is due to the ability of this fungus to produce many organic acids such as oxalic, gluconic, gallic and fumaric (Bahadur et al., 2015) and these acids play an important role in dissolving important nutrients for plant growth (Nascimento et al., 2020) In addition to the phosphatase enzyme, which is one of the dissolving factors, that converts triple calcium phosphate into single and binary (Mahamuni et al., 2012), the elements become available for absorption by the plant especially the phosphorus, which is reflected on plant's growth and yield positively. The fungus also has the ability to support plant growth and reduce biotic and abiotic stresses, which makes the environment of plants safe and healthy by supporting growth and preserving it from pathogens and stimulating plant growth by providing nutrients and increasing plant resistance at drought, disease infections and salty environments and it is considered as one ways of sustainable agriculture (Pandey et al ., 2019; Vassileva et al., 2020) and the most important elements that these fungi facilitate are phosphorus, zinc and potassium (Sutarman, 2022). The positive effect could be attributed to the release of hormones and semi-hormones such as auxins (IAA) and gibberellins (GAs) and compounds with low molecular weights such as siderophores, which are characterized by their ability to attract iron and make it available and accessible for absorption by plants (Lubna et al., 2018). Iron is important in the development of vegetative growth indicators, as it is important for the formation of chlorophyll, even more it enters in respiratory enzymes such as oxidase, peroxidase and cytocrom (Sakr, 2010). The hormones also have an effective and important effect in improving the indicators of vegetative growth and productivity. auxin stimulate the efficiency of Photosynthesis by activating the effectiveness of enzymes, regulating the growth and prolongation of cells, and increasing the growth of root (Al-Asadi and Al –Khikani, 2019). The growth of roots, their intrusion and the positive impact on the absorption of nutrients and water from the soil, which in turn directly affects plant growth. GAs are effective hormones in breaking the dormancy of sprouts in potato plant tubers and raising the germination of plants. This is important in increasing developing buds and increasing the number of stems that increase as a result of the number of tubers because there is a relationship between the number of stems and the number of tubers (Koch, 2020). GAs also stimulates work for the division and elongation of cell plants (Al-Asadi and Al –Khikani, 2019). GA also increases carbohydrates manufactured in leaves which is reflected in the increase in the weight of tubers and productivity (1,16).The positive effects of the bacterial bio-fertilizer *Bacillus megaterium*, which has a similar role to *Aspergillus niger*, is attributed to its release of organic acids a solvent for phosphate (Misgina, 2016) and possesses many properties in terms of improving the growth and development of roots and increasing the rate of absorption of water and minerals and. It increases plants' resistance to stress (Nascimento et al., 2020). In addition to possessing properties that increase plant growth, buds, and their growth, the release of hormones GA, IAA, siderophores enzyme and Acc deaminase reduce ethylene in the root area (Chinnaswamy et al., 2018), Growth regulators have a positive role to play in increasing plant height, number of leaves, and growth of roots, thus reflecting their absorption of nutrients, photosynthesis, and the production of carbohydrates storage in tubers (Kumar et al., 2015). These microorganisms are characterized by facilitating nutrients for plants and improving their availability and absorption as a result increasing the efficiency of the plant to carry out biological and physiological processes of cell division, cell elongation, respiration,

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energy providing, element transfer, and photosynthesis that increases manufacture carbohydrates, which was reflected in vegetative growth indicators and yield (Ram et al., 2017,taiz et al., 2015). The levels of phosphate mineral fertilization have a role in increasing vegetative growth indicators in addition to N and K fertilizers, which were added to all treatments, nitrogen enters the construction of proteins, enzymes and nucleic acids, which increases vegetative growth and rapid growth of the plant in the presence of sufficient amounts of N.P.K , Phosphorus enters the synthesis of nucleic acids and energy enzymes which are important for the process of photosynthesis and respiration in addition to its role in the bonds of energy compounds and has the ability to encourage the growth of roots, especially transverse and fibrous roots (Hassan, 2018). The results agree with (Ibrahim and Abed, 2018; Jain and Singh., 2015; Li et al 2021). also The positive results of *Bacillus megaterium* agree with the results of (AL Rubaye and Abdul Ratha, 2019; Radhi et al., 2018) in the highest phosphorus rate on potato plant. The positive effect of phosphorus is agreed with (AL-juboori and Mohammed, 2021; Martins, 2020; Misgina, 2016). The positive effect of Brassinolide spraying on the industrial potato plant could be attributed to its role and effect on cell divisions, cell differentiation and elongation and its importance in reducing various environmental stresses (Hussain et al., 2020), In addition to its role in the root's growth (Rehman et al., 2022). Plant growth and development through its effect on plant biological operation and improving plant structure and photosynthesis (Song et al., 2022), which is reflected in the synthesis of carbohydrates on which the plant depends for its growth (Siddiqui et al., 2018) . As well as its importance in the formation of nucleic acids and proteins and the distribution of nutrients produced by photosynthesis (AL-Khafaji, 2014.), this is reflected in the biological and physiological structure of the plant, which gives a positive effect on vegetative growth indicators and yield indicators. Its positive effect on the plant agrees with the results found by (Ali et al., 2006; Nasrawi and Al-Abadi, 2019; Upadhyay et al., 2015). The SOD enzyme is one of the anti-oxidant enzymes secreted by the plant if the conditions are not suitable for plant growth, so we note from Table 4 the low content of the leaves from this enzyme as a result of the use of treatments and this could be returned to the role of bio-fertilizers to reduce biotic and abiotic stress if the plant is exposed to it, as the *Aspergillus niger* fungus works to reduce both stresses and make the plant environment healthy and safe from pathogens (Pandey et al., 2029; Vassileva et al., 2020) as well as *Bacillus megaterium* that play the same role as the fungus *Aspergillus niger* in reducing stresses and increasing plant resistance (Nascimento et al., 2020) or it could be attributed to the role of phosphate fertilizer in supporting the root system and its role in enzymatic reactions, growth, and respiration (Hassan, 2016), which reflects positively on plant growth and health and increase resistance, also it could be attributed to the role of growth regulator Brassinolide in reducing non-suitable environmental conditions and its role in stimulating plant growth through its effects in supporting plant resistance against stresses (Hussain et al., 2020; Rehman et al., 2022) and these results agree with (Allawi, 2013; Kang and Guo, 2010).

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**Table 4. Effect of bio-fertilization and phosphate and spray with Brassinolide in Leaves content of superoxide dismutase (unit.g$^{-1}$ wet weight) for industrial potatoes**

| T | | Fall season (2021) | | | | Spring season (2022) | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | BL0 | BL1 | BL2 | A*P | BL0 | BL1 | BL2 | A*P |
| | $P_0$ | 287.333 | 274.667 | 271.000 | 265.667 | 293.667 | 284.000 | 275.333 | 284.333 |
| A0 | $P_1$ | 271.000 | 261.000 | 242.000 | 263.333 | 289.667 | 269.333 | 251.667 | 270.222 |
| | $P_2$ | 238.667 | 254.333 | 237.000 | 250.000 | 243.667 | 257.000 | 242.333 | 247.667 |
| | $P_0$ | 198.000 | 210.667 | 201.667 | 203.444 | 209.000 | 215.667 | 212.000 | 212.222 |
| A1 | $P_1$ | 182.667 | 188.667 | 177.333 | 182.889 | 192.000 | 198.000 | 181.333 | 190.444 |
| | $P_2$ | 171.333 | 157.000 | 155.667 | 161.333 | 170.667 | 165.000 | 156.667 | 164.111 |
| | $P_0$ | 253.333 | 266.000 | 245.333 | 254.889 | 257.667 | 267.333 | 250.000 | 258.333 |
| A2 | $P_1$ | 244.667 | 236.000 | 225.667 | 235.444 | 255.333 | 242.000 | 229.000 | 242.111 |
| | $P_2$ | 215.667 | 194.000 | 188.667 | 199.444 | 219.667 | 211.667 | 202.333 | 211.222 |
| | $P_0$ | 172.333 | 159.333 | 152.333 | 161.333 | 175.000 | 163.667 | 155.333 | 164.667 |
| A3 | $P_1$ | 137.667 | 139.333 | 132.333 | 136.444 | 142.000 | 148.667 | 138.333 | 143.000 |
| | $P_2$ | 129.000 | 128.000 | 121.667 | 126.222 | 131.333 | 134.333 | 126.000 | 130.556 |
| L.S.D$_{0.05}$ | | | 9.711 | | 5.607 | | 6.926 | | 3.999 |
| A*BL | | BL0 | BL1 | BL2 | A | BL0 | BL1 | BL2 | A |
| A0 | | 265.667 | 263.333 | 250.000 | 259.667 | 275.667 | 270.111 | 256.444 | 267.407 |
| A1 | | 184.000 | 185.444 | 178.222 | 182.556 | 190.556 | 192.889 | 183.333 | 188.926 |
| A2 | | 237.889 | 232.000 | 219.889 | 229.926 | 244.222 | 240.333 | 227.111 | 237.222 |
| A3 | | 146.333 | 142.222 | 135.444 | 141.333 | 149.444 | 148.889 | 139.889 | 146.074 |
| L.S.D$_{0.05}$ | | | 5.607 | | 3.898 | | 3.999 | | 4.102 |
| P*BL | | BL0 | BL1 | BL2 | P | BL0 | BL1 | BL2 | P |
| $P_0$ | | 227.750 | 227.667 | 217.583 | 224.333 | 233.833 | 232.667 | 223.167 | 229.889 |
| $P_1$ | | 209.000 | 206.250 | 194.333 | 203.194 | 219.750 | 214.500 | 200.083 | 211.444 |
| $P_2$ | | 188.667 | 183.333 | 175.750 | 182.583 | 191.333 | 192.000 | 181.833 | 188.389 |
| L.S.D$_{0.05}$ | | | 4.856 | | 2.803 | | 3.463 | | 2.000 |
| BL | | 208.472 | 205.750 | 195.889 | | 214.972 | 213.056 | 201.694 | |
| L.S.D$_{0.05}$ | | | 2.803 | | | | 2.000 | | |

## CONCLUSION

Through the study results for both seasons, we conclude that the combination of both types of biofertilizers with phosphorus fertilization at the level of 100 kg $p_2o_5$ ha$^{-1}$ and spraying with Brassinolide at the level of 0.1 mg L$^{-1}$ had an effect in increasing plant height, number of stems, tuber weight, and yield.of industrial potato tuber.

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## CONFLICT OF INTEREST

The authors declare that they have no conflicts of interest.

## AUTHOR/S DECLARATION

We confirm that all Figures and Tables in the manuscript are original to us. Additionally, any Figures and images that do not belong to us have been incorporated with the required permissions for re-publication, which are included with the manuscript.

Author/s signature on Ethical Approval Statement.

Ethical Clearance and Animal welfare

Funds:

## AUTHOR'S CONTRIBUTION STATEMENT

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# تحسين النمو والانتاجية للبطاطا الصناعية بالتسميد الحيوي والفوسفاتي والرش بالبراسينولايد

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**المستخلص**

**نُفذت التجربة في جنوب غرب بغداد للموسم الخريفي 2021 والموسم الربيعي 2022 بهدف دراسة تأثير المخصبات الحيوية والتسميد الفوسفاتي والرش بالبراسينولايد على نمو وانتاج البطاطا الصناعية صنف ارسنال، ونفذت كتجربة عامليه بثلاث عوامل (4×3×3) بترتيب الألواح المنشقة (split plot) ضمن تصميم القطاعات العشوائية الكاملة (RCBD)، وزع المخصب الأحيائي ضمن الالواح الرئيسية والتداخل بين مستويات الفسفور ومنظم النمو البراسينولايد ضمن الألواح الثانوية وبثلاث مكررات تضمنت المخصبات الاحيائية فطر *Aspergillus niger* لوحده وبكتريا *Bacillus megaterium* لوحدها والتوليفة بينهما إضافة الى معاملة المقارنة والفسفور بثلاث مستويات هي(0،100،200) كغم $p_2o_5$ هـ$^{-1}$ والرش بالبراسينولايد بثلاث مستويات(0،0.1،0.2) ملغم لتر$^{-1}$. أظهرت النتائج تفوق التوليفة الثلاثية بين إضافة المخصبين الحيويين معا مع الفسفور بالمستوى 100 كغم $p_2o_5$ هـ$^{-1}$ والرش بالبراسينولايد بالتركيز 0.1 ملغم لتر$^{-1}$ تفوق معنوياً في ارتفاع النبات (78.78 و 102.830) سم نبات$^{-1}$ وفي عدد السيقان الرئيسة (3.333 و 2.250) ساق نبات$^{-1}$ لكلا الموسمين على الترتيب. كان اعلى عدد أوراق عند إضافة المخصبين معا مع التسميد بالفسفور بالمستوى 200 كغم $p_2o_5$ هـ$^{-1}$ مع الرش بالتركيز 0.1 ملغم لتر$^{-1}$ من البراسينولايد (105.333 و 194.111) ورقه نبات$^{-1}$ للموسمين على الترتيب، وتميزت التوليفة ذاتها في معدل وزن الدرنة 105.185 غم درنة$^{-1}$ في الموسم الخريفي وانعكس ذلك على التفوق في الانتاجية (35.254 و 36.923) طن هـ$^{-1}$ للموسمين على الترتيب. كما أعطت التوليفة ذاتها مع تركيز 0.2 ملغرام لتر$^{-1}$ براسينولايد اقل قيمة من أنزيم SOD في الأوراق لكلا الموسمن (121.667 و 126.000) وحدة غم$^{-1}$ وزن طري.**

**الكلمات المفتاحية:** ***Aspergillus niger*** **،** ***Bacillus megaterium*** **، أنزيم SOD، L** ***Solanum tuberosum*** **، الزراعة المستدامة.**

*** جزء من أطروحة دكتوراه للباحث الأول**