The Effect of Humic Acid, Vermicompost and Nano-Phosphorous on Growth and Yield Characteristics of Maize (Zea mays L.)

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Abstract

In order to study the effect of adding humic acid, vermicompost and nano-phosphorous on the growth characteristics and yield of maize. An experiment was carried out in one of the fields located in Afak sub-district - Diwaniyah Governorate - Iraq in the autumn season 2020.

The experiment was carried out according to a Complete Randomized Blocks Design with three replications. The treatments included adding humic acid at three levels (0, 10 and 20) kg H⁻¹ and coded (H₀, H₁ and H₂) sequentially, while vermicompost was added at two levels (0 and 4) tons H⁻¹ and coded (V₀ and V₁) sequentially. While nano-phosphorous was added at three levels (0, 5 and 10) kg H⁻¹ that coded by (nP₀, nP₁ and nP₂) sequentially.

The results of the experiment showed outperform the fertilizer combination (VnP₁), which consisted of vermicompost (4) ton and nano-phosphorous (5) kgH⁻¹, as it recorded the highest content of chlorophyll in leaves, the highest plant height, the highest weight of the vegetative and root system, the percentage of protein and the total grain yield (66.53). SPAD and 269.93 cm, 53.53 g and 11.853 g) compared to the control treatment that recorded the lowest values, followed by treatment (V) with a single effect of vermicompost (4) tonH⁻¹, which outperformed in the content of leaves from chlorophyll, plant height, dry weight of the vegetative and root system and the percentage of the protein and total yield which recorded (SPAD 65.77, 263.50 cm, 53.04 g, 11.520 g, 12.25% and 12,393 mcg H⁻¹) compared to the control treatment that recorded the lowest values, as the second level of single nano-phosphorous fertilizer (nP₂) was significantly superior compared to the levels addition of nP and comparison treatment.

1. Introduction

Iraqi soils in general suffer from a low percentage of organic matter and a relatively high degree of soil interaction and a content of high percentage of carbonate minerals. These factors lead to a decrease in the availability of most nutrients that are already present in the soil and to a lack of efficiency in the use of added fertilizers. In order to improve soil productivity and maintain its fertility, a scientific approach must be followed in soil nutrient management programs, which requires work to apply the appropriate fertilizer programs for each soil and the resulting improvement in the physical, chemical and biological properties of the soil, as a result, increase its fertility[1].

Fertilizers are characterized as having more efficiency and effectiveness than traditional fertilizers because of their positive effects on the quality of food crops and reducing the stresses that occur to the plant. It is also characterized by its low added quantities and costs, rapid absorption by plant cells, penetration into cells, rapid transport and representation within plant tissues, as nano-fertilizers are nutrient carriers that are developed using raw materials with nanoscale dimensions ranging from 1-100 nm. The nanoparticles have a high surface area and the ability to hold an abundance of nutrients and release them slowly and steadily so as to facilitate the absorption of nutrients that meet the requirements of the crops without any disadvantages associated with the input of customized fertilizers [2].

The organic fertilizers added to the soil are considered a specific food material for the activity of enzymes in the soil, as the soils rich with organic matter are characterized by a large number of micro-organisms density compared to poor soils. To reduce the problems resulting from the use of traditional fertilizers, environmentally friendly organic fertilizers are added, such as vermicompost, which is one of the most important modern organic fertilizers, as earthworms produce it by breaking down and digesting organic waste and accelerating its decomposition. It is rich in important macro and micro nutrients such as nitrogen, phosphorous, potassium, calcium, magnesium, iron and other elements that are easy to dissolve in water and encourages increased absorption of nutrients by the plant [3] [4] Humic acids are great importance in improving the biological properties of the soil, due to the changes that it occur, which are represented in encouraging the growth and
reproduction of beneficial microorganisms to the soil. It also has a vital role in the biological and abiotic reactions that occur in the rhizosphere of the plant, which is positively reflected in various biochemical processes, such as increasing the activity of enzymes in the soil and the activity of physiological processes that occur inside the plant, thus increasing production [5] [6] founded when adding humic acid at three levels (H₁, H₂ and H₃) a significant increase in the characteristics of vegetative growth and yield of maize, as the H₂ level achieved a significant increase in the level of chlorophyll, dry weight of the vegetative and root system, plant height, protein percentage and total yield, which recorded (1.01 mg). g⁻¹ plant fresh weight, 10.50g, 3.31g, 182.00 cm, 8.50%, 7.15 mcg H⁻¹) compared to the control treatment that recorded the lowest values. [7] noticed a significant increase in the content of chlorophyll, the dry weight of the shoot and root system, the percentage of protein and the total yield, as the third level achieved the highest values of chlorophyll and plant height amounted to (44.99 SPAD and 254.1 cm), and the second level of vermicompost recorded the highest values for the vegetative and root system, the percentage of protein and the total yield which amounted to (57.13 g, 11.429 g, 12.30% and 11.299 mcg H⁻¹) compared to the comparison treatment that recorded the lowest values.

A study conducted by [8] showed the significant indication of the use of nano-fertilizers of various kinds, as they positively affected on the vegetative growth and yield of maize plants. Therefore, the study aimed to know the effect of humic acid, vermicompost and nano-phosphate fertilizer on some growth characteristics and yield of maize.

2. Martials and Methods

A field experiment was carried out during the autumn season of 2020-2021 in one of the fields located in Afak sub-district of Al-Diwaniyah Governorate - Iraq in a soil explaining some of its chemical, physical and biological properties in table (1), in order to study the effect of humic acid, vermicompost and nano-phosphorous and the interaction between them on some characteristics of vegetative growth and yield for maize plant.

| Character      | Value | Unit     | Source                  |
|----------------|-------|----------|-------------------------|
| pH 1:1         | 7.48  | -        | (Black-1965b) [9]       |
| Ec 1:1         | 2.69  | Ds m⁻¹   | (Black-1965b)           |
| CEC            | 24.47 | Cmol Kg⁻¹ soil | (Papanicolaou-1976) [10] |
| CaCO₃          | 231.00| gKg⁻¹ soil | (Black-1965b)           |
| Organic matter | 8.51  |          | (Black-1965b)           |
| Potassium      | 28.05 |          | (Black-1965b)           |
| Phosphorus     | 14.3  |          | (Black-1965b)           |
| Soil separators|       |          | (Black-1965a) [12]      |
| Sand           | 20.83 |          |                         |
| Silt           | 31.24 | gKg⁻¹ soil |                         |
| Clay           | 47.92 |          |                         |
| Textures       |       |          |                         |
| Apparent density| 1.27  | Mgm⁻³    |                         |
| Total bacteria | 20.3  | 10⁶ CFUg⁻¹ dry soil | (Black-1965b) |
| Total fungi    | 8.23  | 10⁶ CFUg⁻¹ dry soil | (Black-1965b) |

The experiment was carried out according to a Complete Randomized Blocks Design, where the number of experiment treatments was 14, including the comparison treatment, with three replicates (Table 2), and these treatments were randomly distributed to each sector. Cultivation was carried out in the experimental unit in the form of lines. The number of lines in the experimental unit was four lines, the distance between one line and another was 75 cm and 25 cm between one plant and another, ie 48 plants in the experimental unit, at a rate of 53,333 plants H⁻¹.

Potassium fertilizer was added in the form of potassium sulfate (41.5% K) at a rate of 120 kg K kg H⁻¹ in one batch before planting, while urea fertilizer (46% N) was added in two batches, the first at planting and the second at the flowering stage (the beginning of the silk stage) at a rate of 240 kg N H⁻¹, as for vermicompost fertilizer, it was added at a rate of 4 tons H⁻¹ in conjunction with the addition of urea, while humic acid was added at two levels of 20, 40 Kg H⁻¹ in the form of powder at one patch in planting after mixing it with the soil and according to the treatments, and the fertilizer was also added Nanoparticles at a rate of 5, 10 kg H⁻¹ in conjunction with the addition of humic acid, according to the treatments.
Chlorophyll was estimated by the SPAD unit in the field using chlorophyll-meter 502 device, as it was measured at the 75% stage of flowering completion by taking the flag leaf of ten plants taken randomly from each treatment. The dry weight of the root and shoot system of the plant (g plant⁻¹) at the stage of full maturity was also calculated, as five plants were randomly taken from the two middle lines of each experimental unit and the plant height (cm plant⁻¹) was measured, starting from the area of contact of the plant with the soil to the male inflorescence by using the measuring tape. The mean of the five readings was taken, then the five plants were taken and the shoot separated from the roots, washed with distilled water and dried aerobically, then dried in an electric oven at 65°C until the weight was stable, then the mean dry weight of the root and vegetative group was calculated.

2.2 Total yield (tons H⁻¹)

The total yield was calculated in the stage of full maturity after the vegetative growth stopped and the plant started to be yellow, as the yield of five plants was taken randomly from each experimental unit and the pods were weighed and the yield of one plant was extracted from then the yield of the experimental unit, then calculated per hectare.

2.3 Protein percentage in grains (%)

After drying, the plant samples were ground by a mill and the digestion process was carried out as stated in the determination of the NPK elements in the plant, then the nitrogen in them was estimated using the Micro-kjeldal device and the protein percentage was calculated based on [11]:

\[
%\text{Protein} = \%\text{N} \times 6.25
\]

3. Results and Discussion

3.1 Leaves content of Chlorophyll (SPAD)

The results of Table (3) showed the significant superiority of the treatment (VnP₁) in the estimation of chlorophyll in the leaves, as it recorded the highest value compared to the other treatments, which amounted to (66.53) SPAD, the reason for the superiority of this treatment, which consisted of vermicompost and nano-phosphorous fertilizer at the second level, may be attributed to the positive role of nano-fertilizers, so the stimulation of the major nano-fertilizers, especially phosphorous, led to the encouragement of vegetative growth, as it stimulates the absorption of additional quantities of elements from phosphorous and nitrogen, which led to an increase in chlorophyll in the leaves.

The results of Table (3) showed the superiority of treatment (V), which did not differ significantly from treatment (VnP₁), as it recorded (65.77) SPAD, followed by treatment (VnP₂) and then treatment (V₁H₂) compared to the comparison treatment, as it recorded (65.77) SPAD, followed by treatment (VnP₂) and then treatment (V₁H₂) compared to the comparison treatment.
which recorded the lowest values, which reached (39.00) SPAD. The reason for the superiority of the treatment of vermicompost (4) ton H\(^1\) is due to the role of adding vermicompost to the soil, which contains a large proportion of nutrients, especially nitrogen and phosphorous, in addition to its role in increasing their absorption by the roots and increasing their percentage in the leaves. [6] indicated that there is Significant effect of adding organic fertilizer in increasing the amount of chlorophyll in leaves.

Table 3. Determination of Chlorophyll (SPAD).

| No | Symbol | Mean |
|----|--------|------|
| 1. | Control | 39.00 d |
| 2. | V      | 65.77 a |
| 3. | nP\(_1\) | 54.00 c |
| 4. | nP\(_2\) | 56.47 bc |
| 5. | H\(_1\) | 54.47 c |
| 6. | H\(_2\) | 55.77 bc |
| 7. | VnP\(_1\) | 66.53 a |
| 8. | VnP\(_2\) | 59.88 b |
| 9. | VH\(_1\) | 60.20 b |
| 10. | VH\(_2\) | 58.90 bc |
| 11. | H\(_1\)nP\(_1\) | 56.37 bc |
| 12. | H\(_1\)nP\(_2\) | 56.03 bc |
| 13. | H\(_2\)nP\(_1\) | 54.87 c |
| 14. | H\(_2\)nP\(_2\) | 58.87 bc |

3.2 Plant height (plant cm\(^{-1}\))

The results of Table (4) showed that there were significant differences in the height of maize plant among the study treatments, as the treatment (VnP\(_1\)) achieved a significant superiority, as it recorded the highest value compared to the other treatments, which amounted to (269.93) cm.

The reason for the superiority of this treatment may be attributed to the effect of the added organic fertilizers (vermicompost), as [13] showed that the organic matter plays an important role in increasing the height of the plant, and when vermicompost was added with nano-phosphorous, vermicompost had a positive effect in reducing the degree of soil interaction, which led to an increase in the readiness of nutrients in the soil and some micro-nutrients, and an increase in the uptake of them by the roots, and then increasing the height of the plant.

Also, treatment (V), followed by treatment (VnP\(_2\)) and treatment (VH\(_1\)) outperformed, as these treatments recorded (263.50, 254.87 and 244.40) cm sequentially compared to the comparison treatment, which recorded the lowest height of maize, which was (211.53) cm.

Adding vermicompost had a significant effect because of its role in improving the physical, chemical and biological properties of the soil and providing nutrients in a balanced manner in the soil solution and then increasing its readiness for absorption by the plant, and this agree with [14].

The levels of addition of humic acid affected each individually and outperformed the second level of acid (H\(_2\)), as it recorded a rise of (224.33) compared to the first level and the comparison treatment, as the reason was due to the main benefit in the ability of humic acid to form complex compounds with some micro-nutrients to save them from the process sedimentation and adsorption in addition to its active role in the process of photosynthesis, as it contributes to the process of building the chlorophyll molecule [15].
Table 4. Plant height (plant cm$^{-1}$).

| No | Treatment Symbol | Mean        |
|----|------------------|-------------|
| 1  | Control          | 211.53 h    |
| 2  | V                | 263.50 ab   |
| 3  | nP$_1$           | 232.10 def  |
| 4  | nP$_2$           | 240.90 cd   |
| 5  | H$_1$            | 212.80 h    |
| 6  | H$_2$            | 224.33 fg   |
| 7  | VnP$_1$          | 269.93 a    |
| 8  | VnP$_2$          | 254.87 b    |
| 9  | VH$_1$           | 244.40 c    |
| 10 | VH$_2$           | 236.87 cde  |
| 11 | H$_1$nP$_1$      | 209.67 g    |
| 12 | H$_1$nP$_2$      | 228.77 ef   |
| 13 | H$_2$nP$_1$      | 216.87 gh   |
| 14 | H$_2$nP$_2$      | 228.47 ef   |

Table 5. Dry weight of the root and vegetative complex of the plant(gm plant$^{-1}$).

| No | Treatment symbol | Means of dry weight for root | Means of dry weight for shoot |
|----|------------------|-----------------------------|------------------------------|
| 1  | Control          | 8.233 g                     | 45.12 g                      |
| 2  | V                | 11.520 a                    | 53.04 a                      |
| 3  | nP$_1$           | 9.177 def                   | 47.72 def                    |
| 4  | nP$_2$           | 9.567 cd                    | 48.34 def                    |
| 5  | H$_1$            | 8.730 ef                    | 46.90 f                      |
| 6  | H$_2$            | 8.843 ef                    | 47.10 ef                     |
| 7  | VnP$_1$          | 11.853 a                    | 53.53 a                      |
| 8  | VnP$_2$          | 11.543 a                    | 52.51 ab                     |
| 9  | VH$_1$           | 10.100 b                    | 51.09 bc                     |
| 10 | VH$_2$           | 10.090 b                    | 50.78 c                      |
| 11 | H$_1$nP$_1$      | 9.807 bc                    | 48.88 d                      |
| 12 | H$_1$nP$_2$      | 9.717 bc                    | 48.66 de                     |
| 13 | H$_2$nP$_1$      | 8.683 fg                    | 47.21 ef                     |
| 14 | H$_2$nP$_2$      | 9.217 de                    | 47.92 def                    |
3.4 Protein percentage in grains (%)

The results of Table (6) proven that there were significant differences between the treatments in the percentage of protein in grains for maize crop, as the treatment (VnP\textsubscript{1}) achieved significant superiority, as it recorded the highest percentage of protein, which amounted to (12.98)\%, followed by the treatment (VnP\textsubscript{2}) which recorded (12.83)\%.

The interaction between vermicompost and nano-phosphorous levels had a positive effect because of the positive role of nanocomposites in encouraging vegetative growth, which stimulates the absorption of additional quantities of different nutrients to meet the needs of the plant and the continuity of its vital activities. This role is complemented by the organic fertilizer vermicompost, which contains major nutrients such as nitrogen. Nitrogen is included in the formation of amino acids, which are the basic building blocks for building proteins [15][16].

The effect of adding vermicompost (V) fertilizer individually was significant as it reached (12.25)\%, followed by the addition of nano-phosphorous fertilizer at the level (nP\textsubscript{2}), which recorded a percentage of (10.43)\%.

Then followed by the addition of humic acid at the level (H\textsubscript{2}), which recorded a percentage of (8.60)\% compared to the comparison treatment, which recorded (4.01)\%.

The results show the positive role of adding vermicompost to it and its positive impact on improving the characteristics of vegetative growth and yield by increasing the availability of the necessary nutrients necessary for the plant’s need and raising the efficiency of the root system to absorb these elements, and as a result, raising the efficiency of the photosynthesis process, and producing the highest rates of the vegetative and root system of the plant.

| No | Treatment Symbol | Mean   |
|----|------------------|--------|
| 1  | Control          | 4.01 e |
| 2  | V                | 12.25 ab |
| 3  | nP\textsubscript{1} | 9.41 cd |
| 4  | nP\textsubscript{2} | 10.43 bc |
| 5  | H\textsubscript{1} | 7.51 d |
| 6  | H\textsubscript{2} | 8.60 cd |
| 7  | VnP\textsubscript{1} | 12.98 a |
| 8  | VnP\textsubscript{2} | 12.83 a |
| 9  | VH\textsubscript{1} | 12.32 ab |
| 10 | VH\textsubscript{2} | 11.96 ab |
| 11 | HnP\textsubscript{1} | 9.04 cd |
| 12 | HnP\textsubscript{2} | 10.57 bc |
| 13 | HnHnP\textsubscript{1} | 9.63 cd |
| 14 | HnHnP\textsubscript{2} | 10.21 bc |

3.5 The total quotient (mg H\textsuperscript{-1})

The results of Table (7) showed that there were significant differences between the means in the total grain yield, as the treatment (VH\textsubscript{1}) achieved significant superiority, as it recorded the highest total yield of (13.550) mcg H\textsuperscript{-1}, followed by treatment (V), which recorded (12.393) mcg H\textsuperscript{-1}. The reason for the superiority of vermicompost is due to the superiority of the same treatment in the content of leaves chlorophyll. (Table 3) and the dry weight of the root and shoot (Table 5), which was positively reflected on the increase in the percentage of pollination and fertilization, and then the increase in the total yield, this agree with [17,18].

While the results of Table (7) showed the superiority of the treatment (VnP\textsubscript{1}) which recorded (11.778) mcg H\textsuperscript{-1} compared to the control treatment which recorded the lowest grain yield, the reason for the superiority of this fertilizer combination is due to the role of vermicompost, which is rich in nutrients and contributes to increasing its readiness in the soil and increasing their uptake by the plant by secreting stimulating substances for the growth and producing chelating compounds and acidifying the medium, as well as the integrated role of phosphorous nano fertilizers and vermicompost.

The addition of single nano-phosphorous fertilizer affected the level (VnP\textsubscript{1}) followed by the addition of humic acid at the level (H\textsubscript{2}), which achieved (11.363, 9.345) mcg H\textsuperscript{-1} compared to the control treatment that recorded the lowest values.
Table 7. The total product (mg H\(^{-1}\)).

| No  | Symbol treatment | Mean  |
|-----|------------------|-------|
| 1.  | Control          | 3.788 h |
| 2.  | V                | 12.393 b |
| 3.  | nP\(_1\)         | 5.105 g |
| 4.  | nP\(_2\)         | 8.337 f |
| 5.  | H\(_1\)          | 8.159 f |
| 6.  | H\(_2\)          | 9.345 e |
| 7.  | VnP\(_1\)        | 11.778 bc |
| 8.  | VnP\(_2\)        | 11.363 cd |
| 9.  | VH\(_1\)         | 13.550 a |
| 10. | VH\(_2\)         | 12.073 bc |
| 11. | H\(_1\)nP\(_1\)  | 10.609 d |
| 12. | H\(_1\)nP\(_2\)  | 9.008 ef |
| 13. | H\(_2\)nP\(_1\)  | 10.715 d |
| 14. | H\(_2\)nP\(_2\)  | 9.050 ef |

References

[1] Colombo, C. G.; Palumbo, F.; Sannion, L.; Gianfreda, L. (2002). Chemical and biochemical indicators of managed agriculture soils in: 17th World Congress of Soil Science, Bangkok, Thailand. P. 1-9.

[2] Kothari, R. and Wani, K.A. (2019). Environmentally friendly slow release nanochemicals in agriculture: a synoptic review. In: Smart Farming Technologies for Sustainable Agricultural Development (pp. 220-240). IGI Global.

[3] Coyne, K. and Knutzen, P. (2008). The Urban Homestead: Your Guide to Self-Sufficient Living in the Heart of the City. Port Townsend: Process Self Reliance Series, 2008.

[4] AL-Khafajee, N. F.; AL-Obaidi, A.; L-Shadeeddi, A. (2012). Effect of earthworms coelomic fluid treating on seed germination of cress (Lepidium sativum) and radish (Raphanus Saltivus). Asian J. of Plant Science and Research 2(4):337-383.

[5] Al-budairy, Zahraa Jaissm Cadhum (2021). Effect of the Vermicompost, Seaweed extract and Urea fertilization on the enzymatic activity in the Rhizosphere of Maize (Zea mays L.). Master Thesis. Al-Qadisiyah University-College of Agriculture. Department of Soil and Water Resources.

[6] Alzreejawi, Safa A. M. (2020). Effect of Foliar Application of Nano Nutrients and Amino Acids as a Complementary Nutrition on Quantity and Quality of Maize Grains. Master Thesis. Al-Qadisiyah University-College of Agriculture. Department of Soil and Water Resources.

[7] Black, C.A. (1965b). Methods of soil analysis, Part 2. Chemical and microbiological Properties, Am. Soc. Agron. Inc. Madison, Wisconsin, USA.

[8] Page, A.L.; Miller, R.H. (1982). Methods of soil analysis. Part 2. ed. Agronomy Series 9. Amer. Soc. of Agron. Madison, Wisconsin, U.S.A.

[9] Papanicolaou, E.F. (1976). Determination of cation exchange capacity of calcareous soils and their percent base saturation. Soil Sci. 121:65-71.

[10] Abu Dhabi, Youssef Muhammad and Muayyad Ahmad Al-Younis (1988). Guide to plant Nutrition. Ministry of Higher education and Scientific research. University of Baghdad.
[16] Kamle, M., Mahato, D. K., Devi, S., Soni, R., Tripathi, V., Mishra, A. K., and Kumar, P., (2020). Nanotechnological interventions for plant health improvement and sustainable agriculture. Biotech, 10(4), 1-11.

[17] Farhad, W. M. F., Saleem, M. A., Cheema, A. M., and H. M. Hammad. (2009). Effect of poultry manure levels on the productivity of spring maize (Zea mays L.). The Journal of Animal & Plant Sciences, 19(3):122-125.

[18] Nasim, W., A. Ahmad, T. Khaliq, A. Wajid, M. F. H. Munis, H. J. Chaudhry, M. M. S. Ahmad, and H. M. Hammad. (2012). Effect of organic and inorganic fertilizer on maize hybrids under growth environmental conditions of Faisalabad-Pak. Afr. J. of Agri. Res., 7(17):2713-2719.