Study of Seed Soaking and Foliar Application of Ascorbic Acid, Citric Acid and Humic Acid on Growth, Yield and Active Components In Maize

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Abstract

Foliar application and seed soaking has been used as a means of supplying supplemental doses of nutrients, plant hormones, stimulants, and organic components. The effects of these applications have included yield increases, and improved drought tolerance, and enhanced crop quality, so a field experiment was carried out during spring seasons in 2019 and 2020 for styding. Seed soaking and Foliar Application of Ascorbic acid, Citric acid and Humic acid on Growth, Yield and Active Components IN Maize. Randomized complete block design in split plots arrangement was used with three replicates. Main-plots were for seeds soaking with ascorbic, citric (100 mg l⁻¹) frequently and humic at (1 ml l⁻¹). Sub-plots were for vegetative parts nutrition with same acids above. Results showed a significant superiority of seeds soaking in humic acid for traits of ears number per plant (1.3 and 1.6), rows number per ear (16.6 and 17.5), grains number per row (39.3 and 45.3), grains number per ear (644.3 and 793.5), weight of 1000 grains (75.3 and 100.6 g), total grain yield (6.0 and 8.3 ton ha⁻¹), shelling ratio (79.3 and 85.1%), biological yield (20.7 and 26.8 ton ha⁻¹), harvesting index (30.4 and 31.2%), in both seasons respectively. Effect of vegetative parts nutrition or interaction between studied factors was non-significant on most traits studied. It can be concluded that soaking maize seeds in humic acid improves yield and yield components.

Keywords: Chlorophyll, Crop growth, Dry matter weight, Foliar spraying, Priming.

1.Introduction

Many studies referred that seed priming improved seedling growth in corn different plants, sorghum, and under drought stress in wheat and improved embryos vitality of deteriorated seed which reflected positively on callus induction in wheat. Also improved seedling growth of deteriorated seed in oat [1-10]. Vitamin C [ascorbic acid (AsA)] is an antioxidant molecule and a key substrate for the detoxification, there levels influence hormonal balance, growth responses, MAPK signaling cascades and antioxidant enzyme activities, while glutathione levels remain unaffected. Consequently, due to its apoplastic localization, AsA constitutes a vital role in stress perception, redox homeostasis and subsequent regulation of oxidative stress and plant physio-biochemical responses under normal as well as different abiotic stresses [11,12].

[13], results pointed to the role of gibberelic acid, salicylic acid, cytokine, and ascorbic acid 30 mg liter⁻¹, that treatment with ascorbic acid achieved the highest value of 1000 grains and total grains yield. [14], mentioned that soaking wheat seeds with ascorbic acid at different concentrations for 8 hours, the best level was 50 mg liter⁻¹ led to an increase the growth, yield and biological yield.

Foliar nutrition is an effective way to better absorption of nutrients, which contributes to increasing growth and yield by allowing absorption and rapid utilization of the nutrients used. Ascorbic acid is one of the basic components necessary in the normal growth of high-end plants because of its many functions in plant tissues, including reducing heat stress and toxicity, stimulating respiration and cell division, increasing the activity of enzymes, and preserving cell components from photo-oxidation, especially chlorophyll [15,16]. Citric acid plays an influential role in formation and production of compounds that contribute to building of cell plant and compounds formation such as fats, proteins and carbohydrates, chlorophyll, phytochromes and cytochromes during growth period [17]. Humic acid spraying or soil application is an effective source of carbon that necessary for the activity of microorganisms, which increases root growth, also it has a hormonal effect on cell protoplasm and cell wall, which leads to rapid cell division and growth [18,19]. [20], pointed that citric acid led to improve the maize growth by increased the ear length, ear diameter, rows per ear, grains number per ear, weight of 100 grains and
total grain yield of maize. Accordingly, this study aimed to investigate the effect of seeds soaking and vegetative part nutrition with ascorbic, citric and humic acids on yield and its components in maize.

2. Materials and Methods

A field experiment was carried out during two spring seasons at the fields of the College of Agricultural Engineering Sciences, University of Baghdad in 2019 the experiment was repeated at Babylon governorate in 2020 due to the the corona pandemic (COVID-19). Randomize complete block design in split plot arrangement was used with three replicates. Main-plots were for seeds soaking with acids of ascorbic and citric (100 mg l\(^{-1}\)) for both of them and humic (1 ml l\(^{-1}\)), as well as the control treatment. The seeds were soaked for 18 hours. Sub-plots were for vegetative parts nutrition with the same acids above, in addition to the control treatment. Two nutrition stages for acids were fixed when 6 and 10 real leaves appeared. Maize seeds (cv. Baghdad3) were obtained from the Agricultural Research Department, Ministry of Agriculture. The soil was analyzed before planting by taking samples with a depth of 0-30 cm to study some physical and chemical characteristics (Table 1).

| Characteristic       | Unit          | Spring season 2019 | Spring season 2020 |
|----------------------|---------------|-------------------|-------------------|
| Sand                 | g kg\(^{-1}\) soil | 592               | 233               |
| Silt                 | g kg\(^{-1}\) soil | 320               | 342               |
| Clay                 | g kg\(^{-1}\) soil | 88                | 425               |
| Soil texture         |               | silty loam        | silty clay loam   |
| pH                   |               | 7.12              | 7.46              |
| Available nitrogen   | mg kg\(^{-1}\) soil | 25.11             | 27.7              |
| Available phosphorus | mg kg\(^{-1}\) soil | 8.35              | 11.4              |
| Available potassium  | mg kg\(^{-1}\) soil | 80.71             | 100.8             |
| Organic material     | g kg\(^{-1}\) soil | 6.3               | 10.7              |
| EC                   | dS m\(^{-1}\)  | 3.30              | 3.20              |
| HCO\(^3\)           | meq l\(^{-1}\) | 2.10              | 2.12              |
| Cl\(^{1}\)          | meq l\(^{-1}\) | 28.22             | 26.18             |
| SO\(^4\)            | meq l\(^{-1}\) | 2.56              | 2.44              |
| Ca                   | meq l\(^{-1}\) | 18.10             | 20.11             |
| Mg                   | meq l\(^{-1}\) | 10.41             | 12.25             |
| Na                   | meq l\(^{-1}\) | 3.89              | 4.10              |
3. Results and Discussion

3.1 Ears number per plant (ear plant\(^{-1}\))

Table 2 showed that there was a significant effect of seed soaking on the number of ears per plant, while the effect of vegetative parts nutrition and the interaction treatments was not significant during both seasons. Seeds soaking in humic acid outperformed significantly by giving the highest mean of ears number per plant (1.3 and 1.6), which didn't differ significantly with seeds soaking in citric and ascorbic acids during spring of 2019, while seeds soaking in distilled water gave the lowest mean 1.2 ear plant\(^{-1}\) during both seasons. This may be attributed to the role of humic acid in increasing the units of carbonate representation and increasing the efficiency of the plant to give the largest number of ears.

Table 2. Ears number per plant (ear plant\(^{-1}\)) affected by seeds soaking and vegetative parts nutrition with acids of ascorbic, citric and humic in maize during spring seasons of 2019 and 2020

| Vegetative parts nutrition | Distilled water | Ascorbic | Citric | Humic | Mean |
|----------------------------|-----------------|----------|--------|-------|------|
| 2019                       |                 |          |        |       |      |
| Distilled water            | 1.2             | 1.2      | 1.3    | 1.3   | 1.3  |
| Ascorbic                   | 1.2             | 1.3      | 1.4    | 1.3   | 1.3  |
| Citric                     | 1.2             | 1.3      | 1.3    | 1.3   | 1.3  |
| Humic                      | 1.2             | 1.2      | 1.3    | 1.3   | 1.3  |
| LSD 5%                     | NS              | NS       |        |       |      |
| Mean                       | 1.2             | 1.3      | 1.3    | 1.3   | 1.3  |
| LSD 5%                     | 0.06            |          |        |       |      |

| 2020                       |                 |          |        |       |      |
| Distilled water            | 1.2             | 1.4      | 1.5    | 1.6   | 1.4  |
| Ascorbic                   | 1.3             | 1.6      | 1.3    | 1.5   | 1.4  |
| Citric                     | 1.2             | 1.5      | 1.4    | 1.7   | 1.4  |
| Humic                      | 1.3             | 1.4      | 1.5    | 1.7   | 1.5  |
| LSD 5%                     | NS              | NS       |        |       |      |
| Mean                       | 1.2             | 1.5      | 1.5    | 1.6   | 1.5  |
| LSD 5%                     | 0.08            |          |        |       |      |

LSD 5%: least significant difference at the probability level of 0.05; NS: Non-significant at P>0.05

3.2 Rows number per ear (row ear\(^{-1}\))

Table 3 showed the significant superiority of seeds soaking in humic acid by giving the highest mean of rows number per ear (16.6 and 17.5), while the control treatment gave the lowest mean (14.5 and 15.0) during both seasons, respectively. The reason may be explained by the fact that seeds soaking in humic acid improves growth, reduces the rate of ovarian abortion, increases fertilization, and thus increases the number of rows per ear. This is consiste\(\)d with the results of [23,24]. The effect of vegetative parts nutrition or the interaction between two factors wasn’t significant during both seasons.

Table 3. Rows number per ear (row ear\(^{-1}\)) affected by seeds soaking and vegetative parts nutrition with acids of ascorbic, citric and humic in maize during spring seasons of 2019 and 2020.

| Vegetative parts nutrition | Distilled water | Ascorbic | Citric | Humic | Mean |
|----------------------------|-----------------|----------|--------|-------|------|
| Spring of 2019             |                 |          |        |       |      |
| Distilled water            | 14.7            | 15.0     | 16.6   | 16.3  | 15.7 |
| Ascorbic                   | 14.4            | 15.3     | 16.5   | 16.7  | 15.7 |
| Citric                     | 14.5            | 15.1     | 16.0   | 16.6  | 15.7 |
| Humic                      | 14.5            | 15.1     | 16.2   | 17.1  | 15.6 |
| LSD 5%                     | NS              |          |        |       |      |
| Mean                       | 14.5            | 15.1     | 16.4   | 16.6  | 15.6 |
| LSD 5%                     | 0.38            |          |        |       |      |

| Spring of 2020             |                 |          |        |       |      |
| Distilled water            | 14.7            | 15.7     | 16.7   | 17.5  | 16.1 |
| Ascorbic                   | 15.1            | 16.3     | 15.7   | 17.3  | 16.1 |
| Citric                     | 14.7            | 16.3     | 16.0   | 17.6  | 16.2 |
| Humic                      | 15.3            | 16.0     | 16.0   | 17.6  | 16.2 |
| LSD 5%                     | NS              |          |        |       |      |
| Mean                       | 15.0            | 16.1     | 16.1   | 17.5  | 16.1 |
| LSD 5%                     | 0.43            |          |        |       |      |

LSD 5%: least significant difference at the probability level of 0.05; NS: Non-significant at P>0.05
3.3 Grains number per row (grain row\(^{-1}\))

Table 4 showed that seeds soaking in humic acid giving the highest mean of grains number per row (39.3 and 45.3), while the control treatment gave the lowest mean (32.3 and 39.5) during both seasons, respectively. Humic acid contains major elements and a group of trace elements, vitamins and growth regulators that are used in plant nutrition and improve growth properties, which was reflected in the increase of grains number per row. The effect of vegetative parts nutrition or the interaction between the two factors wasn't significant.

Table 4. Grains number per row (grain row\(^{-1}\)) affected by seeds soaking and vegetative parts nutrition with acids of ascorbic, citric and humic in maize during spring seasons of 2019 and 2020.

| Vegetative parts nutrition | Seeds soaking | Mean |
|----------------------------|---------------|------|
|                            | Distilled water | Ascorbic | Citric | Humic |      |
| Spring of 2019             |               |         |       |       |      |
| Distilled water            | 32.0          | 33.1    | 37.3  | 36.6  | 34.8 |
| Ascorbic                   | 31.4          | 34.1    | 36.8  | 39.3  | 35.9 |
| Citric                     | 31.5          | 35.6    | 38.3  | 40.1  | 36.4 |
| Humic                      | 34.2          | 35.3    | 37.8  | 41.1  | 36.7 |
| LSD 5%                     | NS            | NS      |       |       |      |
| Mean                       | 32.3          | 34.5    | 37.6  | 39.3  |      |
| LSD 5%                     | 1.22          |         |       |       |      |
| Spring of 2020             |               |         |       |       |      |
| Distilled water            | 38.3          | 42.1    | 42.3  | 44.6  | 41.8 |
| Ascorbic                   | 39.4          | 42.5    | 43.9  | 45.4  | 42.8 |
| Citric                     | 40.2          | 42.8    | 43.5  | 44.5  | 42.8 |
| Humic                      | 40.1          | 43.5    | 42.7  | 46.7  | 43.3 |
| LSD 5%                     | NS            | NS      |       |       |      |
| Mean                       | 39.5          | 42.7    | 43.1  | 45.3  |      |
| LSD 5%                     | 1.25          |         |       |       |      |

LSD 5%: least significant difference at the probability level of 0.05; NS: Non-significant at P>0.05

3.4 Grains number per ear (grain ear\(^{-1}\))

Results in table 5 showed that there was a significant effect of seed soaking treatments on the grains number per ear during both seasons, while the effect of vegetative parts nutrition and the interaction between the two factors wasn’t significant during both seasons. Soaking the seeds with humic acid was superior significantly and gave the highest mean (644.3 and 793.5) during both seasons, respectively, which didn't differ significantly with citric acid during spring of 2019, while the control treatment gave the lowest mean (469.2 and 591.6) during both seasons, respectively, and the reason may be due to the increase in the rows number per ear and grains number per row (Tables 3, 4), and this is in agreement with the results of [25,26].

Table 5. Grains number per ear (grain ear\(^{-1}\)) affected by seeds soaking and vegetative parts nutrition with acids of ascorbic, citric and humic in maize during spring seasons of 2019 and 2020.

| Vegetative parts nutrition | Seeds soaking | Mean |
|----------------------------|---------------|------|
|                            | Distilled water | Ascorbic | Citric | Humic |      |
| Spring of 2019             |               |         |       |       |      |
| Distilled water            | 471.6         | 496.0   | 620.5 | 595.4 | 545.9 |
| Ascorbic                   | 454.4         | 515.9   | 596.3 | 641.6 | 562.2 |
| Citric                     | 457.6         | 539.1   | 657.2 | 658.1 | 573.9 |
| Humic                      | 493.0         | 539.5   | 624.9 | 682.2 | 578.9 |
| LSD 5%                     | NS            | NS      |       |       |      |
| Mean                       | 469.2         | 522.6   | 624.7 | 644.3 |      |
| LSD 5%                     | 25.9          |         |       |       |      |
| Spring of 2020             |               |         |       |       |      |
| Distilled water            | 576.5         | 686.3   | 666.6 | 772.9 | 675.6 |
| Ascorbic                   | 591.0         | 674.8   | 727.3 | 776.6 | 692.4 |
| Citric                     | 582.1         | 693.5   | 704.5 | 801.0 | 695.3 |
| Humic                      | 617.0         | 696.3   | 686.0 | 823.3 | 705.7 |
| LSD 5%                     | NS            | NS      |       |       |      |
| Mean                       | 591.6         | 687.7   | 696.1 | 793.5 |      |
| LSD 5%                     | 26.1          |         |       |       |      |

LSD 5%: least significant difference at the probability level of 0.05; NS: Non-significant at P>0.05
3.5 Weight of 300 grains (g)

It can be noted from the results of Table 6 that weight of 300 grains was affected significantly by soaking the seeds during both seasons and by the interaction between seeds soaking and vegetative parts nutrition during spring of 2019, only, while the effect of vegetative parts nutrition during both seasons and the interaction between two factors during spring 2020, only, weren't significant. Soaking the seeds in humic acid was superior significantly by giving the highest mean of weight of 300 grains (75.3 and 100.6 g), which didn't differ significantly with soaking the seeds in citric acid during spring 2019, while the control treatment gave the lowest mean (67.7 and 85.8 g) during both seasons, respectively. The reason for the superiority of the treatment of seeds soaking in humic acid may be attributed to the role of humic acid in increasing the rate of crop growth, and the increase in the accumulation of dry matter in the plant, which is transferred to the grains later by increasing the net photosynthesis stored in the stem and leaves [27-29].

Table 6. Weight of 300 grains (g) affected by seeds soaking and vegetative parts nutrition with acids of ascorbic, citric and humic in maize during spring seasons of 2019 and 2020.

| Vegetative parts nutrition | Seeds soaking | Mean |
|---------------------------|---------------|------|
|                          | Distilled water |   |     |
|                          | Ascorbic       |   |     |
|                          | Citric         |   |     |
|                          | Humic          |   |     |
|                          | LSD 5%         |   |     |
|                          | Mean           |   |     |
|                          | LSD 5%         |   |     |
| Distilled water          | 64.7           | 66.7 | 76.7 | 74.0 | 70.5 |
| Ascorbic                 | 64.7           | 69.3 | 74.7 | 75.3 | 71.0 |
| Citric                   | 71.3           | 68.0 | 73.3 | 76.0 | 72.2 |
| Humic                    | 70.0           | 72.0 | 73.3 | 76.0 | 72.8 |
| LSD 5%                   | 3.08           |   |     |     |     |
| Mean                     | 67.7           | 69.0 | 74.5 | 75.3 |     |
| LSD 5%                   | 1.85           |   |     |     |     |
| Distilled water          | 84.7           | 88.7 | 94.7 | 96.7 | 91.2 |
| Ascorbic                 | 86.0           | 96.0 | 93.3 | 95.0 | 92.6 |
| Citric                   | 81.3           | 92.7 | 93.3 | 106.0 | 93.3 |
| Humic                    | 91.3           | 89.0 | 92.0 | 104.7 | 94.3 |
| LSD 5%                   | 3.08           |   |     |     |     |
| Mean                     | 85.8           | 91.6 | 93.3 | 100.6 |     |
| LSD 5%                   | 2.07           |   |     |     |     |

LSD 5%: least significant difference at the probability level of 0.05; NS: Non-significant at P>0.05

3.6 Total grains yield (ton ha\(^{-1}\))

The results in Table 7 showed that there was a significant effect of seeds soaking on the total grain yield, while the effect of the vegetative parts nutrition and the interaction between the two factors weren't significant during both seasons. Soaking seeds in humic acid outperformed significantly by giving the highest mean of total grain yield (6.0 and 8.3 ton ha\(^{-1}\)) during both seasons, respectively, which didn't differ significantly with seeds soaking in citric acid during spring 2019, only, while the control treatment gave the lowest mean (4.7 and 6.2 ton ha\(^{-1}\)) during both seasons, respectively. This can be explained by the role of humic acid in increasing the yield components (ears number per plant, rows number per ear, grains number per row, grains number per ear, and weight of 300 grains (Tables 2, 3, 4, 5 and 6), which was reflected in the increase in the total grain yield [30,31].

3.7 Shelling ratio (%)

The results in Table 8 showed that there was a significant effect of seeds soaking on the shelling ratio, while the effect of vegetative parts nutrition and the interaction between the two factors weren't significant during both seasons. Seeds soaking in humic acid outperformed significantly by giving the highest shelling ratio (79.3 and 85.1%), while the control treatment gave the lowest ratio (73.0 and 77.9%) during both seasons, respectively. This is attributed to the increase in the number of grains per ear (Table 5), which in turn led to an increase in the percentage of shelling.
Table 7. Total grains yield (ton ha\(^{-1}\)) affected by seeds soaking and vegetative parts nutrition with acids of ascorbic, citric and humic in maize during spring seasons of 2019 and 2020.

| Vegetative parts nutrition | Seeds soaking | Ascorbic | Citric | Humic | Mean |
|---------------------------|--------------|---------|-------|-------|------|
| Distilled water           | 4.7          | 5.7     | 5.6   | 5.2   |
| Ascorbic                  | 4.8          | 5.1     | 5.5   | 6.3   | 5.4  |
| Citric                    | 4.6          | 5.4     | 6.4   | 6.1   | 5.6  |
| Humic                     | 4.8          | 5.7     | 5.8   | 6.1   | 5.6  |
| LSD 5%                    | NS           |         |       |       |      |
| Mean                      | 4.7          | 5.3     | 5.8   | 6.0   |
| LSD 5%                    | 0.3          |         |       |       |      |

Spring of 2020

| Distilled water           | 6.2          | 7.0     | 8.0   | 6.9   |
| Ascorbic                  | 6.1          | 7.0     | 8.0   | 7.0   |
| Citric                    | 6.3          | 8.0     | 8.6   | 7.5   |
| Humic                     | 6.2          | 7.8     | 8.7   | 7.5   |
| LSD 5%                    | NS           |         |       |      |
| Mean                      | 6.2          | 7.4     | 8.3   |
| LSD 5%                    | 0.26         |         |       |      |

LSD 5%: least significant difference at the probability level of 0.05; NS: Non-significant at P>0.05.

Table 8. Shelling ratio (%) affected by seeds soaking and vegetative parts nutrition with acids of ascorbic, citric and humic in maize during spring seasons of 2019 and 2020.

| Vegetative parts nutrition | Seeds soaking | Ascorbic | Citric | Humic | Mean |
|---------------------------|--------------|---------|-------|-------|------|
| Distilled water           | 71.6         | 73.7    | 77.7  | 78.8  | 75.5 |
| Ascorbic                  | 74.0         | 75.2    | 76.5  | 77.7  | 75.8 |
| Citric                    | 73.0         | 73.8    | 78.2  | 80.9  | 76.5 |
| Humic                     | 73.5         | 76.0    | 77.7  | 79.7  | 76.7 |
| LSD 5%                    | NS           |         |       |       |      |
| Mean                      | 73.0         | 74.7    | 77.6  | 79.3  |
| LSD 5%                    | 1.06         |         |       |       |      |

Spring of 2020

| Distilled water           | 77.4         | 79.8    | 81.6  | 84.1  | 80.7 |
| Ascorbic                  | 77.7         | 80.2    | 82.0  | 85.2  | 81.3 |
| Citric                    | 77.7         | 81.7    | 81.2  | 85.4  | 81.5 |
| Humic                     | 78.8         | 81.2    | 82.9  | 85.6  | 82.1 |
| LSD 5%                    | NS           |         |       |       |      |
| Mean                      | 77.9         | 80.7    | 81.9  | 85.1  |
| LSD 5%                    | 0.8          |         |       |       |      |

LSD 5%: least significant difference at the probability level of 0.05; NS: Non-significant at P>0.05

3.8 Biological yield (ton ha\(^{-1}\))

The results in the table 9 showed that there was a significant effect of seeds soaking during both seasons, and a significant effect of the vegetative parts nutrition and the interaction between the two factors during spring 2020, only, while the effect of the vegetative parts nutrition and the interaction between the two factors weren't significant during spring 2019, only. Seeds soaking in humic acid was superior significantly and gave the highest mean of biological yield (20.7 and 26.8 ton ha\(^{-1}\)), which didn't differ significantly with seeds soaking in citric acid during spring 2019, while the control treatment gave the lowest mean of biological yield (16.7 and 22.3 ton ha\(^{-1}\)) during both seasons, respectively. The vegetative parts nutrition in humic acid outperformed significantly in comparison to the citric and ascorbic acids by giving the highest mean of biological yield (25.2 ton ha\(^{-1}\)), but it didn't differ significantly with the treatment of spraying with distilled water during spring 2020. Also, the results indicated that the interaction between the two treatments of seeds soaking and the vegetative parts nutrition in humic acid was superior significantly by giving the highest mean of biological yield (28.8 ton ha\(^{-1}\)), while the treatment of seeds soaking and the vegetative parts nutrition in ascorbic acid gave the lowest mean of biological yield (21.0 ton ha\(^{-1}\)) during spring 2020. Perhaps the effect of using humic acid led to an increase in the average of plant growth, as well as an increase in the total grain yield (Table 8), so there was an increase in the biological yield and this is in agreement with [31].
Table 9. Biological yield (ton ha\(^{-1}\)) affected by seeds soaking and vegetative parts nutrition with acids of ascorbic, citric and humic in maize during spring seasons of 2019 and 2020.

| Vegetative parts nutrition | Seeds soaking | Mean | LSD 5% |
|----------------------------|---------------|------|--------|
|                            | Distilled water | Ascorbic | Citric | Humic |      |
| Spring of 2019             | 16.7          | 18.0 | 19.7 | 20.1 | 18.6 |
| Distilled water            | 16.8          | 17.9 | 19.1 | 20.6 | 18.6 |
| Ascorbic                   | 16.8          | 18.3 | 19.4 | 20.1 | 18.7 |
| Citric                     | 16.4          | 18.9 | 21.5 | 22.2 | 19.8 |
| Humic                      | NS            |      |      |      |      |
| LSD 5%                     | 16.7          | 18.3 | 19.9 | 20.7 |      |
| Mean                       | 21.0          | 22.2 | 23.8 | 26.4 | 23.4 |
| Distilled water            | 23.3          | 23.6 | 25.0 | 25.5 | 24.4 |
| Ascorbic                   | 21.8          | 26.0 | 26.3 | 26.4 | 25.1 |
| Citric                     | 23.0          | 26.0 | 23.3 | 28.8 | 25.2 |
| Humic                      | 26.7          | 28.3 | 32.5 | 31.6 | 29.8 |
| LSD 5%                     | 22.3          | 24.4 | 24.6 | 26.8 |      |
| Mean                       | 26.7          | 27.1 | 27.8 | 28.2 | 27.4 |
| Distilled water            | 26.4          | 27.2 | 29.5 | 30.7 | 28.5 |
| Ascorbic                   | 27.4          | 28.2 | 28.6 | 31.3 | 28.9 |
| Citric                     | 26.7          | 28.3 | 32.5 | 31.6 | 29.8 |
| Humic                      | NS            |      |      |      |      |
| LSD 5%                     | 26.8          | 27.7 | 29.6 | 30.4 |      |
| Mean                       | 26.8          | 27.7 | 29.6 | 30.4 | 1.19 |
| LSD 5%                     | 26.6          | 29.2 | 26.9 | 27.7 | 27.6 |
| Distilled water            | 28.8          | 26.6 | 30.7 | 32.5 | 29.6 |
| Ascorbic                   | 29.3          | 27.7 | 31.4 | 30.4 | 29.7 |
| Citric                     | 26.7          | 29.8 | 33.1 | 34.1 | 30.9 |
| Humic                      | 27.8          | 28.3 | 30.5 | 31.2 |      |
| LSD 5%                     | 27.8          | 28.3 | 30.5 | 31.2 | 1.05 |

LSD 5%: least significant difference at the probability level of 0.05; NS: Non-significant at P>0.05

3.9 Harvesting index (%)

The results in table 10 showed that there was a significant effect of seeds soaking during both seasons and a significant effect of the interaction between two factors during spring 2020, while the effect of the vegetative parts nutrition during both seasons and the interaction effect between the two factors during spring 2019 weren’t significant. Seeds soaking in humic acid outperformed significantly by giving the highest mean of harvest index (30.5 and 31.2%), which didn’t differ significantly with seeds soaking in citric acid, while the control treatment gave the lowest mean of harvest index (26.8 and 27.8%) during both seasons, respectively. Also, the results indicated that seeds soaking and the vegetative parts nutrition in humic acid was superior significantly by giving the highest mean of harvest index (34.1%), while the control treatment gave the lowest mean of harvest index (26.6%) during the spring 2020. The superiority of the treatment of seeds soaking in humic acid and gave the highest mean of harvest index is attributed to the superiority of this treatment in the total grain yield and biological yield (tables 8, 9), which reflects the efficiency of humic acid in converting the dry matter from the vegetative system (source) to the sink represented by the grains, and this is consistent with [32].

Table 10. Harvesting index (%) affected by seeds soaking and vegetative parts nutrition with acids of ascorbic, citric and humic in maize during spring seasons of 2019 and 2020.

| Vegetative parts nutrition | Seeds soaking | Mean | LSD 5% |
|----------------------------|---------------|------|--------|
|                            | Distilled water | Ascorbic | Citric | Humic |      |
| Spring of 2019             | 26.7          | 27.1 | 27.8 | 28.2 | 27.4 |
| Distilled water            | 26.4          | 27.2 | 29.5 | 30.7 | 28.5 |
| Ascorbic                   | 27.4          | 28.2 | 28.6 | 31.3 | 28.9 |
| Citric                     | 26.7          | 28.3 | 32.5 | 31.6 | 29.8 |
| Humic                      | NS            |      |      |      |      |
| LSD 5%                     | 26.8          | 27.7 | 29.6 | 30.4 |      |
| Mean                       | 26.8          | 27.7 | 29.6 | 30.4 | 1.19 |
| Distilled water            | 26.6          | 29.2 | 26.9 | 27.7 | 27.6 |
| Ascorbic                   | 28.8          | 26.6 | 30.7 | 32.5 | 29.6 |
| Citric                     | 29.3          | 27.7 | 31.4 | 30.4 | 29.7 |
| Humic                      | 26.7          | 29.8 | 33.1 | 34.1 | 30.9 |
| LSD 5%                     | 27.8          | 28.3 | 30.5 | 31.2 |      |
| Mean                       | 27.8          | 28.3 | 30.5 | 31.2 | 1.05 |

LSD 5%: least significant difference at the probability level of 0.05; NS: Non-significant at P>0.05
Conclusions

The seeds soaking of humic acid has been improved the yield and its components while the vegetative parts nutrition didn't show significant effect, which refers to the necessity of reconsider concentrations that would be used in future studies. It can be recommended to soak seeds of maize in humic acid at a concentration of 1 ml l⁻¹ before planting based on our study conditions.

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