Effect of Foliar Spraying with Ascorbic Acid and Dry Yeast Extract on Some Vegetative Growth Traits and Chemical Content of Bitter Almond (Prunus Amygdalus Var. Amara) Seedlings

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Abstract. Bitter almond seedlings are an important rootstock of sweet almond and other stone fruit species. The suitable stem diameter of rootstock for budding and grafting is the aim of nurseries. Thus, the seedlings are treated with nutrients, hormones and organic materials to enhance the vegetative growth and produce healthy and typical rootstocks. In this study, the emerged bitter almond seedlings were sprayed with three concentrations of ascorbic acid (AsA) (150, 300 and 450 mg. L$^{-1}$), two concentration of dry yeast extract (DY) (4 and 8 g. L$^{-1}$) and their interactions, as well as the control treatment (Tap water). The treatments were applied three times throughout the 2017 growing season. The results showed that the ascorbic acid spraying especially 300 mg.L$^{-1}$ significantly increased leaf area, total leaves area per plant, seedling height, stem diameter, branches length and leaves' content of phosphorus and ascorbic acid. Meanwhile the effect of dry yeast extract treatments when separately sprayed were less than expected, but the interaction treatments affected positively on some studied measurements. The foliar spray with 150 mg.L$^{-1}$ AsA + 4.0 g.L$^{-1}$ DY gave the highest values of stem diameter, branch length and carbohydrate concentration in leaves of bitter almond seedlings. Finally, the foliar spray with 300 mg. L$^{-1}$ AsA alone or 150 mg.L$^{-1}$ AsA + 4.0 g.L$^{-1}$ DY are the recommended to obtain rootstocks of suitable diameter to budding or grafting during one growing season.

1. Introduction

Almond is one of the deciduous trees belonging to the family Rosaceae. There are two types of almonds i.e. Prunus amygdalus var. dulcis (that produces sweet edible almonds) and Prunus amygdalus var. amara (that produces bitter almonds) which is used for extraction of almond oil [1]. The horticultural use of bitter almond seedlings is a rootstock of sweet almond cultivars and some species of stone fruit trees, particularly when planted in semi-desert and rain-fed area due to its a deeper root system and ability live under severe environmental condition [2] and [3]. The duration of almond seedlings needs to get a suitable stem diameter for grafting or budding is about one to three years [4]. Therefore, ascorbic acid and dry yeast (DY) extract as biofertilizers are applied to accelerate the growth rate of seedlings and short a vegetative growth period. Ascorbic acid (AsA) stimulate the growth of plants were applied because it has a similar effect of plant growth regulators and antioxidant [5] and [6], also its plays some roles in plant physiology such as reduces the effect of stress caused by temperature and toxins, stimulates a respiration and cell division, participates into the electron transport system and protect the chloroplast against oxidation, further, it increases the efficiency of photosynthesis by increasing the leaves' area and their content of chlorophyll pigment and nitrogen [5]. Due to all reasons, the plants need AsA in their tissues in small quantities to maintain its natural growth [7]. Improvement in vegetative growth and chemical characteristics of plants have been well documented with application of ascorbic acid on seedlings and trees of different plant species, as stated of Al-Douri [8] on young trees of two apple cultivars Anna and Vistabella, Kassim et al. [9] on Costata persimmon trees, Al-Douri and Al-Araji [10] on pomegranate trees, and Mayi, et al. [11] and Al-Atrashy and Abdul-Qader [12] on olive trees, respectively.
Beside AsA, dry yeast (Saccharomyces cervisiae L.) extract is a biofertilizer and used through spraying on the plant canopy or adding to the soil in order to enhance the vegetative growth and mineral content of the treated plants. Dry yeast (DY) extract treatments maybe enhance photosynthesis process during the releasing CO$_2$ that is an important input of this process [13]. In addition, DY contains some nutrients, vitamins, amino acids, enzymes and carbohydrates [14]. Practically, there are some studies were performed to investigate the effect of dry yeast extract on vegetative growth and mineral content of leaves for fruit trees, and they get a positive result, such as Bakry and Wanas [15] and Stino, et al. [16] reported on apricot trees respectively, Kassim, et al. [9] on persimmon trees, Abd El-Motty, et al. [17] on mango trees and El-Shazly and Mustafa [18] on Washington Navel orange trees.

Keeping in mind, the importance of bitter almond seedling in world wide; there is lack of studies on investigating the influence of ascorbic acid and dry yeast extracts. Therefore, this study has been designed to investigate the AsA and DY effects on vegetative growth and chemical constituents of bitter almond seedlings.

2. Materials and Methods

2.1. Place of work
The experiment was conducted at the Research Station, the Department of Horticulture and Landscape Design/College of Agriculture/Tikrit University, during the growing season of 2017-18, on the bitter almond seedlings which were produced from seeds of wild trees. The seeds were stratified for 30 days and cultivated in a plastic bags that is 20 cm diameter and 30 cm height. The plastic bags were filled with soil, that the table (1) obtain the soil physical and chemical properties.

| Table (1) Some physical and chemical properties of the soil* |
|-----------------------------------------------|
| Properties | Values | Units |
| Sand | 37% | % |
| Silt | 32% | % |
| Clay | 31% | % |
| Clay Loam | - | - |
| pH | 7.55 | - |
| EC | 0.7 | ds.m$^{-1}$ |
| Organic matter | 1.12 | gm.Kg$^{-1}$ |
| Available N | 0.14 | % |
| Available P | 0.9 | % |
| Available K | 1.3 | % |

*The soil sample was analyzed in the laboratory of the Soil and Water Resources Department/College of Agriculture/Tikrit University

2.2. Experimentation
The experiment investigated the effect of foliar spray of three levels of ascorbic acid (AsA), two levels of dry yeast extract (DY), their interactions and the control treatment, in this state, the experiment included eleven treatments as bellow:

$T_0$= The control (without).
$T_1= 150$ mg.L$^{-1}$ AsA.
$T_2= 300$ mg.L$^{-1}$ AsA.
$T_3= 450$ mg.L$^{-1}$ AsA.
$T_4= 4.0$ g.L$^{-1}$ DY.
$T_5= 8.0$ g.L$^{-1}$ DY.
$T_6= 150$ mg.L$^{-1}$ AsA + 4.0 g.L$^{-1}$ DY.
$T_7= 150$ mg.L$^{-1}$ AsA + 8.0 g.L$^{-1}$ DY.
$T_8= 300$ mg.L$^{-1}$ AsA + 4.0 g.L$^{-1}$ DY.
$T_9= 300$ mg.L$^{-1}$ AsA + 8.0 g.L$^{-1}$ DY.
$T_{10}= 450$ mg.L$^{-1}$ AsA + 4.0 g.L$^{-1}$ DY.
$T_{11}= 450$ mg.L$^{-1}$ AsA + 8.0 g.L$^{-1}$ DY.
Ascorbic acid solution with deferent concentrations were prepared directly in the field, whereas DY extract was prepared according to the method previously described by El-Tohamy, et al. [19]. All the treatments were done three times in the morning during the growing season using a 2 lit hand sprayer. The first spray was applied on 4th April, 2017 followed by two more sprays at weekly intervals. The standarised agronomic practices (fertilization, weeding and insects control) for raising seedlings were taken.

2.3. The measurements:

2.3.1. Vegetative growth: the leaves measurements (Leaf area (cm²), Total leaves area of seedling (cm²) and chlorophyll content of leaves (SPAD)) and structural parts of seedling parameters (Seedling height (cm), stem diameter (mm), branches number per plant, branch’s length (cm) and branch’s diameter (mm)) were measured in the second week of October 2017.

2.3.2. NPK nutrients (%) in leaves: 15 leaves from every experimental unit were collected on mid-June [20], dried and digested according to procedure given by Al-Sahaf [21], after that the nitrogen, phosphorus and potassium were determined according to procedures mentioned by A.O.A.C. [22], Olsen and Sommers [23] and Temminghoff and Houbá [24] respectively.

2.3.3. Carbohydrate (%): the total carbohydrate in leaves was determined according to procedure described by Joslyn [25] in the second week of October 2017.

2.3.4. Ascorbic acid (mg. 100 g⁻¹ fresh weight): ascorbic acid content in leaves was measured by 2,6 dichlorophenol-indophenol as described by Meng et al. [26].

2.4. Experimental design and data Analysis: The treatments were arranged in Randomized Completed Block Design (RCBD) with three replicates, each experimental unit contains five seedlings. The collected data were subjected to ANOVA statistically analysis and the means were compared by L.S.D. test at 0.05 probability [27].

3. Results and Discussion

3.1. The leaves measurements

The data in the table (2) obtained the effect of foliar spray with ascorbic acid or/and dry yeast extract on leaf area, total leaves area per seedling and the chlorophyll index (SPAD). The single leaf area was increased significantly with increasing of ascorbic acid to 300 mg L⁻¹ (T₃) compared to control treatment. The foliar spray with dry yeast extract did not affect this parameter, while the highest value of leaf area (13.59 cm²) came from T1 treatment when the seedlings were sprayed with 150 mg L⁻¹ AsA + 8 g L⁻¹ DY, this treatment exceeded all treatments except the spraying with 300 mg L⁻¹ AsA (T₃). Regarding total leaves area of seedling, the data showed that the treatments of AsA (T₂ and T₃) and DY (T₄ and T₅) solely increased significantly the total leaves area of bitter almond seedling over control (T₀), however, T₃ (300 mg L⁻¹ AsA) gave the highest value of this parameter and dominant of all treatments statistically except T₁ (150 mg L⁻¹ AsA + 8 g L⁻¹ DY). The chlorophyll content of leaf was varied from each treatment to other, table (2) displays obviously that the foliar spray of the first level of AsA (T₁) and DY (T₄) increased significantly the chlorophyll index (SPAD) compared the control treatment (T₀). Moreover, T₀ (300 mg L⁻¹ ASA + 8.0 g L⁻¹ DY) ranked statistically first regarding its effectiveness to increase the total leaves area of bitter almond seedlings.

Table (2) Effect of foliar application with ascorbic acid and dry yeast extract on leaves measurements of bitter almond seedlings

| Treatments¹  | Leaf area (cm²) | Total leaves area (cm²) | Chlorophyll (SPAD) |
|--------------|----------------|-------------------------|--------------------|
| T₀ (Control) | 8.15           | 600.76                  | 48.50              |
| T₁           | 9.86           | 753.16                  | 52.37              |
| T₂           | 13.47          | 1439.06                 | 49.67              |
| T₃           | 8.70           | 932.47                  | 49.63              |
| T₄           | 5.99           | 812.24                  | 51.10              |
| T₅           | 8.69           | 1061.35                 | 48.47              |

¹The treatments were arranged in Randomized Completed Block Design (RCBD) with three replicates, each experimental unit contains five seedlings.
Generally, the effect of ascorbic acid (AsA) on leaf area, total leaves area and chlorophyll content of leaves goes in line that pointed out by Elham and Shahin [28] on Canino apricot, Al-Douri [8] on young apple trees Anna and Vistabella cultivars, Al-Douri and Al-A’araji [10] on Salimi pomegranate trees. The beneficial effect of ascorbic acid on the vegetative measurements may be attributed to its important physiological roles in cell division and bio-synthetic of carbohydrates processes [29]. The present results about the effect of spraying with dry yeast extract agreed with those obtained by Al-Dulaimy and Jumaa [30] on Black Hamburg grape, Mahmoud, et al. [31] on Manzanillo olive trees, and Fatma, et al. [32] on Canino apricot trees. The positive effects of activated dry yeast application might be referred to its role on increasing endogenous hormones such as IAA and GA3 in treated seedlings, which stimulated the cell division and enlargement. As well as the role of amino acids and vitamins in stimulating the metabolic processes and their effects in activating the photosynthesis through the release of CO2 of treated plants [33 and 34].

### 3.2. Structural parts of seedling parameters

The data presented in table (3) indicated that the seedling height affected positively by foliar spray of ascorbic acid and dry yeast extract levels were applied alone or in combination, whereas T1 treatment (450 mg L-1 ASA + 8.0 g L-1 DY) gave the high value of seedling height (81.46 cm) and surpass significantly all treatments, meanwhile, the control treatment gave the least value of seedling height (59.27 cm). Concerning the stem diameter, all concentrations of AsA and the low concentration of DY extract treatments (T2 T3, T4 and T5) increased the stem diameter significantly over the control treatment (T0), moreover, the greatest effect was by T6 (150 mg L-1 ASA + 4.0 g L-1 DY) that caused a significant increment of seedling stem diameter and dominated on all treatments except T3 (300 mg L-1 ASA).

Regarding sprayed solutions on branches number per plant, the results in a table (3) revealed that the spraying of ascorbic acid levels alone didn’t affect in this characteristic, but the foliar spray of 4.0 g. L-1 dry yeast (T4) flowed by T1 (150 mg L-1 ASA + 8.0 g L-1 DY) gave height number of branches per seedling and surpass significantly the control and some other treatments. The average of branch length was affected by foliar spraying of AsA particularly 300 and 450 mg. L-1 treatments (T1 and T4), whereas the dry yeast extract treatments hadn’t a significant effect on this parameter. On the other hand, all interaction treatments between ascorbic acid and dry yeast extract levels (T6 – T11) increased statistically the branch length of seedlings comparison with the control treatment.

The results in the table (3) showed that the foliar spray with ascorbic acid or/ and dry yeast extract treatments didn’t affect significantly on branches diameter of bitter almond seedlings when compared with the control treatment whereas, the T6 (150 mg L-1 ASA + 4.0 g L-1 DY) gave the highest value of this parameter without statistical deference for the control treatment.

The foliar spray of ascorbic acid (AsA) enhanced some measurements such as seedling height, stem diameter and branches length, these results agreed with the findings reported by Al-Douri [8] on Anna and Vistabella apple cultivars, Al-A’areji and Al-Hamadany [35] on Coronet peach transplants, Al-Douri and Al-A’araji [10] on Salimi pomegranate trees and El-Badawy [29] on Canino apricot trees and Mayi, et al. [31] on olive trees. The effect of AsA on encouraging these characteristics might be concerned to AsA acting in increase the leaf area, total leaves area and their content of chlorophyll pigment (Table 2), also to its role in the biological processes as co-factor to many enzymes like Hydroxylase enzymes that participate in the biosynthesis of plant growth regulators which control on growth such as gibberellins, Ethylene and Absciscic acid [36].

| Treatment | Seedling Height (cm) | LSD 0.05 |
|-----------|----------------------|----------|
| T6        | 8.29                | 1159.24  |
| T7        | 13.59               | 1265.53  |
| T8        | 7.50                | 699.56   |
| T9        | 6.74                | 825.47   |
| T10       | 7.82                | 777.45   |
| T11       | 7.99                | 1073.66  |
| LSD       | 2.51                | 185.67   |

[^31]: Mahmoud, et al. [31] on Manzanillo olive trees, and Fatma, et al. [32] on Canino apricot trees. The positive effects of activated dry yeast application might be referred to its role on increasing endogenous hormones such as IAA and GA3 in treated seedlings, which stimulated the cell division and enlargement. As well as the role of amino acids and vitamins in stimulating the metabolic processes and their effects in activating the photosynthesis through the release of CO2 of treated plants [33 and 34].

[^32]: Concerning the stem diameter, all concentrations of AsA and the low concentration of DY extract treatments (T2 T3, T4 and T5) increased the stem diameter significantly over the control treatment (T0), moreover, the greatest effect was by T6 (150 mg L-1 ASA + 4.0 g L-1 DY) that caused a significant increment of seedling stem diameter and dominated on all treatments except T3 (300 mg L-1 ASA).

[^33]: Regarding sprayed solutions on branches number per plant, the results in a table (3) revealed that the spraying of ascorbic acid levels alone didn’t affect in this characteristic, but the foliar spray of 4.0 g. L-1 dry yeast (T4) flowed by T1 (150 mg L-1 ASA + 8.0 g L-1 DY) gave height number of branches per seedling and surpass significantly the control and some other treatments. The average of branch length was affected by foliar spraying of AsA particularly 300 and 450 mg. L-1 treatments (T1 and T4), whereas the dry yeast extract treatments hadn’t a significant effect on this parameter. On the other hand, all interaction treatments between ascorbic acid and dry yeast extract levels (T6 – T11) increased statistically the branch length of seedlings comparison with the control treatment.

[^34]: The results in the table (3) showed that the foliar spray with ascorbic acid or/ and dry yeast extract treatments didn’t affect significantly on branches diameter of bitter almond seedlings when compared with the control treatment whereas, the T6 (150 mg L-1 ASA + 4.0 g L-1 DY) gave the highest value of this parameter without statistical deference for the control treatment.

[^35]: The foliar spray of ascorbic acid (AsA) enhanced some measurements such as seedling height, stem diameter and branches length, these results agreed with the findings reported by Al-Douri [8] on Anna and Vistabella apple cultivars, Al-A’areji and Al-Hamadany [35] on Coronet peach transplants, Al-Douri and Al-A’araji [10] on Salimi pomegranate trees and El-Badawy [29] on Canino apricot trees and Mayi, et al. [31] on olive trees. The effect of AsA on encouraging these characteristics might be concerned to AsA acting in increase the leaf area, total leaves area and their content of chlorophyll pigment (Table 2), also to its role in the biological processes as co-factor to many enzymes like Hydroxylase enzymes that participate in the biosynthesis of plant growth regulators which control on growth such as gibberellins, Ethylene and Absciscic acid [36].
The foliar spray of dry yeast extract (DY) had a positive effect on almond seedlings height, stem diameter and the branches number. These results conform with those of Mohammed [37] on the hazelnut trees, Mustafa and El-Shazly [38] and El-Shazly and Mustafa [18] on Washington Navel orange trees. Attala, et al. [39] and Fatma, et al. [40] documented that, the various positive effects of activated dry yeast extract were attributed to its content of nutrients, the relative amount of proteins, vitamin B and the natural hormones (IAA, GA3 and Cytokinins). Also, the dry yeast application was very effective in releasing CO2 which reflected on improving net photosynthesis, so all these roles might be supplied the seedlings with their requirements to growth.

3.3. NPK Nutrients in leaves (%)

The data presented in table (4) obtained that, the concentration of N in bitter almond leaves was affected positively by foliar spray with the first levels of AsA and DY (T1 and T4) whereas the highest value of nitrogen concentration was the effecting result of T10 (450 mg L⁻¹ AsA + 4.0 g L⁻¹ DY), and the previous three treatments dominated significantly on the control treatment which didn't differ about T6 (150 mg L⁻¹ AsA + 4.0 g L⁻¹ DY) that gave the minimum concentration of nitrogen in the leaves. Concerning the concentration of phosphorus in leaves, all treatments increased its values significantly except T4 (150 mg L⁻¹ AsA) comparison with the control treatment. The maximum value of P concentration was by T7 (150 mg L⁻¹ AsA + 8.0 g L⁻¹ DY). As for potassium concentration, the foliar spraying with AsA or DY alone didn't affect statistically, but more the interaction treatments caused a significant increment especially T2 (150 mg L⁻¹ AsA + 8.0 g L⁻¹ DY) that gave the highest value of potassium concentration in almond leaves. El-Badawy [30] reported a similar results in increase NPK nutrients concentrations by spraying Canino apricot trees with AsA (1000 and 2000 mg L⁻¹). The positive effect of AsA on concentrations of nutrients in leaves might be attributed to its roles on roots growing through induced cells division in the apical meristem, growth rate, roots length and increase the biomass of the root system [41] and [42], that enhanced the plants' ability to absorb nutrients from the soil solution and increase their concentrations in plant tissues.

The foliar spray with dry yeast extract had a positive increase in NPK content for almond seedling leaves, that agreed to documented results of Abd Al-Hamied [43] on mango trees, Mahmoud, et al. [31] on Manzanillo olive trees and Fatma, et al. [40] on Canino apricot trees. These results might be attributed to the dry yeast extract content of nutrients and amino acids [14] that were absorbed directly by leaves, on the other hand, the dry yeast had many growth stimulants and the precursor of IAA (Tryptophan) that induced the physiological processes, root system development and absorption more water and nutrients.

| Treatments     | Seedling height (cm) | Stem diameter (mm) | Branches No. (branch.plant⁻¹) | Branch length (cm) | Branch diameter (mm) |
|----------------|----------------------|--------------------|--------------------------------|---------------------|----------------------|
| T₀ (Control)   | 59.27                | 4.40               | 1.53                           | 14.61               | 2.36                 |
| T₁             | 66.93                | 4.97               | 1.93                           | 15.49               | 2.53                 |
| T₂             | 68.00                | 5.15               | 2.00                           | 21.64               | 2.66                 |
| T₃             | 62.53                | 4.91               | 2.62                           | 19.33               | 2.11                 |
| T₄             | 61.47                | 4.87               | 4.20                           | 16.69               | 2.03                 |
| T₅             | 65.86                | 4.51               | 2.80                           | 13.65               | 2.57                 |
| T₆             | 68.20                | 5.00               | 3.40                           | 27.30               | 3.05                 |
| T₇             | 64.93                | 4.68               | 3.66                           | 25.30               | 2.15                 |
| T₈             | 69.00                | 4.17               | 1.46                           | 20.97               | 1.83                 |
| T₉             | 64.60                | 4.61               | 2.66                           | 20.35               | 2.24                 |
| T₁₀            | 66.27                | 4.52               | 2.17                           | 21.16               | 1.97                 |
| T₁₁            | 81.46                | 4.97               | 2.46                           | 28.07               | 2.44                 |
| LSD Value:0.05 | 7.03                 | 0.40               | 1.66                           | 2.94                | 0.72                 |

Table (3) Effect of foliar application with ascorbic acid and dry yeast extract on structural parts measurements of bitter almond seedlings
Table (4) Effect of foliar application with ascorbic acid and dry yeast extract on NPK nutrients concentration in leaves of bitter almond seedlings.

| Treatments | N%  | P%  | K%  | Carbohydrate (%) | Ascorbic Acid (mg.100 g) |
|------------|-----|-----|-----|------------------|--------------------------|
| T0 (Control) | 1.62 | 0.206 | 0.96 | 1.26 | 0.79 |
| T1         | 2.05 | 0.246 | 1.07 | 2.24 | 0.68 |
| T2         | 1.58 | 0.406 | 1.007 | 1.49 | 1.11 |
| T3         | 1.80 | 0.430 | 0.866 | 1.71 | 0.55 |
| T4         | 2.32 | 0.283 | 1.050 | 1.03 | 0.62 |
| T5         | 1.49 | 0.456 | 1.007 | 1.22 | 0.66 |
| T6         | 1.40 | 0.360 | 1.096 | 2.57 | 1.14 |
| T7         | 2.22 | 0.466 | 1.210 | 2.42 | 1.23 |
| T8         | 2.01 | 0.340 | 1.166 | 2.47 | 1.27 |
| T9         | 2.12 | 0.450 | 1.116 | 2.03 | 0.92 |
| T10        | 2.61 | 0.316 | 1.140 | 1.54 | 1.54 |
| T11        | 1.78 | 0.453 | 1.090 | 2.55 | 1.31 |
| LSD        | 0.35 | 0.052 | 0.151 | 0.80 | 0.45 |

3.4. Carbohydrate (%):
The results in a table (4) showed that the first level of AsA (T1) increased significantly the concentration of Carbohydrates in leaves, but the DY levels didn’t affect this characteristic. Whereas the interaction treatments between AsA and DY (T6 – T11) surpassed the control treatment except for T10 (450 mg L⁻¹ ASA + 4.0 g L⁻¹ DY). The highest value of carbohydrate in almond seedling leaves (2.57%) was by T6 (150 mg L⁻¹ ASA + 4.0 g L⁻¹ DY). This result is in line with the finding of Al-Aa’raji and Al-Douri [44] on Anna and Vistabella young apple trees. This result might be attributed to AsA role in increasing the leaves area and their content of chlorophyll pigment (Table 3), that reflected as increasing of biosynthesis rate and its products [45 and 46].

3.5. Ascorbic acid in leaves (mg. 100 g⁻¹ fresh weight):
The concentration of AsA in leaves was affected with the foliar spray of AsA and the interaction treatments between AsA and dry yeast levels but not the DY extract alone. The treatments T1 and T2 (150 and 300 mg L⁻¹ AsA) increased the concentration of AsA in leaves, whereas the highest value of this parameter (1.54 mg 100 g⁻¹ fresh weight) by the T10 (450 mg L⁻¹ ASA + 4.0 g L⁻¹ DY), these three treatments surpass the control and some other treatments. This result might be attributed to the AsA role in increase leaf area and total leaves area per seedling (Table 3) and induced the production of ascorbic acid in leaves which were the source of AsA [47] on the other hand the dry yeast extract contains some of ascorbic acid so the interaction treatment was the best.

4. Conclusion
The foliar spray of ascorbic acid alone or in combination with dry yeast extract enhanced the vegetative growth and nutrients content of bitter almond seedlings, whereas the dry yeast extract had the least effectiveness under this experiment condition. In conclusion, foliar spray with a relatively low concentration of ascorbic acid (150-300 mg L⁻¹) is recommended to improve vegetative growth and nutrient status of bitter almond seedlings.

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